REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-TM-84105) REPORT OF APOLLO 204 REVIEW BOARD (NASA) 142 p N82-72199

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APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 5, 1967

The Honorable James E. Webb
Administrator
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Mr. Webb:

Pursuant to your directive as implemented by the memorandum of February 3, 1967, signed by the Deputy Administrator, Dr. Robert C. Seamans, Jr., the Apollo 204 Review Board herewith transmits its final, formal report, each member concurring in each of the findings, determinations, and recommendations.

Sincerely,

Dr. Floyd L. Thompson
Chairman

Frank Borman, Col., USAF

Dr. Robert W. Van Dolah

Dr. Maxime A. Faget

George C. White, Jr.

E. Barton Geer

John J. Williams

Charles F. Strang, Col., USAF

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REPORT
OF
APOLLO 204 REVIEW BOARD

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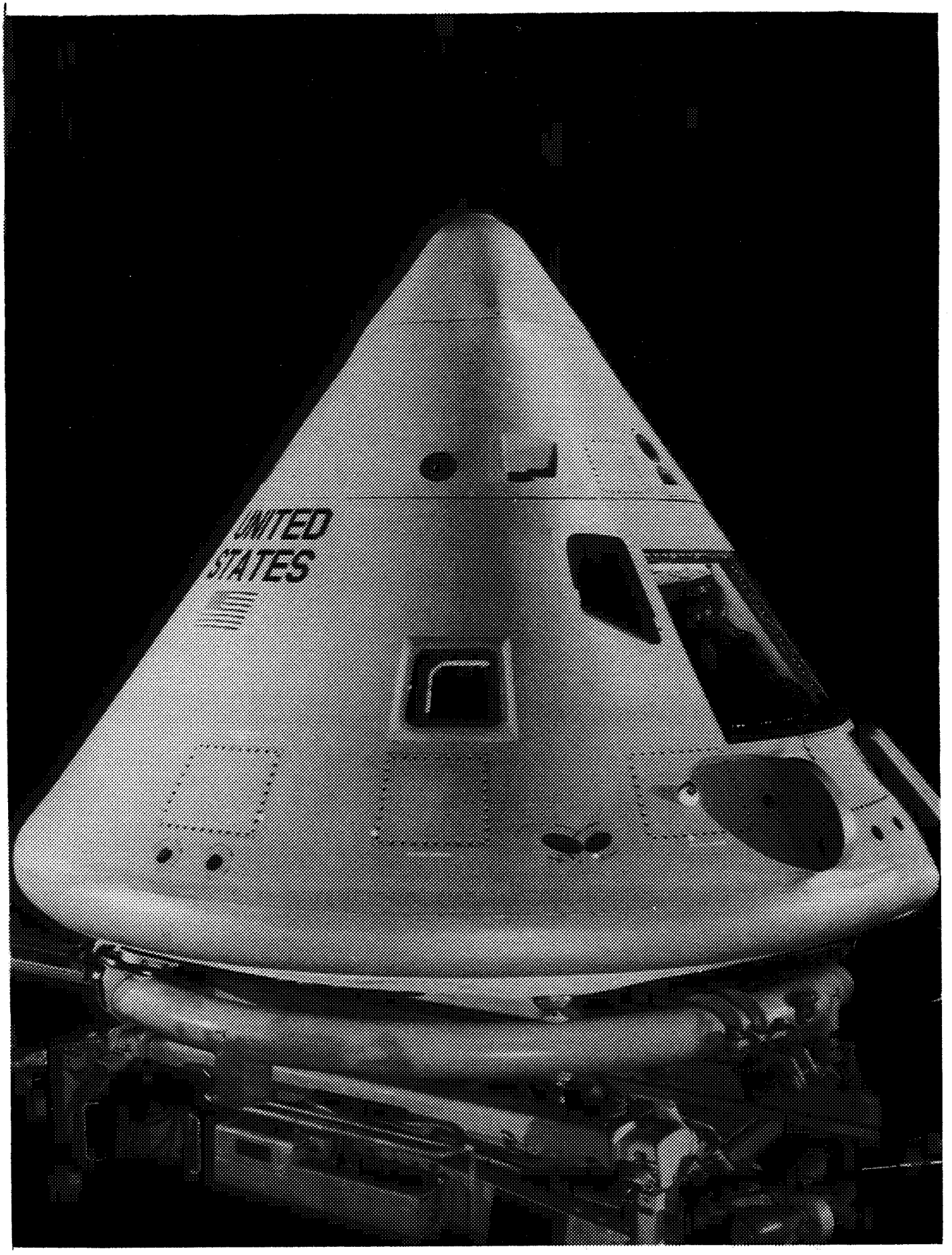
UNITED
STATES

PREFACE

The Nation's space program requires that man and machine achieve the highest capability to pursue the exploration of space. Three gallant men lost their lives in line of duty during the development of that capability.

The Apollo 204 Review Board was charged with the responsibility of reviewing the circumstances surrounding the accident, reporting its findings relating to the cause of the accident, and formulating recommendations so that inherent hazards are reduced to a minimum.

Throughout its proceedings, the Board recognized the need for an impartial and totally objective review in order to arrive at its findings. The Board believes that this was accomplished.

The Board is very concerned that its description of the defects in the Apollo Program that led to the condition existing at the time of the Apollo 204 accident will be interpreted as an indictment of the entire manned space flight program and a castigation of the many people associated with that program. Nothing is further from the Board's intent. The function of the Board has been to search for error in the largest and most complex research and development program ever undertaken. This report, rather than presenting a total picture of that program, is concerned with the deficiencies uncovered.

The Board has been greatly impressed by the integrity, candor and dedication of those people upon whom the Board relied in conducting this investigation. All have felt a personal loss in this accident, and all are determined that a comparable tragedy shall not occur.

This report represents the dedicated effort of many hundreds of individuals in government, industry and educational institutions. In addition, useful advice was received from many private individuals in this country and abroad. The Board acknowledges with appreciation these contributions.

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PART I

AUTHORITY

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NARRATIVE OF BOARD HISTORY

By authority of the Administrator, National Aeronautics and Space Administration, the Apollo 204 Review Board was established January 27, 1967. This action was initiated through oral instructions issued by the Deputy Administrator, followed by written confirmation February 3, 1967, setting forth, in detail, the broad powers and responsibilities of the Board.

The Review Board convened at Kennedy Space Center (KSC), Florida, on January 28, 1967, under the Chairmanship of Dr. Floyd L. Thompson, Director of the Langley Research Center. The sessions and organized activities of the Board continued at KSC until the Board submitted its Report.

During this period an intensive review was carried out in accordance with the responsibilities placed on the Board by the Administrator. A principal element of this Review was the creation of 21 Task Panels manned by experts in their respective fields. The report of these Task Panels provided the main source of information from which the Board has formulated its findings and recommendations. Periodic interim reports were provided the Administrator.

With completion of this report, the Board has been recessed subject to being reconvened at the call of the Chairman.

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NMI 8621.1

April 14, 1966
Effective date

Management Instruction

SUBJECT: MISSION FAILURE INVESTIGATION POLICY AND PROCEDURES

1. PURPOSE

This Instruction establishes the policy and procedures for investigating and documenting the causes of all major mission failures which occur in the conduct of NASA space and aeronautical activities.

2. APPLICABILITY

This Instruction is applicable to NASA Headquarters and field installations.

3. DEFINITION

For the purpose of this Instruction, the following term shall apply:

In general, a failure is defined as not achieving a major mission objective.

4. POLICY

a. It is NASA policy to investigate and document the causes of all major mission failures which occur in the conduct of its space and aeronautical activities and to take appropriate corrective actions as a result of the findings and recommendations.

b. The Deputy Administrator may conduct independent investigations of major failures in addition to those investigations required of the Officials-in-Charge of Headquarters Program Offices as set forth in paragraph 5a.

5. PROCEDURES

a. Officials-in-Charge of Headquarters Program Offices are responsible, within their assigned areas, for:

(1) Informing promptly the Deputy Administrator of each major failure and apprising him of the nature of the failure, status of investigations, and corrective or other actions which are or will be taken.

(2) Determining the causes or probable causes of all failures, taking corrective or other actions, and submitting written reports of such determinations and actions to the Deputy Administrator.

b. When the Deputy Administrator decides to conduct an independent investigation, he will:

(1) Establish a (name of project) Review Board, comprised of appropriate NASA officials;

(2) Define the specific responsibilities of each Board, encompassing such tasks as:

(a) Reviewing the findings, determinations and corrective or other actions which have been developed by contractors, field installations and the Official-in-Charge of cognizant Headquarters Program Office and presenting the Board's conclusions as to their adequacy to the Deputy Administrator.

(b) Reviewing the findings during the course of investigations with cognizant field installation and Headquarters officials.

(c) Recommending such additional steps (for example additional tests) as are considered desirable, to determine the technical and operational causes or probable causes of failure, and to obtain evidence of nontechnical contributing factors.

(d) Developing recommendations for corrective and other actions, based on all information available to the Board.

(e) Documenting findings, determinations and recommendations for corrective or other actions and submitting such documentation to the Deputy Administrator.

c. Procedures for implementing the Board's recommendations shall be determined by the Deputy Administrator.

6. CANCELLATION

NASA Management Manual Instruction 4-1-7 (T.S. 760), March 24, 1964.

Robert C. Seamans, Jr.

Deputy Administrator

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

January 28, 1967

MEMORANDUM For the Apollo 204 Review Board

1. The Apollo 204 Review Board is hereby established in accordance with NASA Management Instruction 8621.1, dated April 14, 1966, to investigate the Apollo 204 accident which resulted in the deaths of Lt. Col. Virgil I. Grissom, Lt. Col. Edward H. White and Lt. Cmdr. Roger B. Chaffee on Launch Complex 34, on January 27, 1967.

2. The Board will report to the Administrator of the National Aeronautics and Space Administration.

3. The following are hereby appointed to the Board:

Dr. Floyd L. Thompson, Director, Langley Research Center, NASA, Chairman

Lt. Col. Frank Borman, Astronaut, Manned Spacecraft Center, NASA

Maxime Faget, Director, Engineering & Development, Manned Spacecraft Center, NASA

E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division, Langley Research Center, NASA

George Jeffs, Chief Engineer, Apollo, North American Aviation, Inc.

Dr. Frank A. Long, PSAC Member, Vice President for Research and Advanced Studies, Cornell University

Col. Charles F. Strang, Chief of Missiles & Space Safety Division
Air Force Inspector General
Norton Air Force Base, California

George C. White, Jr., Director, Reliability & Quality, Apollo Program Office, Headquarters, NASA

John Williams, Director, Spacecraft Operations, Kennedy Space Center, NASA

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4. George Malley, Chief Counsel, Langley Research Center, will serve as counsel to the Board.

5. The Board will:

   a. Review the circumstances surrounding the accident to establish the probable cause or causes of the accident, including review of the findings, corrective action, and recommendations being developed by the Program Offices, Field Centers, and contractors involved.

   b. Direct such further specific investigations as may be necessary.

   c. Report its findings relating to the cause of the accident to the Administrator as expeditiously as possible and release such information through the Office of Public Affairs.

   d. Consider the impact of the accident on all Apollo activities involving equipment preparation, testing, and flight operations.

   e. Consider all other factors relating to the accident, including design, procedures, organization, and management.

   f. Develop recommendations for corrective or other action based upon its findings and determinations.

   g. Document its findings, determinations, and recommendations and submit a final report to the Administrator which will not be released without his approval.

6. The Board may call upon any element of NASA for support, assistance, and information.

Robert C. Seamans, Jr.
Deputy Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

1. The Apollo 204 Review Board was established on January 28, 1967, in accordance with NASA Management Instruction 8621.1, dated April 14, 1966, to investigate the Apollo accident which resulted in the deaths of Lt. Col. Virgil I. Grissom, Lt. Col. Edward H. White, and Lt. Cmdr. Roger B. Chaffee on Launch Complex 34, on January 27, 1967. In order to reflect the current Board membership and to provide further guidance to the Chairman in the conduct of his duties, this memorandum supersedes that of January 28, 1967.

2. The Board will report to the Administrator of the National Aeronautics and Space Administration.

3. The following are hereby appointed to the Board:

Dr. Floyd L. Thompson, Director, Langley Research Center, NASA, Chairman

Col. Frank Borman, Astronaut, Manned Spacecraft Center, NASA

Maxime Faget, Director, Engineering & Development, Manned Spacecraft Ctr., NASA

E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division, Langley Research Center, NASA

Col. Charles F. Strang, Chief of Missiles & Space Safety Division, Air Force Inspector General, Norton Air Force Base, California

George C. White, Jr., Director, Reliability & Quality, Apollo Program Office, Headquarters, NASA

John Williams, Director, Spacecraft Operations, Kennedy Space Center, NASA

Dr. Robert W. Van Dolah, Research Director for the Explosive Research Center, Bureau of Mines, Department of Interior

4. George Malley, Chief Counsel, Langley Research Center, will serve as counsel to the Board.

5. The Board will:

a. Review the circumstances surrounding the accident to establish the probable cause or causes of the accident, including review of the findings, corrective action, and recommendations being developed by the Program Offices, Field Centers, and contractors involved.

5.

b. Direct such further specific investigations as may be necessary.

c. Report its findings relating to the cause of the accident to the Administrator as expeditiously as possible and release such information through the Office of Public Affairs.

d. Consider the impact of the accident on all Apollo activities involving equipment preparation, testing, and flight operations.

e. Consider all other factors relating to the accident, including design, procedures, organization, and management.

f. Develop recommendations for corrective or other action based upon its findings and determinations.

g. Document its findings, determinations, and recommendations and submit a final report to the Administrator which will not be released without his approval.

6. The following amplifies and documents the verbal instructions given to the Chairman, January 28, 1967:

a. The Chairman shall establish such procedures for the organization and operation of the Board as he finds most effective; such procedures shall be part of the Board's records.

b. Board members shall be appointed or removed by the Deputy Administrator after consultation with the Chairman as necessary for the Board's effective action.

c. The Chairman may establish procedures to assure the execution of the Chairman's responsibility in his absence.

d. The Chairman shall appoint or designate such representatives, consultants, experts, liaison officers, observers, or other officials as required to support the activities of the Board. The Chairman shall define their duties and responsibilities as part of the Board's records.

e. The Chairman shall keep the Deputy Administrator advised periodically concerning the organization, procedures, and operations of the Board and its associated officials.

f. The Chairman shall assure that the counsel to the Board develops and maintains memoranda records covering areas of possible litigation.

7. The Board may call upon any element of NASA for support, assistance, and information.

Robert C. Seamans, Jr.
Deputy Administrator

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

After consultation with the Chairman, Dr. Frank A. Long, PSAC Member, Vice President for Research and Advanced Studies, Cornell University, is no longer a member of the Apollo 204 Review Board, effective February 1, 1967.

Robert C. Seamans, Jr.
Deputy Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

Dr. Robert W. Van Dolah, Research Director for the Explosive Research Center, Bureau of Mines, Department of Interior, is hereby appointed to the Apollo 204 Review Board effective February 1, 1967.

Robert C. Seamans, Jr.
Deputy Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

After consultation with the Chairman, Mr. George Jeffs, Chief Engineer, Apollo, North American Aviation, Inc., is no longer a member of the Apollo 204 Review Board, effective February 2, 1967.

Robert C. Seamans, Jr.
Deputy Administrator

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BIOGRAPHICAL DATA
DR. FLOYD LAVERNE THOMPSON

Dr. Floyd LaVerne Thompson is Director, Langley Research Center, National Aeronautics and Space Administration, Hampton, Virginia. He plans and directs research designed to provide the science and technology for a variety of important aeronautical and space programs, including the national effort to land a man on the moon and safely return him to earth. He guided research leading to a number of programs of world importance including Project Mercury, the concept of erectable space vehicles which led to the development of the world's first passive communications satellite, and the first solid fueled launch vehicle to propel a satellite into orbit.

Dr. Thompson was born in Salem, Michigan, November 25, 1898; graduated from high school in Salem in 1917 and served the following four years in the United States Navy. After his war service, he entered University of Michigan and was awarded a B. S. Degree in Aeronautical Engineering in June 1926.

He began his science career July 8, 1926, as a member of the staff of the Langley Research Center of the former National Advisory Committee for Aeronautics, nucleus of the National Aeronautics and Space Administration. Starting as an aeronautical engineer in the Flight Research Division, he progressed through various assignments to Chief of Research in 1945. He was appointed Associate Director in charge of all research September 14, 1952, and in May 1960, became Director of the Center. In addito his duties as Langley Director, Dr. Thompson completed a two-year period of service as Chairman of the Policy Planning Board at NASA Headquarters, Washington, D. C.

He is the author or co-author of 20 technical reports based on research he conducted. He has lectured and participated in a number of technical conferences conducted by NASA, the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers and many other professional organizations. Dr. Thompson was elected in 1949 as a Fellow of the American Institute of Aeronautics and Astronautics. He is a member of the American Association for the Advancement of Science.

Dr. Thompson was cited by the University of Michigan in 1953 as a distinguished alumnus in recognition of his outstanding career in the flight sciences and honored him again in June 1963 by awarding him the honorary degree of Doctor of Science. The College of William and Mary awarded him the honorary degree of Doctor of Science in June 1963.

In May 1963, the President of the United States presented the NASA Medal for Outstanding Leadership to Dr. Thompson at ceremonies at the White House.. He was honored by the NASA "for his outstanding leadership of the scientists and engineers who were responsible for the original technical concepts and who comprised the nucleus of the development team for the space flight missions of the United States in Project Mercury."

Active in civic affairs in Hampton, Virginia, and surrounding communities, Dr. Thompson is a member of the Hampton Rotary Club and the Board of Trustees of the Dixie Hospital. He is an honorary member of the Board of Directors of the Virginia Peninsula Chamber of Commerce, a trustee of The War Memorial Museum of Virginia, and an honorary life member of the Engineers' Club of the Virginia Peninsula.

Dr. Thompson lives at 94 Alleghany Road, Hampton, with his wife - the former Jean Geggie of Hampton. They have three daughters.

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PART II

BIOGRAPHIES

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BIOGRAPHICAL DATA
CHARLES F. STRANG
COLONEL, USAF

Colonel Charles F. Strang is Chief, Missile and Space Safety Division, Directorate of Aerospace Safety, Deputy Inspector General for Inspection and Safety, Headquarters, United States Air Force. In this and prior assignments, Colonel Strang has obtained extensive experience in aircraft and missile accident investigation. He was alternate President of the Air Force Board which investigated the Titan II Missile Accident of August 1965 at Little Rock Air Force Base, Arkansas.

Colonel Strang entered the United States Air Force in January 1940. He was commissioned a Second Lieutenant in March 1943 after graduation from Officer Candidate School, Miami Beach, Florida. He has served in various staff and management positions in the fields of aircraft and missile maintenance engineering and materiel. These assignments included: Chief of Maintenance, 7th Bombardment Wing, Carswell Air Force Base, Texas; Director of Materiel, 72d Bombardment Wing, Ramey Air Force Base, Puerto Rico; Deputy Director of Weapon Systems, Headquarters, 13th Strategic Missile Division, Francis E. Warren Air Force Base, Cheyenne, Wyoming; and Chief of Weapons Maintenance Management, Directorate of Materiel, Headquarters, Strategic Air Command, Omaha, Nebraska.

Colonel Strang has been awarded the Legion of Merit, the Air Force Commendation Medal with Oakleaf Cluster, the Army Commendation Medal and other Service Medals. He has served in South America, Puerto Rico and Europe.

Colonel Strang was born in Philadelphia, Pennsylvania, in 1918. He completed high school at Havertown, Pennsylvania and attended Texas Christian and Florida State Universities. In 1956, he graduated from the Air Force Command and Staff College at Maxwell Air Force Base, Alabama. He is a 1965 graduate of the Industrial College of the Armed Forces, Washington, D. C.

Colonel Strang is married to the former Mildred Irene Wells of Benton, Illinois. They have two daughters and a son. Daughter Charlene is married to Mr. R. James Mitchell of Lincoln, Nebraska. Their son, Charles II, who attends San Bernardino College, and daughter, Karen Sue, reside with the Colonel and Mrs. Strang in Redlands, California.

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BIOGRAPHICAL DATA
E. BARTON GEER

Mr. E. Barton Geer has been Associate Chief of the Flight Vehicle and Systems Division, Langley Research Center, Hampton, Virginia, since 1961. He is responsible for directing and reviewing the design and development work of the three Branches of this Division covering mechanical, structural, dynamic analysis, reliability, qualification testing of spacecraft systems and subsystems. Included are considerations of thermal balance, life support, cryogenics, hypergolic, hydrogen peroxide and cold gas control systems, deployment devices, structures, dynamic vehicles and reentry and orbiting payloads.

Mr. Geer was born April 28, 1919, in Rockwell, Iowa. He attended Iowa public schools and received his Bachelor of Science Degree in Mechanical Engineering from Iowa State College in 1942, at which time he joined the Langley Research Center. From 1942 to 1950, Mr. Geer designed and developed vacuum systems, high pressure air systems, air dryers, refrigeration systems and heat exchangers. In 1950, Mr. Geer became Group Leader of the Mechanical Engineering Group and he held this position for six years. In 1956, Mr. Geer was made Head of the Systems Engineering Section, supervising twenty-five specialists and engineers in the field of thermodynamic, pressure and fluid systems. In addition, he directed the detail design of the 9 foot x 6 foot Thermal Structures air storage and supervised investigation of materials and design methods for obtaining air temperatures up to 5,000° F.

In 1960, Mr. Geer was made Branch Head of Systems Engineering Branch, consisting of 60 specialists and engineers working on systems and controls. In January 1964, Mr. Geer was named Chairman of the Scout Vehicle Design Environmental and Quality Control Committee which consisted of ten members to review the relationship among design, environment, quality control, testing and operations on the reliability of the total Scout Vehicle System. In September 1964, he was appointed Chairman of the structural, mechanical, electrical and pyrotechnic committee to review the related systems of the Pegasus Project. In 1965, Mr. Geer was appointed Chairman of a committee to review the systems, reliability and operational status of the Explorer Injun IV spacecraft. On Project Fire, he participated in the design and flight reviews of the spacecraft and directed the design and review of the tracking telespectrograph. On the Lunar Orbiter Spacecraft, Mr. Geer participated in all the Preliminary and Critical Design reviews.

He is married to the former Iris J. Carr of Fertile, Iowa, and they live at 3203 Matoaka Road, Hampton, Virginia. They have two daughters, Diane and Cheryl.

Mr. Geer is active in Civic and Church work. He is a registered professional engineer in the State of Virginia and is a member of the Engineers' Club of the Virginia Peninsula.

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BIOGRAPHICAL DATA
FRANK BORMAN
COLONEL, USAF
NASA ASTRONAUT

Colonel Frank Borman was assigned as Commander of the third manned Apollo flight. He was Commander on the fourteen-day Gemini VII mission.

Colonel Borman entered the Air Force in June 1950 after graduation from West Point. He received his pilots' wings in 1951. From 1951 to 1956 he was assigned to various fighter squadrons in the United States and the Philippine Islands.

Colonel Borman became an assistant professor of thermodynamics and fluid mechanics at the United States Military Academy in 1957. In 1960 he graduated from the USAF Aerospace Research Pilots School. He remained there as an instructor until 1962 when he was selected by NASA as an astronaut. Colonel Borman served as back-up command pilot for the Gemini IV mission prior to flying on Gemini VII. He has accumulated over 5200 hours flying time, including 4300 hours in jet aircraft.

Colonel Borman has been awarded the NASA Exceptional Service Medal and the Air Force Command Astronaut Wings. He also received the 1966 American Astronautical Flight Achievement Award and the 1966 Air Force Association David C. Shilling Flight Trophy. He was corecipient of the 1966 Harman International Aviation Trophy.

Colonel Borman was born in Gary, Indiana on March 14, 1928, and was raised in Tucson, Arizona. He graduated from Tucson High School in 1946, the United States Military Academy in 1950 and received a Master of Science Degree (Aeronautical Engineer) from the California Institute of Technology in 1957.

Colonel Borman is married to the former Susan Bugbee of Tucson, Arizona. The Borman's have two sons, Fredrich, age 15 and Edwin, age 13.

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BIOGRAPHICAL DATA
GEORGE C. WHITE, JR.

George C. White, Jr., is Director, Apollo Reliability and Quality in the Apollo Program Office, NASA Headquarters. Prior to his appointment to this position in November 1966, he was Chief, Spacecraft and Launch Vehicle Test Performance in the Apollo Test Division since December 1963. He had joined NASA in February 1963 as Chief, Command and Service Module Development.

During the period from October 1953 to February 1963, Mr. White had been with Fairchild Aircraft (now Fairchild-Hiller) in Advanced Design, Engineering Management and Program Management on the WS-123A Goose Missile and the SD-5 Surveillance Drone.

Six years, beginning in October 1947, were spent with NACA, Langley Research Center, in mechanical and structural design of rocket powered research models and special projects in the helicopter and airplane fields.

Mr. White had resigned from the Curtiss-Wright Corporation, Buffalo, New York in December '945 to organize and manage the Dansaire Corporation where he was responsible for design, manufacture and flight test of a three place personal aircraft. He had, previous to this, been in structures engineering at Curtiss-Wright for six years, and in manufacturing at Curtiss-Wright and Piper Aircraft for a total of four years, having started at Piper in 1935.

Mr. White was born in West Grove, Pennsylvania in 1914. He received a B.S. Degree in Aeronautical Engineering from Tri-State College, Angola, Indiana, in 1937. He is married to the former Marcia C. McOmber of Bradford, Pennsylvania and they have two daughters now in college. They reside in Rockville, Maryland, where they are both active in the Rockville Presbyterian Church. Mr. White is a Registered Professional Engineer and an Associate Fellow in the AIAA and he holds a Commercial Pilot's License.

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BIOGRAPHICAL DATA
DR. ROBERT WAYNE VAN DOLAH

Dr. Robert Wayne Van Dolah is Research Director, Explosive Research Center, Bureau of Mines, U.S. Department of Interior, Pittsburgh, Pennsylvania. In this position which he has occupied over twelve years, he plans and directs research in the fields of combustion, explosions and explosives. In addition to the programs supported by direct appropriation, he directs investigations related to a variety of space, military and private industry problems in the field of combustion and explosions. He has provided consultative service to military agencies on a number of occasions. He has participated in several accident investigations involving fire and explosions.

Prior to joining the Bureau of Mines in 1954, Dr. Van Dolah was head of the Organic Chemistry Branch and then head of the Chemistry Division at the U.S. Naval Ordnance Test Station beginning in 1946. In those positions he planned and directed research on the chemistry of propellants and fuels and their combustion characteristics. Before that he served first as assistant to the Scientific Director and later as research Chemist and Group Leader of the William S. Merrell Company, Cincinnati, Ohio.

Dr. Van Dolah was born in Cheyenne, Wyoming, February 1, 1919. He received a Bachelor of Arts Degree in Chemistry from Whitman College, Walla Walla, Washington, in 1940 and a Ph.D. in Organic Chemistry from the Ohio State University, Columbus, Ohio, in 1943. He is a member of the honorary societies: Phi Beta Kappa, Phi Lambda Upsilon and Sigma Xi; and of the professional societies: American Chemical Society, American Association for the Advancement of Science (Fellow), Combustion Institute, American Institute of Aeronautics and Astronautics (Senior Member). He is on the Board of Directors of the National Fire Protection Association.

Dr. Van Dolah is author or co-author of 97 publications and three patents. He is very active in committee work in areas relating to fire and explosions including being Chairman of National Fire Protection Association Committee on Chemicals and Explosives, the Working Group on Hazards, Committee on Safety Criteria of the Interagency Chemical Rocket Propulsion Group. He is a member of American Chemical Society Committee on Chemical Safety and of numerous other committees. In July 1965, he received the Department of Interior Distinguished Service Award.

Dr. Van Dolah lives at 202 Cherokee Road, Upper St. Clair Township (Pittsburgh), Pennsylvania, with his wife, the former Elizabeth M. Becker of Portland, Oregon. They have one daughter in college and two sons in high school.

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BIOGRAPHICAL DATA
JOHN J. WILLIAMS

John J. Williams, Director, Spacecraft Operations, John F. Kennedy Space Center, is responsible to the Director of Launch Operations for the management and technical integration of KSC operations related to preparation, checkout and flight readiness of manned spacecraft.

Since joining the National Aeronautics and Space Administration in 1959, Mr. Williams was the Head of Capsule Systems Branch during the Mercury Program and was the Assistant Manager for Gemini, MSC-Florida Operations until he was moved to his current position in December 1964.

From 1954 to 1959 he was employed by the U.S. Air Force as an electronic engineer in the Directorate of Test Engineering, Air Force Missile Test Center, Florida. He was responsible for the evaluation of various missile prelaunch and flight tests.

From 1951 to 1954 Mr. Williams was employed as an electronic engineer in the Technical Systems Laboratory, Air Force Missile Test Center, Fla., where he was engaged in ground instrumentation and antenna fabrication and testing.

Mr. Williams was employed as an electronic engineer by the U.S. Air Force at Wright Patterson Air Force Base, Dayton, Ohio. He engaged in the development of a cooling system for electronic devices at extremely high altitudes and in the miniaturization of airborne power supplies.

Mr. Williams, a native of New Orleans, Louisiana, graduated from high school in 1944. He served in the U.S. Navy during World War II as an electronic technician and upon his discharge from service entered Louisiana State University. He graduated in 1949, receiving a Bachelor of Science Degree in Electrical Engineering.

Mr. Williams and his organization won many honors, receiving the Group Achievement Award in 1966 for contribution to the success of the Gemini VII/VI Launch Operations and to the success of Project Gemini. In 1966 Dr. Seamans presented him the Outstanding Leadership medal for his work in Manned Space Programs.

He now lives in Eau Gallie, Florida, with his wife, Peggy; daughters, Barbara and Jo Ann; and son Michael.

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BIOGRAPHICAL DATA
DR. MAXIME A. FAGET

Dr. Maxime A. Faget has been the Director of Engineering and Development, Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Texas, since February 1962. He is responsible for technical support of the Gemini and Apollo manned space flight programs and advanced studies into space systems. As a NASA member of the Polaris Missile Steering Task Group, he contributed to the design of that Navy missile. Dr. Faget served on the Steering Committee which helped the NASA Administrator make Project Mercury policy decisions.

Dr. Faget was born at Stann Creek, British Honduras, August 26, 1921. He attended San Francisco, California, Junior College and received a Bachelor of Science degree in Mechanical Engineering from Louisiana State University. He served three years as a naval officer during World War II.

Dr. Faget joined the staff of Langley Research Center, NASA, in 1946 as a research scientist. He worked in the Pilotless Aircraft Research Division; later was named head of the Performance Aerodynamics Branch. He conceived and proposed the development of a one-man spacecraft, later used in Project Mercury. Dr. Faget was one of the original group of 35, assigned as a nucleus of the Space Task Group to carry out the Mercury project.

Dr. Faget has authored and co-authored numerous technical papers on aerodynamics, rocketry, high-speed bomb ejection, reentry theory, heat transfer, and aircraft performance. He is co-author of a textbook, "Engineering Design and Operation of Spacecraft," and is author of a book entitled, "Manned Space Flight." Dr. Faget holds joint patents on the "Aerial Capsule Emergency Separation Device" (escape tower), the "Survival Couch," the "Mercury Capsule," and a "Mach Number Indicator.."

Dr. Faget is a member of the following: Tau Beta Pi, National Engineering Honor Society; Omicron Delta Kappa, National Leadership Honor Society; International Academy of Astronautics of the International Astronautical Federation. He is an Associate Fellow, American Institute of Aeronautics and Astronautics.

Dr. Faget was presented the Arthur S. Fleming Award in 1960. He was presented the Golden Plate Award in 1961 by the Academy of Achievement. In 1963 he was awarded the NASA Medal for Outstanding Leadership and in 1965 he was presented the Award of Loyola. Dr. Faget was honored by the University of Pittsburg, March 1966 by awarding him the Honorary Degree of Doctor of Engineering. Dr. Faget served as visiting Professor teaching graduate level courses at the Louisiana State University, Rice University and the University of Houston.

Dr. Faget is married to the former Nancy Carastro of Philadelphia, Pennsylvania. They reside with their 3 daughters - Ann Lee, Carol Lee and Nanette, and son, Guy, at Dickinson, Texas.

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BIOGRAPHICAL DATA
GEORGE T. MALLEY
Counsel to the Board

Born April 24, 1913, Rochester, New York. Attended public and parochial schools in Rochester and received A.B. Degree from the University of Rochester, and L.L.B. Degree from Cornell University, Ithaca, New York.

Member of the New York Bar.

Attorney, Office of General Counsel, Department of the Navy – 1950 to 1959.

Chief Counsel, Langley Research Center, National Aeronautics and Space Administration, 1959 to present.

Retired Naval Reserve Officer – Active duty World War II – 1939 to 1946, chiefly in South Pacific serving on various types of ships.

Married to Sally E. Wren, 2 step-sons, resident of Newport News, Virginia.

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PART III

BOARD

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 4, 1967

MEMORANDUM FOR RECORD

SUBJECT : Establishment of Apollo 204 Review Board Advisory Group

REFERENCE: Memorandum for the Apollo 204 Review Board from Dr. Robert C. Seamans, Jr., Deputy Administrator, NASA, dated February 3, 1967

1. An Advisory Group is hereby established to support the Apollo 204 Review Board in its investigation. This Group consists of Representatives, Consultants, Liaison Officers, Observers, and Secretariat.

2. The Advisory Group will report to the Chairman, Apollo 204 Review Board.

3. The Advisory Group will consist of:

a. Representative: Represent a major element of NASA or other Government agency having programs and activities associated with the Apollo Program.

b. Consultant: Serve as an advisor to Apollo 204 Review Board by providing views, opinions, information, and recommendations, as appropriate, based on his field of competence.

c. Liaison Officer: Represent an activity having an interest in the Apollo 204 review and provide liaison with that activity by the acquisition of information.

d. Observer: Acquire information relative to his area of expertise and normal responsibility.

e. Secretariat: Provide administrative, secretarial, clerical, and other supporting services to the Review Board.

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4. The following are hereby designated the Advisory Group:

Representatives

Gen. C. H. Bolender	OMSF, represents Apollo Program Director
Mr. C. Mathews	OMSF, Director, Apollo Applications Program
Mr. R. A. Petrone	KSC, Director, Launch Operations
Dr. J. Shea	MSC, Manager, Apollo Spacecraft Program Office
Lt. Col. W. Baxter	USAF, Chief, Range Safety Office, Air Force Eastern Test Range
Dr. G. F. Kelly	Flight Medicine Branch, Center Medical Office, MSC

Consultants

Dr. Frank A. Long	Vice President for Research and Advanced Studies, Cornell University
Mr. J. Yardley	Technical Director, Astronautics Company, Division of McDonnell Company
Mr. G. W. Jeffs	Chief Engineer, Apollo Program, North American Aviation, Inc.
Alternate: Mr. R. L. Benner	Assistant Chief, Engineer, Apollo Program, North American Aviation, Inc.
Mr. Irving Pinkel	Chief, Fluid Systems Research Division, Lewis Research Center
Mr. Thomas G. Horeff	Propulsion Program Manager, Engineering and Safety Division, Aircraft Development Service, Federal Aviation Agency
Dr. H. Carhart	Chief, Fuels Branch, Chemistry Division, Naval Research Laboratory
Mr. John S. Leak	Chief, Technical Services Section, Engineering Division, Bureau of Safety, Civil Aeronautics Board

Liaison

Mr. Duncan Collins	Special Advisor, Secretary of the Air Force, SL Program

Observers

All Astronauts, MSC

Maj. P. A. Butler, USAF

Dr. Kurt H. Debus, KSC

Mr. P. C. Donnelly, KSC

Lt. Col. W. Dugan, USAF

Mr. John Hodge, MSC

Mr. J. King, KSC

Mr. H. E. McCoy, KSC

Mr. R. E. Moser, KSC

Dr. George Mueller, OMSF

Mr. W. P. Murphy, KSC

Gen. S. C. Phillips, OMSF

Mr. G. M. Preston, KSC

Gen. J. G. Shinkle, KSC

Mr. A. F. Siepert, KSC

Mr. W. Williams, KSC

Secretariat

Mr. Ernest Swieda	Executive Secretary

Floyd L. Thompson

Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 7, 1967

MEMORANDUM FOR RECORD

SUBJECT : Establishment of Apollo 204 Review Board Panels

REFERENCE: Memorandum for the Apollo 204 Review Board from the Deputy Administrator, NASA, dated February 3, 1967

1. Task Panels are hereby established to support the Apollo 204 Review Board in its investigation. A Board member, appointed by the Chairman, will serve as Monitor for each Panel.

2. The Task Panels will report to the Chairman, Apollo 204 Review Board.

3. The Panels, under the direction of their Chairmen appointed by the Board Chairman will:

a. Perform all functions within their respective statements of work as approved by the appropriate Board Monitors.

b. Submit work plans through the Panel Coordination Committee to the Review Board for approval.

c. Provide reports to the Review Board, when required, on the progress of work.

d. Work with each other under the cognizance and guidance of the Panel Coordination Committee.

4. The following Panels are hereby designated, together with respective appointed Panel Chairmen and Board Monitors:

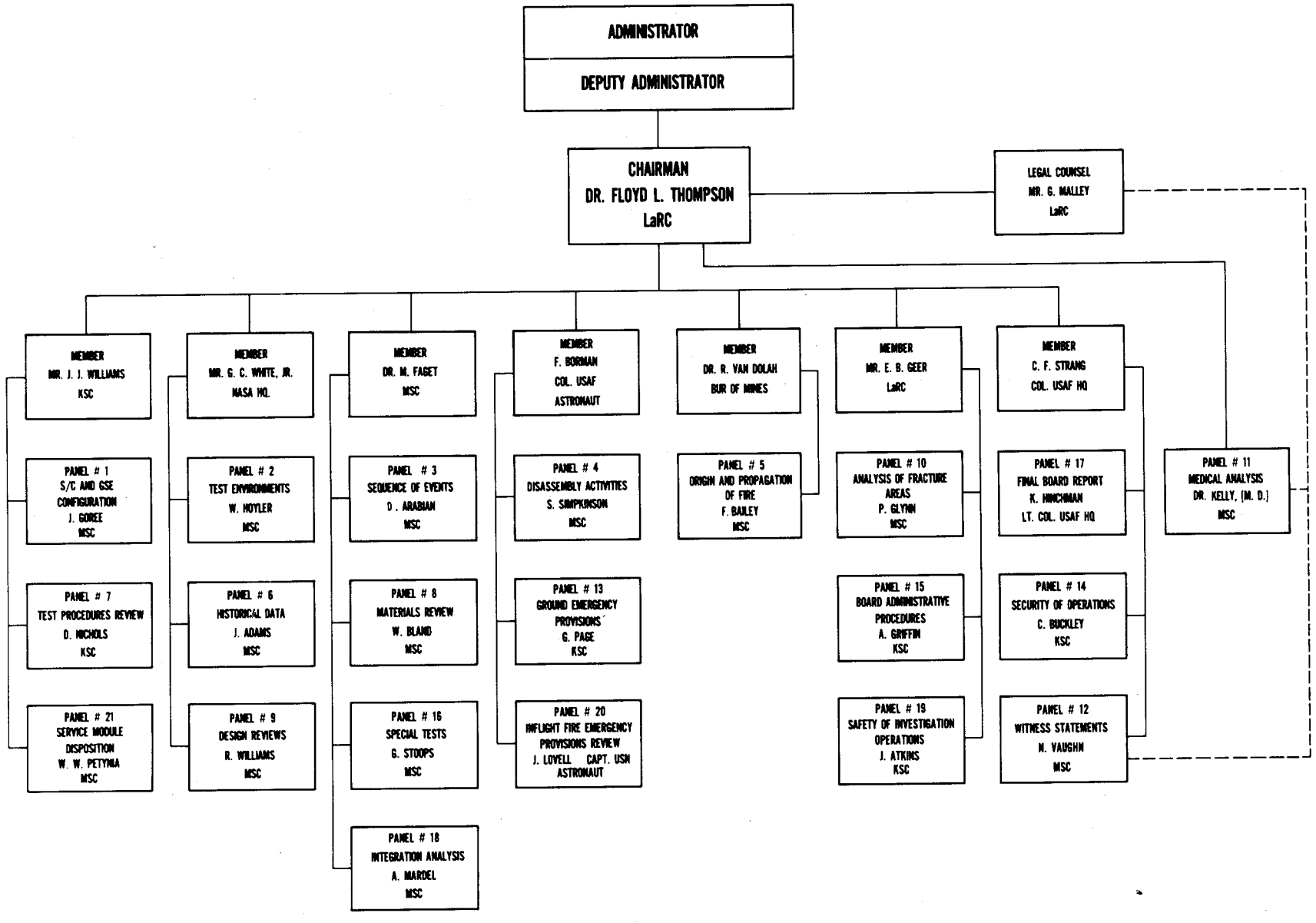
PANEL NO.	PANEL TITLE	PANEL CHAIRMAN	BOARD MONITOR
1	S/C and GSE Configuration	J. Goree, MSC	J. Williams, KSC
2	Test Environments	W. Hoyler, MSC	G. White, NASA Hqs
3	Sequence of Events	D. Arabian, MSC	Dr. M. Faget, MSC
4	Disassembly Activities	S. Simpkinson, MSC	Col. F. Borman, MSC

PANEL NO.	PANEL TITLE	PANEL CHAIRMAN	BOARD MONITOR
5	Origin & Propagation of Fire	F. Bailey, MSC	Dr. Van Dolah
6	Historical Data	J. T. Adams, MSC	G. White, NASA Hqs
7	Test Procedures Review	D. Nichols, KSC	J. Williams, KSC
8	Materials Review	W. Bland, MSC	Dr. M. Faget, MSC
9	Design Reviews	R. Williams, MSC	G. White, NASA Hqs
10	Analysis of Fracture Areas	P. Glynn, MSC	B. Geer, NASA LaRC
11	Medical Analysis	G. Kelly, MSC	Dr. F. Thompson, NASA LaRC G. Malley, Counsel
12	Witness Statement	N. Vaughn, MSC	Col. C. Strang, USAF G. Malley, Counsel
13	Ground Emergency Provisions Review	G. Page, KSC	Col. F. Borman, MSC
14	Security of Operations	C. Buckley, KSC	Col. C. Strang, USAF
15	Board Administrative Procedures	A. Griffin, KSC	B. Geer, LaRC
16	Special Tests	G. Stoops, MSC	Dr. M. Faget, MSC
17	Final Board Report	Lt. Col. K. H. Hinchman, USAF	Col. C. Strang, USAF
18	Integration Analysis	A. Mardel, MSC	Dr. M. Faget, MSC
19	Safety of Investigation Operations	J. Atkins, KSC	B. Geer, NASA LaRC
20	In Flight Fire Emergency Provisions Review	Capt. J. Lovell MSC	Col. Borman, MSC
21	Service Module Disposition	W. W. Petynia, MSC	J. Williams, KSC

Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD AUTHORITY



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BOARD PROCEDURES

The Apollo 204 Review Board was established by the Administrator, National Aeronautics and Space Administration, under the authority of NASA Management Instruction 8621.1, dated April 14, 1966. Dr. Robert C. Seamans, Jr., Deputy Administrator, NASA, in Memoranda dated January 28, 1967, and February 3, 1967, appointed Board Members, defined Board responsibilities and amplified oral instructions to the Board Chairman, Dr. Floyd L. Thompson.

The Board was composed of eight members, including the Chairman. Six members were NASA personnel; one member was an officer from the Aerospace Safety Directorate of the Air Force Inspector General and one member was from the Bureau of Mines, Department of Interior. A Counsel was assigned to provide legal advice.

Twenty-one Task Panels were formed, each reporting to a Monitor who was a Board Member. Task Panels were assigned the responsibility of providing administrative assistance and technical investigation for the Board. Each Panel, with the exception of the Final Board Report Panel, was chaired by NASA personnel experienced in the area of interest of that particular Panel. The Final Board Report Panel was chaired by an Air Force Officer. Each Panel was manned by NASA personnel assisted by contractor personnel in defined technical areas.

In addition, Representatives, Consultants and Observers participated in General Board Meetings and Panel activities. These individuals assisted the Panels and Board Members in their area of expertise and responsibilities.

The established procedure for the Board was to convene a General Session Daily at 10:30 a.m. for approximately one hour. During these meetings, plans and schedules were reviewed. Reports on proposed actions were presented for approval of plans and schedules and the determination of requirements for testing and analyses.

An Executive Session was held each afternoon at 4:00 p.m. This Meeting was restricted to Board Members; however, additional personnel were requested to attend when necessary.

Basic direction to all Board activities was developed and consummated during Executive Sessions. The Executive Sessions provided the Board the opportunity to freely discuss sensitive matters. Plans, schedules and other investigating actions were formally approved by the Board in these Sessions.

Operational procedures for the activities of the Board, the Advisory Group and supporting personnel were delineated in a series of Administrative Procedures authorized by the Chairman of the Board.

The investigation techniques employed by the Board required the coordinated effort of numorous agencies. An overall Master Plan was developed to insure that the investigation was accomplished systematically without disturbing or destroying evidence. This plan required disassembly if the Spacecraft on a component or system basis with continual observation by appropriate Panel personnel and photography before, during and after the removal of each component. The technique of disassembly was validated in Spacecraft 014 Command Module prior to the actual component removal from Spacecraft 012 Command Module involved in the accident. During the disassembly, extreme caution was exercised to prevent disruption of adjacent areas. As components were removed they were identified and placed in a bonded area and made available for inspection as authorized by the Board.

Simultaneously with Spacecraft disassembly, extensive testing and numerous analyses were accomplished. These tests and analyses were accomplished by many agencies: i.e., Kennedy Space Center, Manned Spacecraft Center, United States Air Force, Bell Laboratories, contractors, sub-contractors

and vendors. All Telemetry data, Spacecraft Records, and Design Documents were reviewed in detail. When anomalies were discovered, they were analyzed completely to determine their relationship to the accident.

The investigation technique also provided rigid control for all material associated with the review. Immediately after the accident, all possible relevant material was impounded. This material was analyzed in detail and released only after determination that it did not contribute to the accident or was no longer required by the Apollo 204 Review Board

The Final Report of the Apollo 204 Review Board was designated to document the findings, determinations and recommendations for submission to the Administrator, National Aeronautics and Space Administration.

A General File of the materials of the Apollo 204 Review Board investigation has been established. The Director, Langley Research Center, NASA, Virginia, has been designated the custodian of the file. The General File containing Telemetry Data, Spacecraft Design Records, Data from special tests and analyses conducted, and other documents relating to the investigation will be physically located at Langley Research Center. The Spacecraft, related hardware and drawings, residue from the fire and Astronaut's equipment will be stored at Kennedy Space Center with the Manager, Apollo Spacecraft Program Office, Manned Spacecraft Center, Houston, Texas, acting as custodial agent for the Langley Research Center. Medical records specifically associated with the investigation will be stored at Manned Spacecraft Center, in custody of the Director of Medical Research and Operations, who is Custodial Agent for Langley Research Center. All materials in the General File will be securely stored at the designated locations for a period of ten years, unless sooner released by proper authority.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

February 8, 1967

IN REPLY REFER TO Chairman, Apollo 204 Review Board

TO: DISTRIBUTION

SUBJECT: Transcripts of Review Board Sessions

1. During the first days of the sessions of the Apollo 204 Review Board, the Board heard discussion, suggestions, extemporaneous remarks by Board members, Advisory Group members and technical experts engaged in studies relevant to the review, and accounts, to be verified, from two on-the-scene witnesses and one individual who was observing the monitors in the blockhouse.

2. In the free and open discussion, in many cases the identity of the speakers was not established and the remarks were not clearly related to the subject under discussion. The result is that the transcript of the proceedings of the first days (other than eye witness accounts) is valuable primarily as background material that provides a useful source for identifying potential review action.

3. In view of the foregoing, the minutes of the Review Board meetings on January 28, 29, and 30 will be utilized only as reference material with limited distribution, with the exception of identifiable eye witness accounts which will be appropriately incorporated in the final report.

Dr. Floyd L. Thompson

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Note: The Board Proceedings are the highlights of Board activities. Complete transcripts of General Sessions of the Apollo 204 Review Board are contained in Appendix A.

January 28, 1967

(1) The Chairman and several Members of the Board assembled at Kennedy Space Center (KSC) at midday, January 28 and met with the Deputy Administrator, Dr. Robert C. Seamans, Jr.; the Apollo Program Director, Major General Samuel C. Phillips; and other officials from NASA Headquarters, the Manned Spacecraft Center (MSC) and Kennedy Space Center. These NASA officials provided a quick appraisal of the circumstances surrounding the accident and actions already taken at KSC. This meeting was followed by an initial general session of the Board in the Mission Briefing Room, a secure area used to conduct Board business.

(2) After a general discussion, the meeting was adjourned to permit the Board to visit the scene of the accident at Launch Complex (LC) 34. Upon completion of this inspection, the Board reconvened in general session and initiated detailed procedural planning for conduct of the Review.

January 29, 1967

(1) Colonel Frank Borman briefed the Board on his inspection of the Spacecraft (Command and Service Modules). The purpose of this inspection was to verify the position of circuit breakers, switches, etc. Immediately following the inspection, many photographs were taken of the exterior and interior of the Command Module (C/M) with emphasis on switches and circuit breaker panels.

(2) The Board interviewed Mr. Donald O. Babbitt for approximately 45 minutes and Mr. James D. Gleaves for approximately 30 minutes. Both are employees of North American Aviation, Inc. (NAA) and were on level A-8 of L C 34 at the time of the Apollo 204 accident.

(3) The Pyrotechnic Installation Building (PIB) was assigned to the Board to display the debris and Spacecraft (S/C) components after removal from the Launch Complex.

(4) Dr. Thompson, Board Chairman, asked Dr. George E. Mueller, Associate Administrator for Manned Space Flight (who was at KSC), for assistance in obtaining flame propagation experts to assist the Apollo 204 Review Board. Dr. Thompson suggested these experts might be obtained from the following organizations:

a. Lewis Research Laboratory, NASA
b. Bureau of Mines
c. Federal Aviation Agency

(5) Dr. Thompson authorized selected personnel from the local press pool to photograph and observe the C/M. Dr. Thompson authorized one still and one motion picture photographer with one writer representative to visit LC 34. They were escorted by Mr. Charles L. Buckley, Jr., Chief, Security Office, KSC and Mr. John W. King, Chief, Public Information Office, KSC. Dr. Thompson instructed Mr. Buckley and Mr. King to restrict the press personnel to photography and observation and not allow any questions pertaining to the accident.

(6) Dr. Thompson established an ad hoc committee composed of Mr. John J. Williams, Mr. E. Barton Geer, Mr. Charles Mathews, Mr. John F. Yardley, Mr. George Jeffs and Colonel Charles F. Strang. They were to organize Task Panels to accomplish the accident investigation in a systematic manner.

January 30, 1967

(1) Dr. Robert W. Van Dolah, Bureau of Mines, Mr. I. Irving Pinkel, Lewis Research Center, Mr. T. Horeff, Federal Aviation Agency, joined the Apollo 204 Review Board as Consultants.

(2) Membership on the special ad hoc committee that was established on January 29, 1967 to make recommendations on the types of special Panels was changed to: Colonel Borman, Mr. Jeffs, Mr. Yardley, Mr. Mathews, Dr. Maxime A. Faget and Mr. Williams, Chairman. Dr. Thompson directed that the assignment of tasks will be supported by a statement of work, i.e., "guidelines and basis for understanding." Mr. Mathews presented an oral outline of the 19 recommended Panels and the work objectives of each. A Board Member was assigned to monitor each Panel and to serve as the focal point through which the Panels would report to the Board.

(3) Dr. Thompson designated Colonel Strang to assume the responsibility of managing the assembly of all information and data that will be embodied in the Final Report. Colonel Strang was also assigned to to plan the format of the Report.

(4) Lt. Colonel James W. Rawers, Range Safety Division, Analysis Section, presented on oral report on what the Air Force Eastern Test Range (AFETR) personnel saw at the time of the accident.

(5) Dr. Thompson announced that Mr. George T. Malley, Chief Counsel at Langley Research Center, will serve as Counsel for the Board.

(6) Dr. Faget introduced Mr. Alfred D. Mardel, who presented a briefing on data and sequence of events.

January 31, 1967

(1) Dr. Thompson received from Dr. Seamans a "Memorandum for the Apollo 204 Review Board" dated January 28, 1967, which established the Review Board. Dr. Thompson discussed the memorandum at length and made distribution of copies to all Board Members.

(2) The Board was advised by Colonel Strang that the accident which occurred in an altitude chamber at Brooks Air Force Base, Texas on January 31, 1967, might be of particular interest to the Board. He presented a short briefing of the circumstances. The Chairman requested Colonel Strang to provide follow-up for the Board.

(3) Lt. Colonel William D. Baxter (AFETR Representative to the Board), advised of existing hazards associated with the spacecraft. These included: high pressure oxygen bottles which may be pressurized to 485 pounds per square inch (psi) and subject to embrittlement; pyrotechnics on the Service Module; and the Launch Escape System (LES), which has a 9000 pound thrust rocket motor. An engineering review was made of thise potential hazards and it was agreed that before any work could proceed, these specific items must be removed.

(4) A technical briefing on telemetry data, recorded prior to and during the accident was presented to the Board. These data indicate discrepancies in certain channels. Therefore, without further evaluation, the telemetry data are inconclusive.

(5) In lieu of classifying Review Board records as confidential, a special cover sheet will be used to comply with the Chairman's instruction that all Apollo 204 Review Board records and material be treated as "Confidential." A supply of these cover sheets was provided.

(6) The Chairman of Panel 4, Disassembly Activities, presented a briefing on the Spacecraft Debris Removal Plan. The Board approved the plan to the point of removing the astronauts' couches.

(7) Panel 19, Safety of Investigation Operations, was formed.

February 1, 1967

(1) The task of removal of the Launch Escape System was delayed until retro rockets and other ordnance devices could be removed from the Saturn Launch Vehicle (SLV) and Spacecraft.

(2) Dr. Van Dolah, Bureau of Mines, replaced Dr. Frank A. Long, Vice President for Research and Advanced Studies, Cornell University, as a Member of the Board. Dr. Long, whose other responsibilities precluded full time service with the Board, will continue to serve as a Consultant. (Dr. Van Dolah was assigned the responsibility of Panel Monitor for the Panel on Origin and Propagation of Fire.)

(3) Dr. Thompson appointed a committee, composed of two Board Members and three Consultants, to coordinate Panel activities and bring to the attention of the Board those actions requiring specific approval. This group will be known as the Panel Coordinating Committee and be required to present daily activity reports to the Board. This committee supplanted the ad hoc committee that had planned the organization of the Panels. A procedure was established for orderly, controlled (numerically sequenced from 0001) presentation of proposed "Action Items" to the Board for approval prior to implementation of hardware removal, special tests and other Review Board activities.

(4) Proposed Action Items 0001-0007 were presented for consideration by the Board. 0001-0006 were approved, 0007 was deferred.

(5) The Board reviewed the methods used in releasing public statements. Dr. Thompson advised that no public statements will be made until approved by him.

(6) Colonel Strang briefed the Board on a proposed Final Report format. It was necessary that a Report format be approved at an early date in order that an orderly flow of data from the Panels could be maintained. The proposed Final Report format was a modified version of the one used by the Air Force for accident investigations. The proposal was tentatively accepted.

(7) Colonel Strang requested copies of all witness statements be provided each Board Member as they are developed. This will permit a prompt review so that additional interviews can be arranged if necessary.

(8) Dr. Thompson announced an Executive Session (Board Members) will be held daily at 4:00 p.m.

(9) Dr. Faget presented a status report on work in progress. He outlined the daily reports as follows:

a. Activities accomplished on the Launch Complex and in other related areas,

b. Items needing Board approval for future activities,

c. Progress analysis and anticipated work.

February 2, 1967

(1) Dr. Seamans attended the General Board Session. He reiterated and emphasized that all news releases would be made through the Board Chairman.

(2) Dr. Thompson announced that Mr. Jeffs had been appointed a Consultant in lieu of Board membership.

(3) Command Module 014 arrived from Downey, California and is in place at the Pyrotechnic In-

stallation Building (PIB), KSC. This Module will be used for training of technicians who will dis-disassemble C/M 012; i.e., prior to the removal of any component from 012, the technicians will perform similar tasks on 014. In this way, they will become familiar with all actions required to remove any single component. Consequently, little or no damage or disruption will take place during the removal of items from 012 as it is disassembled. As a component is removed, it will be transported from the LC and placed in the PIB. It was agreed that all equipment associated with the accident will also be located in the PIB. This includes Command Module hardware and support equipment. Spacesuits and other associated flight equipment will be placed in a special room within the PIB where strict access control will be maintained.

(4) The most significant event to date was the removal of the Launch Escape System from the Command Module, thereby removing the greatest potential hazard to disassembly operations. With this task completed, it is estimated that members of the Fire Propagation Panel will enter the Command Module on February 3, 1967. Completion of the Launch Escape System removal will also permit extensive photographic coverage of the inside of the Command Module.

(5) Colonel Strang distributed copies of a status report on the recent accident at Brooks Air Force Base for the Board's information. He stated that authority had been received from the Chief of Staff, USAF, for him to maintain direct contact with the Accident Investigation Board at Brooks AFB.

(6) Mr. Malley, Counsel for the Board, was requested to prepare a statement to be read to each witness prior to making a statement. It will inform the witness of the Board's precise intention with respect to use of the statement.

(7) Proposed Action Items 0008 - 0024 were presented for consideration and approved by the Board.

(8) The matter of samples for analysis was again brought up and it was decided as a general directive that samples be reserved to provide for testing by two outside or independent agencies. If certain conditions make this impossible, appropriate action should be brought back to the Board for approval.

February 3, 1967

(1) The Chairman announced he had received a telephonic draft of the revised authority from NASA under which the Board is to be conducted. He also explained to the Board that this new authorization grants him, as Chairman, the authority to change the composition of the Board advisory group, to appoint an Acting Chairman and appoint any other positions of the advisory group he deems necessary. Dr. Thompson appointed Colonel Strang to serve as Acting Chairman in the absence of the Chairman.

(2) The Board reviewed the Lockheed Aircraft Corporation film entitled, "Investigation Report, Aircraft Wire Harness Fires, Revision 2." Through telephone conversations with Colonel Strang and Mr. Malley, Mr. Gilley, Lockheed Georgia Company of the Lockheed Aircraft Corporation, granted permission for the Board to reproduce the film and copies of the report thereto. Three Panels requested copies of the reports, which were made available.

(3) Dr. Thompson requested a document be written establishing procedures for entry to Command Module 012. Coordination of requirements and priorities will be controlled by the Panel Coordinating Committee. Entry to the C/M will be controlled by Colonel Borman or his delegated representative.

(4) A sequence of events display (immediately preceding and following the accident) was prepared from telemetry data and positioned in the Mission Briefing Room. The time span of the display is from 23:30 to 23:33 hours, Greenwich Mean Time (6:30 to 6:33 p.m. EST) on January 27, 1967. Significant information on several spacecraft systems such as communications, instrumentation, electrical power, environmental control, guidance and navigation and stabilization and control is included on the display.

It will be updated as additional data are analyzed and will be available for easy reference by Board Members.

(5) Dr. Thompson requested that Board Members have their Panel Chairmen submit work requirements and priorities in writing to the Panel Coordination Committee so a schedule can be developed.

(6) Colonel Borman reported that the Debris Removal Plan, as approved by the Board, had progressed satisfactorily. The next phase will involve the use of protective covers (plywood) for the couches so detailed examinations of the C/M interior can be accomplished.

(7) Proposed Action Items 0025 - 0027 were presented and approved by the Board.

(8) Procedures to further control entry to the Command Module, Launch Complex 34 and the Pyrotechnic Installation Building were approved by the Board.

(9) Dr. Homer Carhart, Chief of Fuels Research, Chemistry Division, Naval Research Laboratory, Washington, D. C., was assigned to the Fire Propagation Panel.

(10) Dr. Thompson appointed the following as Representatives to the Board: Brig. General C. H. Bolender, USAF and Mr. Charles Mathews, NASA, Washington, D.C.; Dr. Joseph F. Shea and Dr. G. Fred Kelly (M.D.), MSC; Mr. Rocco Petrone, KSC; Lt. Colonel William D. Baxter, Air Force Eastern Test Range.

February 4, 1967

(1) Dr. Thompson asked the Board Members to support the Public Information Office (PIO) in obtaining photographs to keep the public informed of activities and progress.

(2) A system was established to ensure that all recommendations and offers of assistance received by NASA, regardless of source, be referred to the Review Board for appropriate action and acknowledgment.

(3) A draft report of the use of internal/external power on the C/M was distributed by Dr. Faget for the Board's information.

(4) Dr. Thompson stated that the list of advisory groups (Representatives, Observers, Liaison, Consultants) is being prepared. The individuals assigned to these advisory groups will be identified within their respective organizations and by position held in that organization.

(5) Dr. Thompson directed Mr. Williams to develop an overall master plan including important milestones and estimated time frames. He called a meeting following today's General Board Session to discuss this with Mr. Williams and some of his committee members.

(6) Mr. Scott Simpkinson, Panel 4 Chairman, presented and distributed the disassembly schedule. He estimated removal of the couches from C/M 012 by 5:00 a.m., and installation of the false floor by 12:00, February 5. This false floor was installed in C/M 014 last night as an exercise prior to having it installed in C/M 012.

(7) Colonel Borman asked for and was permitted release of the impounded flight suits of the backup crew for use in an egress test. The Board will view this test in the Simulator Building, Sunday, February 5, at 10:00 a.m.

February 5, 1967

(1) Members, Consultants and Observers of the Board visited the Spacecraft Simulator. The simulator performs many functions including navigation, earth observation and inflight procedures. At the time of the visit three astronauts were practicing inflight emergency procedures. One of the procedures was donning the space suits. This was carefully timed and required a total of 12 minutes to perform the task. Two astronauts gave a detailed briefing on the composition, function and operating procedures for all components of the space suit. The Board Members also inspected the inside of the simulator which is configured to duplicate Spacecraft 012 in most areas.

(2) Dr. Thompson, Mr. Geer and Mr. Malley departed for Langley Research Center, Virginia. They are scheduled to return in the late afternoon on February 6, 1967. In accordance with Dr. Thompson's previous instructions, Colonel Strang served as Acting Chairman of the Board.

(3) Representatives of the Board visited Launch Complex 34 and made a very detailed inspection of movable platforms A-7 and A-8 which surrounded the Apollo Spacecraft. During this inspection, the installation of the false floor in the Command Module was observed. Since removal of the astronauts' couches a false floor was constructed and suspended from the Command Module ceiling and entrance hatch. This will facilitate inspection of the floor of the module without disturbing any evidence of the fire damage.

February 6, 1967

(1) Colonel Strang, acting for Dr. Thompson, conducted the General Session.

(2) The Master Plan Milestone Display was distributed and explained by Mr. Williams. The Systems Integration Panel will prepare a Phase "A" plan today and submit same for Board approval. The Board Members were asked to review this Master Plan with their Panel Chairmen and provide comments to Dr. Thompson.

(3) Lt. Colonel Baxter reported the status of the Witness Statements as of 10:30 a.m., February 6. There were 90 statements; the original package distributed on February 2, the first addition on February 3 and the third and fourth addition on February 4 and 6 respectively. The distribution list is amended to include copies for Panels 6, 14, 17 and 18.

(4) Mr. Jeffs announced that a team made up of representatives of AiResearch and North American Aviation, Inc., arrived at KSC on February 6 to inspect the Command Module and to propose further action relative to the Environmental Control Unit (ECU) and Environmental Control System (ECS).

(5) Reconsideration was requested of Action Item 0007, Medical Data Acquisition System Removal, that was presented to the Board on February 1 and deferred at that time. Technicians are now prepared to remove the tape recorder from the C/M and remove the tapes for analysis. Action Item 0028 was distributed to the Board. Approval was granted for work to proceed on both Items 0007 and 0028, providing that appropriate members of Panels 4 and 5 are present.

(6) Colonel Strang stated that Dr. Thompson had requested that the "Life Sciences" part of the Final Report include an analysis of the escape system and appropriate re-design recommendations. This system falls within the purview of the Ground Emergency Procedures Review Panel 13, the In-flight Fire Emergency Provisions Review Panel 20 and the Design Review Panel 9 in addition to the Medical Analysis Panel 11. Dr. G. Fred Kelly, Chairman of Panel 11, was requested to coordinate and interface the findings of the above Panels.

February 7, 1967

(1) The Board received a detailed preliminary report from Mr. Pinkel, a Member of the Fire Propagation Panel. This report described the areas of the Command Module (C/M) which received the greatest fire damage, the most probable fire paths and a description of combustible material in the C/M. He stated the oxygen available in the C/M would permit burning of only 12-15 lbs. of combustible material. Solid combustible materials used in the C/M includes plastics in the nylon, polyurethane and silicone rubber class. The liquid coolant ethylene glycol could also become a fuel if it escaped from the closed coolant system. Additional inspections and investigations are required by this Panel to develop conclusive findings.

(2) Request for approval of Action Items 0029 through 0052, approved by the Board at the Executive Sessions held February 6 and 7 were read for the record by Mr. Williams.

(3) A technical team from AiResearch Company and North American Aviation, Inc., under NASA supervision, completed an inspection of the Environment Control Unit in C/M 012, preparatory to developing a removal plan. The plan will be coordinated with the appropriate Panels.

(4) The Board approved the Master Planning Schedule of the Board's activities as submitted by Mr. Williams on February 6, 1967.

(5) The Board approved the procedures for material testing and analysis. These procedures establish specific channels for all agencies involved in testing and analysis. Included in the channel were several check points to ensure the establishment of adequate control.

(6) A new Panel 21, Service Module Disposition, has been formed. This Panel will plan and execute the necessary Service Module activities. The Panel will obtain Board approval for the demating of the Command and Service Modules.

February 8, 1967

(1) The Chairman reviewed and re-emphasized the Board's charter as amplified in a memorandum from Dr. Seamans dated February 3, 1967. In consonance with guidance contained therein, he also defined the relationship of the personnel supporting the Board, i.e., Representatives, Consultants, Liaison, Observers, the Secretariat and Panel Chairmen.

(2) The batteries used for reentry power were removed from the C/M after approval by the Board. There was no indication that these batteries contributed to the mishap.

(3) It was agreed that each system in the C/M would be removed individually, inspected and evaluated. However, each system will be removed only after it is conclusively determined it did not contribute to the source of ignition and is no longer required to evaluate interface with other systems and the Service Module.

(4) As a result of the interest shown by the Apollo 204 Review Board in the film, "Aircraft Wire Harness Fires," Manned Spacecraft Center (MSC) has been requested to conduct research on the phenomena shown in the film. The research will attempt to determine the validity of the wet wire phenomena as related to the type of wires used in the C/M when exposed to wide range of checkout and mission environments, including 100 per cent oxygen.

(5) Proposed Action Items 0053 through 0063 were presented and approved by the Board.

(6) It was brought up by Mr. C. Mathews that fairly heavy activity might take place in the area of testing systems and components as they are moved from the C/M to the plants of prime contractor and vendors. Discussion followed resulting in a requirement for the Board to determine who should accompany this material, i.e., representatives from NASA, NAA, subcontractors and/or an independent representative. An ad hoc committee was called to meet with Mr. Malley at 1:00 p.m. today to prepare a recommendation for the Board on this matter.

February 9, 1967

(1) A standardized diagram of various Apollo Command Module views was distributed for use by Panel members and for reference in the Final Report.

(2) A method for controlled handling of accident material for testing, analysis, etc., was approved by the Board. This applies to tests at both Kennedy Space Center and material sent off-site.

(3) The Chairman of each Panel presented a briefing to the Board on Panel accomplishments, future plans and, in a few cases, specific findings.

(4) A detailed report on the initial assessment of structural damage of the Command Module was presented to the Review Board. This report was based upon a visual inspection only. A more complete assessment of structural damage is to be accomplished in conjunction with the removal of each system.

(5) Proposed Action Items 0064 through 0080 were presented and approved by the Board subject to certain clarifications.

February 10, 1967

(1) Dr. Seamans and staff members attended the meetings at KSC this date. Short presentations were made to them on plans for the Final Report, fire propagation, photographic control, data integration and medical analysis. These officials also visited the Pyrotechnic Installation Building (PIB) and other areas under the Review Board's jurisdiction.

(2) The Chairman advised that Panel reports will be signed by Panel Chairmen only. Board Monitors of Panels were requested to assume the responsibility for assuring minority views are given proper consideration. If serious differences are not resolved they are to be included in Panel reports for the Board's consideration.

(3) The Chairman emphasized to the Board Members who are Panel Monitors that copies of all Panel reports should be forwarded to the, Panel 18 Integration Analysis for coordination and integration.

(4) A report on the assessment of manning requirements to assure proper implementation of tasks and to meet present schedules was requested of Board Monitors for each Panel. This assessment is due Tuesday morning, February 14.

(5) Following the adjournment of the Board meeting, a film was shown of approximately 10 minutes duration depicting Flammability of Paraffin at zero g in 100% Oxygen.

(6) Proposed Action Items 0081 and 0084 through 0107 were considered by the Board and approved. Note: Numbers 0082 and 0083 were not used.

February 11 and 12, 1967

(1) No formal meetings of the Board were conducted. Investigation continued on C/M and on debris and components that had been removed to the PIB.

(2) Reviews of work progress were conducted individually by Board Members.

February 13, 1967

(1) A nine-minute film, recently completed at MSC on C/M 008, was shown. This film was the result of a photographic study of what could be seen through the hatch window by a TV monitor, with varying degrees of external and internal lighting. This film will be available for correlation with eye witness accounts.

(2) Dr. Thompson advised that a meeting of the Board and Deputy Administrator, NASA, has been scheduled for February 22, 1967. The meeting will be primarily concerned with interim reports of the Panels.

(3) Dr. Thompson requested the Office of Manned Space Flight, Marshall Space Flight Center, Kennedy Space Center and Manned Spacecraft Center to provide the Board a detailed description of their responsibilities and organizational relationships and alignment in the Apollo program. This information will be used to perform a review of the Apollo Program organization.

(4) Proposed Action Items 0108 through 0112 were considered and approved by the Board.

(5) Dr. Van Dolah was requested to prepare a report by February 15, 1967, on flame propagation, for submission to Dr. Seamans.

(6) A group of specially built tables have been placed in the main bay of the Pyrotechnic Installation Building. Items removed from C/M 012 are displayed on these tables to permit required inspections without handling.

(7) It was decided by the Board to have special studies of the space suits conducted by the manufacturer and Manned Spacecraft Center's Crew Systems Division. This would enable the Board to obtain expert opinions regarding possible contributing factors to the accident and to gain information regarding future space suit design.

(8) Dr. Thompson reported that seven people from Marshall Space Flight Center and one person from Langley Research Center had arrived to support various Panels.

February 14, 1967

(1) The Chairman read excerpts from the report of the "Apollo Accident Hearing Before the Committee on Aeronautical and Space Sciences, United States Senate, Ninetieth Congress, February 7, 1967." He emphasized the importance being given this review by that Committee and the responsibility of the Board to respond promptly and completely to the Administrator.

(2) Selected Board Members and Panel Chairmen were instructed to prepare an interim report on actions to date with significant information and tentative findings. The Board will conduct a critique of the material to be presented on February 19, 1967. On February 22, 1967, the interim report will be presented to Dr. Seamans. The content and order of this briefing will be: (a) Board Organization and Investigation Techniques, Colonel Strang; (b) Description and Course of Fire, Mr. Pinkel; (c) Background, Mr. White; (d) Analysis and Tests in Pursuit of Cause, Dr. Faget; (e) Tentative Findings and Preliminary Recommendations, Colonel Borman.

(3) Dr. Van Dolah presented a report on the propagation of fire and tentative findings of Panel 5 for submission to Dr.. Seamans.

(4) The removal of systems from the C/M has progressed satisfactorily. As a result, the C/M is scheduled to be removed from the Launch Vehicle on Friday, February 17, 1967. This action coincides

with the Master Planning Schedule developed by the Review Board on February 7, 1967.

(5) Proposed Action Items 0113 through 0117 were considered and approved by the Board.

February 15, 1967

(1) Dr. Thompson received a letter dated February 10, 1967 from Dr. Seamans. The letter emphasized the importance of the investigation and transmitted copies of four letters from Senator Anderson to the Administrator, NASA, concerning the investigation. In essence, these letters state that the Senate Committee expects to be advised on a recurring basis as to the findings of Apollo Review Board.

(2) The Board received a detailed briefing on the recorded anomalies prior to and during the accident, These anomalies were transmitted by the C/M telemetry system to several recording stations. The principle anomalies were:

a. Communication difficulties

b. High flow rate in oxygen system

c. Disruption of alternating current

d. Telemetry readings from a disconnected gas chromatograph connector

e. Change in gimbal angle of the inertial measurement unit which may indicate movement in the C/M

At the conclusion of this briefing, direction was given to conduct further analyses and testing in an effort to obtain specific conclusions.

(3) A briefing and written report on Astro-Communication Circuits was presented to the Board.

February 16, 1967

(1) The task of removing the Command Module from the Space Vehicle was approved by the Board. Extensive photograph (motion and still) of this task was accomplished for review by the Board and possible release to the Press.

(2) Colonel Borman suggested the work schedule be reduced to a 2-shift, 6-day week, rather than the 3-shift, 7-day week, which has been in effect since the accident on January 27, 1967. This suggestion was approved and will be implemented after the C/M is positioned in the bonded area of the Pyrotechnic Installation Building (PIB) on February 17, 1967.

(3) Proposed Action Items 0118 through 0144 were considered and approved by the Board.

February 17, 1967

(1) Proposed Action Items 0145 through 0147 were considered and approved by the Board.

(2) The Board met with the Panel Chairmen to review the Panel preliminary reports. These reports will be used as a basis for preparation of the briefing for Dr. Seamans, February 22, 1967.

(3) Material Release Record Items 0001 through 0056 have been considered and approved by the Board. This system provides a formal and controlled means of releasing for normal program use various hardware, software, spares, tools and expendable supplies that were impounded at the time of the accident

and have been determined not to be related to the accident.

(4) The Command Module was separated from the Service Module and moved to the PIB where disassembly and investigation will continue.

February 18, 1967

(1) To clarify the content of the interim report briefing for Dr. Seamans, Colonel Strang presented an outline to the Board for approval. The outline was approved.

(2) In addition to the briefing for Dr. Seamans on February 22, 1967, the interim report briefing will be presented on February 21, 1967 to Dr. Mueller and his staff. Both briefings will be given at Kennedy Space Center.

(3) Panel summary reports were distributed to Board Members and Panel Chairmen. Dr. Thompson cautioned on the distribution control of these reports.

(4) Proposed Action Items 0148 and 0149 were considered and approved by the Board.

February 19, 1967

(1) The Board met to further develop the briefing for Dr. Seamans. Each speaker made an initial presentation using visual aids. Additions and corrections were discussed.

February 20, 1967

(1) The Board approved a plan for removing the Service Module from the Launch Vehicle. The actual removal was scheduled for February 21, 1967, whereupon the Service Module will be transported to the Manned Spacecraft Operations Building at KSC for detailed examination and testing.

(2) Dr. Thompson directed that a plan be developed to release Launch Complex 34 to Kennedy Space Center for normal use, following removal of the Service Module.

(3) Proposed Action Items 0150 and 0151 were considered and approved by the Board.

(4) Preparations are being made to remove the heat shield from the Command Module so that the floor of the Command Module can be inspected from the lower side.

February 21, 1967

(1) A briefing on the significant information, tentative findings and preliminary recommendations as developed by the Apollo 204 Review Board, was presented to Apollo Program officials by Board Members. The officials attending this briefing included: Dr. George E. Mueller, NASA, Washington, D. C., Dr. Kurt H. Debus, KSC, Dr. Robert R. Gilruth, MSC, Dr. Wernher Von Braun, MSFC, Major General Samuel C. Phillips, USAF, NASA, Washington, D. C., Brig. General C. H. Bolender, USAF, NASA, Washington, D.C., Lt. General Frank A. Bogart, USAF (Ret.), NASA, Washington, D. C., Major General Julian B. Bowman, USAF (Ret.), NASA, Washington, D. C., Mr. Christopher C. Kraft, Jr., MSC, Mr. George A. Low, MSC. These officials were accompanied by key staff personnel. In addition to the Board, Panel Chairmen and Representatives to the Board were in attendance. The briefing was a preview of that to be given to Dr. Seamans on February 22, 1967. The Apollo Program officials and their staffs were expressly invited by Dr. Thompson.

(2) Proposed Action Item 0152 was considered and approved by the Board.

(3) Material Release Record Items 0057 through 0072 were considered and approved by the Board.

(4) Mr. Ashmun Brown, Office of Chief Counsel, KSC, was assigned to assist the Counsel to the Board.

February 22, 1967

(1) The formal briefing on the progress of the Apollo 204 Review Board was presented to Dr. Seamans. This briefing was generally similar to the one given on February 21, 1967 to Apollo Program officials, who were also in attendance on February 22, 1967. Additionally, Dr. Charles A. Berry (M. D.), Dr. Joseph F. Shea, Mr. Donald K. Slayton and Captain Walter H. Schirra, Jr., USN, of MSC; and Mr. David Williamson of Dr. Seamans' staff, attended the briefing.

(2) Dr. Thompson announced to the Board in general session that a survey showed some 1500 people were directly supporting the investigation. This number, which is considered quite conservative, included 600 personnel from the NASA, Air Force, Navy, Department of the Interior and other Government agencies; and 900 personnel from industry and universities.

(3) Proposed Action Items 0153 through 0157 were considered and approved by the Board.

(4) Material Release Record Items 0073 through 0103 were considered and approved by the Board.

February 23, 1967

(1) The Apollo Program officials, under the chairmanship of Dr. Mueller, briefed Dr. Seamans and the Apollo 204 Review Board. In attendance were those who received the Review Board briefing on February 22, 1967. The briefings included a status report of the Apollo Program, special tests being conducted or planned as a result of the accident and proposed actions relative to the tentative findings of the Review Board.

(2) Dr. Thompson, Colonel Borman and Dr. Van Dolah accompanied Dr. Seamans to Washington, D. C., to brief the Honorable James E. Webb, Administrator, NASA on the tentative findings and preliminary recommendations of the Board.

(3) Upon the departure of Dr. Thompson, Colonel Strang assumed the responsibilities of Acting Chairman. A plan was approved to consolidate three Panels into a single Panel. This consolidation of Panels 3, 16 and 18 will permit better utilization of personnel.

(4) The Spacecraft/Lunar Module Adapter (SLA) was removed from the Saturn Launch Vehicle and transported to the Manned Spacecraft Operations Building for investigation.

February 24, 1967

(1) Colonel Strang conducted a special meeting of the Board and Panel Chairmen to ascertain the status of each Panel's final report. He emphasized that the reports should be sufficiently detailed to enable the Board to arrive at sound, appropriate recommendations. He also stressed that findings should apply not only to proximate causes of accident, but to any deficiency that could adversely affect the Apollo Program.

(2) The Board approved the release of Launch Complex 34 through Level 4 to KSC for operations. The Board will continue to control access to Levels 5 through 8, (Material Release Record (MRR) Item 0123). MRR Items 0104 through 0122 were also approved.

(3) Dr. Thompson, Colonel Borman and Dr. Van Dolah met at NASA Headquarters with the Honorable James E. Webb, Administrator, and Dr. Seamans, to present the Apollo 204 Review Board interim findings.

(4) Proposed Action Items 0158 through 0162 were considered and approved by the Board.

February 25, 1967

1. Members of the Board visited the PIB to view the Environmental Control Unit removed from C/M 012.

2. Panel work plans and schedules for accomplishment of tasks and submission of final reports were reviewed by the Board. Dr. Thompson emphasized that Panel Chairmen will not be released from their responsibilities until the Board has formally accepted their respective reports. A memorandum to this effect will be sent all Panel Chairmen. Specific comment will be included requesting submission of final reports as soon as possible.

3. Following the Executive Session, Dr. Thompson, Colonel Borman, Dr. Faget, Dr. Van Dolah, Mr. Geer and Mr. White departed for their respective parent organizations. They are scheduled to return to KSC on February 28, 1967. During their absence, the Panels will continue to perform their investigation functions and Colonel Strang will be Acting Chairman of the Board as previously designated.

February 26, 27, 28, 1967

1. In the absence of Dr. Thompson and other Members of the Board, no formal meetings were conducted.

2. Panels continued to conduct their portions of the investigation. The disassembly of the Command Module and detailed analysis of components was accomplished as scheduled in the master plan. Several Panels initiated preparation of their final reports.

3. Proposed Action Item 0163, Service Module Investigation Plan, was approved by Col. Strang, due to its urgency, on February 27.

4. All Members of the Board, with the exception of Dr. Van Dolah, returned to KSC at approximately 6:30 p.m., February 28, 1967.

5. Initial visual inspection and X-ray analysis of the Environmental Control Unit was completed on February 28, 1967. The unit was moved from the PIB to the Life Support Building for disassembly and detailed analysis.

March 1, 1967

1. Dr. Thompson announced to the Board that a memorandum from Dr. Seamans, dated February 27, 1967, had been received designating the Director, Langley Research Center, the Custodian of Apollo 204 Review Board Material.

2. A general discussion was held (in Executive Session) regarding the future activities of the Panels and other Board activities, with the objective of developing assurance that the Board's Final Report will be completed by the end of March. An additional objective was to establish a mode of operation whereby the Board will be able to effect an orderly reduction of its activities at KSC, eventually re-

cess, and finally recommend to the Administrator that the Board be disbanded. Dr. Thompson remarked that certain tests and analyses which were stimulated by the Board's activities may more appropriately be of prime interest and concern to the Apollo Program Office. Such tests and analyses would not be followed in detail by the Board, however, the Board will require reports from the Program Office on the results so that the Final Report Appendix E, may include a statement of the results.

3. Dr. Faget presented a plan for the screening of removed equipment that is intended to reduce the amount of effort and time required to investigate and analyze equipment from Spacecraft 012. This plan was discussed by the Board and it was agreed that the Panel Coordination Committee establish an ad hoc group to perform the screening as proposed in the plan. The Panel Coordincatiòn Committee will report back to the Board on this activity.

4. Dr. Thompson announced that General Sessions would henceforth be held on Monday, Wednesday, and Friday of each week. Executive Sessions will continue on a daily schedule.

5. Proposed Action Items 0158 through 0162 and 0164 through 0167 were considered and approved by the Board. Item 0163 had previously been approved by Col. Strang.

6. Material Release Record Items 0127 through 0137 were considered and approved by the Board. Items 0124 through 0126 had previously been approved for release.

7. Following the Geners l Session, the Board viewed a film on fire propagation tests conducted at MSC in a boilerplate mock-up of the Command Module.

March 2, 1967

1. Proposed Action Items 0168 and 0169 were considered and approved by the Board.

2. Material Release Record Items 0138 through 0141 were considered and approved by the Board.

March 3, 1967

1. All material from the Command Module will be retained by the Board and will be designated Category A or B. Items in Category A are those that are damaged, or identified as suspect and/or associated with anomalies. Category B Items are those that appear to be absolved of association with the incident. They (Category B) will be eligible for use by the Apollo Program Office for nondestructive testing; however, the Board will require copies of all test reports. An Administrative Procedure will be released on this matter.

2. Col. Borman reported that the disassembly of the Command Module was expected to be complete by March 10, 1967. An around-the-clock work schedule was approved for the removal of the heatshield.

3. The Board met with the Panel Chairmen to discuss final Panel report content and submission schedule. Tests that are not complete, when the Panel reports are submitted, will subsequently be integrated into the Final Board Report.

March 4, 5, 1967

1. Material Release Record Items 0142 through 0144, and 0146, were considered and approved by the Board. Item 0145 was held in abeyance pending further action.

2. Board Members reviewed transcripts and other material for inclusion in the Final Report.

March 6, 1967

1. Mr. Mardel, Chairman, Panel 18, reported on an arc indication that was found on the Lower Equipment Bay junction box cover plate. A metallurgical analysis on the cover plate will be accomplished. Investigation will continue in an effort to identify and remove the wire that appears to have caused the arc.

2. Mr. Simpkinson, Chairman, Panel 4, presented a status report on the disassembly plan. Approval was granted by the Board to start removal of the heat-shield.

3. Proposed Action Items 0170 through 0177 were considered and approved by the Board.

4. Material Release Record Item 0147 was considered and approved by the Board.

March 7, 1967

1. The aft heat shield was removed from C/M 012 in accordance with the master plan for disassembly. Close inspection of the C/M disclosed that the rupture in the floor extended approximately 2/3 around its circumference. This is much greater than originally estimated.

2. Material Release Record Items 0148 through 0150 were considered and approved by the Board.

3. The Board viewed a 30 minute film entitled "Apollo Mock-up Flame Propagation, Test No. 2". The Test was conducted in a biolerplate Apollo mock-up at MSC on March 4, 1967. The Board concluded that this was a valid test procedure for assessment of flame propagation, and to qualify materials for use in the spacecraft.

4. A general discussion was held on the subject of subsystem and component design as related to the ability to ensure that such hardware may be installed and subsequently maintained in a manner consistent with established quality control procedures.

March 8, 1967

1. Dr. Faget gave a follow-up report on analysis of the arc indication on the Lower Equipment Bay junction box cover plate. The plate has been delivered to KSC Material Analysis Laboratory. In addition to the analysis of the arc indication, analysis will also be made of molten material found on the bottom of the plate.

2. Col. Strang briefed the Board on a proposed procedure for screening and processing final Panel Reports. Initial review and editing will be accomplished by Final Board Report Panel 17. After preliminary editing, the reports will be amended as necessary and distributed to each Board Member and Counsel for review. Panel Chairmen will then meet with the Board for oral erview, critique and acceptance of the report, or additional actions as necessary. The procedure was accepted by the Board.

3. A progress report on status of test analysis was presented to the Board. A total of 104 tests have been identified of which 45 have been closed and 59 remain in the open category.

4. Proposed Action Item 0178 was considered by the Board and approved.

March 9, 1967

1. It was announced that the Crew Heat Shield had been removed from the Command Module, and that a total of 891 items have been removed to date.

2. Proposed Action Item 0179 was considered and approved by the Board.

3. Material Release Record Items 0151 through 0154 were considered and approved by the Board.

4. Dr. Faget suggested construction of a simple fixture, in the configuration of the Command Module, upon which the wire harnesses and bundles removed from C/M 012 can be placed for subsequent inspection. The study of this or other approaches to implement a detailed inspection of the harnesses was recommended by Dr. Faget. The Board approved this recommendation.

5. The Board appointed Mr. Robert Bruce, Langley Research Center, as an alternate Board designated agent for the Environmental Control System (ECS) investigation.

March 10, 1967

1. A report from the Screening Committee was made by Mr. Sasseen. An assessment of activity of the Committee and a written report were requested for the General Session on March 15, 1967. The crew compartment and the aft heat shields have been removed from the C/M and reclassified to Category B in order to remove the requirement for a special 24-hour guard.

2. Colonel Borman presented the Disassembly report. Command Module (C/M) disassembly activities are now scheduled to be completed by March 18.

3. A film on Fire Propagation Test 3 conducted in the boilerplate mock-up at Manned Spacecraft Center (MSC) was shown. The C/M was simulated in Flight Configuration.

4. The Board met with Mr. L. Barnett of Panel 13 to conduct a critical review of that Panel's draft final report. The Board's comment were noted by Mr. Barnett and corrective and/or amplifying statements will be incorporated in the report.

5. Proposed Material Release Record Items 0155 and 0156 were presented for the Board's consideration and approved.

March 11, 12, 1967

1. Colonel Strang reported that Panels, 2, 12, 13, 16, 19 and 20 have submitted Final Reports. These six reports have been distributed to the Board Members for review.

2. Formal Board sessions were not held on March 11 and 12, 1967. The Board Members devoted their time to study of the final reports from six Panels. Disassembly and analysis continued as scheduled.

March 13, 1967

1. Board Members and Panel Members who received copies of witness statements in connection with their responsibilities were requested to return all copies to Panel 12 when this material is no longer needed.

2. A progress report on dismantling the Environmental Control Unit (ECU) was made to the Board by Mr. Williams. He also presented a proposed modification to Action Item 0153, Command Module Equipment Removal Plan. Following discussion by the Board, this modification was approved.

3. Mr. Robert Allnutt of NASA Headquarters was introduced by Mr. Malley. Mr. Allnutt, with Mr. Ashmun Brown, KSC Legal Staff, will assist Mr. Malley in the legal review of the Panel Reports and the Final Board Report.

4. The Board met with the following Panel Chairmen to conduct a critical review of their draft final report: Capt. J. Lovell, Panel 20; N. Vaughn, Panel 12; J. Atkins, Panel 19; G. Stoops, Panel 16. Each of the reports was accepted subject to editorial corrections.

5. The Board discussed reviews of Panel draft reports not yet received. Colonel Strang reported Panel 15, Final Report, will be available for review on March 13. The Board scheduled a meeting with Panel 5 on March 14. Further scheduling of meetings with Panels will be accomplished as reports are available.

March 14, 1967

1. Dr. Thompson advised that Dr. Gilruth and certain members of his staff will be at KSC on March 20 for the purpose of making a presentation to the Board on the subject of solder joints.

2. Colonel Borman presented the modified Panel 13 report for acceptance. The Board agreed with the report as modified and requested distribution to the Board Members for a final review.

3. Material Release Record Item 0161 was presented for the Board's consideration and approved. Items 0157, 0158, 0159 and 0160 were approved by Mr. Geer on March 13.

4. The Board met with Panel 21, Service Module Disposition, to review the final Panel Report. The Report was accepted subject to correction.

March 15, 1967

1. Disassembly of the ECU was completed this date.

2. The Board met with the Chairmen of Panels 5 and 6 for a preliminary review of their final reports.

3. Mr. Eldon E. Mathauser and Mr. Andrew G. Swanson, Langley Research Center, and Mr. Richard B. Ferguson, Manned Spacecraft Center, were appointed by Dr. Thompson to support the Board in the capacity of technically reviewing Final Panel Reports.

March 16, 1967

1. The Final Report from Panel 15, Administrative Procedures, was submitted to the Apollo 204 Review Board for individual study by Board members. In a special session the Board accepted the Final Report of Panel 15, subject to editorial corrections.

2. The Board met with Dr. Charles A. Berry (Chief, Division of Medical Research and Operations, MSC), Dr. Kelly, and Dr. Harter for a briefing on the life sciences portion of the Apollo 204 Review including the proposed final report of Panel 11, Medical Analysis. In addition to the Board Members, Mr. Malley, Counsel to the Board and Mr. Robert F. Allnutt, Assistant to the Counsel, were in attendance.

March 17, 1967

1. During the General Session, discussion was conducted by Dr. Thompson with the Panel Chairmen on preparation of their Final Reports and responsibilities of the Apollo 204 Review Board.

2. Mr. Simpkinson, Chairman of Panel 4, Disassembly Activities, reported on the status of C/M Disassembly. It is now scheduled for completion by March 22, 1967.

3. Colonel Borman presented MRR Items 0162 - 0166 which were approved.

4. Mr. Sasseen gave an interim report for the Screening Committee. Their report is expected to be completed by March 24, 1967.

5. Mr. Williams presented proposed Action Item 0180, whih was considered and approved.

6. The Board met with the Chairman of Panel 8, Materials Review, to review the Final Panel Report. It was suggested that one additional test be accomplished, and reviewed by the Board prior to acceptance by the Board.

7. Colonel Strang discussed the selection of photographs for inclusion in the Panel reports and the Final Board Report. The photographs selected thus far were made available for review by the Board.

8. Mr. Simpkinson was appointed Special Assistant to the Board for technical matters pertaining to preparation of the Final Report.

March 18, 19, 1967

1. The Board met with the Chairmen of Panel 1, S/C and GSE Configuration; Panel 5, Origin and Propagation of Fire; Panel 10, Analysis of Fracture Areas; and Panel 14, Security of Operations, to review their Final Panel Reports. The reports were accepted subject to correction.

2. Material Release Record Items 0167 - 0192 were approved by the Board.

March 20, 1967

1. Col. Strang presented a progress report on the Final Panel Reports. As of March 19, 1967, Reports from the following Panels have been received and accepted by the Board, subject to editorial corrections: Panels 1, 8, 10, 12, 13, 14, 15, 16, 17, 19, 20 and 21. The Board accepted, subject to editorial correction, the findings and determinations of Panel 5.

2. The Deputy Administrator, NASA, designated Langley Research Center as the custodian of all materials dealing with the investigation and review of the Apollo 204 Accident. The Chairman of the Board, who has the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files, and working materials.
2. Medical reports.
3. Spacecraft 012 Command Module, its systems, components, and related drawings.

Category 1 will be stored at Langley Research Center, Category 2 at Manned Spacecraft Center and Category 3 at Kennedy Space Center.

As long as the materials are under the jurisdiction of the Board, access to materials shall be in accordance with the Board's policy. When the Langley Research Center assumes custody of the materials, access will be in accordance with the policy established by the Director, Langley Research Center.

3. Dr. Van Dolah reported on a test being made in C/M 014 to attempt to determine the amount of static electricity that may be generated by a suited crewman.

4. Mr. Williams presented proposed Action Items 0181 and 0182. Explanatory comments were made by Dr. Van Dolah on Item 0181. Mr. Sasseen made distribution of a memorandum, subject: "Plan of Action for AC Inverter 2" relative to Action Item 0182. Both of these Action Items were approved by the Board.

5. Colonel Borman presented MRR Item #0193 for consideration. This item was approved by the Board.

6. Prior to the Executive Session, the Board met with Dr. Robert R. Gilruth, Director, MSC, and members of his staff, plus management and engineering personnel from North American Aviation, Inc. for a presentation on the subject of solder joints in the Command Module.

March 21, 1967

1. The Board reviewed and accepted, subjected to editorial correction, the Panel 4 Final Report. The Final Reports from Panels 7 and 11 were submitted to the Board for review.

2. The Board Chairman appointed Mr. F. E. Eastman (MSC) as the Board's agent to witness activities associated with removal, transportation, disassembly, and testing of the Static Inverter 2, S/N 09240 ML 0088, in accordance with Apollo Spacecraft Hardware Utilization Request 012503 dated March 21, 1967.

3. MRR Items 0194-0199 were presented for consideration and approved by the Board.

March 22, 1967

1. The Apollo 204 Review Board witnessed a demonstration on the removal of C/M crew hatches. The demonstration was conducted in the PIB using a mock-up C/M. The purpose of the demonstration was to provide the Review Board a thorough understanding of hatch removal both from the inside and outside of the C/M. Following this demonstration the Board went to the ACE Control Room (MSOB) to get first-hand knowledge of the operations that are carried out there.

2. Major Butler, in Colonel Strang's absence, presented a progress report on the Final Panel Reports. As of March 21, 1967, the Board has reviewed and accepted, subject to editorial corrections, the Final Reports of Panels 4, 5, and 11. The Final Reports from Panels 15, 16, 17, 19 and 21 have been submitted for printers copies. The Final Reports from Panels 10, 13, 14 and 20, presently being edited, are scheduled for submittal to the printers by early March 23.

3. Dr. Faget distributed a report on the updated status of the analysis of items under investigation by Panel 18. To date there are 105 items; 27 remain open and 78 are closed. None of the closed items fall into the category, "May have caused the accident."

March 23, 1967

1. The Board met with the Chairman and Members of Panel 7 to review the Panel's Final Report. The Report was returned for further action prior to acceptance.

March 24, 1967

1. The Board met with Panels 9 and 6 to review their Final Reports. These meetings required the full day, therefore, the General Session which had been scheduled for 10:30 a.m. was postponed.

2. MRR Item 0200 was considered by the Board and approved.

3. The Board will recess at 1:30 p.m., March 25 until 8:00 a.m., March 28. Regular activity of the Board will be discontinued during that period; however, Panel Report preparation and detailed testing and analysis will continue.

March 25, 1967

1. The Board met with the Chairman and Members of Panel 18 for a brief preliminary review of their Report. The Board also met with the Chairman and Members of Panel 2 to review that Panel's Final Report. The Report was accepted, subjected to incorporation of corrections and amplifying statements.

2. The Board reported that all Panel Reports have been reviewed. A second review of the Reports from Panels 5, 9 and 18 will be accomplished next week.

3. The Board recessed until 8:00 a.m., March 28.

March 28, 1967

1. The Board was in recess from March 25 at 1:00 p.m. until March 28 at 8:00 a.m., however, work continued in the preparation of Panel Reports.

2. Colonel Strang made the following report on the progress and preparation of the Final Reports:

A follow-on review by the Board of Final Reports from Panels 3, 5, 7, 9, 12 and 18 is required. The Panel 18 Report will be available for Board review at 8:00 a.m., March 29. The Board scheduled a meeting with Panel 18 for 1:00 p.m., March 29 to conduct a critical review of their Report. It is tentatively planned that the Board will review Final Reports with Panels 7 and 9 on March 30. Reviews with Panels 3, 5 and 12 will also be scheduled.

Eleven Panel Reports have been submitted for varityping. Final Reports from Panels 4, 10, 14, 16, 17, 19 and 21 plus Parts I and II of the Final Report and General Session Minutes were distributed by Col. Strang. This material is to be reviewed by the Board Members and Counsel prior to printing of the Final Report.

Specific assignments have been made regarding preparation of a narrative describing the Spacecraft 012 test sequences and their objectives, the time line of events from start of the T-10 hold through medical determination of death and the investigation and analysis activities of the Board.

3. Mr. Malley discussed preparation of findings, determinations and recommendations. He also stated that if corrections are made after varityping, they can be included in the Final Report as Addenda and Corrigenda.

4. Dr. Thompson asked for a report on PIB activity. Colonel Borman introduced MRR Items 0201, 0202 and 0203 which were considered by the Board and approved. Disassembly of the Spacecraft was completed on March 27 during the first shift. 1241 items are logged in as having gone through the Bond Room for display to Review Board and Panel personnel. Of these, approximately 1000 came from the C/M.

5. The Final Report of the Screening Committee was distributed by Mr. Sasseen to the Board Members for their review. Mr. Sasseen stated that the following eight items will be retained in Category A:

Lower Equipment Bay Junction Box Cover Plate
Command Pilot's Torso Harness
Velcro and Raschel Netting
Static Inverter 2
Main Display Control Panel 8
Instrumentation Data Distribution Panel J800/J850
Octopus Cable

6. Dr. Faget advised that LiOH cartridge has been sent to MSC for analysis. Mr. Callahan of OMSF was appointed courier to handcarry this Item to MSC. Mr. R. S. Johnston has been designated the Board's witness for the analysis. MSC's Crew Systems Laboratory will perform the analysis and provide

the Board with a report. Objective of the analysis will be to identify contaminants in the LiOH and to determine the quantity of CO_2 in the LiOH.

7. Members of the Board and other interested personnel viewed a demonstration in the Spacecraft Mock-up at the PIB of hatch removal conducted by NAA personnel who performed this function at the time of the accident.

8. Mr. William D. Mangan, LaRC, Office of the Chief Counsel, joined the Legal Staff supporting the Board.

March 29, 1967

1. The Board Members met with Panel 18 to conduct a critical review of the Panel 18 Report.

2. Colonel Strang reviewed the status of Final Report preparation. The Board scheduled a review meeting with Panel 9 for March 20 at 9:00 a.m., to be followed by meetings with Panels 7, 6 and 3, as time permits. The reports from Panels 11 and 12 are being clarified in certain places prior to varityping.

March 30, 1967

1. The Board met with the Chairmen and Members of Panels 9, 7 and 3, to complete acceptance of their Final Panel Reports.

March 31, 1967

1. Col. Strang made the following report on the status of Final Panel Reports:

Reports from the following Panels have had printer's copies prepared and distributed to the Board for final review: 4, 10, 14, 16, 17 and 21. Most of these reports have been returned by Board Members for final editing and printing.

The following Panel Reports are being processed today for preparation of printer's copies: 3, 5, 7, 11 and 6.

Printer's copies of Panel Reports 1, 13, 15 and 20 are to be distributed to the Board today for final review.

Final draft copies of Panel Reports 2, 8, 7 and 12 are being reviewed by Board Members. After return of these reports to Panel 17, they will be processed for preparation of printer's copies and subsequently distributed to the Board for final review.

The Final Report from Panel 18 is still undergoing rewrite by the Panel.

2. Col. Borman introduced MRR 0204 to release the complete Launch Escape System from Category A to C. He requested approval for a general MRR to release from Category A to C all parts and equipment that were not attached to the Spacecraft at the time of the accident. Approval was granted on both of these items.

4. The Final Report of the Screening Committee was distributed by Mr. Sasseen at the General Session for Board review. The Board approved the categorizing of the parts, components and assemblies of the Spacecraft. Dr. Thompson stated that the Board accepts the report as the basis on which the handling of these parts, components and assemblies will be followed regarding custody and access to them.

5. Mr. William E. Guilian, Chief Counsel, Marshall Space Flight Center, has joined the Legal Staff supporting the Board.

6. Dr. Thompson announced that in view of the imminent completion of the Investigation and Final Report, the March 31 General Session would be the last scheduled meeting of the Board. Any subsequent meetings which may be required prior to the time the Board is recessed at the completion of the Final Report will be called by the Chairman.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

February 27, 1967

OFFICE OF THE ADMINISTRATOR

MEMORANDUM

To: Chairman, Apollo 204 Review Board

From: Robert C. Seamans, Jr.
Deputy Administrator

Subject: Custody of Apollo 204 Review Board materials

The Langley Research Center, Hampton, Virginia, is designated as the custodian of all pertinent physical evidence, reports, files, and working materials dealing with the investigations and review of the Apollo 204 accident.

The Director, Langley Research Center, shall assure that adequate secure storage and warehousing is made available at appropriate locations for this purpose. These materials will be in the final custody of the Director, and access thereto shall be determined by him or by the general counsel at the Center as his designee.

The Chairman of the Board shall determine the materials that are to be included in the final repository and shall arrange for the most useful disposition of the remaining materials not selected for final retention.

Robert C. Seamans, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

MAR 1 1967

IN REPLY REFER TO

TO : Director, Langley Research Center

FROM : Chairman, Apollo 204 Review Board

SUBJECT: Custody of Apollo 204 Review Board Materials

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The materials are divided into three categories:

1. Reports, files and working materials
2. Medical reports
3. Spacecraft 012, its systems and components

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center. Custodial agents have been designated at the three Centers, Enclosures 2, 3 and 4. Administrative Procedure 23A, Enclosure 5, sets out the procedure for custodial agents to follow.

It will be the responsibility of the Director, Langley Research Center to provide suitable secure storage space for the materials, to insure that an index file is established for location of materials, and, at the appropriate time, to transfer custody and storage of the materials in accordance with regulations of the Administrator, General Services Administration.

The provisions of Title 44 U. S. C. § 396 and NMI 1440.1 are applicable.

Dr. Floyd L. Thompson

Enclosures
As Stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

TO: Assistant Chief, Administrative Services Division
Langley Research Center

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files and working materials

2. Medical reports

3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 1. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended as Enclosures 2, 3 and 4, are applicable.

Dr. Floyd L. Thompson

Enclosures
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

TO: Manager, Apollo Spacecraft Program Office
Manned Spacecraft Center

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files and working materials

2. Medical reports

3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 3. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended as Enclosures 2, 3 and 4, are applicable.

This delegation of authority is made with the power of redelegation to a member of the Spacecraft Program Office.

Dr. Floyd L. Thompson

Enclosures
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

TO: Director, Kennedy Space Center

MAR 20 1967

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Custody of Apollo 204 Review Board Materials

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The materials are divided into three categories:

1. Reports, files, and working materials
2. Medical reports
3. Spacecraft 012 Command Module, its systems, components, and related drawings.

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center. Custodial agents have been designated for each category, Enclosures 2, 3, and 4. Administrative Procedure 23A, Enclosure 5, sets out the procedure for custodial agents to follow.

The Director, KSC, is requested to provide suitable secure storage space for the Spacecraft 012 Command Module, its systems, components, and related drawings.

I would appreciate being advised of the nature and location of the proposed storage area at your earliest convenience.

Dr. Floyd L. Thompson

Enclosure: a/s

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

TO: Director of Medical Research and Operations
Manned Spacecraft Center

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files and working materials

2. Medical reports

3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 2. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended at Enclosures 2, 3 and 4, are applicable.

This delegation of authority is made with the power of redelegation to a member of your staff.

Dr. Floyd L. Thompson

Enclosures
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM

To: Mr. James E. Webb
Administrator

From: Robert C. Seamans, Jr.
Deputy Administrator

Subject: Report on Apollo 204 Review Board Discussions

I spent yesterday at the Kennedy Space Center with the Apollo Review Board and other key personnel involved in the current investigation of the causes and circumstances of the Apollo 204 accident.

First, there has been no determination of the specific cause of the fire that resulted in the deaths of Lt. Colonel Grissom, Lt. Colonel White, and Lt. Commander Chaffee. The retracing of possible, and then of probable, chains of events in such an accident is a complex task that is demanding the complete attention of the Review Board headed by Dr. Floyd Thompson, of the assistants and consultants to the Board, and of many of the elements of government, industry, and universities involved in the Apollo program.

The Board is taking full advantage of the extensive taped data available as well as records made prior to the accident, the present condition of the spacecraft, and the reports of those involved in the test. All the physical evidence and data concerned with the test were impounded immediately following the accident. This was to assure that no pertinent information would be lost and that no actions would be taken except in the full context of all the data available.

As I have stated, the preliminary review of this information has not provided any direct indication of the origin of the fire; the preliminary analyses point to the conclusion that a clear identification of the source of ignition or of its possible source will depend upon detailed step-by-step examination of the entire spacecraft and its related test support equipment.

At present, the spacecraft is still mated to the unfueled launch vehicle at the pad. However, it is being prepared for removal to our industrial area where it will be disassembled and where experts in many technical and scientific areas can work with the physical evidence. Prior to disassembly of the damaged spacecraft, an undamaged and nearly identical (#014) spacecraft will be used to establish the conditions existing prior to the accident. The 014 spacecraft was flown from the North American plant in California to Cape Kennedy on February 1.

The current plans are to go through a parallel, step-by-step disassembly process, first working on the undamaged vehicle and then repeating as closely as possible the procedure on the damaged vehicle.

In addition to analyses of recorded and physical data and equipment, the Board is defining a series of investigative tasks and is assigning these to teams for execution. For example, a team is charged with the chemical and spectrographic analysis of damaged elements aimed at identifying the propagative history of the fire. Another is working on relating the propagation history to the flammability characteristics of the spacecraft materials. Another is dealing with design analyses and experimental tests to help establish possible ignition sources. As work progresses and a pattern of information emerges, additional tasks, analyses, and reviews will undoubtedly be instituted by the Board.

From information now available to the Board, I had an opportunity to learn more about certain specific aspects of the simulated mission and the test sequence itself than we had previously had before us in a clearly related pattern.

> At 6:31:03 pm EST the fire was first detected. The mission was holding at T-10 minutes. Up to this time there had been only minor difficulties with the equipment. The purpose of the hold was to provide an opportunity to improve the communications between the spacecraft and the ground crew.
>
> Up to this time the cabin pressure, the cabin temperature, and the oxygen suit supply temperature were nominal. The oxygen rate of flow into the suits had shown an increase 4 seconds prior to this time but we have not been able to relate this to the accident.
>
> Lt. Col. White was the only astronaut instrumented for heart rate and respiration. His heart rate had shown an increase 40 seconds prior to this time, but at 6:31:03 his heart was at the normal level for him when in a relaxed prone position.

The spacecraft was operating on external power. Earlier in the day, at 9:30 a.m. EST, the system for transfer from external (ground) power to simulated internal (spacecraft) power had been tested, and operated normally. The fuel cells in the service module were not in use, and the so-called internal power was being supplied by batteries having the same characteristics as the fuel cells but located external to the spacecraft. If the accident had not occurred, the transfer from external to simulated internal power would have taken place on resumption of the count.

> At the press conference on Saturday morning, Apollo Program Director S. C. Phillips was asked whether the spacecraft was on internal or external power when the fire occurred. At that time he did not realize that the spacecraft was still on external power since he had in mind primarily the eyewitness reports. Subsequent examination of the data has established the above power supply sequences. There is no evidence up to this time that the source of power whether simulated internal or external was related to the accident.

Lt. Colonel Grissom was the command pilot, sitting in the left seat; Lt. Colonel White, the senior pilot, sitting in the middle seat; and Lt. Commander Chaffee, the pilot, was in the right seat. In the event of emergency, the procedure is for the senior pilot (White) to reach high over his left shoulder to actuate the inner hatch release handle. The command pilot (Grissom), after lowering the center headrest, aids the senior pilot in lifting the inner hatch and removing it to the floor of the spacecraft. The main duty of the pilot (Chaffee) during this procedure is to maintain communication and assist in the removal of the inner hatch if needed. From the following data, you will note that the crew appeared to follow the correct procedure.

At 6:31:03, Pilot Chaffee reported that a fire existed in the spacecraft. At about this time Senior Pilot White's heart rate started to increase. At 6:31:04 the inertial platform in the capsule gave an indication of a small amount of motion which may have been caused by movement of the crew. At 6:31:05 the cabin temperature began to rise. At 6:31:09 Senior Pilot White repeated the previous report saying that there was a fire in the cockpit. At the same time the cabin pressure commenced to rise and a larger amount of motion was indicated by the inertial platform. This means that the crew were commencing their emergency egress procedure.

At 6:31:12, or nine seconds after the first indication of fire, the cabin temperature started to increase rapidly and pilot Chaffee reported that a bad fire existed in the cabin. Also at this time pilot Chaffee increased the illumination of the cabin lights and actuated the entry (internal) batteries. No other intelligible communications were received although some listeners believe there was one sharp cry of pain. Loss of radio signal occurred a few seconds later.

The oxygen supply to the astronaut suits, which had been holding nearly constant, pressure and temperature started to fluctuate at the time of signal loss. At 6:31:17 or fourteen seconds after the fire was first detected, the cabin pressure reached a level of approximately 29 psi and the cabin ruptured.

One and one-half minutes after the start of the fire, the ground power was switched off. Various command module systems continued to operate on the entry (internal) battery power until about 12:30 am EST on Saturday when the batteries ran down.

The official death certificates for all three crew members list the cause of death as asphyxiation due to smoke inhalation due to the fire.

I would like to emphasize that this report is based on preliminary information. This information has not as yet been extensively analyzed by the Apollo Review Board under Dr. Thompson. Since the data were recorded at a number of different stations, the time sequences may not be perfectly synchronized, possibly giving rise to errors of one or two seconds.

During my meetings with the Board a number of other items of information were discussed but I believe that the data I have outlined include all events having a significant bearing on an understanding of the accident.

Robert C. Seamans, Jr.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 14, 1967

MEMORANDUM

To: Mr. James E. Webb
Administrator

From: Robert C. Seamans, Jr.
Deputy Administrator

Subject: Further report on Apollo 204 Review Board Activities

On February 10 I met with the Apollo 204 Review Board at KSC to discuss their progress in the investigation of the Apollo accident.

The Board now has 21 panels established and operating, each with a specific assigned task, each chaired by a Government employee, and each reporting to a specific Board member. A detailed Review Board activity schedule has been established and is reviewed daily to ensure that milestones are being met or that scheduled adjustments are made as early as necessary. This permits close coordination and integration of all the necessary activities, analyses, and studies.

In order to speed up the investigative effort, the Apollo 012 spacecraft is being mapped in detail, using a 3-dimensional coordinate system to which all physical spacecraft elements can be referred. Complete photographic coverage is being maintained, color film being preferred since it permits more ready identification of components and their condition. Each photograph is cross-referenced to the master grid.

The Board has implemented a data control system that permits a visual display, against a time-line background, of each step of the investigation. As spacecraft systems are examined and as their utilization in the 204 test is established, these are noted and color coded: at a glance, one can determine whether a system might have caused the accident or has proven to be non-contributory, and also whether a particular analysis is still underway or completed. This method of data control focuses on the critical areas requiring the greatest attention.

I reviewed at some length the work and procedures of the panel that is investigating the origin and propagation of the fire. While their work is far from complete, I am satisfied that the procedures they are following are well worked out. When this work is completed, it will give us as clear a view as can be obtained from the evidence. The panel has begun by examining each possible combustible within the spacecraft, its distribution and characteristics, and its proximity to each possible ignition source. Such combustibles include both solids and liquids. At each step of spacecraft disassembly, panel members are carefully removing both damaged and undamaged materials for micro-analysis which, in turn, permits the identification of the material that was burned. This allows a reconstruction of the final location of all combustibles in the spacecraft and will point up irregularities in this distribution if any exist. The physical evidence thus far examined points to the following:

> First, it appears the fire had considerable variation and directionality, since damage in the spacecraft indicates differences of intensity and timing. For example, an aluminum tubing handle has a hole burned through it indicating a temperature at that point of at least 1,400° F, while its nylon hinge within two inches of the melted spot is relatively undamaged indicating a temperature there of less than 500° F.
>
> Second, there is evidence that the fire may have had more than one phase, but this is difficult to prove since the last phase would obscure the evidence of the earlier. One hypothesis, supported by the cabin pressure history, assumes a small, low-grade fire whose heat was at first largely absorbed by the spacecraft structure and that was burning at the time of the first crew report; that fire may have continued for as long as ten seconds. A more intense fire may have then developed, causing the rapid increase in cabin pressure. This fire was probably then extinguished by the depletion of oxygen.
>
> Other peculiarities require further analysis. These deal with the ruptures in the spacecraft and the role of the fire in burning through into the space between the inner and outer hulls.

At this time, there has been no determination as to the source of the ignition itself.

Additional information relating to the progress of the accident has been identified and is being analyzed. A recording from an onboard bio-sensor that appears relatively undamaged is in the process of being read out at this time. Additional work to interpret all background sounds on a high fidelity recording obtained over the S-band link is being carried out in the hope of gaining further information on the course of the fire. I also reviewed with the physician who heads the medical analysis panel the condition of the personal effects, suits, and equipment of the crew as well as data available on their actions during the course of the accident. It is now clear that all three suits were burned through, though the extent of suit damage varies; the command pilot's received the greatest exposure to flame and the pilot's the least.

Spacecraft disassembly is proceeding with great care; for example, a false floor with plexiglass viewing ports has been installed to permit continued examination without the danger of disturbing physical evidence. Current plans are for the final removal of the spacecraft to the industrial area by the end of this week. Detailed plans for the continued disassembly of both the command module and service module are in preparation and will be reviewed and approved by the Board before further work is undertaken. It is important to note that no single spacecraft element is touched or removed for analysis without full Board approval and evaluation of its possible effect on any of the other on-going studies or analyses.

Robert C. Seamans, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 25, 1967

MEMORANDUM

To: Mr. James E. Webb
Administrator

From: Dr. Robert C. Seamans, Jr.
Deputy Administrator

Subject: Interim report of the Apollo 204 Review Board

On February 22, 1967, I heard a presentation by the Apollo 204 Review Board at Kennedy Space Center of the significant information developed to date and of their tentative findings concerning the circumstances of the accident. The Board also discussed preliminary recommendations. These tentative findings and preliminary recommendations will serve as guides for those interim decisions to be made in the conduct of the Apollo Program prior to the completion of the Board report. I also reviewed the status of the investigation and of spacecraft disassembly, and followed up on items previously noted in earlier reports.

The spacecraft has been removed from the launch vehicle and is now housed in the industrial area. There detailed disassembly continues under careful supervision, each action being undertaken in response to a specific Board directive. This disassembly is far from complete, but a number of the major systems have been removed and are being checked for further verification of the part they played during the fire, the effect of fire on the equipment, and the evidence that analysis might add to the overall picture being built up of the accident. The heat shield has not yet been removed, nor has sufficient internal equipment to permit full view from inside of the entire pressure hull, and a large number of tests, checks and analysis are continuing at NASA, university, and industrial facilities around the country. At present, the Board has over 1,500 individuals, from nine government agencies and departments in addition to NASA, from thirty-one industrial groups, and from several universities, directly participating in the review and analysis. The Board currently estimates that its report will be completed by the end of March. The Board is developing procedures to assure that an orderly and rapid transition of the personnel under its control from the current accident investigation to redesign, qualification, and test effort where required can be made.

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OF POOR QUALITY

In my last report, I noted that an intact on-board biosensor recording was being analyzed for possible additional information; this analysis is now complete and provides a little more than one second's additional information and duplicates data already examined that was available from the telemetry recorded during the test and subsequent accident. The S-band recording also mentioned in the previous report has been completely analyzed by the Bell Laboratories, including computer reconstruction and comparison, but no significant new information could be derived therefrom.

The Board has not identified the source of ignition at this time. Ignition sources that have been under review include: possible chemical reactions, such as those in the on-board batteries or in the air purifier of the environmental control unit; possible spontaneous combustion of certain materials used in the spacecraft; and possible electrical phenomena, such as electro-static spark discharges, electrical arcing, or wiring overheating from shorts or malfunctions.

Examination of the environmental control unit lithium hydroxide and of the batteries indicates these were not the source of ignition. Tests of the combustible materials used in the spacecraft show that at least a 400°F temperature would be necessary for spontaneous combustion, and that no such materials could have been subjected to that temperature except by the malfunction of some other part of the spacecraft systems. An electrical malfunction is therefore regarded as the most likely source of ignition. While not wholly ruled out, electro-static discharge is deemed unlikely in that all reasonable concentrations of flammable vapors that could have been present in the spacecraft were not sensitive to this type of sparking ignition.

By the time it has completed its final report, the Board expects to have significantly narrowed the list of ignition sources that had a relatively high possibility of contributing to the initiation of the fire, but the possibility exists that no single source will ever be pinpointed.

A good deal of the work involved in tracing the history of the fire after ignition has been completed. The Board has considerable confidence in its present theory as to the initial location, propagation mechanisms, and phasing of the fire. This hypothesis, and some of the supporting evidence, is summarized as follows:

Present evidence indicates that the fire had three distinct phases. The fire originated in the left, or command pilot side, in the front corner of the spacecraft, near the floor. It probably burned for several seconds without being noticed by the crew or recorded on instrumentation. Because it was below the couch level it was not visible

at this stage; because the crew were fully suited and breathing oxygen from the environmental control system rather than from the cabin, it was not smelled or heard. The left front corner shows the evidence of highest heat and longest duration of the fire, and the witnesses watching the television monitors place the first appearance of flame in that corner (the television camera was mounted outside the spacecraft, looking in through the window in the hatch). The first crew report of fire was at 6:31:04, EST, indicating the fire had become visible. Because the metal structure of the spacecraft absorbed the initial heat, the fire did not initially cause an increase in cabin pressure.

By 6:31:12, the fire had spread and become intense, igniting various materials along the left side of the cabin. Flames were hot and smoke-free, rising along the wall and spreading across the ceiling. The cabin shows heavy damage in this area but little smoke, indicating that the oxygen in the cabin had not been depleted at this time. The fire spread and fed on nylon netting (installed to prevent objects from floating into equipment crevices while in zero-g), Velcro fastening material (used to fasten equipment to the spacecraft interior), and the environmental control unit insulation. The cabin pressure began to rise rapidly at this time as the atmosphere became heated.

At approximately 6:31:19, the internal pressure had risen to an estimated 36 pounds per square inch and the sealed cabin ruptured. This first puncture of the pressure vessel was a long tear in the floor on the right, or pilot's, side of the cabin. With the high internal pressure released, cabin gases and flames flowed both over and under the couches toward and through the hole, moving from left to right. This was the second phase of the fire. Flames passed through the hole into the air space between the cabin pressure shell and the surrounding heat shield; these flames then escaped through access hatches in the heat shield and partially enveloped the outside of the spacecraft for a moment. The short duration, left-to-right, flame motion is evidenced by heavier damage on the left than right side of equipment and wiring on the floor, of the couches, and of the front panels.

With the rupture of the cabin and the rush of flame and gas outside, the oxygen content of the cabin atmosphere was quickly reduced and the fire smoked heavily, laying a film of soot on many interior surfaces. This third and final phase of the fire was also characterized by continued localized burning. The environmental control system uses a water/glycol coolant that leaked from burnt or burst pipes. Both high and low pressure oxygen lines were connected with solder joints that fail at temperatures below 400°F. The glycol mixture from the cooling system, acting as a fuel and supported by the flowing oxygen from the failed lines, caused continued hot burning in the left corner and melted a large hole in the floor there.

The Board noted that the underlying design approach in Apollo was to control the known risk of fire--on the pad or in orbit--by isolating and rendering safe all possible ignition sources. The experience in flight and in tests prior to the accident had suggested that the probability of a spacecraft fire was low. Continued alertness to the possibility of fire had become dulled by previous ground experience and six years of successful manned missions. Ground tests at the pad were classified as especially hazardous only when propellants or pyrotechnics were involved, and different procedures and safety precautions are taken in handling or working under such conditions. Potential ignition sources inside the spacecraft had been treated so as to be considered safe; neither the crews nor the test and development personnel felt the risk of spacecraft fire to be high. The Apollo 204 accident now proves this assumption to have been wrong.

The assumption of ignition source safety led to the use of several solid combustible materials within the spacecraft, including nylon and polyurethane foams. From the point of view of possible fire, these materials were distributed within the cabin without breaks specifically designed to help localize fire if it occurred.

The Board noted that, in the event of a fire emergency, the time and effort required to open the hatch was too long, and that pad emergency procedures were focused on propellant hazards and did not include provisions to meet spacecraft fires.

The principal preliminary recommendations of the Board are designed to assist the Administrator in making his decisions concerning the continuing Apollo program effort prior to completion of the Board review. These are:

That combustible materials now used be replaced wherever possible with non-flammable materials, that non-metallic materials that <u>are</u> used be arranged to maintain fire breaks, that systems for oxygen or liquid combustibles be made fire resistant, and that full flammability tests be conducted with a mockup of the new configuration.

That a more rapidly and more easily operated hatch be designed and installed.

That on-the-pad emergency procedures be revised to recognize the possibility of cabin fire.

In addition, the Board has drawn attention to a number of components, subsystems, techniques, and practices which it feels can be improved to increase crew safety and mission reliability. These include findings on the environmental control system solder joints, location of wiring, electrical equipment qualification and design, and the development of checkout procedures.

An important area of Board attention has been that of the cabin atmosphere. The atmosphere and pressure selected for the suit and the cabin, before launch and in orbit, have a very important relation to spacecraft design, hatch type, crew physiology, launch procedures, and mission capability. The Board did not recommend a change in the use of pure oxygen in the suit for either pre-launch or orbital operations. The Board did not recommend that cabin atmosphere for operations in space be changed from the currently planned 5 psi pure oxygen but did recommend that the trade-offs between one- and two-gas atmospheres be re-evaluated. The Board specifically recommended that pressurized oxygen no longer be used in pre-launch operations.

Robert C. Seamans, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 25, 1967

STATEMENT BY
JAMES E. WEBB

NASA is releasing today a third interim report on the work of the Apollo 204 Review Board resulting from two days of meetings with the Board by Deputy Administrator Robert Seamans at Cape Kennedy. These meetings took place on February 23 and 24.

This statement and Dr. Seamans' third interim report have been reviewed with Chairman Clinton Anderson and Senior Minority Committee Member Senator Margaret Chase Smith and with Congressman George Miller. In continuation of the Senate Committee's review of the Apollo 204 accident, Senator Anderson has announced that the Senate Committee will hold an open hearing on the preliminary findings of the Board and actions to be taken by NASA at 3 p.m., Monday, February 27.

In addition to the information set forth by Dr. Seamans in his three interim reports, I have had the benefit of a review by three members of the Board -- the Chairman, Dr. Floyd Thompson, Astronaut Frank Borman, and Department of Interior combustion expert Dr. Robert Van Dolah. This included the preliminary views of the Board as to the most likely causes of ignition, the contributing factors in the rapid spread of the fire, the inadequacy of the means of emergency egress for the astronauts, and the need to recognize that all future such tests be classified as involving a higher level of hazard.

The following emerges from the preliminary views of the Board and the Board's preliminary recommendations:

(1) The risk of fire that could not be controlled or from which escape could not be made was considerably greater than was recognized when the procedures for the conduct of the test were established. Our experience with pure oxygen atmospheres included not only the successful Mercury and Gemini flights but a number of instances where a clearly positive source of ignition did not result in a fire. In one such instance an electric light bulb was shattered, exposing the incandescent element to the oxygen atmosphere without starting a fire.

(2) Our successful experience with pure oxygen atmospheres in Mercury and Gemini, our experience with the difficulty of storing and using hand-held equipment under zero-gravity conditions, and our experience with the difficulty of making sure before flight that no undiscovered items had been dropped or found their way into the complex maze of plumbing, wiring, and equipment in the capsule, led us to place in the Apollo 204 capsule such items as Velcro pads to which frequently used items could be easily attached and removed, protective covers on wire bundles, nylon netting to prevent articles dropped in ground testing from being lost under or behind equipment in the capsule, and a pad or cushion on which, in the planned escape exercise, the hatch could be placed without damage to the hatch itself or to the equipment in the spacecraft. While most of these were constructed of low-combustion-potential material, they were not so arranged as to provide barriers to the spread of a fire. Tests conducted in an Apollo-type chamber since the accident have shown that an oxygen fire in the capsule will spread along the surface of Velcro and along the edges of nylon netting much faster than through the material itself.

(3) Soldered joints in piping carrying both oxygen and fluids were melted away, with resultant leakage contributing to the spread of the fire.

(4) The bursting of the capsule happened in such a way that the flames, as they rushed toward the rupture and exhausted through it, traveled over and around the astronauts' couches. Under these conditions, and with just a few seconds of time available, the astronauts could not reach the hatch and open it.

(5) This fire indicates that a number of items related to the design and performance of the environmental control unit will require the most careful examination and may require redesign.

Astronaut Borman, in commenting on his reactions to the conditions surrounding the Apollo 204 test and the subsequent knowledge he has gained as a result of serving on the Review Board, stated to Dr. Seamans, Dr. Thompson, and to me that he would not have been concerned to enter the capsule at the time Grissom, White and Chaffee did so for the test, and would not at that time have regarded the operation as involving substantial hazard. However, he stated that his work on the Board has convinced him that there were hazards present beyond the understanding of either NASA's engineers or astronauts. He believes the work of the Review Board will provide the knowledge and recommendations necessary to substantially minimize or eliminate them.

Dr. Thompson, Astronaut Borman, and Dr. Van Dolah have returned to Cape Kennedy and are proceeding with the work of the Board. This will require several weeks to complete.

Chairman George Miller, of the House Committee on Science and Astronautics, has announced that as soon as the Board's work is complete, the Committee's Oversight Subcommittee, chaired by Congressman Olin Teague, will conduct a complete investigation of all factors related to the accident and NASA's actions to meet the conditions disclosed. Chairman Teague spent Friday and Saturday at Cape Kennedy with members of the Manned Space Flight Subcommittee, of which he is also Chairman, reviewing progress in the Apollo program. Dr. Seamans, Dr. George Mueller, and I will report further to him at 10 a.m., Monday, February 27.

PART IV

HISTORY
OF
THE ACCIDENT

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PART IV - HISTORY OF SPACECRAFT 012 AND THE ACCIDENT

1. EVENTS FROM INITIATION OF FABRICATION UNTIL THE INITIATION OF THE "PLUGS OUT" TEST

Spacecraft 012, assigned to Mission AS-204, was built at North American Aviation, Inc., Space and Information Systems Division, Downey, California. Enclosure 1 shows sketches of the complete space vehicle, the spacecraft and the Command Module. Fabrication was begun in August 1964 and the basic structure was completed in September 1965. While the structure was being fabricated, each component of every subsystem was subjected to acceptance tests and subsystems were assembled. During this period a series of Preliminary Design Reviews were held between November 1964 and January 1965. Installation and final assembly of subsystems into the Command Module took place between September 1965 and March 1966. Critical Design Reviews were held during February and March 1966. Checkout of all subsystems was then initiated followed by integrated testing of all spacecraft subsystems. A series of reviews of the spacecraft and checkout was held during the checkout and integrated testing process. A two-phase Customer Acceptance Readiness Review was conducted by NASA at Downey in conjunction with NAA in July and August 1966. After the August review NASA issued a Certificate of Flight Worthiness and authorized the spacecraft to be shipped to the John F. Kennedy Space Center (KSC), Florida. The Certificate included a listing of open items and work to be completed at KSC.

The Command Module was received at KSC on August 26, 1966. It was mated with the Service Module in the altitude chamber at KSC early in September 1966 and alignment, subsystems and system verification tests and functional checks were performed. Many open design change orders were completed and various malfunctions were noted and corrected. The first combined systems tests were begun on September 14 and completed on October 1, 1966. Several malfunctions were noted and correction of some of these was deferred to a later date.

A design Certification Review was held at NASA Headquarters during September and October 1966. This detailed review was conducted by a Board chaired by the Associate Administrator for Manned Space Flight. Board Members were Office of Manned Space Flight Center Directors. This Board issued a Design Certification Document on October 7, 1966 which certified the design as flightworthy, pending satisfactory resolution of listed open items.

After the combined systems tests were completed at KSC in the altitude chamber, the first manned test in this facility was performed. This test was conducted in air at sea level pressure and was made to verify total spacecraft system operation. The test was initiated on October 10 and discontinued on October 11 to replace bent umbilical pins. The test was begun again on October 12 and completed on October 13. On October 14 and 15, an unmanned test was performed at altitude pressures using oxygen to verify spacecraft system operation under these conditions before a manned altitude test was run. made. The manned test (with the flight crew) was initiated on October 18 but was discontinued after reaching a simulated altitude of 13,000 feet because of the failure of a transistor in one of the inverters in the spacecraft. The inverter was replaced and the test was completed on October 19. A second manned altitude test (with the backup crew) was initiated on October 21 but it was discontinued when a failure occurred in an oxygen system regulator in the spacecraft Environmental Control System. This regulator was removed and found to have a design deficiency. While redesign was being accomplished various spacecraft work items were completed..

On October 27 the Environmental Control Unit was removed and returned to the factory for a design change to the water/glycol evaporator.

During this period a propellant tank had ruptured in the Service Module of Spacecraft 017 at Downey. Therefore, it was decided that the tanks on the Spacecraft 012 Service Module should be checked by special testing at KSC. In order to conduct this testing in parallel with further checking of the Spacecraft 012 Command Module, the Command Module was removed from the altitude chamber. The Service Module was later removed for tests related to the propellant tanks. The Service

Module and Command Module were reinstalled in the altitude chamber and the ECU was installed. A water/glycol leak developed in the ECU, and it was again returned to the factory for further examination of the leak problem. It was returned on December 14, 1966.

Also, during this period on December 21, 1966 the Apollo Program Director conducted a Recertification Review which closed out the majority of the open items remaining from previous reviews.

After The Command and Service Modules were reinstalled in the altitude chamber and testing in the chamber was resumed. The sea level and unmanned altitude tests were conducted on December 27 and 28 and the manned altitude test with the backup flight crew was conducted on December 29 and 30.

It should be noted that this final manned test in the altitude chamber was very successful with all spacecraft systems functioning normally. At the post-test debriefing the backup flight crew expressed their satisfaction with the condition and performance of the spacecraft.

It should also be noted that in the altitude chamber tests the Command Module was pressurized with pure oxygen four times at pressures greater than 14.7 psia for a total time of 6 hours and 15 minutes. The total time was about 2½ times longer than the time the Command Module was pressurized with oxygen during the test which was in progress when the accident occurred.

The Command Module was removed from the altitude chamber on January 3, 1967 and the spacecraft was mated to the launch vehicle on January 6 at Launch Complex 34. Various tests and equipment installations and replacements were then performed.

The system was determined to be ready for the intiation of the Plugs-Out Test on January 27, 1967.

Of the many events which took place at KSC subsequent to the arrival of the spacecraft a few stand out as possible indications of deficiencies in the program and some appear to have possible relation to the fire.

The events that possibly may be related to the fire are those concerned with the occasions when water/glycol spillage or leakage from the Environmental Control System was noted. This may be of significance in that water/glycol coming into contact with electrical connectors can cause corrosion of these connectors. Dried water/glycol on wiring insulation leaves a residue which is electrically conductive and combustible. Of the six recorded instances where water/glycol spillage or leakage occurred (a total of 90 ounces leaked or spilled is noted in the records) the records indicate that this resulted in wetting of conductors and wiring on only one occasion. Action was taken to clean the water/glycol from the connectors and wiring on this one occasion. There is no evidence which indicates that damage resulted to the conductors or that faults were produced on connectors due to water/glycol which contributed to the fire. If the cleaning were inadequate, residue would have remained on the wires. Also, undetected wetting could have occurred which would leave a residue. Small quantities of water/glycol were found in the Command Module after the fire. This, however, could have been due to water/glycol line breakage which is known to have occurred during the fire. And while water/glycol and its residue may have contributed to the spread of the fire there is no positive evidence that residue was related to the ignition of the fire.

The number of open items at the time of shipment of Command Module 012 was not known. There were 113 significant Engineering Orders not accomplished at the time Command Module 012 was delivered to NASA; 623 Engineering Orders were released subsequent to delivery. Of these, 22 were recent releases which were not recorded in configuration records at the time of the accident.

The effort and rework required on Spacecraft 012 at KSC was greater than that experienced on the first manned Gemini spacecraft. However since the Apollo Spacecraft are considerably more com-

plex than Gemini Spacecraft this does not necessarily indicate that the quantity of problems encountered was excessive. There is, however, an inference that the design, qualification and fabrication process may not have been completed adequately prior to shipment to KSC.

Another item should be noted when considering the problems that were found at KSC including some of the problems encountered in the Plugs-Out Test prior to the fire. The prime purpose of all tests conducted prior to launch is to verify and demonstrate that the space vehicle ground support equipment, procedures and personnel are all ready for flight operations. Many of the tests involve a "first-time" operation particularly in an overall sense. Therefore, inherent in the verification process is the likelihood that faults will be found in procedures and in equipment. This Plugs-Out Test had not been classified as hazardous because only those tests involving fueled vehicles, hypergolic propellants, cryogenic systems, high pressure tanks, live pyrotechnics or altitude chamber tests were routinely classified as hazardous.

2. EVENTS FROM INITIATION OF THE PLUGS-OUT TEST UNTIL THE T-10 MINUTE HOLD

The purpose of the Space Vehicle Plugs-Out Integrated Test, Operational Checkout Procedures (OCP) FO-K-0021-1, Spacecraft 012 is to demonstrate all space vehicle systems and operational procedures in as near a flight configuration as is practical and to verify their capability in a simulated launch. System verfication is performed, an abbreviated final countdown conducted and a flight simulation made. All communication and instrumentation systems are activated and proper measurements are monitored at appropriate ground stations. At the start of the simulated flight, umbilicals are disconnected and the spacecraft is on simulated fuel-cell power.

Specific objectives of this test for Spacecraft 012 as stated in the Final Procedure Document were:

a. To verify overall spacecraft/launch vehicle compatibility and demonstrate proper function of spacecraft systems with all umbilicals and Ground Support Equipment disconnected.

b. To verify no electrical interference at the time of umbilical disconnect.

c. To verify astronaut emergency egress procedures (unaided egress) at the conclusion of the test.

The preliminary outline for this test procedure was written by North American Aviation, Inc. (NAA) in July 1966. The test procedure was reviewed and revised periodically over the next few months. In September the flight crew requested that emergency egress practice which was not in the original test outline be added. This addition was requested because a subsequent test, Countdown Demonstration, would involve a fully fueled Launch Vehicle and this latter test was identified as hazardous. This egress test was then added to the Space Vehicle Plugs Out Integrated Test.

The first draft of the Procedure was issued on September 26, 1966. After informal review and revision a second draft was issued on October 19, 1966. After formal review by both NASA and NAA, and further revision the formally approved procedure was issued on December 13, 1966. This procedure was reviewed at KSC and operational and minor technical changes made. A major revision was issued at 5:30 p.m. EST on January 26, 1967 and 4 additional pages were issued at 10:00 a.m. EST on January 27, 1967.

The Plugs-Out Test was initiated on January 27, 1967 at 12:55 GMT (7:55 a.m. EST) when power was applied to the spacecraft for this test. After completion of initial verification tests of system operation the flight crew entered the Command Module. The Command Pilot entered at 18:00 GMT (1:00 p.m. EST) followed by the Pilot and Senior Pilot. The Command Pilot noted an odor in the Spacecraft Environmental Control System suit oxygen loop and the count was held at 18:20 GMT while a sample of the oxygen in this system was taken. This odor has been determined from subsequent analysis not to be related to the fire. The count was resumed at 19:42 GMT with hatch installation and subsequent cabin purge with oxygen beginning at 19:45 GMT. Communication difficulties were encountered and the count was held at approximately 22:40 GMT to troubleshoot the problem. Various final countdown functions were still performed during the hold as communications permitted. From 22:45 GMT until about 22:53 GMT the flight crew interchanged equipment related to the communications systems in an effort to isolate the communications system problem. This problem consisted of

a continuously live microphone that could not be turned off by the crew. The live microphone condition was first noted by the test crew about 22:25 GMT and records indicate that the condition first occurred between about 20:57 GMT and 22:18 GMT. During the troubleshooting period problems developed in the ability of various ground stations to communicate with one another and with the crew. None of the communications problems appear to have had a direct bearing on the fire.

By 22:20 GMT (6:20 p.m. EST) all final countdown functions up to the transfer to simulated fuel cell power were completed and the count was held at T-10 minutes pending resolution of the communications problems.

3. EVENTS FROM THE INITIATION OF THE T-10 MINUTE HOLD AT 23:20 GMT UNTIL THE REPORT OF FIRE

From the start of the T-10 minute hold at 23:20 GMT until about 23:30 GMT there are no events that appear to be related to the fire. The major activity during this period was routine troubleshooting of the communications problem. The records show that except for the communications problem all systems were operating normally during this period. There were no voice transmissions from the spacecraft from 23:30:14 GMT until the transmission reporting the fire which began at 23:31:04.7 GMT (6:31:04.7 p.m. EST).

During the period beginning about 30 seconds before the report there are indications of crew movement. These indications are provided by the data from the Biomedical Sensors, the Command Pilot's live mike, the Guidance and Navigation System and the Environmental Control System.

There is, however, no evidence as to what this crew movement was or that it was related to the fire.

The biomedical data indicate that just prior to the fire report the Senior Pilot was performing essentially no activity (or was in the baseline "rest" condition) until about 23:30:21 GMT when a slight increase in pulse and respiratory rate was noted. At 23:30:30 GMT the electrocardiogram indicates some muscular activity for several seconds. Similar indications are noted at 23:30:39 GMT. The data show increased activity but are not indicative of an alarm type of response. By 23:30:45 GMT, all of the biomedical parameters had reverted to the baseline "rest" level.

Beginning at about 23:30 GMT, the Command Pilot live microphone transmitted brushing and tapping noises which are indicative of movement. The noises were similar to those transmitted earlier in the test by the live mike when the Command Pilot is known to have been moving. These sounds end at 23:30:58.6 GMT.

Any significant crew movement results in minor motion of the Command Module. This motion is detected by the Guidance and Navigation System and is indicative of crew movement; however, the type of movement cannot be determined. Data from this system indicate a slight movement at 23:30:24 GMT with more intense activity beginning at 23:30:39 GMT and ending at 23:30:44 GMT. More movement begins at 23:31:00 GMT and continues until loss of data transmission during the fire.

Increases of oxygen flow rate to the crew suits also indicate movement. All suits have some small leakage. This leakage rate varies with crew positions. Earlier in the Plugs-Out Test, the crew reported that a particular movement, the nature of which was unspecified, provided increased flow rate. This is also confirmed from the flow rate data records. The flow rate shows a gradual rise at 23:30:24 GMT which reaches the limit of the sensor at 23:30:59 GMT.

There is a variation at 23:30:50 GMT in the signal output from the gas chromatograph cable (the gas chromatograph was not installed in the Command Module). When the gas chromatograph is not connected, the cable acts as an antenna. Thus, changes in the electromagnetic field within the spacecraft are sensed when the cable is approached closely, touched or moved or voltage fluctuations occur

in other equipment. Variations found in the signal level from the gas chromatograph cable at earlier times in the test have been correlated with either crew movement or voltage transients when equipment was turned off or on at these earlier times. The variation at 23:30:50 GMT, may have resulted because it was touched or approached by the crew since there does not appear to be any voltage transient condition at this time which could have given the observed signal.

A significant voltage transient was recorded at 23:30:54.8 GMT. The records show a surge in the AC Bus 2 voltage.

Several other parameters being measured also showed anomalous behaviour at this time. There was a 1.7 second dropout in signal from the C-Band decoder and transmitter outputs, a brief dropout of the VHF-FM carrier, a fluctuation in the rotation controller null outputs and a fluctuation in the gas chromatograph signal.

4. EVENTS FROM THE REPORT OF FIRE UNTIL CREW REMOVAL

The events that occurred during this period can be comprehended most readily by examination of Enclosures 2 through 6. These enclosures show a sketch of Launch Complex 34, the Space Vehicle in the service tower and the interior of a mock-up of a Command Module showing detailed reconstruction of Spacecraft 012.

Beginning at 23:31:04.7 GMT (6:31:04.7 P.M. EST), the crew gave the first verbal indication of an emergency - a fire in the Command Module was reported.

Emergency procedures called for the Senior Pilot, occupying the center couch, to unlatch and remove the hatch while retaining his harness buckled. A number of witnesses who observed the television picture of the Command Module hatch window during this stage of the fire discerned motion that suggests that the Senior Pilot was reaching for the inner hatch handle. The Senior Pilot's harness buckle was found unopened after the fire, indicating that he initiated the standard hatch-opening procedure. Data from the Guidance and Navigation System indicate considerable activity within the Command Module after the fire was discovered. This activity is consistent with movement of the crew prompted by proximity of the fire or with the undertaking of standard emergency egress procedures.

Personnel located on adjustable level 8 (A-8) adjacent to the Command Module responded to the report of the fire. The Pad Leader ordered crew egress procedures to be started and technicians started toward the White Room which surrounds the hatch and into which the crew would step upon egress. Then the Command Module ruptured.

All transmission of voice and data from the spacecraft terminated by 23:31:22.4 GMT, three seconds after rupture. Witnesses monitoring television showing the hatch window report that flame spread from the left to the right side of the Command Module and shortly thereafter covered the entire visible area.

Flames and gases flowed rapidly out of the ruptured area, spreading flames into the toroidal space between the Command Module pressure vessel and heat shield, through access hatches and into levels A-8 and A-7 of the service structure. These flames ignited combustibles, endangered pad personnel, and impeded rescue efforts. The burst of fire, together with the sounds of rupture, caused several pad personnel to believe that the Command Module had exploded or was about to explode. Pad personnel fled from the immediate area.

The immediate reaction of all personnel on level A-8 was to evacuate the level. This reaction was promptly followed by a return to effect rescue. Upon running out on the swing arm from the umbilical tower, several personnel obtained a fire extinguisher and returned along the swing arm to the White Room to begin rescue efforts. Others obtained fire extinguishers from various areas of the service structure and rendered assistance in fighting the fires.

The time interval between exit to the swing arm and return to the White Room is estimated variously by the participants. Persons viewing television monitors could not see movement early in the White Room because of heavy smoke. Approximately one minute and thirty seconds after the first crew report of the fire the Pad Leader reported over his headset that attempts had been started to remove the hatches. This report was made after the Pad Leader had gone out on the swing arm, returned and entered the White Room one or two times and left to reach breathable air and his headset. It is therefore estimated that attempts to remove the hatches began one minute after the fire was first reported.

Three hatches were installed on the Command Module. The outermost hatch, called the boost protective cover (BPC) hatch, is part of the cover which shields the Command Module during launch and is jettisoned prior to orbital operation. The middle hatch is termed the ablative hatch and becomes the outer hatch when the BPC is jettisoned after launch. The inner hatch closes the pressure vessel wall of the Command Module and is the first hatch to be opened by the crew in an unaided crew egress.

The outer or BPC hatch was in place but not fully latched because of distortion in the BPC caused by wire bundles temporarily installed for the test. The middle hatch and inner hatch were in place and latched after crew ingress.

Although the BPC hatch was not fully latched it was necessary to insert a specially-designed tool into the hatch in order to provide a hand-hold for lifting the hatch from the Command Module. At this time the White Room was filling with dense, dark smoke from the Command Module interior and from secondary fires throughout level A-8. While some personnel were able to locate and don operable gas masks others were not. Some proceeded without masks while others attempted without success to render masks operable. Even operable masks were unable to cope with the dense smoke present because they were designed for use in toxic rather than dense smoke atmospheres.

Visibility in the White Room was virtually zero. It was necessary to work essentially by touch since visual observation was limited to a few inches at best. A hatch removal tool was in the White Room. Once the small fire near the BPC hatch had been extinguished and the tool located the Pad Leader and an assistant removed the BPC hatch. Although the hatch was not latched removal was difficult.

The personnel who removed the BPC hatch could not remain in the White Room because of the smoke. They left the White Room and passed the tool which was necessary to open each hatch to other individuals. A total of five individuals took part in opening the three hatches and each made several trips into the White Room and out for breathable air.

The middle hatch was removed with less effort than was required for the outer or BPC hatch.

The inner hatch was unlatched and an attempt was made to raise it from its support and to lower it to the Command Module floor. The hatch could not be lowered the full distance to the floor and was instead pushed to one side. When the inner hatch was opened intense heat and a considerable amount of smoke issued from the interior of the Command Module.

When the Pad Leader ascertained that all hatches were open, he left the White Room, proceeded a few feet along the swing arm, donned his headset and reported this fact. From a voice tape it has been determined that this report came approximately five minutes, twenty-seven seconds after the first report of the fire. The Pad Leader estimates that his report was made no more than thirty seconds after the inner hatch was opened. Therefore, it is concluded that all hatches were opened and the two outer hatches removed approximately five minutes after the report of fire or at about 23:36 GMT. A log maintained by a person monitoring voice transmissions from level A-8 sets the time of the Pad Leader's report at 23:36 GMT. All records in this log are noted in minutes with no indication of seconds. Medical opinion, based on autopsy reports, has concluded that chances of resuscitation decreased rapidly once consciousness was lost and that resuscitation was impossible by 23:36 GMT.

Visibility within the Command Module was extremely poor. Although the lights remained on, they could be perceived only dimly. No fire was observed. Initially, the crew was not seen. The personnel who had been involved in removing the hatches attempted to locate the crew without success.

Throughout this period, other pad personnel were fighting secondary fires on level A-8. There was considerable fear that the launch escape tower, mounted above the Command Module, would be ignited by the fires below and destroy much of the launch complex.

Shortly after the report of the fire, a call was made to the fire department. From log records, it appears that the fire apparatus and personnel were dispatched at about 23:32 GMT. After hearing the report of the fire, the doctor monitoring the test from the blockhouse near the pad proceeded to the base of the umbilical tower.

The exact time at which firemen reached Level A-8 is not known. Personnel who opened the hatches unanimously state that all hatches were open before any firemen were seen on the level or in the White Room. The first firemen who reached Level A-8 state that all hatches were open, but that the inner hatch was inside the Command Module, when they arrived. This places arrival of the firemen after 23:36 GMT. It is estimated, on the basis of tests, that seven to eight minutes were required to travel from the fire station to the launch complex and to ride the elevator from the ground to Level A-8. Thus, the estimated time of firemen arrival at level A-8 is shortly before 23:40 GMT.

When the firemen arrived, the positions of the crew couches and crew could be perceived through the smoke but only with great difficulty. An unsuccessful attempt was made to remove the Senior Pilot from the Command Module.

Initial observations and subsequent inspection reveal the following facts. The Command Pilot's couch (the left hand couch) was in the "170 degree position", in which it is essentially horizontal throughout its length. The foot restraints and harness were released and the inlet and outlet oxygen hoses were connected to the suit. The electrical adapter cable was disconnected from the communications cable. The Command Pilot was lying supine on the aft bulkhead or floor of the Command Module, with his helmet visor closed and locked and with his head beneath the Pilot's head rest and his feet on his own couch. A fragment of his suit material was found outside the Command Module pressure vessel five feet from the point of rupture. This indicates that his suit had failed prior to the time of rupture (23:31:19.4 GMT) allowing convection currents to carry the suit fragment through the rupture.

The Senior Pilot's couch (the center couch) was in the "96 degree" postion in which the back portion is horizontal and lower portion in the raised position. The buckle releasing the shoulder straps and lap belts was not opened. The straps and belts were burned through. The suit oxygen outlet hose was connected but the inlet hose was disconnected. The helmet visor was closed and locked and all electrical connections were intact. The Senior Pilot was lying transversely across the Command Module just below the level of the hatchway.

The Pilot's couch (the right hand couch) was in the "264 degree" position in which the back portion is horizontal and the lower portion dropped toward the floor. All restraints were disconnected, all hoses and electrical connections were intact and the helmet visor was closed and locked. The Pilot was supine on his couch.

From the foregoing it has been determined that in all probability the Command Pilot left his couch to avoid the initial fire, the Senior Pilot remained in his couch as planned for emergency egress, attempting to open the hatch until his restraints burned through and the Pilot remained in his couch to maintain communications until the hatch could be opened by the Senior Pilot as planned. With a slightly higher pressure inside the Command Module than outside, opening the inner hatch is impossible because of the resulting force on the hatch. Thus the inability of the pressure relief system to cope with pressure increase due to the fire made opening of the inner hatch impossible until after cabin rupture,

and after rupture the intense and widespread fire together with rapidly increasing carbon monoxide concentrations further prevented egress.

Whether the inner hatch handle was moved by the crew cannot be determined because the opening of the inner hatch from the White Room also moves the handle within the Command Module to the unlatched position.

Immediately after the firemen arrived, the Pad Leader on duty was relieved to allow treatment for smoke inhalation. He had first reported over the headset that he could not describe the situation in the Command Module. In this manner he attempted to convey the fact that the crew was dead to the Test Conductor without informing the many people monitoring the communication channels. Upon reaching the ground the Pad Leader told the doctors that the crew was dead. The three doctors proceeded to the White Room and arrived there shortly after the arrival of the firemen. The doctors estimate their arrival to have been at 23:45 GMT. The second Pad Leader reported that medical support was available at approximately 23:43 GMT. The three doctors entered the White Room and determined that the crew had not survived the heat, smoke, and thermal burns. The doctors were not equipped with breathing apparatus, and the Command Module still contained fumes and smoke. It was determined that nothing could be gained by immediate removal of the crew. The firemen were directed to stop removal efforts

When the Command Module had been adequately ventilated, the doctors returned to the White Room with equipment for crew removal. It became apparent that extensive fusion of suit material to melted nylon from the spacecraft would make removal very difficult. For this reason it was decided to discontinue efforts at removal in the interest of accident investigation and to photograph the Command Module with the crew in place before evidence was disarranged.

Photographs were taken, and the removal efforts resumed at approximately 5:30 GMT (12:30 a.m. EST) on January 28. Removal of the crew took approximately 90 minutes and was completed about seven and one-half hours after the accident.

LIST OF ENCLOSURES

Enclosure

IV-1 Schematic of the Complete Space Vehicle, the Spacecraft and the Command Module.

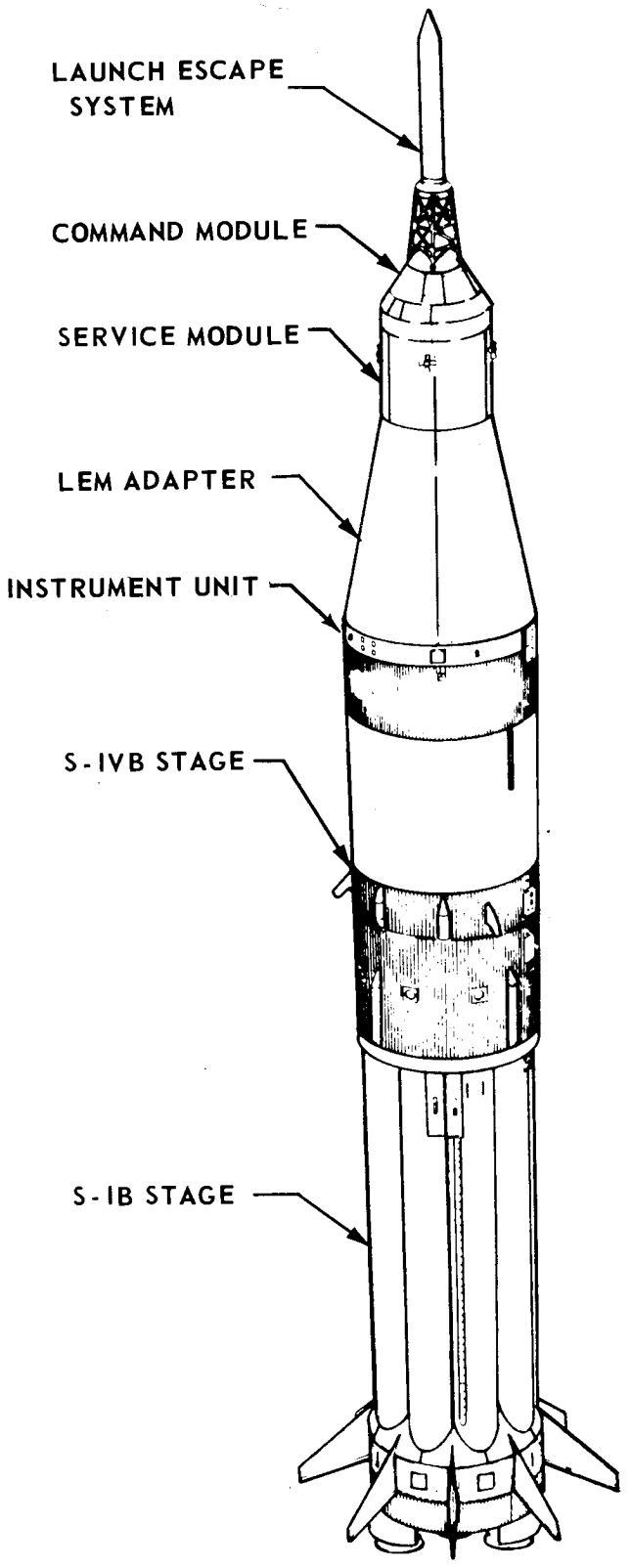
IV-2 Aerial view of Complex 34 with Supporting Facilities.

IV-3 Schematic of Spacecraft Launch Vehicle in Service Structure with Access Arms Extended.

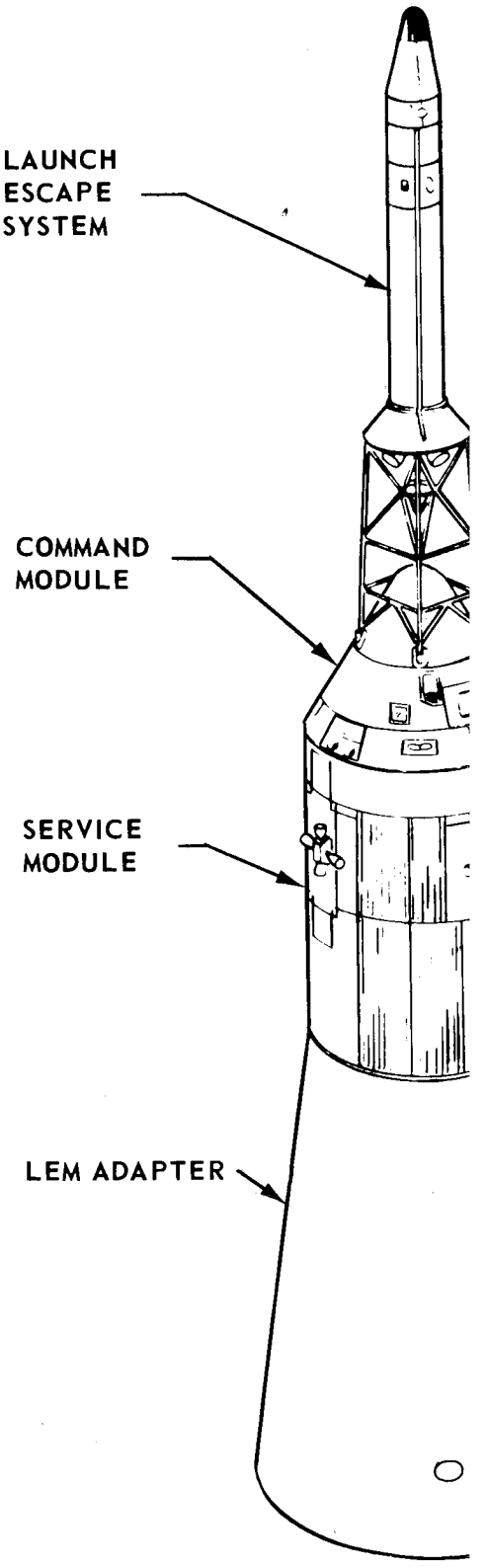
IV-4 Drawing of Umbilical Tower, Access Arm and White Room Positioned at the Command Module.

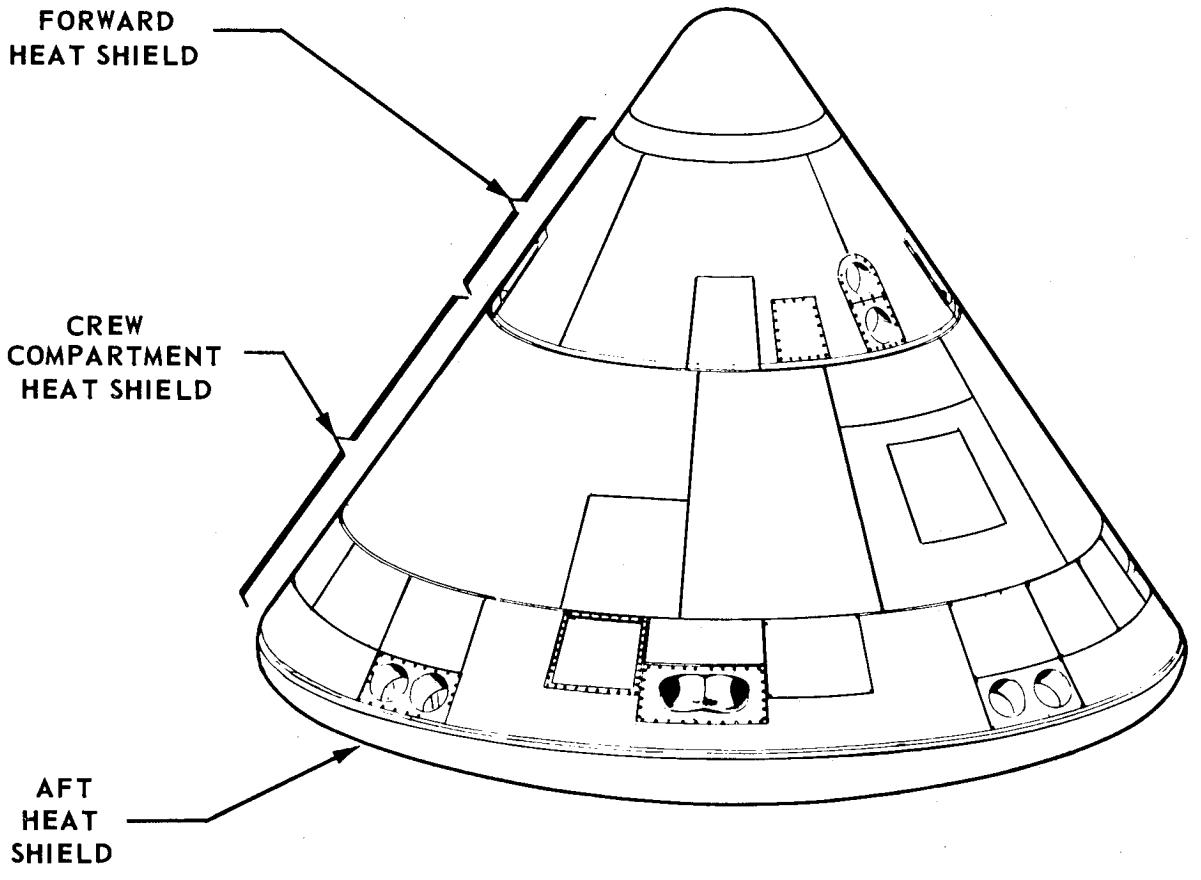
IV-5 Photograph - Interior of a Mock-up Command Module, Without Couches, Configured Similar to Command Module 012 at the Time of the Accident.

IV-6 Photograph - Interior of a Mock-up Command Module, With Couches, Configured Similar to Command Module 012.


LAUNCH ESCAPE SYSTEM
COMMAND MODULE
SERVICE MODULE
LEM ADAPTER
INSTRUMENT UNIT
S-IVB STAGE
S-IB STAGE

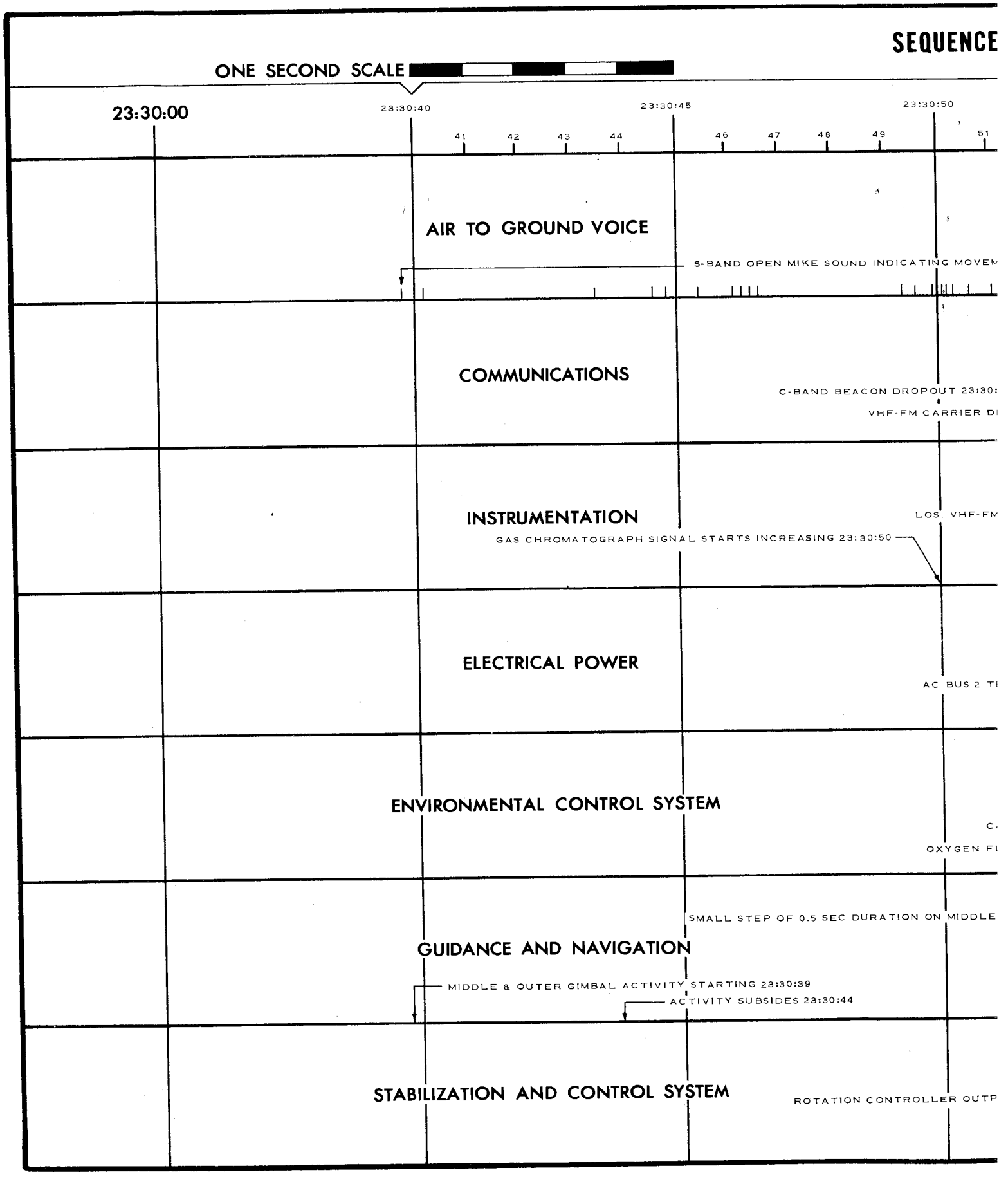
SATURN IB


LAUNCH ESCAPE SYSTEM
COMMAND MODULE
SERVICE MODULE
LEM ADAPTER



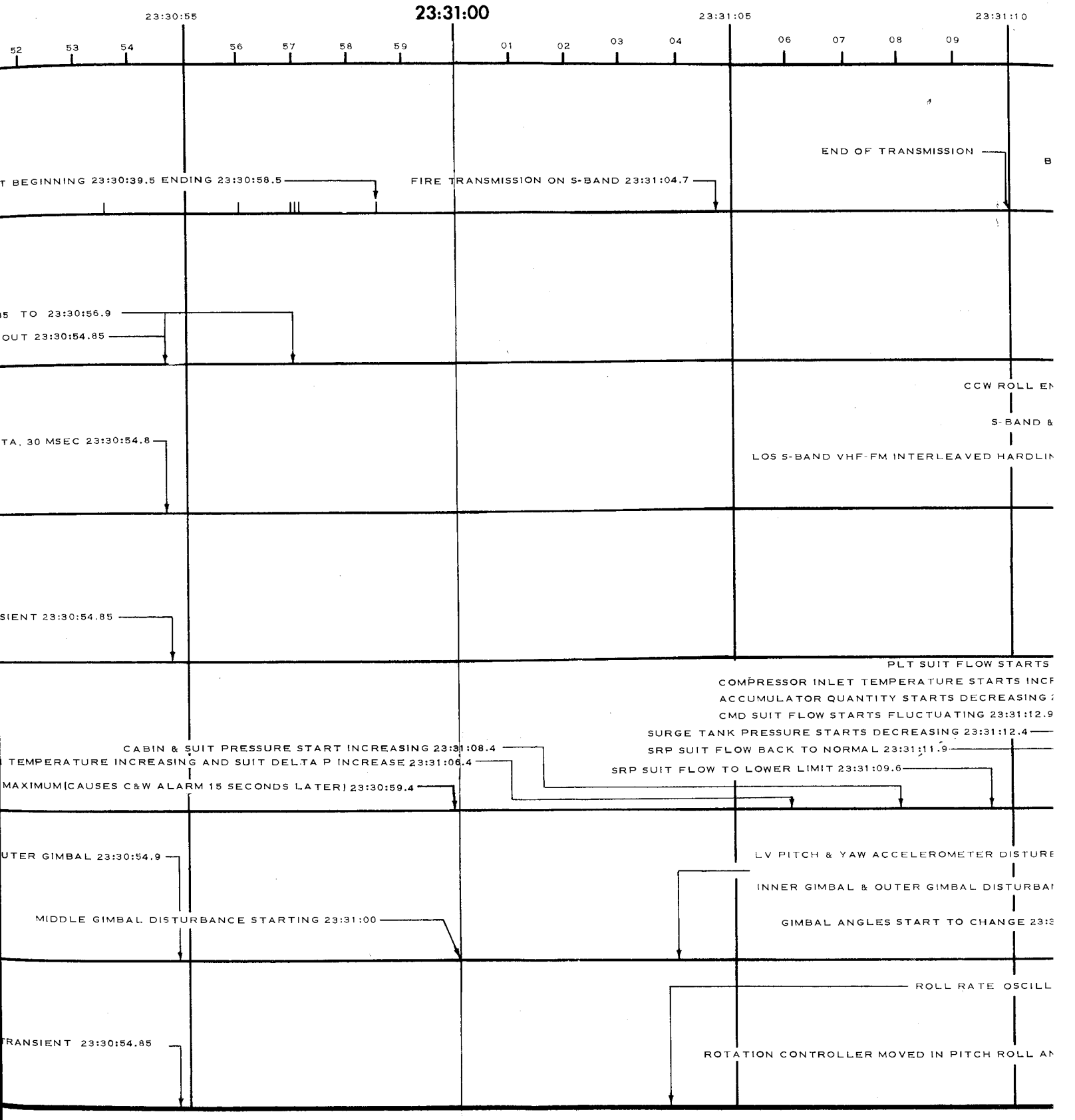
APOLLO COMMAND MODULE

ENCLOSURE IV-1


SEQUENCE
ONE SECOND SCALE
23:30:00
23:30:40
23:30:45
23:30:50
41
42
43
44
46
47
48
49
51
AIR TO GROUND VOICE
S-BAND OPEN MIKE SOUND INDICATING MOVEM
COMMUNICATIONS
C-BAND BEACON DROPOUT 23:30:
VHF-FM CARRIER DI
INSTRUMENTATION
LOS, VHF-FM
GAS CHROMATOGRAPH SIGNAL STARTS INCREASING 23:30:50
ELECTRICAL POWER
AC BUS 2 TI
ENVIRONMENTAL CONTROL SYSTEM
C
OXYGEN FI
SMALL STEP OF 0.5 SEC DURATION ON MIDDLE
GUIDANCE AND NAVIGATION
MIDDLE & OUTER GIMBAL ACTIVITY STARTING 23:30:39
ACTIVITY SUBSIDES 23:30:44
STABILIZATION AND CONTROL SYSTEM
ROTATION CONTROLLER OUTP

OF EVENTS

**TIMES SHOWN ARE DERIVED FROM SAMPLED MEASUREMENTS AN
UNCERTAIN BY THE SAMPLING RATE OF THE SPECIFIC MEASUREM**



) ARE
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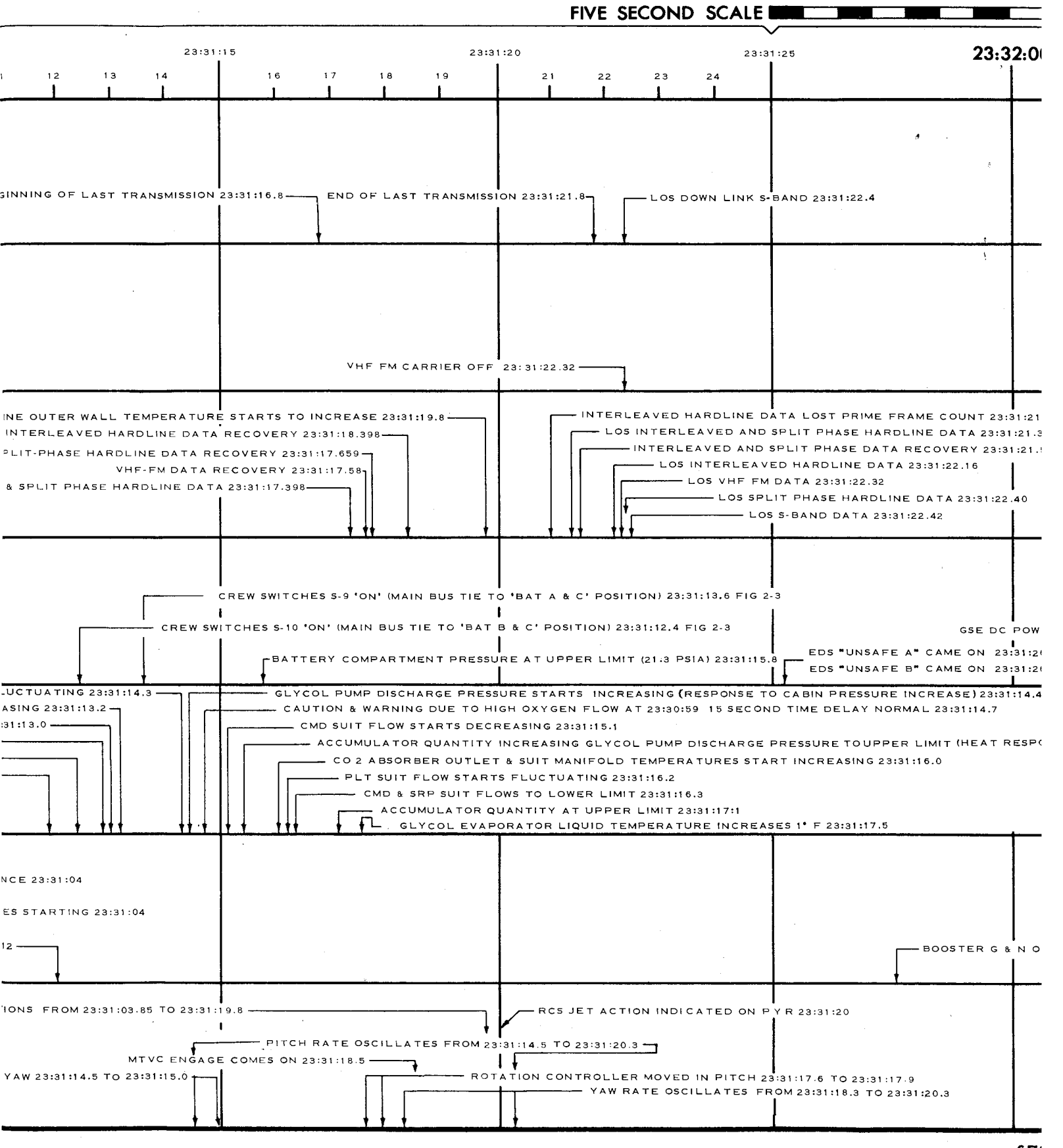
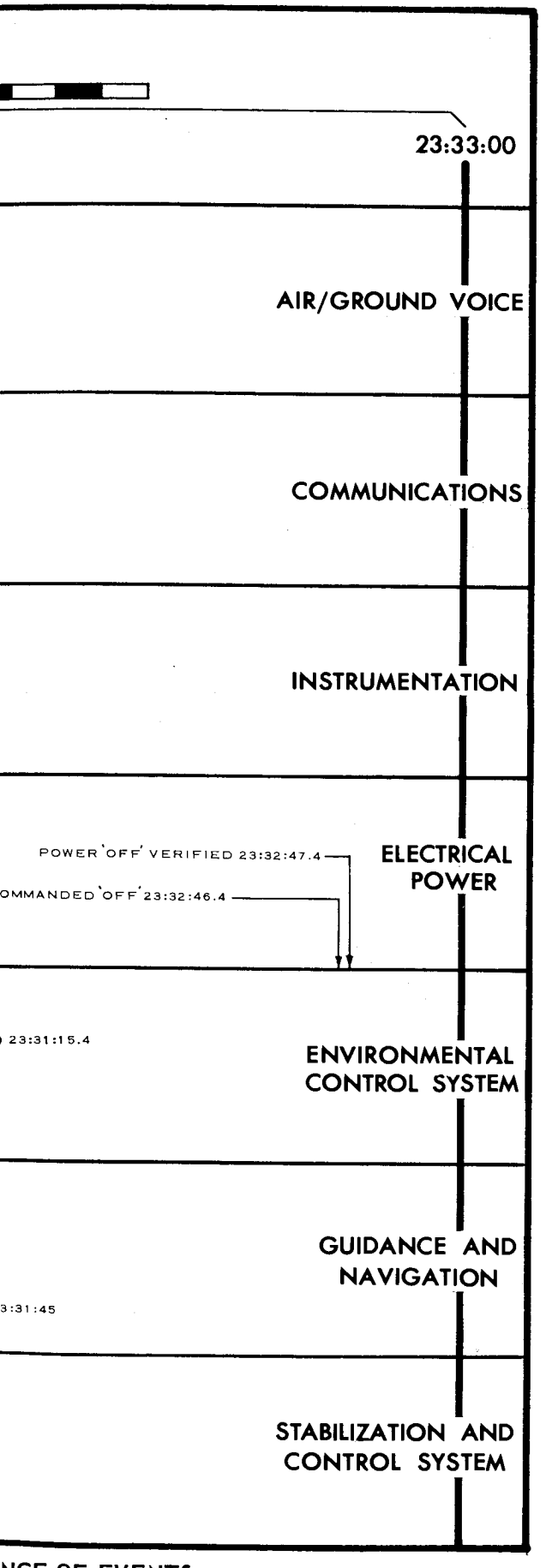
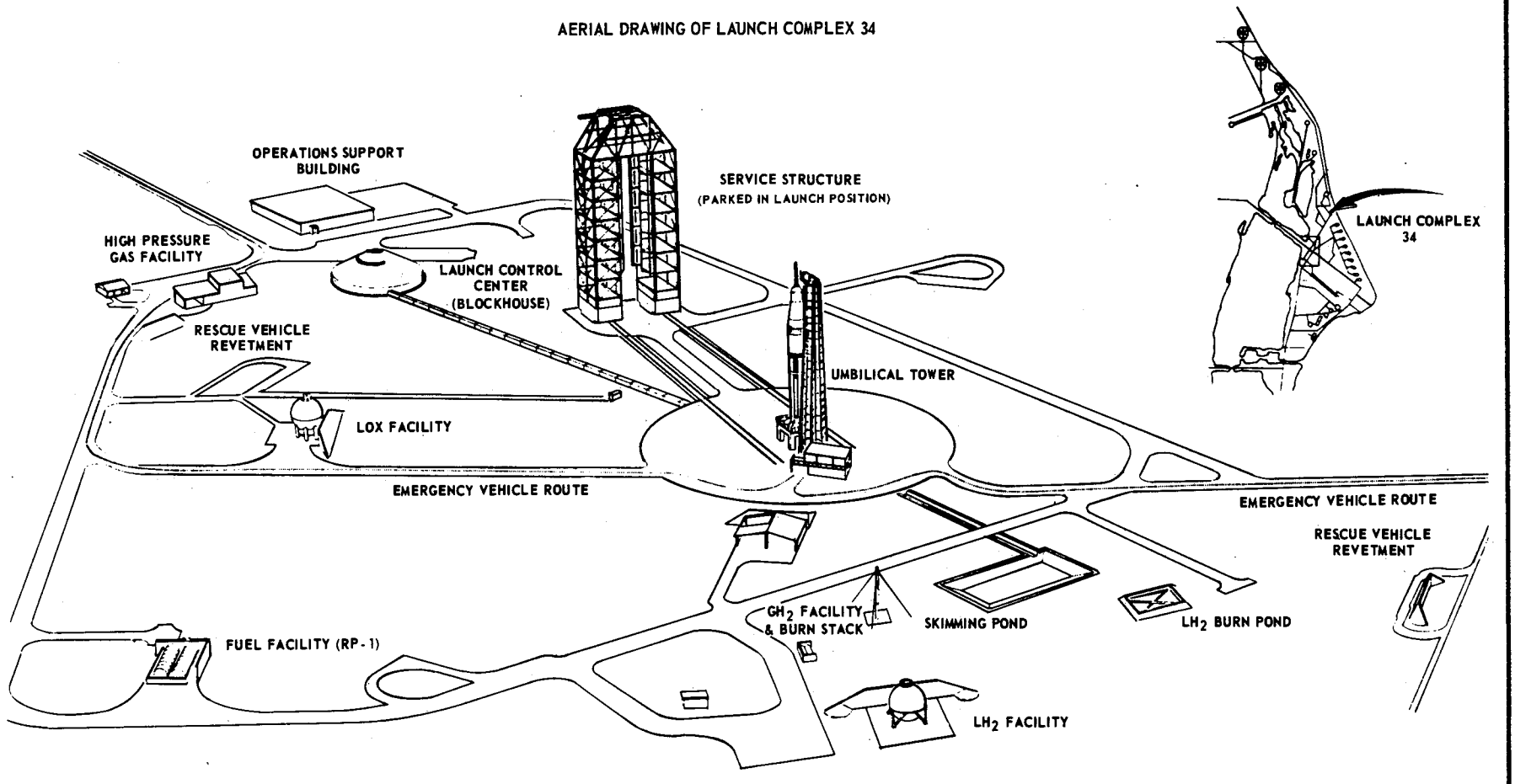

FIVE SECOND SCALE
23:31:15
23:31:20
23:31:25
23:32:0
12
13
14
16
17
18
19
21
22
23
24
GINNING OF LAST TRANSMISSION 23:31:16.8
END OF LAST TRANSMISSION 23:31:21.8
LOS DOWN LINK S-BAND 23:31:22.4
VHF FM CARRIER OFF 23:31:22.32
INE OUTER WALL TEMPERATURE STARTS TO INCREASE 23:31:19.8
INTERLEAVED HARDLINE DATA RECOVERY 23:31:18.398
PLIT-PHASE HARDLINE DATA RECOVERY 23:31:17.659
VHF-FM DATA RECOVERY 23:31:17.58
& SPLIT PHASE HARDLINE DATA 23:31:17.398
INTERLEAVED HARDLINE DATA LOST PRIME FRAME COUNT 23:31:21
LOS INTERLEAVED AND SPLIT PHASE HARDLINE DATA 23:31:21.3
INTERLEAVED AND SPLIT PHASE DATA RECOVERY 23:31:21.
LOS INTERLEAVED HARDLINE DATA 23:31:22.16
LOS VHF FM DATA 23:31:22.32
LOS SPLIT PHASE HARDLINE DATA 23:31:22.40
LOS S-BAND DATA 23:31:22.42
CREW SWITCHES S-9 'ON' (MAIN BUS TIE TO 'BAT A & C' POSITION) 23:31:13.6 FIG 2-3
CREW SWITCHES S-10 'ON' (MAIN BUS TIE TO 'BAT B & C' POSITION) 23:31:12.4 FIG 2-3
GSE DC POW
BATTERY COMPARTMENT PRESSURE AT UPPER LIMIT (21.3 PSIA) 23:31:15.8
EDS "UNSAFE A" CAME ON 23:31:2
EDS "UNSAFE B" CAME ON 23:31:2
LUCTUATING 23:31:14.3
GLYCOL PUMP DISCHARGE PRESSURE STARTS INCREASING (RESPONSE TO CABIN PRESSURE INCREASE) 23:31:14.4
ASING 23:31:13.2
CAUTION & WARNING DUE TO HIGH OXYGEN FLOW AT 23:30:59 15 SECOND TIME DELAY NORMAL 23:31:14.7
:31:13.0
CMD SUIT FLOW STARTS DECREASING 23:31:15.1
ACCUMULATOR QUANTITY INCREASING GLYCOL PUMP DISCHARGE PRESSURE TOUPPER LIMIT (HEAT RESPO
CO 2 ABSORBER OUTLET & SUIT MANIFOLD TEMPERATURES START INCREASING 23:31:16.0
PLT SUIT FLOW STARTS FLUCTUATING 23:31:16.2
CMD & SRP SUIT FLOWS TO LOWER LIMIT 23:31:16.3
ACCUMULATOR QUANTITY AT UPPER LIMIT 23:31:17:1
GLYCOL EVAPORATOR LIQUID TEMPERATURE INCREASES 1° F 23:31:17.5
NCE 23:31:04
ES STARTING 23:31:04
12
BOOSTER G & N O
IONS FROM 23:31:03.85 TO 23:31:19.8
RCS JET ACTION INDICATED ON P Y R 23:31:20
PITCH RATE OSCILLATES FROM 23:31:14.5 TO 23:31:20.3
MTVC ENGAGE COMES ON 23:31:18.5
YAW 23:31:14.5 TO 23:31:15.0
ROTATION CONTROLLER MOVED IN PITCH 23:31:17.6 TO 23:31:17.9
YAW RATE OSCILLATES FROM 23:31:18.3 TO 23:31:20.3

SE



NCE OF EVENTS

AERIAL DRAWING OF LAUNCH COMPLEX 34



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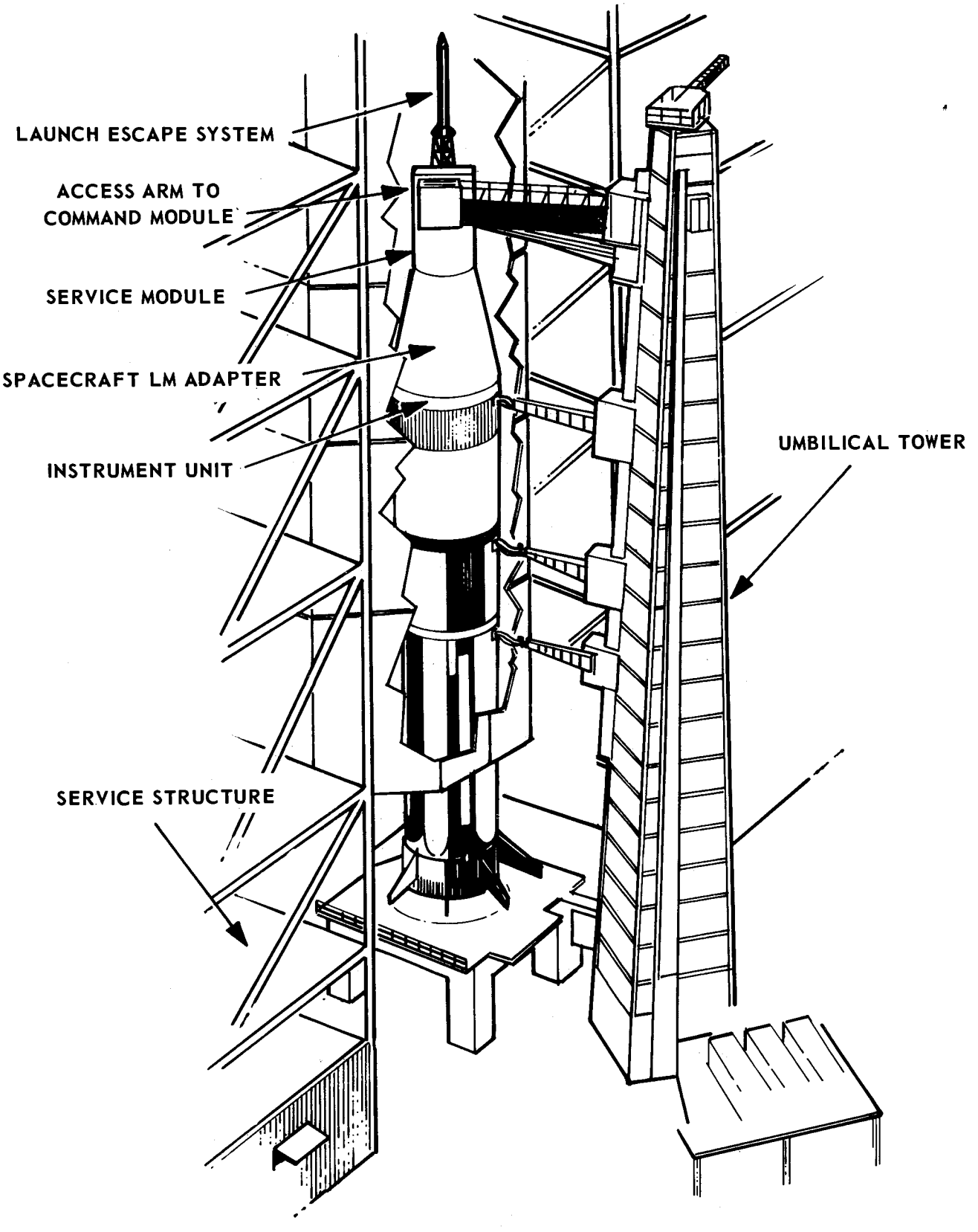
VIEW OF SPACECRAFT LAUNCH VEHICLE IN SERVICE STRUCTURE
WITH ACCESS ARMS EXTENDED



ENCLOSURE IV-3

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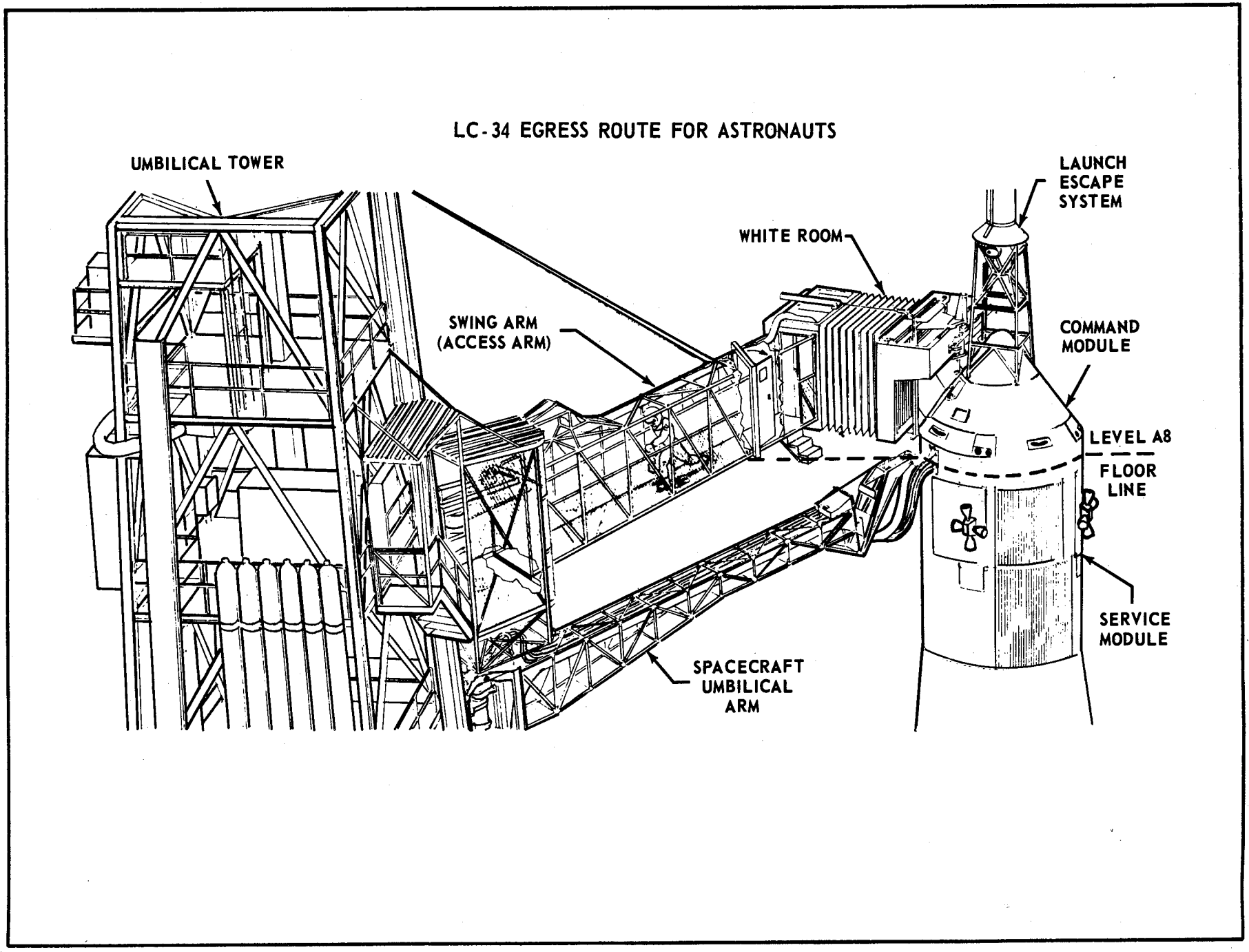
LC-34 EGRESS ROUTE FOR ASTRONAUTS
UMBILICAL TOWER
LAUNCH ESCAPE SYSTEM
WHITE ROOM
SWING ARM (ACCESS ARM)
COMMAND MODULE
LEVEL A8
FLOOR LINE
SERVICE MODULE
SPACECRAFT UMBILICAL ARM

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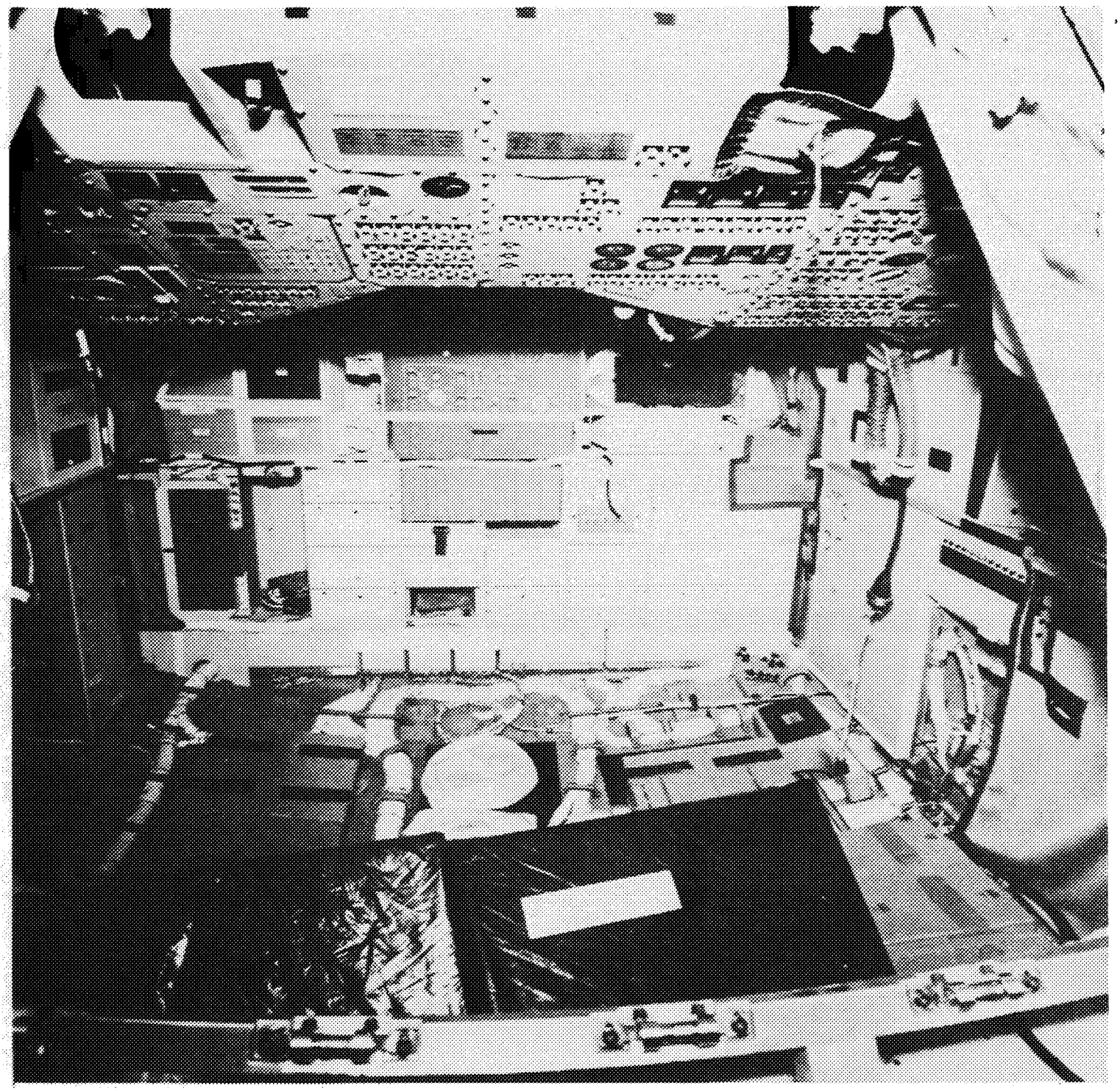
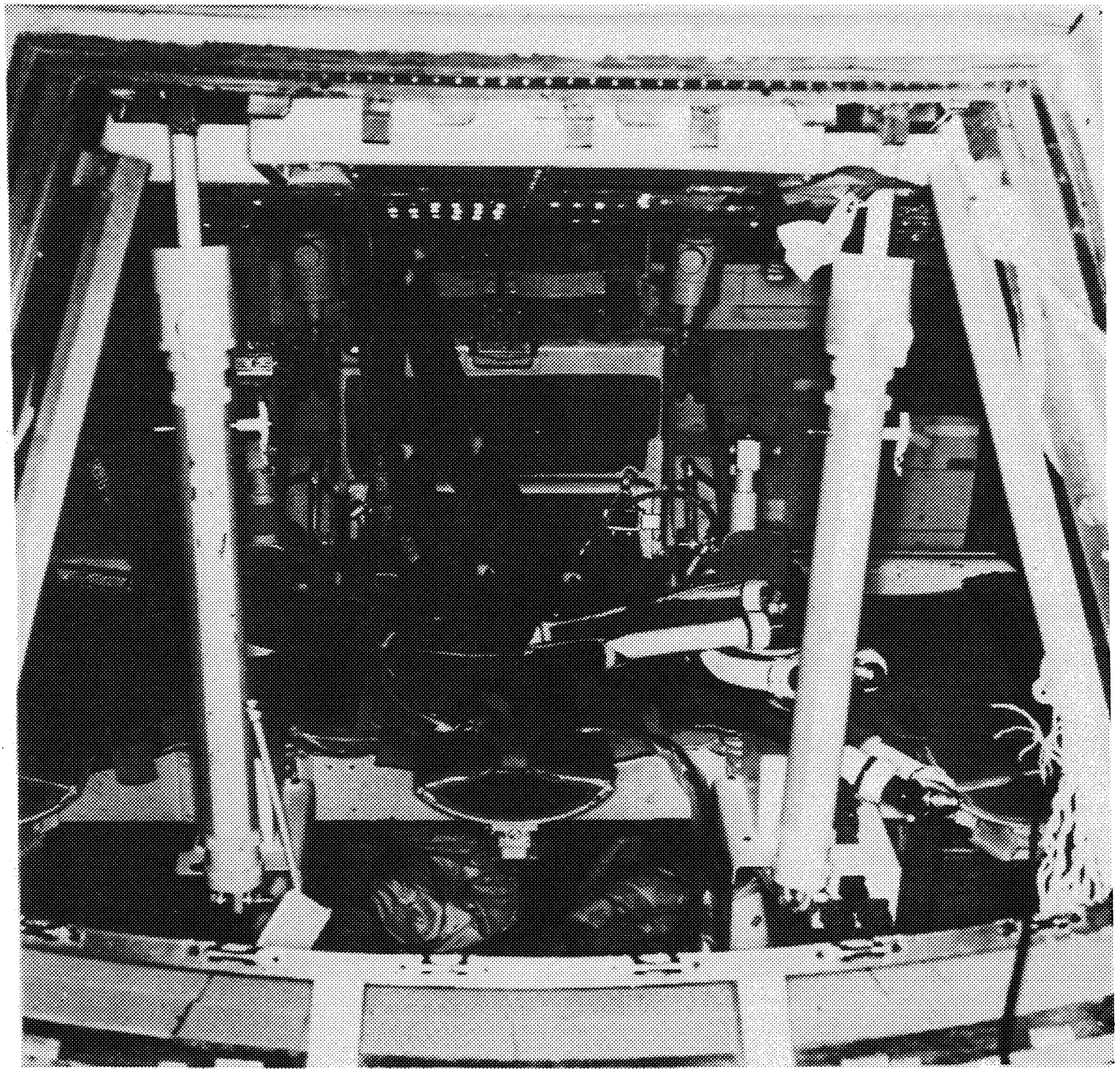


VIEW OF COMMAND MODULE MOCKUP INTERIOR LESS COUCHES

ORIGINAL PAGE IS
OF POOR QUALITY



VIEW OF COMMAND MODULE MOCKUP INTERIOR, COUCHES INSTALLED

PART V

INVESTIGATION AND ANALYSIS

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PART V. INVESTIGATION AND ANALYSES

1. INSPECTION AND DISASSEMBLY

Immediately after the accident additional security personnel were positioned at Launch Complex 34 and the Complex was impounded. Prior to disturbing any evidence numerous external and internal photographs were taken of the spacecraft. After crew removal, two experts entered the Command Module to verify switch positions. Small groups of NASA and North American Aviation management, Apollo 204 Review Board Members, Representatives and Consultants inspected the exterior of Spacecraft 012. On January 28, 1967 an astronaut entered the Command Module to verify additional switch positions needed to clarify data.

The Board established procedures for disassembly of Spacecraft 012. The first step of disassembly was to establish safe working conditions at the spacecraft. This was accomplished by: (1) removal of the Launch Escape System, (2) removal of safetying of all pyrotechnics, (3) examination of spacecraft structure for integrity, (4) examination of all pressure vessels for potential hazards, and (5) sampling of spacecraft atmosphere for harmful contaminants. After safe working conditions were established disassembly proceeded. A series of close-up stereo photographs of the Command Module was taken to document the as-found condition of the spacecraft systems.

The task of searching the physical evidence was difficult and time-consuming because of the small entrance and confined area of the Command Module. In order to remove the components as quickly as possible, two persons at a time were permitted to enter the Command Module for component removal. After the removal of each component, photographs were taken of the exposed area. This step-by-step photography was used throughout the disassembly of the spacecraft (Enclosures 1 through 11). Approximately 5000 photographs were taken.

After the couches were removed, a special false floor with removable 18-inch transparent squares was suspended from the existing couch strut fittings to provide access to the entire inside of the Command Module without disturbing evidence (Enclosure 12). A detailed inspection of the spacecraft interior was then performed followed by the preparation and approval by the Board of a Command Module disassembly plan. Command Module 014 was shipped to KSC on February 1, 1967 to assist the Apollo 204 Review Board in the investigation. This Command Module was placed in the Pyrotechnics Installation Building and was used to develop disassembly techniques for selected components prior to their removal from Command Module 012.

By February 7, 1967 the disassembly plan was fully operational. The concentrated effort of organized and coordinated component removal continued on a three-shift seven-day-a-week basis. All suspect circumstances or conditions were brought to the attention of the Apollo 204 Review Board.

All interfaces such as electrical connectors, tubing joints, physical mounting of components, etc. were closely inspected and photographed immediately prior to, during and after disassembly. Each item removed from the Command Module was appropriately tagged, sealed in clean plastic containers and transported under the required security to bonded storage (Enclosure 13).

On February 17, 1967 the Board decided that removal and wiring tests had progressed to a point which allowed moving the Command Module without disturbing evidence. The Command Module was moved to the Pyrotechnics Installation Building at KSC where better working conditions were available.

C-2

With improved working conditions, it was found that a work schedule of two eight-hour shifts per day for six days a week was sufficient to keep pace with the analysis and disassembly planning. The only exception to this was a three-day period of three eight-hour shifts per day used to remove the aft heat shield, move the Command Module to a more convenient work station and remove the crew compartment heat shield (Enclosure 14 and 15). The disassembly of the Command Module was completed on March 27, 1967.

From the beginning of disassembly, action was taken to catalog and place on display the hundreds of items that would be removed from the Command Module. The Pyrotechnics Installation Building was assigned to the Board for this purpose. A bonded storage room was established to receive and catalog components as they were removed. Command Module components were then displayed in a bonded area. The purpose of this area was to permit investigators to make visual examination of Command Module components (Enclosure 16). During the course of the disassembly over 1000 items were removed from the Command Module. A list of all removed components was maintained and distributed weekly to the Board. This list identified the location of components in the Pyrotechnics Installation Building as well as those undergoing further analyses and tests at other locations.

Throughout the disassembly operation, experts meticulously studied the exposed portions of the Command Module. The relative consumption of combustibles and sooting patterns were studied for clues as to the site of the ignition source. All structural elements, covers and panels were examined for evidence of association with the ignition. Component systems and parts were studied inch by inch with magnifying glasses and frequently parts were taken into the laboratory for microscopic or metallurgical analyses. Wire bundles were given particular attention and after separation, the individual wires were examined under 7 power magnification for sites of possible arcing.

All components that showed evidence of abnormal fire effects were examined internally and many were tested for functionality. Many components showed burning of internal insulation or potting material but in all cases they were exonerated on the basis of direction of flame travel or on the basis that there could be no communication with combustibles outside the component. Particularly suspect components were disassembled for detailed examination and analyses. All of the data developed by these visual and laboratory examinations were coordinated in making the final analysis as to probable ignition sources.

2. CHRONOLOGY OF THE FIRE

It is most likely that the fire began in the lower forward portion of the left-hand equipment bay. This would place the origin to the left of the Command Pilot, and considerably below the level of his couch.

Once initiated, the fire burned in three stages. The first stage with its associated rapid temperature rise and increase in cabin pressure, terminated approximately 15 seconds after the verbal report of fire. At this time (about 23:31:19 GMT) the pressure vessel, which constitutes the Command Module cabin, ruptured. During this first stage of the fire, flames moved rapidly from the point of ignition, traveling along the Raschel net debris traps which were installed in the Command Module to prevent items from dropping into equipment areas during tests or flight. At the same time, Velcro strips positioned near the ignition point also burned.

Based upon pressure and temperature measurements taken during the fire, the fire was not intense until about 23:31:12 GMT. The slow rate of buildup of the fire during the early portion of the first stage is consistent with the view that ignition occurred in a zone containing little combustible material. The slow rise of pressure could also result from absorption of most of the heat by the aluminum structure of the Command Module. The original flames rose vertically and then spread out across the cabin ceiling. The debris traps provided not only combustible material and a path for the spread of the flames but also firebrands of burning molten nylon. The scattering of these firebrands contributed to the spread of the flames.

By 23:31:12 GMT the fire had broken from its point of origin. Evidence is strong that a wall of flames extended along the left wall of the module, preventing the Command Pilot, occupying the left hand couch from reaching the valve which would vent the Command Module to the outside atmosphere. Although operation of this valve, located on a shelf above the left hand equipment bay, is the first step in established emergency egress procedures, such action would have been to no avail because the venting capacity was insufficient to prevent the rapid build-up of pressure due to the fire. It is estimated that opening the valve would have delayed Command Module rupture by less than one second.

Emergency procedures called for the Senior Pilot, occupying the center couch, to unlatch and remove the hatch while retaining his harness buckled. A number of witnesses who observed the television picture of the Command Module hatch window during this stage of the fire discerned motion that suggests that the Senior Pilot was reaching for the inner hatch handle. The Senior Pilot's harness buckle was found unopened after the fire indicating that he initiated the standard hatch opening procedure. Data from the Guidance and Navigation System indicate considerable activity within the Command Module after the fire was discovered. This activity is consistent with movement of the crew prompted by proximity of the fire or with the undertaking of standard emergency egress procedures.

The Command Module is designed to withstand an internal pressure of approximately 13 pounds per square inch above external pressure without rupturing. Data recorded during the fire show that this design criteria was exceeded late in the first stage of the fire and that rupture occurred at about 23:31:19 GMT. The point of rupture was where the floor or aft bulkhead of the Command Module joins the wall, essentially opposite the point of origin of the fire. About three seconds before rupture, the final crew communication began at 23:31:16.8 GMT. This communication ended shortly after rupture at 23:31:21.8 GMT (a detailed discussion of the two voice transmissions during the fire is given in a subsequent section).

Rupture of the Command Module marked the beginning of the brief second stage of the fire. This stage is characterized by the period of greatest conflagration due to the forced convection that resulted from the outrush of gases through the rupture in the pressure vessel. The swirling flow scattered firebrands throughout the crew compartment spreading the fire. This stage of the fire ended at approximately 23:31:25 GMT. Evidence that the fire spread from the left hand side of the Command Module toward the rupture area was found on subsequent examination of the module. For example, the leg rest control handle on the left side of the left hand couch is fabricated from aluminum tubing. Tongues of flame pouring over the control handle melted its left side. However, a nylon button at the base of the handle was unconsumed and only slightly deformed. Similarly, flames spreading across the floor beneath the couches caused more burning on the left side of three nylon helmet covers than on the right. The underside of the couches above the helmet covers was relatively unsooted. A lack of soot indicates a fire of only short duration beneath the couches some time after the couch structure had become heated. Further, storage boxes situated on the floor were damaged only slightly. Fire across the floor of the spacecraft lasted but a few seconds and spread from left to right.

Damage to the crew suits is also indicative of the spread of the fire from left to right. The Command Pilot's suit was damaged worst while the Senior Pilot's and Pilot's suits sustained progressively less damage.

Evidence of the intensity of the fire includes burst and burned aluminum tubes in the oxygen and coolant systems at floor level.

The pressure in the Command Module is estimated to have dropped to atmospheric pressure five or six seconds after rupture. The third and final stage of the fire began at about 23:31:25 GMT.

The third stage was characterized by rapid production of high concentrations of carbon monoxide. Following the loss of pressure in the Command Module and with fire now throughout the crew compartment, the remaining atmosphere quickly became deficient in oxygen so that it could not sup-

port continued combustion. Unlike the earlier stages where the flame was relatively smokeless, heavy smoke now formed and large amounts of soot were deposited on most spacecraft interior surfaces as they cooled. The third stage of the fire could not have lasted more than a few seconds because of the rapid depletion of oxygen. It is estimated that the Command Module atmosphere was lethal by 23: 31:30 GMT, five seconds after the start of the third stage.

Although most of the fire inside the Command Module became extinguished shortly because of lack of oxygen, a localized, intense fire lingered in the area of the Environmental Control Unit. This unit is located in the left hand equipment bay, near the point where the fire is believed to have started. Failed oxygen and water/glycol lines in this area continued to supply oxygen and fuel to support the localized fire that melted the aft bulkhead and burned adjacent portions of the inner surface of the Command Module heat shield.

The loss of telemetry data at 23:31:22.4 GMT during the second phase of the fire makes determination of precise times of subsequent occurrences impossible. Thus all further times are based on less precise evidence such as entries in logs maintained by personnel monitoring various facets of the activity, review of voice tapes maintained of conversations between the Pad Leader and blockhouse monitors, and where so indicated, witness estimates.

3. DATA ANALYSES

a. SCOPE OF INVESTIGATION

All data have been analyzed by the panels and the Board with frequent help from consultants and outside specialist groups. Specific tests of Spacecraft 012 equipment were initiated on approval by the Board where results would contribute to an understanding of the cause of the accident.

A summary of these results follows.

b. ANALYSES OF RELEVANT TIME LINES

Enclosure 17 displays significant data that were obtained just prior to the report of the fire by the astronaut crew. These time lines cover the period of one minute before the fire report until all data signals were lost. The data shown includes signals from the gas chromatograph channel, the voltage of the AC bus 2, the C-band beacon, the VHF telemetry carrier, the flow of oxygen into the suit loop, various indicators of spacecraft motion, the biomedical data from the Senior Pilot, and audio signals (voice and noise) received on the S-band communication link. An analysis of each item and a summary of their correlation follows.

(1) Gas Chromatograph Telemetry Data Anomaly

The gas chromatograph was not installed for the Plugs Out Test and the connector that carried the telemetry data signals and the required AC power was open ended and was placed on the gas chromatograph shelf prior to the test. Power to the AC line in the connector was turned on during the test as required by the test plan.

A careful examination of the data records disclosed activity on this channel eight times up to and including the activity shown at approximately 23:30:50 GMT. Subsequent testing has demonstrated that the telemetry data lead in the connector has the characteristics of an antenna, and consequently can detect changes in electromagnetic fields within the spacecraft. Movement of this cable within a constant electromagnetic field will also produce signals of the magnitude observed during the Spacecraft 012 accident.

The disturbance at approximately 23:30:50 GMT indicates that such a change in the electromagnetic field took place. This change could have resulted from movement of the

connector. Evidence indicates that although the connector was not in its originally stored position after the accident, it probably was there during the initial stages of the fire.

(2) AC Bus 2 Voltage Anomaly

A momentary increase in AC bus 2 voltage on all three phases was noted at approximately 9 seconds before the report of fire, and at the same time telemetry data from equipment powered from AC bus 2 showed abnormalties. These were:

1. Dropout of C-band decoder and transmitter outputs for 1.7 seconds.
2. Momentary dropout of VHF-FM transmitter.
3. Fluctuation of rotation controller null outputs.
4. Gas chromatograph telemetry signal transient. Other equipment connected to AC bus 2 at this time had no data monitoring capability that would detect effects of power transients.

The power distribution system was in the standard configuration at the time of the anomaly. DC bus A was receiving power from the ground DC "A" power supply. This power supply in turn powered AC bus 1 through inverter no. 1. Similarly DC bus B received power from the DC "B" power supply and powered AC bus 2 through inverter no. 2.

A possible explanation for dropout of the C-band decoder and transmitter, the interruption of the VHF-FM transmitter and rise in AC bus 2 voltage follows. The post-landing bus supplies power through a single conductor and circuit breaker to the power relay holding coils for both the C-band beacon and the VHF-FM transmitter. Temporary loss of voltage to the relay holding coils by unknown cause, would temporarily interrupt power to the C-band decoder and VHF-FM transmitter. The resulting transient to the voltage level on AC bus 2 could account for other measured phenomena.

The most probable cause of the AC bus 2 transient and associated indications was a momentary short or interruption of DC bus B. Analyses and subsequent testing correlate with this conclusion as follows:

(a) AC Bus Transient

This high voltage indication can be interpreted as evidence of a momentary drop of DC voltage input to the inverter which results in a drop in AC output and a subsequent overshoot upon recovery. First indication of a disturbance was noted during apparent recovery. The voltage decrease was not seen because the channel was sampled only ten times a second.

(b) C-band Beacon Dropout

The 1.7 second dropout observed is the minimum recovery time of the protective circuit internal to the beacon. A momentary interruption of AC bus 2 power for a period as short as 10 milliseconds would cause the C-band beacon dropout. These results were verified by special tests on a C-band beacon similar to the one used in Spacecraft 012. The most probable cause of the beacon dropout was a momentary loss of AC input power to the beacon particularly since the transponder dropout was coincident with a transient on the AC 2 bus and the beacon performed normally after recovery from the dropout until loss of data.

(c) VHF-FM Transmitter Signal Dropout

The RF carrier dropout was observed by all monitoring ground stations and the duration of the dropout was approximately 20 milliseconds. The recorded data wave train from the VHF-FM transmitter also indicated dropout. A dropout of this nature has been duplicated by several special tests with a similar transmitter under similar conditions. Because the VHF transmitter recovered, the most probable cause of the dropout was a momentary interruption of the AC input power.

(d) Rotation Controller Null Output Transients

Momentary transients were noted on each of the three control axes. The rotation controller, whose output was reading slightly off null just prior to the anomaly (the controller was pinned), was supplied by phase A of AC bus 2. Transient voltages on the

phase A bus would most likely be detected on the controller output. Special tests have shown that the null output transients experienced can be duplicated by a momentary interruption of AC bus 2 phase power.

(e) Gas Chromatograph Telemetry Signal Transient

As previously discussed this transient could result from a change in the electromagnetic field. Such a change in the electromagnetic field could also be the result of electric arcing.

(3) Anomalies in Oxygen Flow

Enclosure 18 is a schematic of the suit loop. Oxygen is normally supplied from the surge tank and the service module cryogenic storage tanks through an oxygen regulator which controls the supply pressure to approximately 100 psig. An oxygen flow transducer is installed in the supply line downstream of the oxygen regulator and oxygen is supplied to the suit loop through a demand regulator. The oxygen in the suit loop is circulated to the three astronauts through three separate branches. Each branch has an individual flow rate transducer.

The flow rate of oxygen started to increase approximately 40 seconds before the reported fire. The output limit or saturation of the flow transducer, which corresponds to a flow of 1.033 pounds per hour, was reached approximately 5 seconds before the first fire report. The oxygen flow transducer stayed in this saturated condition until loss of data occurred. The Caution and Warning Alarm was actuated 15 seconds after the oxygen flow exceeded one pound per hour. This delay is normal and prevents actuation of the Caution and Warning Alarm during normal short duration, high flow conditions.

The stable oxygen surge tank pressure, coupled with the normal oxygen regulated pressure, indicates that oxygen flow rate was not greater than 3 to 6 pounds per hour until approximately 7 seconds after the first fire report. Beyond that time the oxygen flow rate was much higher.

The initial flow rate increase is probably due to crew movement which normally results in increased leakage to the cabin at low differential pressure conditions. Enclosure 19 shows that at approximately 23:31:03 GMT the oxygen flow had increased to the suit loop to the extent that the pressure differentials across the suits and compressor were increasing. There was an indication that suit circuit flow through the Senior Pilot's suit was interrupted for about two seconds at approximately 23:31:09 GMT. This interruption further increased the pressure differentials in the circuit. The interruption in flow to the Senior Pilot's suit is not completely understood; however, it probably was caused by manipulation of the suit hoses or associated controls.

(4) Indications of Spacecraft Motion

A number of individual signals were received which are indicative of slight motions of the spacecraft within the last minute prior to the first fire report. These signals were of a random nature and are similar to signals that were obtained from the spacecraft during known crew movement.

These signals included corrective torque signals to the gyrocompasses in the Inertial Measuring Unit, a brushing or tapping of the Command Pilot's live microphone, the previously mentioned increase in oxygen flow attributed to suit leakage and an increase in the attention level of the Senior Pilot most noticeable between 23:30:30 GMT and 23:30:45 GMT. The Senior Pilot was the only member of the crew from whom biomedical data were recorded.

The nature of activity of the crew during this period could not be determined.

(5) S-Band Transmissions

There were no voice transmissions from the spacecraft from 23:30:14 GMT until the first indication of fire in the spacecraft by the crew. During this time the Command Pilot had a live microphone condition as noted previously. Two voice transmissions were subsequently received. The first of these was the first indication of the existence of a fire by the crew.

(a) The Live Microphone Anomaly

Voice tape analyses and instrumentaion data records show that a live microphone, constant-keying condition, existed from the Command Pilot position during a considerable portion of the final test period. This condition apparently did not exist beyond the first of the final two voice transmissions from the spacecraft.

Audio circuits are normally actuated by a crewman pressing his Push-to-Talk (PTT) button on the cobra cable or in the Command Pilot's case by pressing his controller PTT or his cobra cable PTT button (Enclosure 20). This action serves to ground the microphone amplifier in the individual crewman's audio panel as well as the diode gate in the audio center on the S-band audio output. These functions allow signals to modulate the S-band transmitter.

The problem has been isolated to the PTT or keying line that runs between the cobra cable, translation controller, Command Pilot audio control panel and the audio center. Crew attempts to isolate the problem were unsuccessful although the Command Pilot's cobra cable was absolved after troubleshooting. Subsequent testing has also failed to disclose the cause of this problem.

Power limitations and subsequent testing of this circuitry indicates that sufficient current cannot be carried by this keying circuitry for it to be considered a possible ignition source.

(b) Voice Transmissions

The final two voice transmissions were made on S-band. No voice communications on VHF were made from the spacecraft during this period. The first transmissions lasted from 23:31:04.7 GMT through 23:31:10 GMT and the second lasted from 23:31:16.8 GMT through 23:31:21.8 GMT. The tape recordings of these transmissions have been analyzed extensively and the results are presented subsequently.

(6) Cabin Pressure Rise

The cabin pressure for the period from first report of the fire through loss of signal is shown in Enclosure 21.

First indication by either the cabin pressure or battery compartment (open to the cabin) sensors of a pressure increase occurred at approximately 23:21:11 GMT or about 6 seconds after the crew first reported the fire. The pressure exceeded the range of these transducers, 17 pounds per square inch absolute (psia) for the cabin and 21 psia for the battery compartment transducers by 23:31:16 GMT. Data from this time until loss of signal were derived from the response of Guidance and Navigation equipment to the different pressure changes. The cabin ruptured at a time of about 23:31:19 GMT and at a pressure of at least 29 psia.

Rupture occurred in the +Y, –Z quadrant and the resulting jet of hot gases caused extensive damage to the exterior structure (Enclosures 22 through 25)

(7) Summary of Relevant Events

Between 30 and 45 seconds prior to the report of fire, both the Command Pilot and Senior Pilot were active. The nature and level of the activity remain unknown. Except for the transients in data measurements that occurred approximately 9 seconds prior to the report of the fire, there are no other identified relevant events that preceded the fire. It should be noted that these data transients and subsequent activity of the crew may as easily be associated with the result of the fire as with the cause.

The increase in oxygen flow to the suit loop prior to and immediately following the report of the fire and its effect on the pressure distribution within the suit loop is the result of normal demand regulator response to oxygen leaking from the circuit to the cabin. This is further compounded by the response of the regulator to the rise in cabin pressure.

c. ANALYSES OF CREW VOICE TRANSMISSION DURING THE FIRE

The tape transcripts of the voice tapes from the Command Module during the period of the fire have been analyzed extensively. These analyses included a review of all transmissions prior to the fire that were made by the crew during the test in an attempt to aid in the determination of who made these last two transmissions and what was said. These analyses were made by NASA personnel familiar with the communication systems, the crew and their voice characteristics, the sequence of events before, during and after the fire as determined during the investigation. The Board also reviewed these transmissions. Experts at the Bell Telephone Laboratories performed extensive analyses of the tape record. .

Except for a portion of the first transmission which is quite clear, the remainder of the transmissions is not clear and it is impossible to define exactly what was said by the crew.

Two points made by the Bell Telephone Laboratory experts should be noted:

1. The present state-of-the-art of analyses of voice records is such that little if anything can be determined as to what was said if the recording is not sufficiently clear to be intelligible by listening alone. Analyses can provide some clues as to who may have made the transmissions; however, these clues are not definitive.

2. When the recording of the transmission is not clear, there will be nearly as many interpretations of what was said as there are qualified listeners.

A summary of various interpretations of these transmissions is made in the following paragraphs.

The analysis of the first transmission is as follows:

This transmission began at 23:31:04.7 GMT with an exclamatory remark. This transmission is not clear. Listeners believe this initial remark was "Hey" or "Fire" but this is not certain.

Some listeners believe and laboratory analysis supports this belief that this transmission was made by the Command Pilot. This remark is followed by a short period of noise (bumping sound, etc.).

The second portion of this first transmission begins at 23:31:06.2 GMT with an unclear word. Most listeners believe the first word to be one of the following:

"I've"

"We've"

The remainder of this transmission is quite clear and is: "...Got a fire in the cockpit'', followed by a clipped word sounding like "Vheh'', which ended at 23:31:10 GMT. Many listeners believed this transmission was made by the Pilot and laboratory analyses tend to support this belief. However, no firm conclusion can be drawn.

The analysis of the second transmission is as follows:

Following a 6.8 second period of no transmission, the second transmission began at 23:31:16.8 GMT and ended at 23:31:21.8 GMT. The entire second transmission is garbled and is, therefore, subject to wide variation of interpretation as to content and as to who made the transmission and no definitive transcription is possible.

The general content of this transmission consists of what appears to be three separate phrases. It has been interpreted several ways by many listeners. The following is a list of some of the interpretations that have been made:

1. "They're fighting a bad fire - Let's get out ....Open 'er up."
2. "We've got a bad fire - Let's get out....We're burning up."
3. "I'm reporting a bad fire....I'm getting out...."

This transmission ended with a cry of pain. Some listeners believe this transmission was made by the Pilot.

It should be noted that:

1. The total duration of these two transmission was brief, lasting 10.3 seconds; the first lasted 5.3 seconds and the second lasted 5.0 seconds, with a 6.8 second period of no transmission.

2. The transmissions provide evidence only of the time the crew first reported the existence of the fire and do not provide any direct information as to the cause of the fire.

d. MEDICAL ANALYSES

Loss of conciousness was due to cerebral hypoxia due to cardiac arrest resulting from myocardial hypoxia. Factors of temperature, pressure and environmental concenrations of carbon monoxide, carbon dioxide, oxygen and pulmanary irritants were changing extremely rapidly. It is impossible to integrate these variables on the basis of available information with the dynamic physiological and metabolic conditions they produced, in order to arrive at a precise statement of time when conciousness was lost and when death supervened. The combined effect of these environmental factors dramatically increased the lethal effect of any factor by itself. It is estimated that consciousness was lost between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within 4 minutes.

4. CAUSE OF THE APOLLO 204 FIRE

The fire in Apollo 204 was most probably brought about by some minor malfunction or failure of equipment or wire insulation. This failure, which most likely will never be positively identified, initiated a sequence of events that culminated in the conflagration.

A great deal of effort has been expended in an attempt to find this specific initiator. Although unsuccessful in this search, this effort has produced a fairly good understanding of the types of things that may have been the initiator and the types of things that probably could not have been the initiator.

Electrostatic discharge, spontaneous combustion of flammable material, mechanically produced heat by machinery and heat from the impact of a struck object have been eliminated as reasonable possibilities of ignition of the fire. The flow of oxygen through orifices or metering valves can create heat through the excitation of resonating frequencies in the gas. However, a thorough examination of the hardware and evaluation of recorded performance of the equipment eliminates the energy of flowing oxygen as a possible initiator.

The most obvious source of energy needed to initiate the fire existed in the spacecraft's power distribution system. Current carrying wires were distributed through out every major region of the Command Module. The most likely ways in which electrical power can initiate a fire are the following:

1. Through malfunction of the equipment being powered which in turn ignites or initiates a fire in nearby combustibles.

2. Overload in the conductor resulting from shorts in equipment or wiring. This overload will cause the conductor to overheat and ignite nearby combustibles (Enclosure 26).

3. Electric arcs that are created when the insulation is defeated between power carrying conductors and the spacecraft structure or equipment.

A large majority of the wires were left undamaged. However, there were a number of cases where exposed wire showed extensive burning, overheating or complete destruction. There were also several places where pitting of exposed conductors and adjacent structure indicate that an electric arc had occured.

a. MALFUNCTION OF ELECTRICAL POWERED EQUIPMENT

After removal from the spacecraft, each component or subassembly was critically examined to determine whether or not it could be associated with the initiation of the fire. The vast

majority of these could be classified as non-initiators on the basis of external examination and recorded performance. If, however, there was any suspicion that an item was involved with the initiation of the fire, it was subjected to intensive scrutiny that involved one or more of the following procedures: Laboratory analysis of damage, electrical continuity and resistance tests, functional performance using established procedures for "bench checks" and careful disassembly which included repeating some of the above steps on individual parts of the assembly. The results of this effort led to the conclusion that none of the electrically powered spacecraft systems or subassemblies was associated with the initiation of the fire.

b. ELECTRICALLY OVERLOADED CONDUCTORS

The Apollo spacecraft wiring is protected with Teflon insulation. Teflon was chosen as the insulating material after a series of tests clearly showed that it was the least likely to burn when overheated by shorting. Individual conductors in a wire bundle using Teflon-insulated wires could be melted to destruction without initiating a sustained fire in the bundle when located in a 100-percent oxygen atmosphere at 5 psia. The Teflon-insulating material provided a high degree of fire protection to wire bundles which may contain electrically overloaded wires. Primary protection to wiring in the spacecraft, however, was provided by circuit breakers and fuses which protected all power-carrying conductors. Critical analyses of all circuit breaker installations showed that this protection was provided adequately with only a few exceptions. Several indications of shorted wiring were made the subject of individual detailed investigations. These investigations have all proved negative except for a few cases that could not be exonerated completely.

c. ELECTRIC ARCS

Teflon has excellent fire resistance but low resistance to cold flow. The Teflon covering on the wire used in Apollo 204 could be damaged easily or penetrated by abrasion. The covering could also be damaged when forced against the structure by poor installation. The Board found numerous examples in the wiring of poor installation,design and workmanship. (An example is shown in Enclosure 27 where a wrench socket was found in the spacecraft.) If a power conducting wire experiences penetration of its insulation by the metal structure of the spacecraft or spacecraft components, an instantaneous short to ground is created at the point of conductor contact. An arc or a series of arcs between conductor and structure results. The arcing action may be terminated by the blowing away of molten metal at the point of contact, or if sufficient mechanical pressure exists, fusion between the conductor and structure may occur to create a continuous short. The previous occurrence of an arc can be determined through examination of hardware because a characteristic pit or crater is left at the location of contact. Tests in a 16.5 psia oxygen atmosphere have shown that sparks blown from arcs can ignite combustible material several inches from the arc. Circuit breakers and other practical circuit interrupting devices cannot act rapidly enough to prevent an arc. Thus, arcs cannot be eliminated as a potential source of ignition energy. As noted previously, there were strong data indications of an abrupt, short-duration voltage decrease. This is consistent with a quickly terminated arc. During the examination of hardware and wiring, particular emphasis was placed on locating craters near power cables. While several such craters were found, only one appeared to be linked closely to the time of the fire by other supporting evidence. A complete investigation of the evidence associated with this possible ignition source has relegated it to a low probability. Studies of fire damage patterns indicate that the most likely region for the start of the fire is underneath the lighium hydroxide access door. Damage is so extensive in this location that the physical evidence remaining provides little interpretive information (Enclosure 11). Power cable insulation passing under this door was potentially vulnerable to arbrasion from the corner along the lower edge of the door. (Enclosure 28 shows this cable as it is installed on Spacecraft 014.) If this cable were the cause, it cannot be proven since both the power cable and the inside edge of the door were completely destroyed.It is most probable that the fire was initiated by an electric arc either in this location or in some other region near the Environmental Control Unit. Other powered cables in the Environmental Control Unit may have been the source but extensive destruction of them precludes a positive determination. The time of initiation probably coincides with the spacecraft power interruption at 23:30:55 GMT.

The Board's investigation was facilitated by the wide application of simulation techniques. The consequences of several types of electrical faults were studied in this way. The most valuable simulation, however, employed full-scale fire tests in a boilerplate mock-up with combustibles arranged in the configuration of Command Module 012. These tests were conducted by MSC for the Board. Ignition was obtained by a hot wire in the general area in which ignition is suspected to have occurred in the fire and provisions were made for simulating rupture at proper time and location.

Total time of the fire and the pressure history reproduced those of the fire quite closely thus adding confidence to the deduced origin and mode of propagation of the fire. Such simulation techniques should be applied in examining the fire hazards of future spacecraft. They provide a reliable means of assessing fire hazards. They have also demonstrated that laboratory tests on small samples may give misleading results.

d. EFFECT OF COOLANT ON ELECTRICAL WIRES AND EQUIPMENT

The discussion of possible electric power distribution malfunctions in Apollo 204 cannot be complete without inclusion of the effect of Environmental Coolant System coolant leakages. The Apollo Block I Spacecraft uses RS-89 as a coolant. This coolant is a mixture of 62.5 percent ethylene glycol, 35.7 percent water, and 1.8 percent stabilizer and corrosion inhibitor. Although the mixture is not highly combustible, leakage and spillage of this fluid present a considerable fire hazards. The water evaporates more readily than the ethylene glycol and the inhibitor consists of two combustible salts which do not evaporate. Consequently, spilled coolant can become a dangerous combustible if it is not removed properly. The inhibitor mixture presents a second hazard in that it is also hygroscopic and electrically conductive. Thus, the residue from coolant that was spilled and subsequently evaporated, remained slightly wet. This residue is corrosive and may conduct electricity if it wets electrical wiring or equipment that does not have water-proof insulation. The conductive path so formed will progressively improve itself as dendrites grow through electrolytic action. The RS-89 coolant is particularly dangerous in the presence of damaged or improperly insulated electrical equipment and harnesses. During the design of Apollo Block I Spacecraft a decision was made to seal electrical components and connectors. As a result, many of the Spacecraft 012 electrical systems were watertight. (Block II Spacecraft are designed to have complete sealing of electrical equipment and harnesses.)

Coolant in the spacecraft is used to extract heat from the cabin atmosphere and from the circulation loop to the spacesuits. It also provides direct cooling through coldplates to numerous pieces of electrically powered equipment. Thus, the cooling system is extensive throughout the Command Module. The plumbing that carries the coolant is assembled from aluminum tubing utilizing both metallurgical (soldered, brazed or welded) and mechanical joints. Numerous plumbing joints are distributed throughout the spacecraft. It was found that the solder joints were improperly designed in that strength margins were inadequate to resist damage from unplanned loads. Such loads may result during equipment installation or when tubing is used as hand-holds or is bumped by technicians working in the Command Module. The result was that a number of leaks in solder joints were experienced during the history of all Block I spacecraft. The mechanical joints also had leakage problems.

There is no substantial evidence that coolant was involved in the initiation of the fire. However, this coolant, when spilled on damaged electrical wires and equipment, provides both the fuel and the ignition mechanism to start a fire. This has been demonstrated in laboratory tests.

e. SPACECRAFT ATMOSPHERE

The use of pure oxygen in American spacecraft has been the subject of much consideration. The use of a diluent gas, either nitrogen or helium, in large proportions would undoubtedly reduce the risk of fire to a significant degree. At the same time it would introduce other operational problems and risks. There is no obvious advantage of one diluent over the other, although much pro-

gress has been made in developing the complex technology required for controlling gas concentrations to maintain a proper mixture reliably. This technology is still far from being fully developed. Furthermore, there are many difficult operational problems that must be solved in a reliable manner in order to decrease rather than increase the risks before undertaking the use of a two gas system.

The desirable characteristics of a two gas system, however, should not be ignored. The development of technology that will warrant confidence in the sue of such a system should be continued.

f. SUMMARY

Although the Board was not able to determine conclusively the specific initiator of the Apollo 204 fire, it has identified the conditions which led to the disaster. These conditions were:

1. A sealed cabin, pressurized with an oxygen atmosphere.
2. An extensive distribution of combustible materials in the cabin.
3. Vulnerable wiring carrying spacecraft power.
4. Vulnerable plumbing carrying a combustible and corrosive coolant.
5. Inadequate provisions for the crew to escape.
6. Inadequate provisions for rescue or medical assistance.

Having identified the conditions that led to the disaster, the Board addressed itself to the question of how these conditions came to exist. Careful consideration of this question leads the Board to the conclusion that in its devotion to the many difficult problems of space travel, the Apollo team failed to give adequate attention to certain mundane but equally vital questions of crew safety. The Board's investigation revealed many deficiencies in design and engineering, manufacture and quality control. When these deficiencies are corrected the overall reliability of the Apollo Program will be increased greatly.

LIST OF ENCLOSURES

V-1 Photograph - Upper Left-hand Equipment Bay Avove Environmental Control Unit.

V-2 Photograph - Upper Left-hand Forward Corner of Command Module Interior.

V-3 Photograph - Upper Right-hand Forward Corner of Command Module Interior.

V-4 Photograph - Right-hand Side of Forward Lower Equipment Bay.

V-5 Photograph - Gas Chromatograph Compartment in Lower Left-hand Side of Forward Equipment Bay (Cameras Laying in Compartment).

V-6 Photograph - Lower Left-hand Forward Corner of Command Module Interior.

V-7 Photograph - Command Module Floor Showing Helmet Covers and Lithium Hydroxide Canister Storage Box.

V-8 Photograph - Left Rear Corner of Command Module Floor.

V-9 Photograph - Command Module Electrical Panel Showing Isolated Fire Damage.

V-10 Photograph - Environmental Control Unit in Lower Left-hand Equipment Bay.

V-11 Photograph - Close-up of Failed Environmental Control Unit Tubing.

V-12 Photograph - Transparent False Floor Used During Disassembly.

V-13 Photograph - Bonded Storage Area.

V-14 Photograph - Aft and Crew Compartment Heat Shields After Removal.

V-15 Photograph - Command Module 012 in Final Disassembly Area.

V-16 Photograph - Bonded Area to Display of Removed Command Module Components.

V-17 Time Line of Significant Data.

V-18 Suit Circuit Simplified Schematic.

V-19 Graph Showing Suit Circuit Oxygen Flow Rates.

V-20 Schematic of Audio Push-to-Talk Circuits.

V-21 Time Line Cabin Pressure.

V-22 Drawing of Inner Face Sheet of Aft Bulkhead Showing Ruptured Areas.

V-23 Drawing of Outer Face Sheet of Aft Bulkhead Showing Ruptured Areas.

V-24 Photograph - Inner View of Aft Heat Shield Showing Damage.

V-25 Photograph - External View of Aft Bulkhead Showing Damage (View from Bottom) .

V-26 Cut-away View of Command Module Showing Exposed Nonmetallic Materials.

V-27 Photograph - View of Socket Found Adjacent to Wire Bundles During Disassembly of Command Module 012.

V-28 Photograph - View of Wire Bundle in Command Module 014 Containing DC Power Leads Passing Over Tubing and Entering Environmental Control Unit. A Similar Arrangement Existed in Command Module 012.

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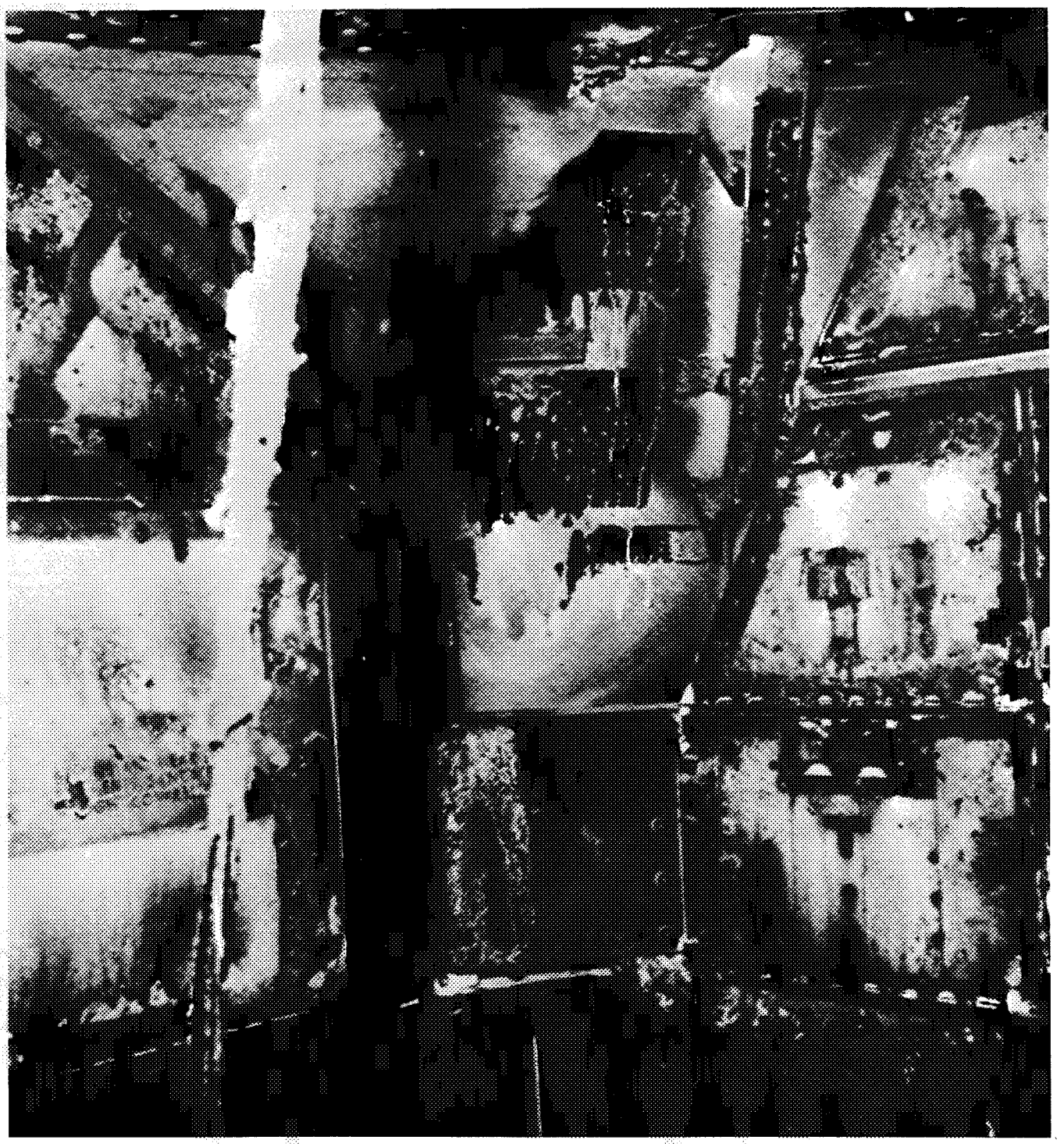
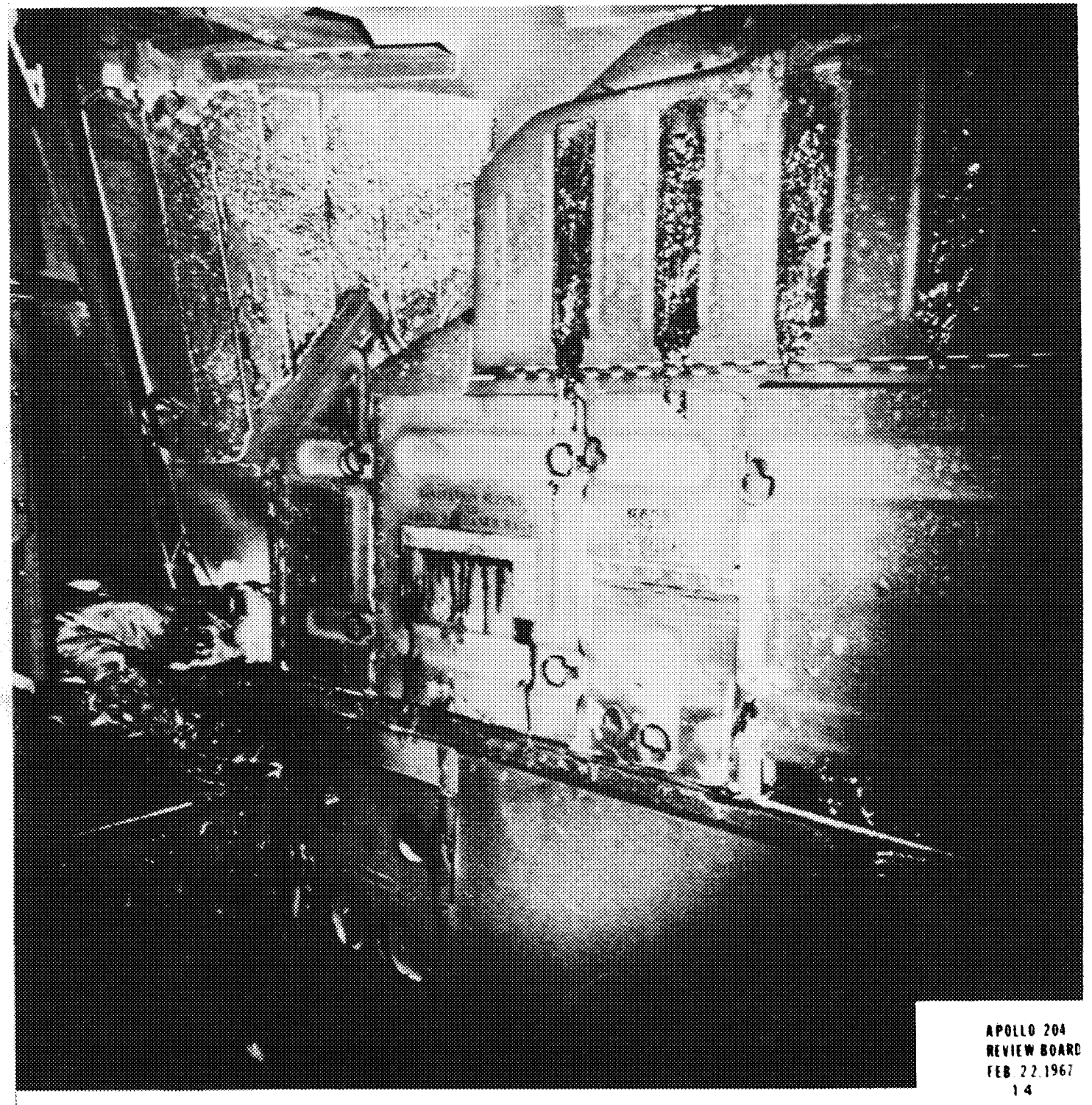
LEFT HAND FORWARD EQUIPMENT BAY



EXTREME UPPER LEFT HAND CORNER BETWEEN LOWER EQUIPMENT BAY AND LEFT HAND EQUIPMENT BAY



APOLLO 204
REVIEW BOARD
FEB 22 1967
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EXTREME RIGHT HAND CORNER ABOVE LOWER EQUIPMENT BAY AND RIGHT HAND EQUIPMENT BAY

ENCLOSURE V-3

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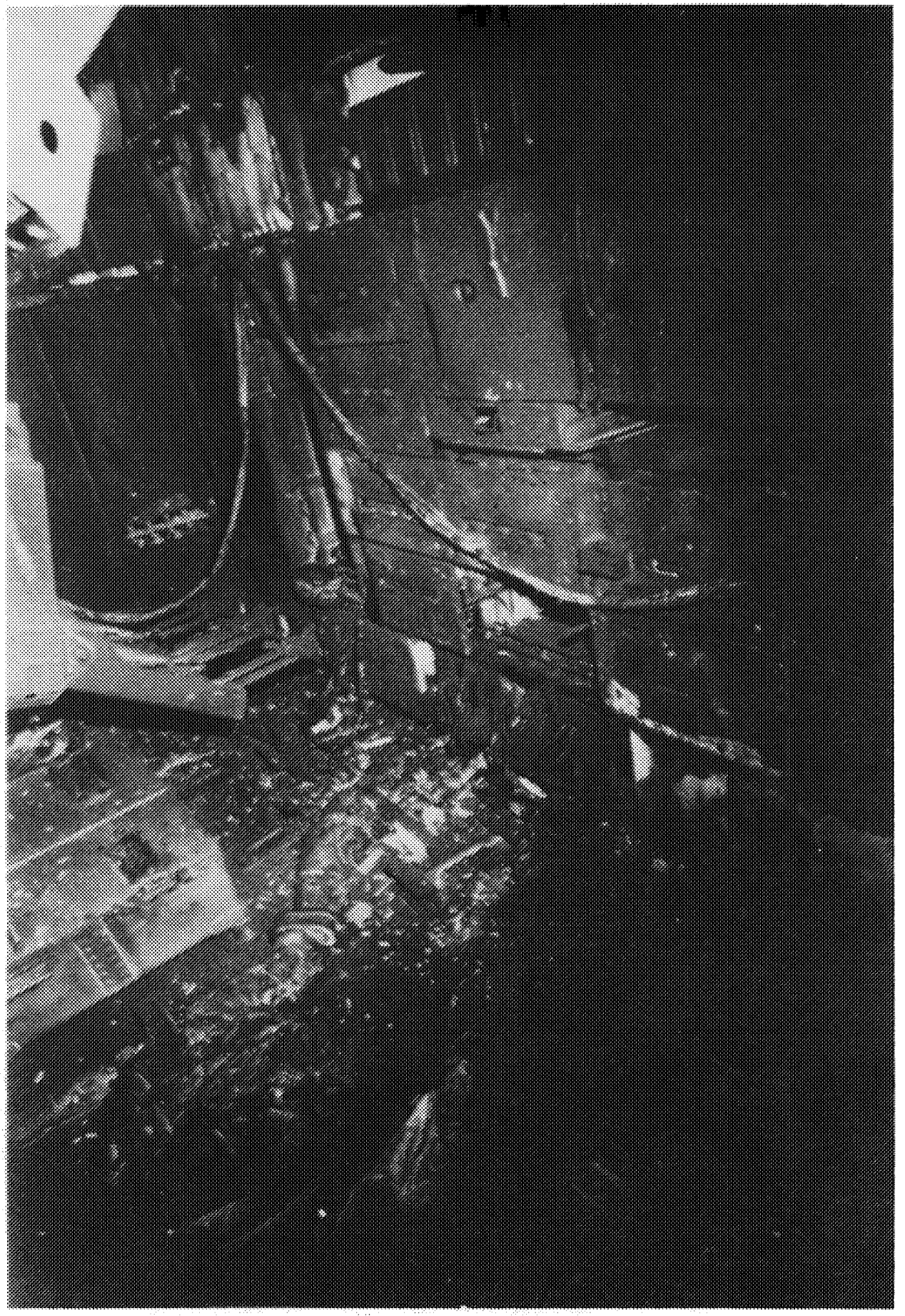
RIGHT HAND SECTION OF LOWER EQUIPMENT BAY

LOWER LEFT HAND SECTION OF LOWER EQUIPMENT BAY



VIEW OF FLOOR BELOW LOWER EQUIPMENT BAY
ENCLOSURE V-6

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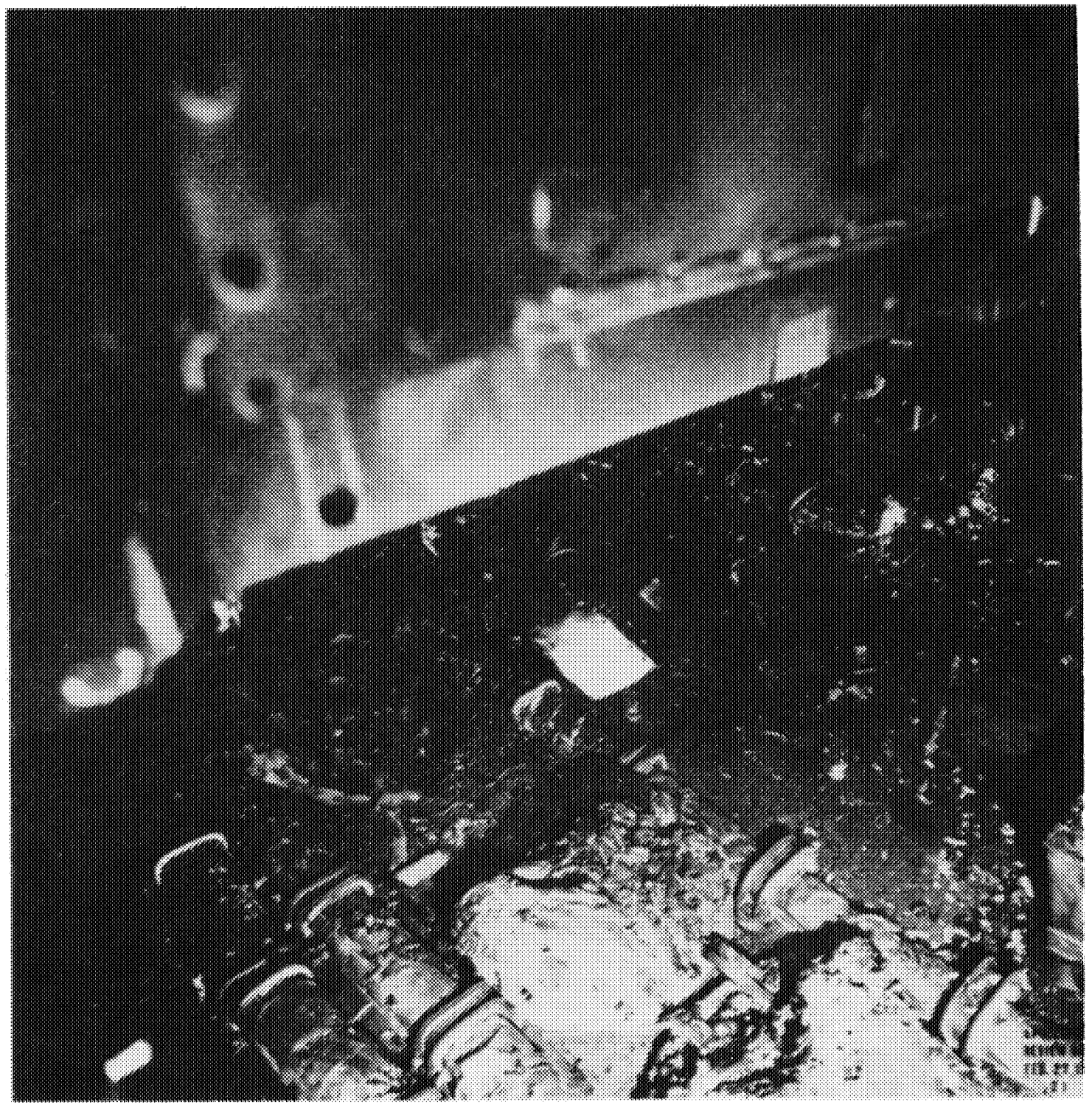
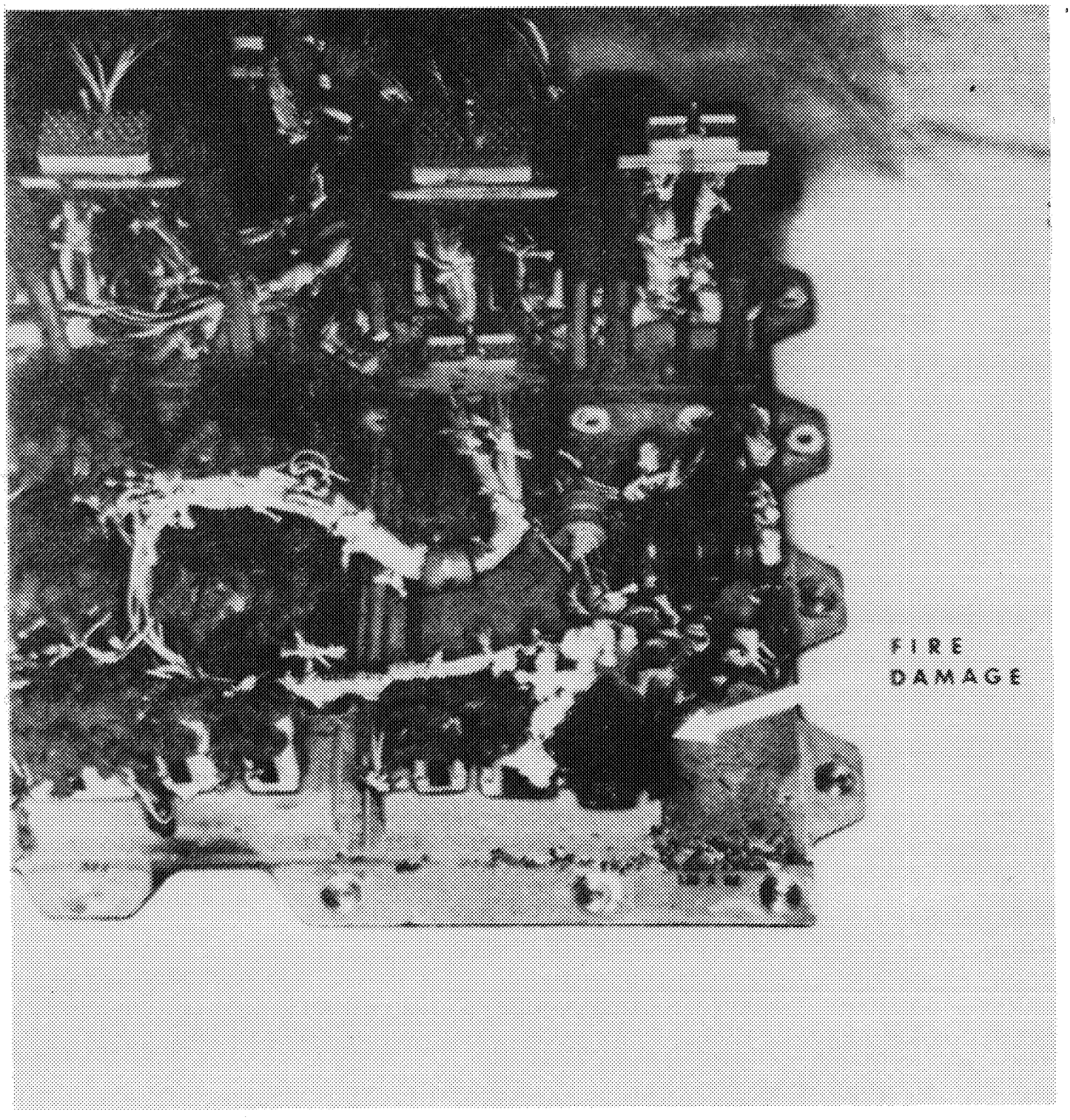
VIEW OF HELMET COVERS

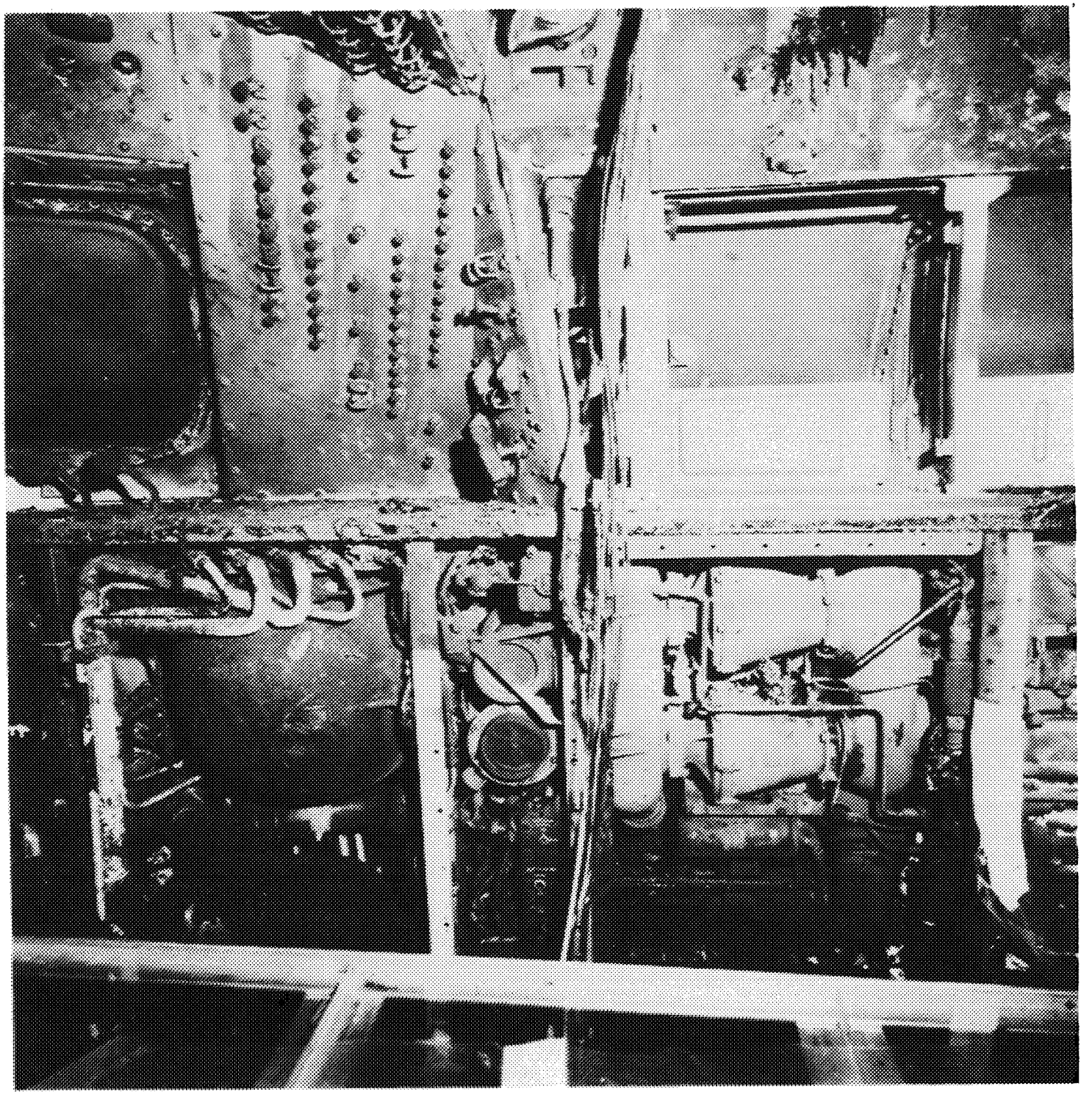
ENCLOSURE V-7



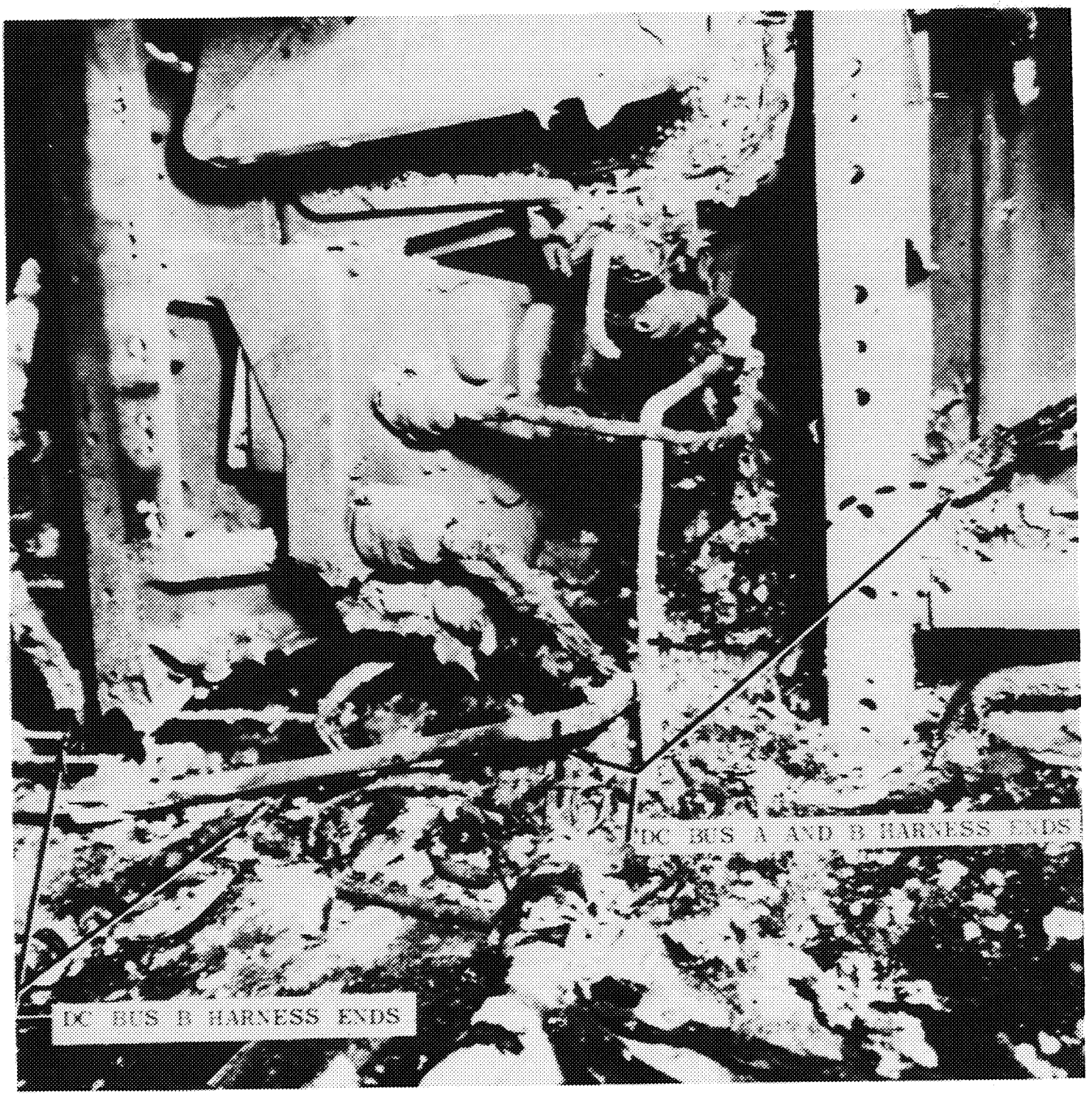
VIEW OF HELMET COVERS



INTERIOR VIEW OF PANEL 13 SHOWING DAMAGE NEAR THUMB WHEELS



VIEW OF ENVIRONMENTAL CONTROL UNIT



ENVIRONMENTAL CONTROL SYSTEM INSTRUMENTATION HARNESSES
AFTER ACCIDENT

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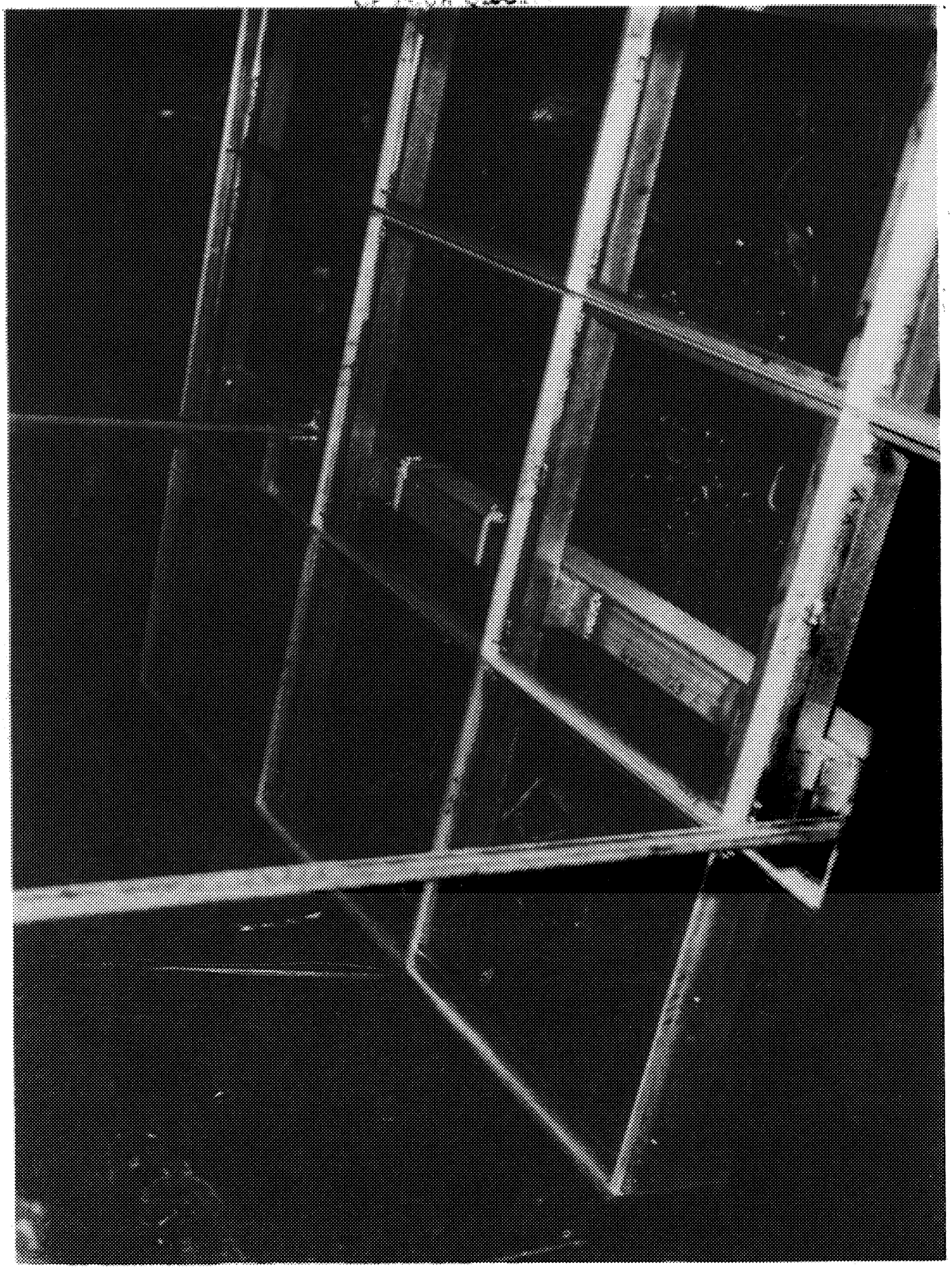
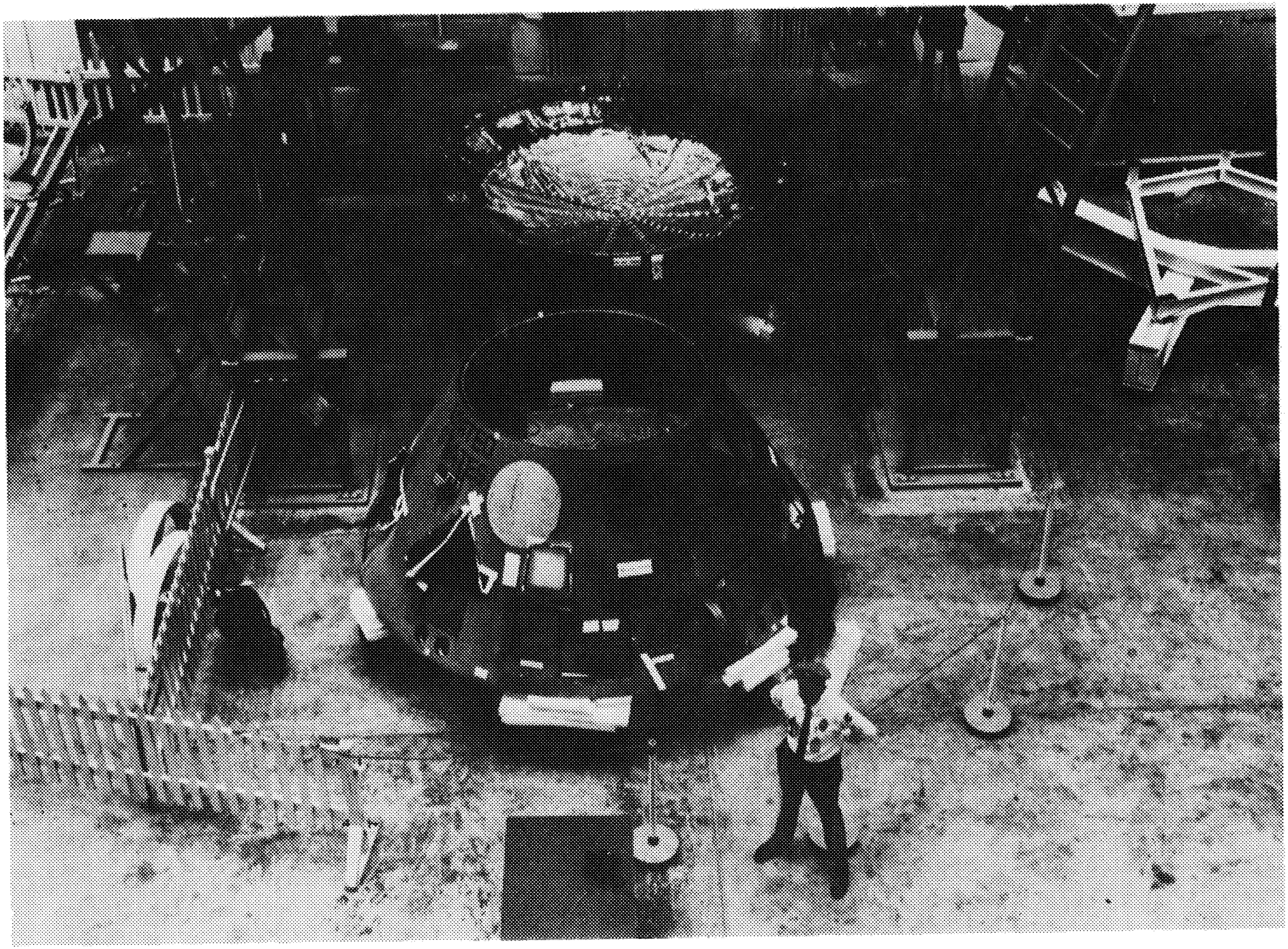


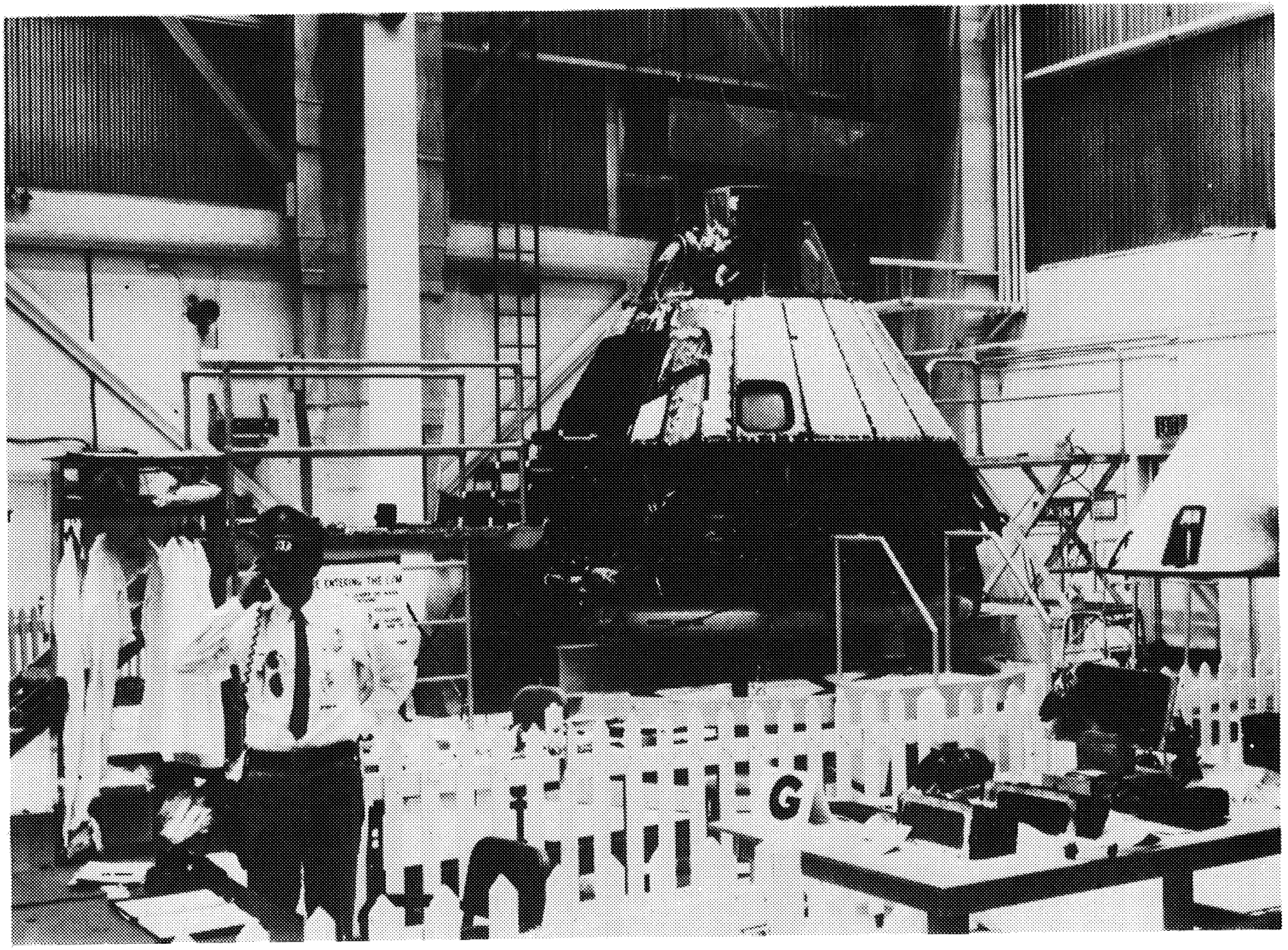
FALSE FLOOR INSTALLED IN SPACECRAFT 012

PYROTECHNICS INSTALLATION BUILDING BOND ROOM, LOOKING TOWARD THE SOUTH WALL



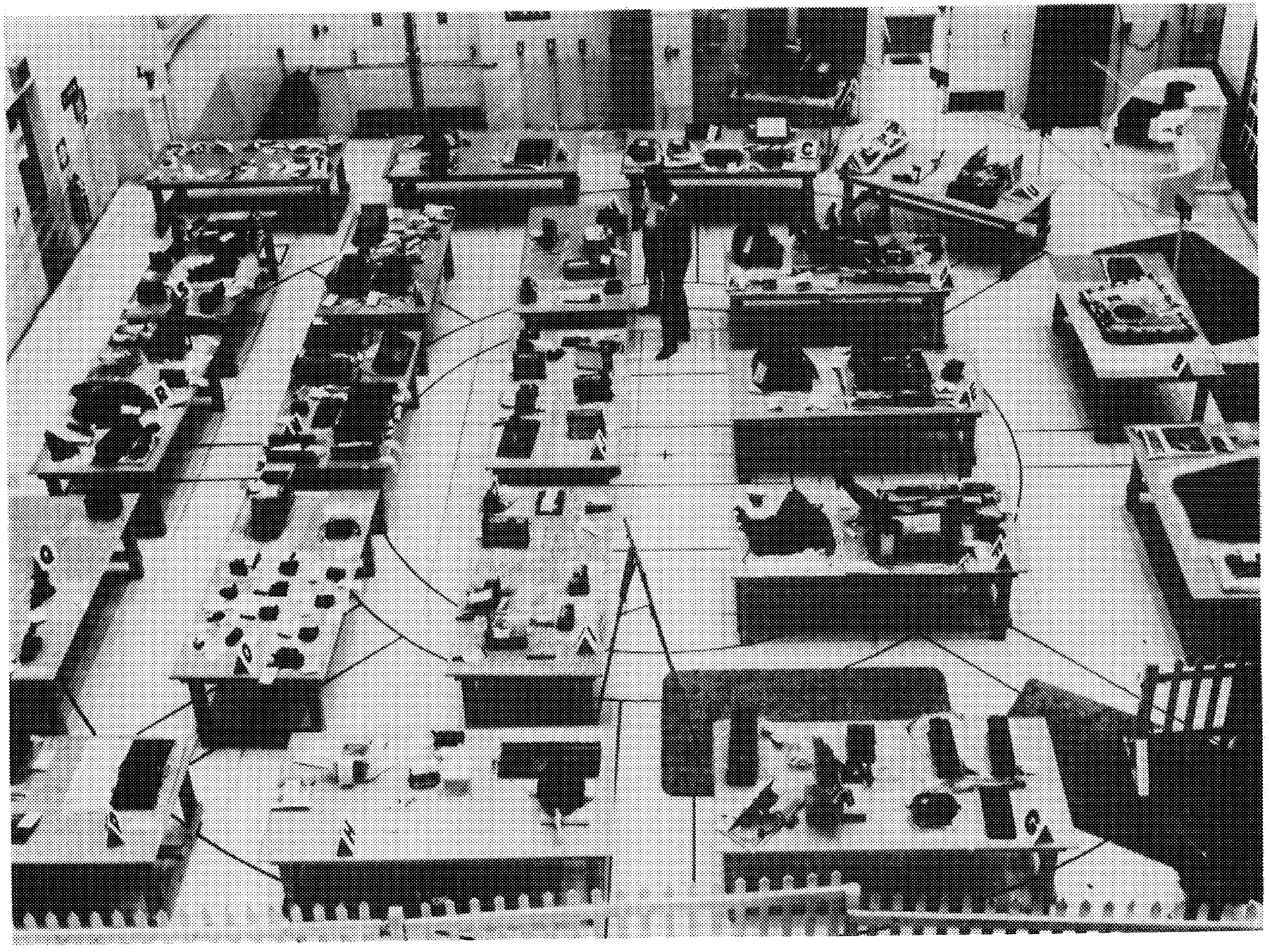
AFT HEAT SHIELD IN ALIGNMENT FIXTURE WITH CREW COMPARTMENT HEAT SHIELD IN THE FOREGROUND

ENCLOSURE V-14

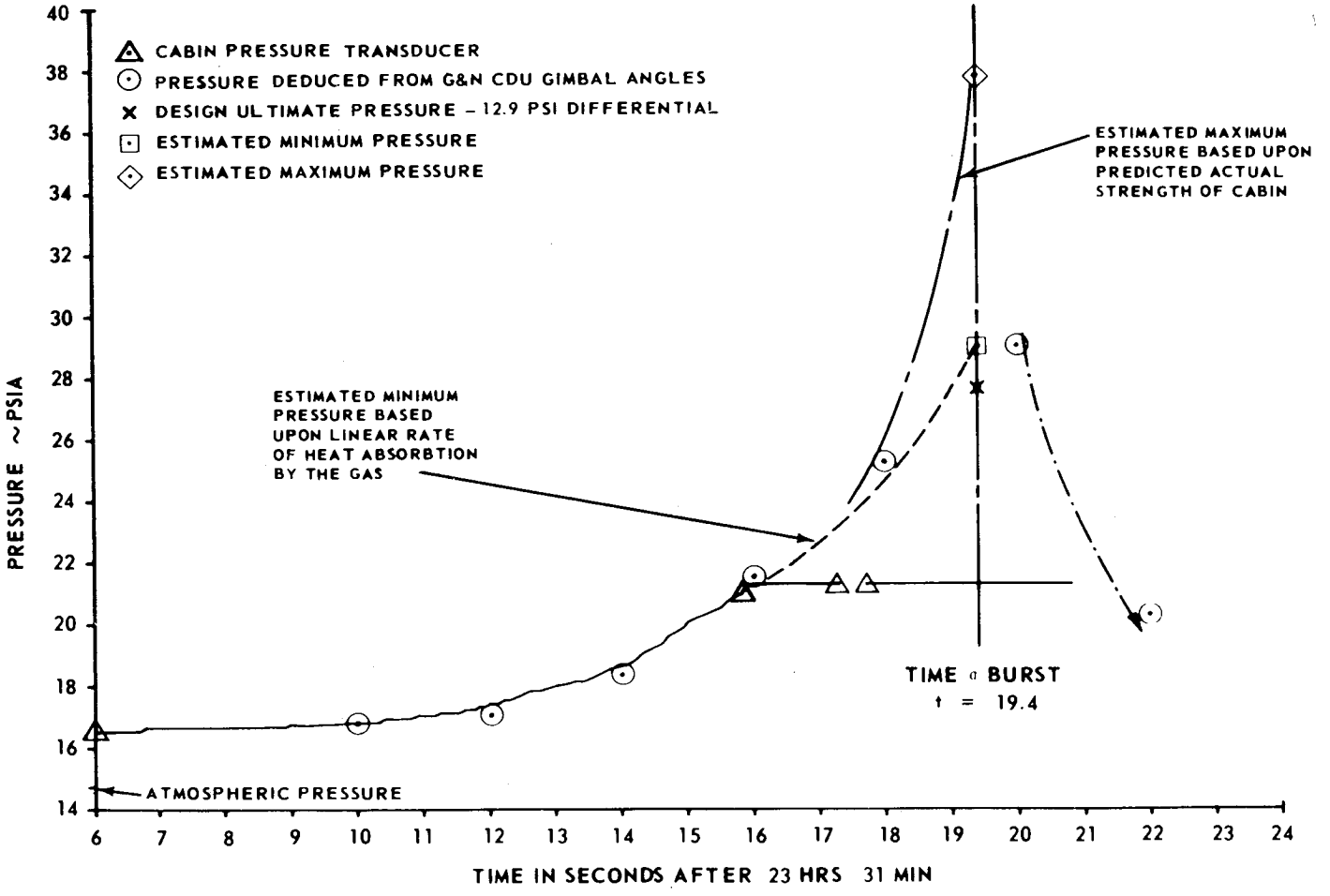


COMMAND MODULE OF SPACECRAFT 012 IN FINAL DISASSEMBLY AT THE PYROTECHNICS INSTALLATION BUILDING

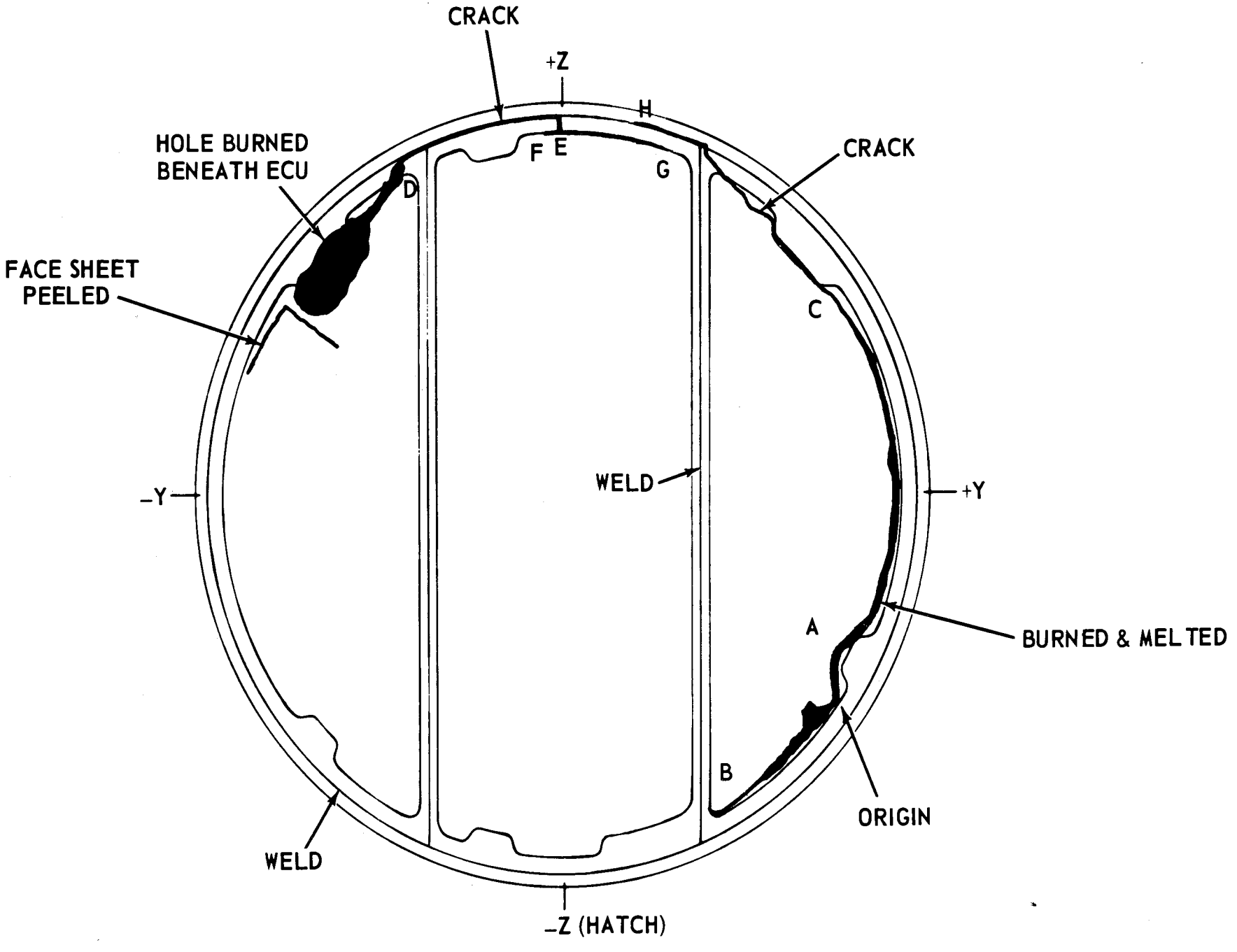
ENCLOSURE V-16



PYROTECHNICS INSTALLATION BUILDING BONDED DISPLAY AREA ON MARCH 14, 1967

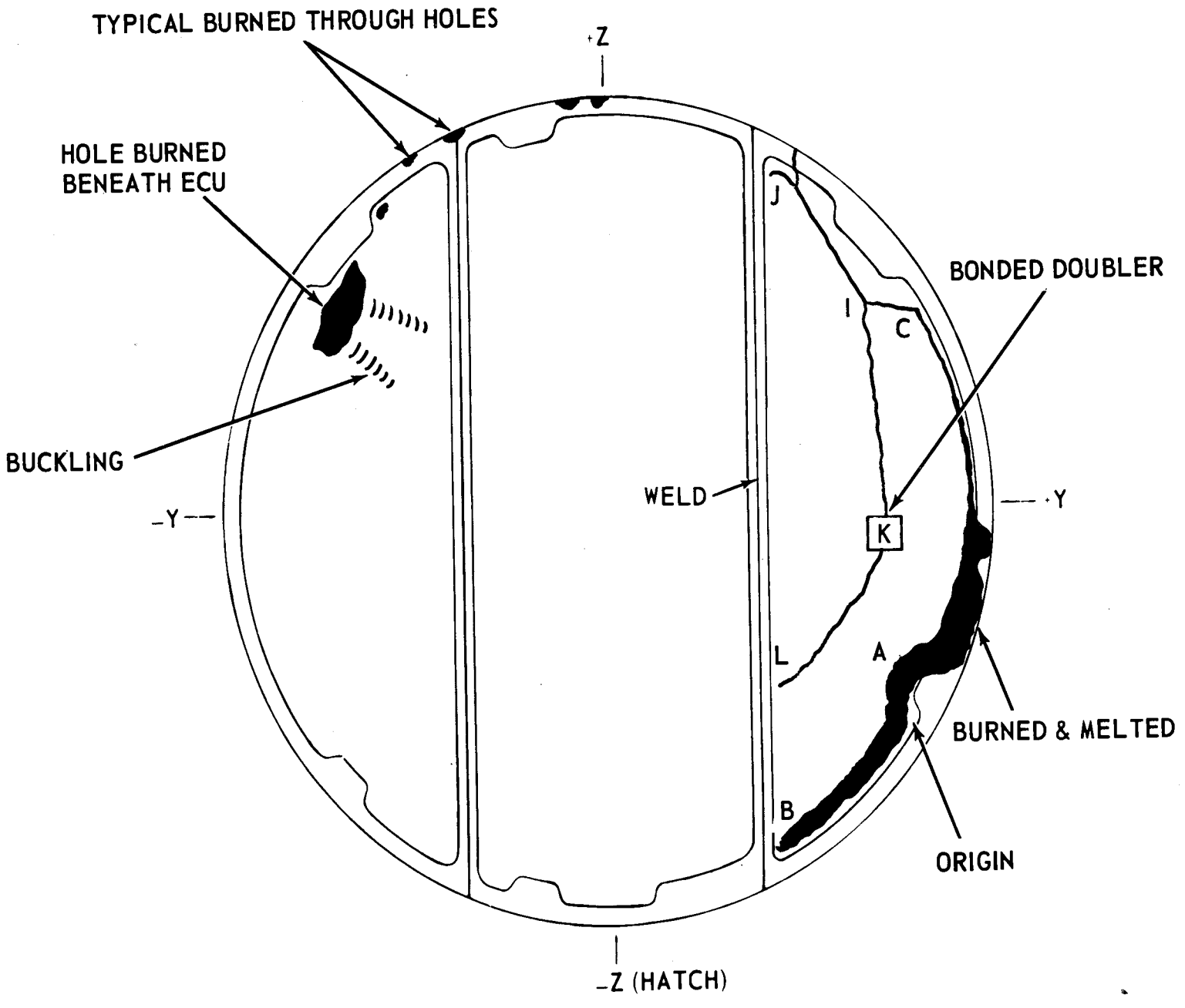


CABIN PRESSURE



INNER FACE OF AFT BULKHEAD

ENCLOSURE V-22



OUTER FACE SHEET OF AFT BULKHEAD

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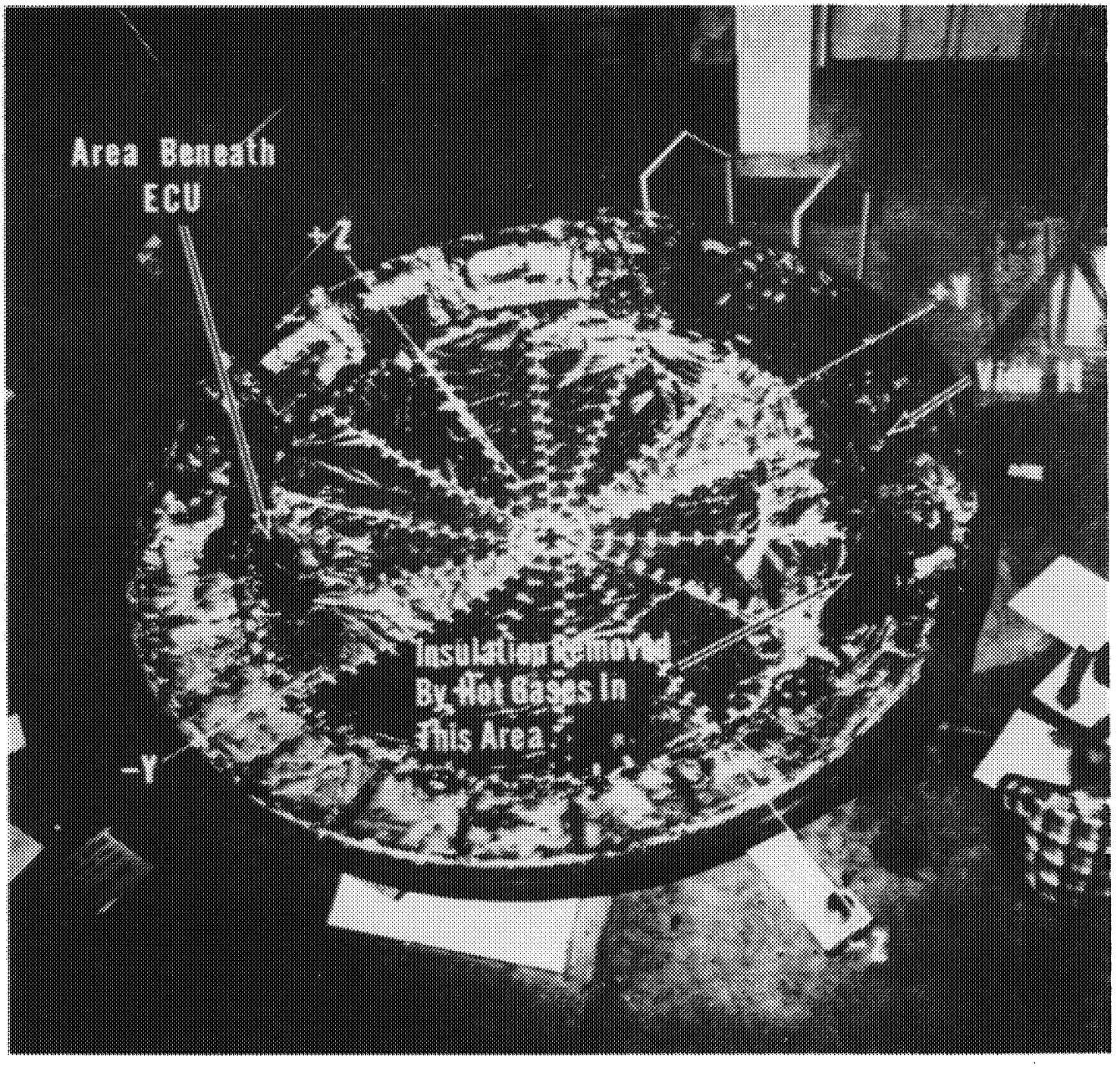

AFT HEATSHIELD DAMAGE

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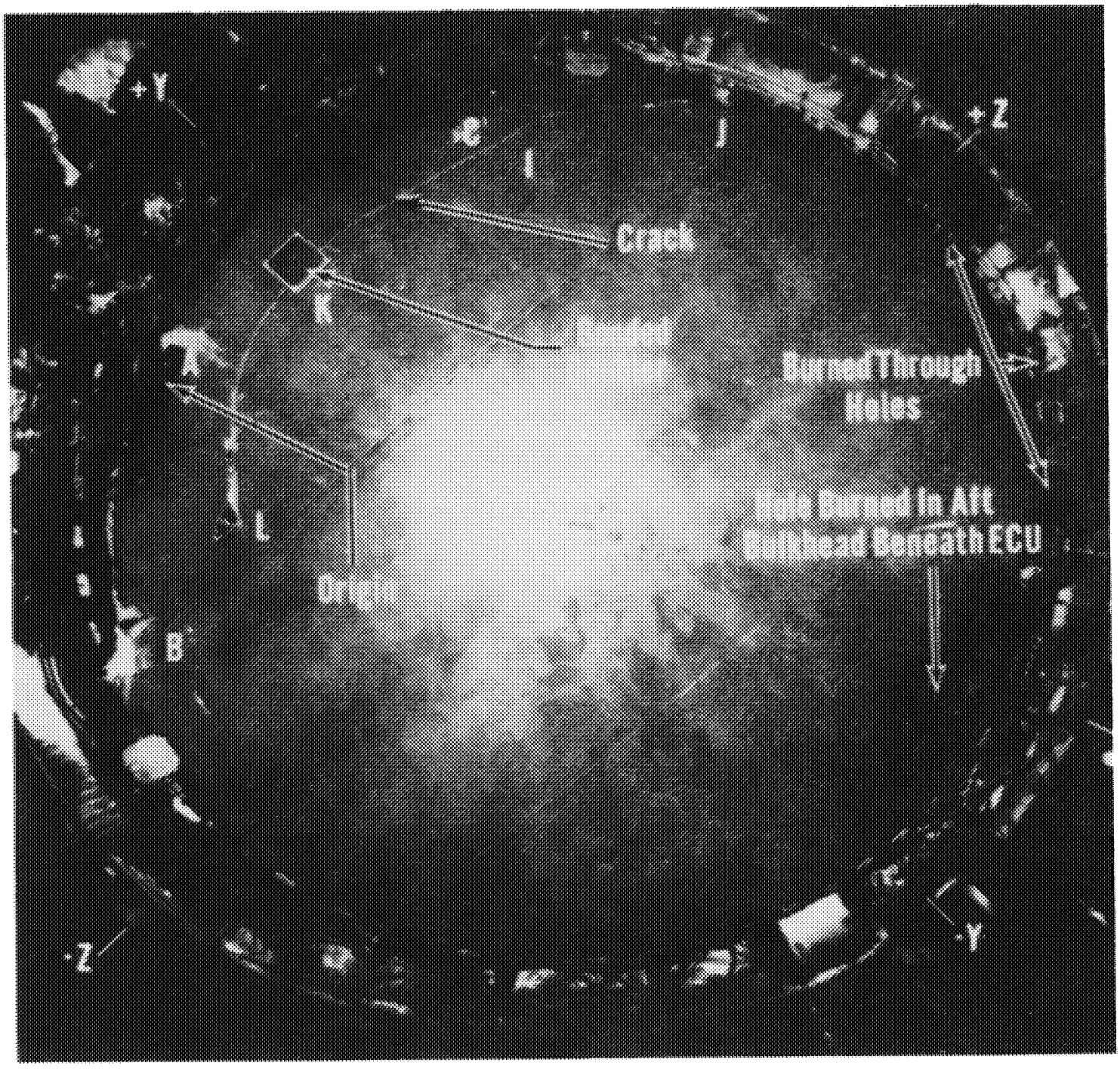
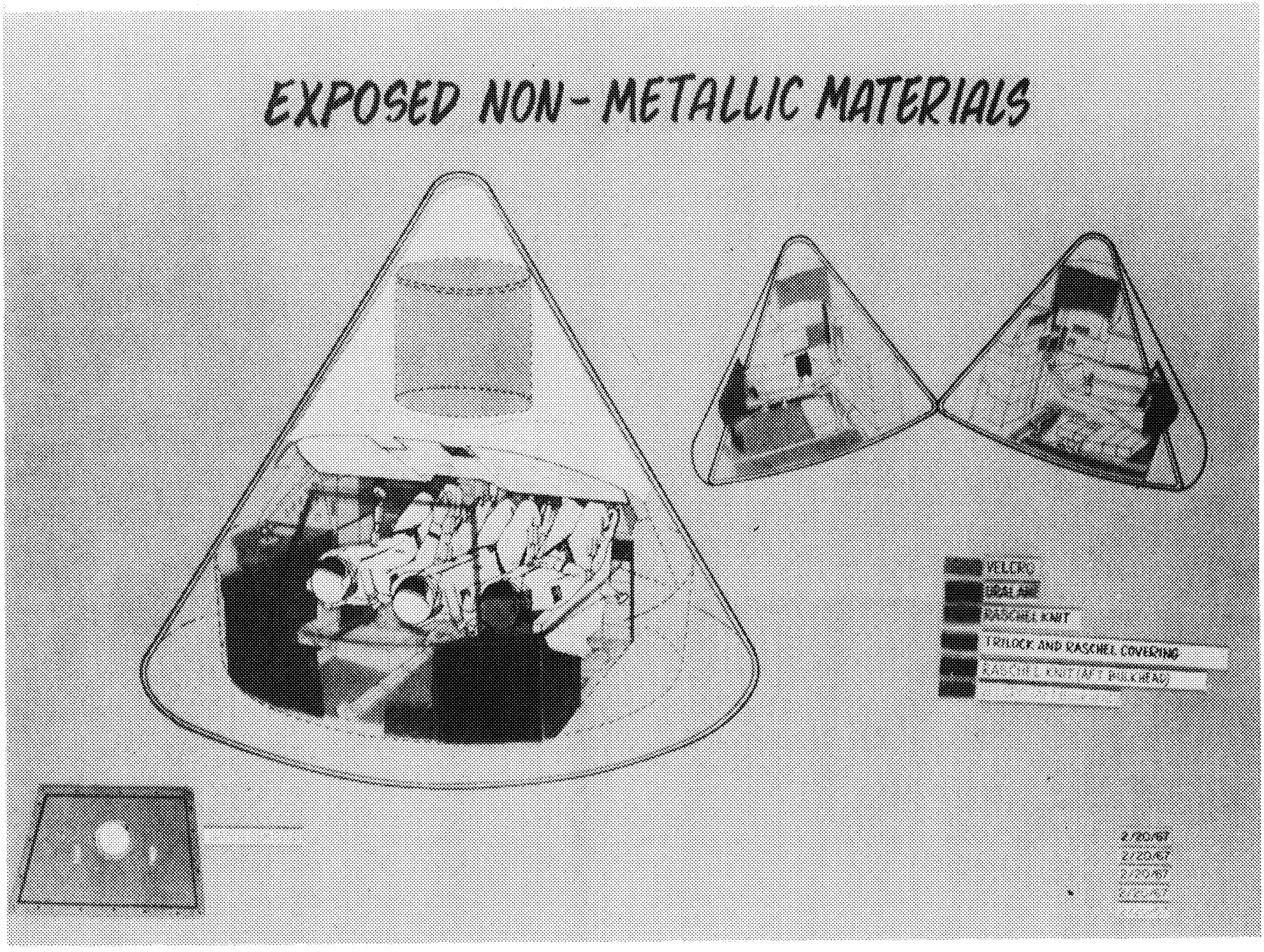
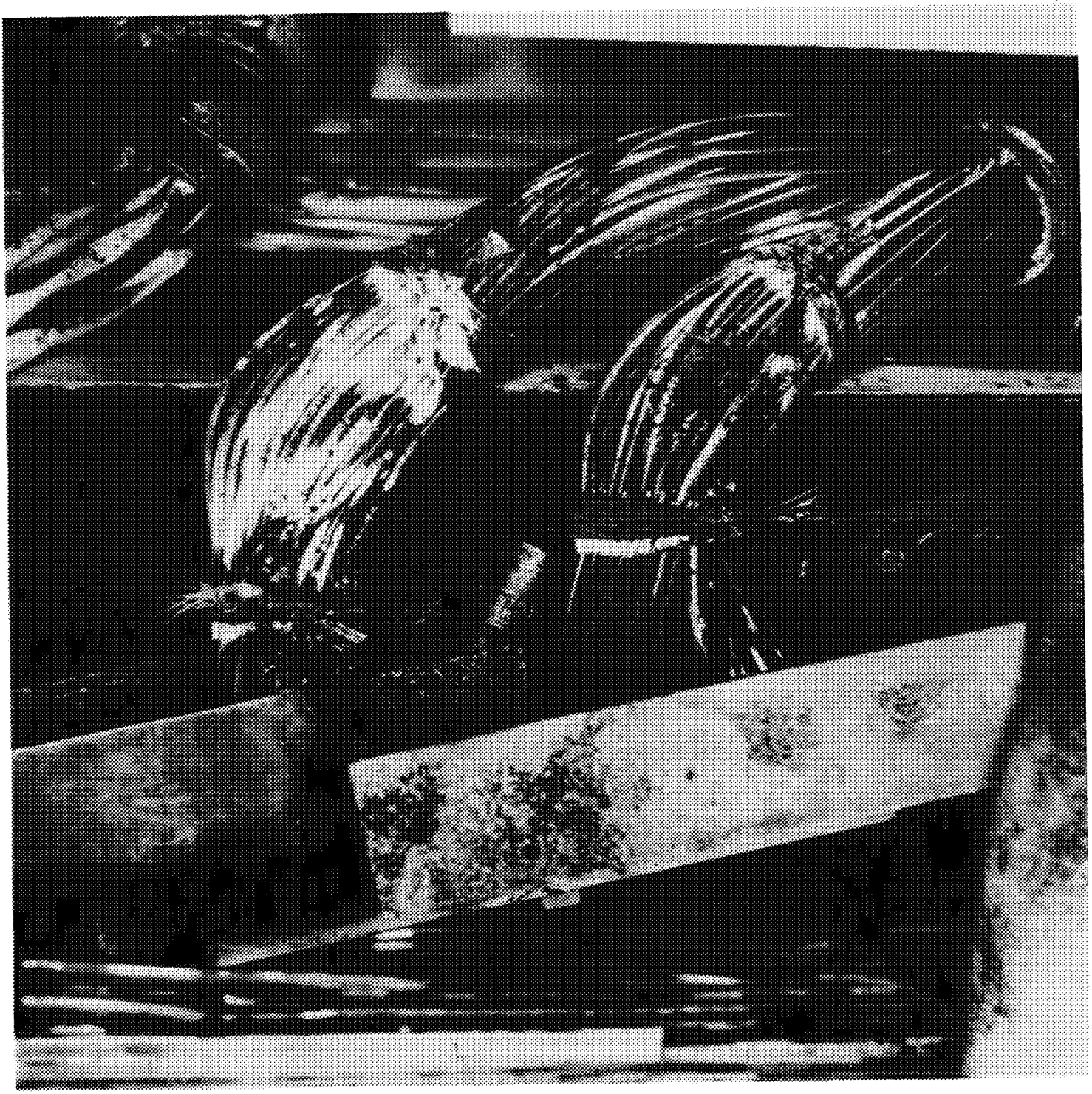


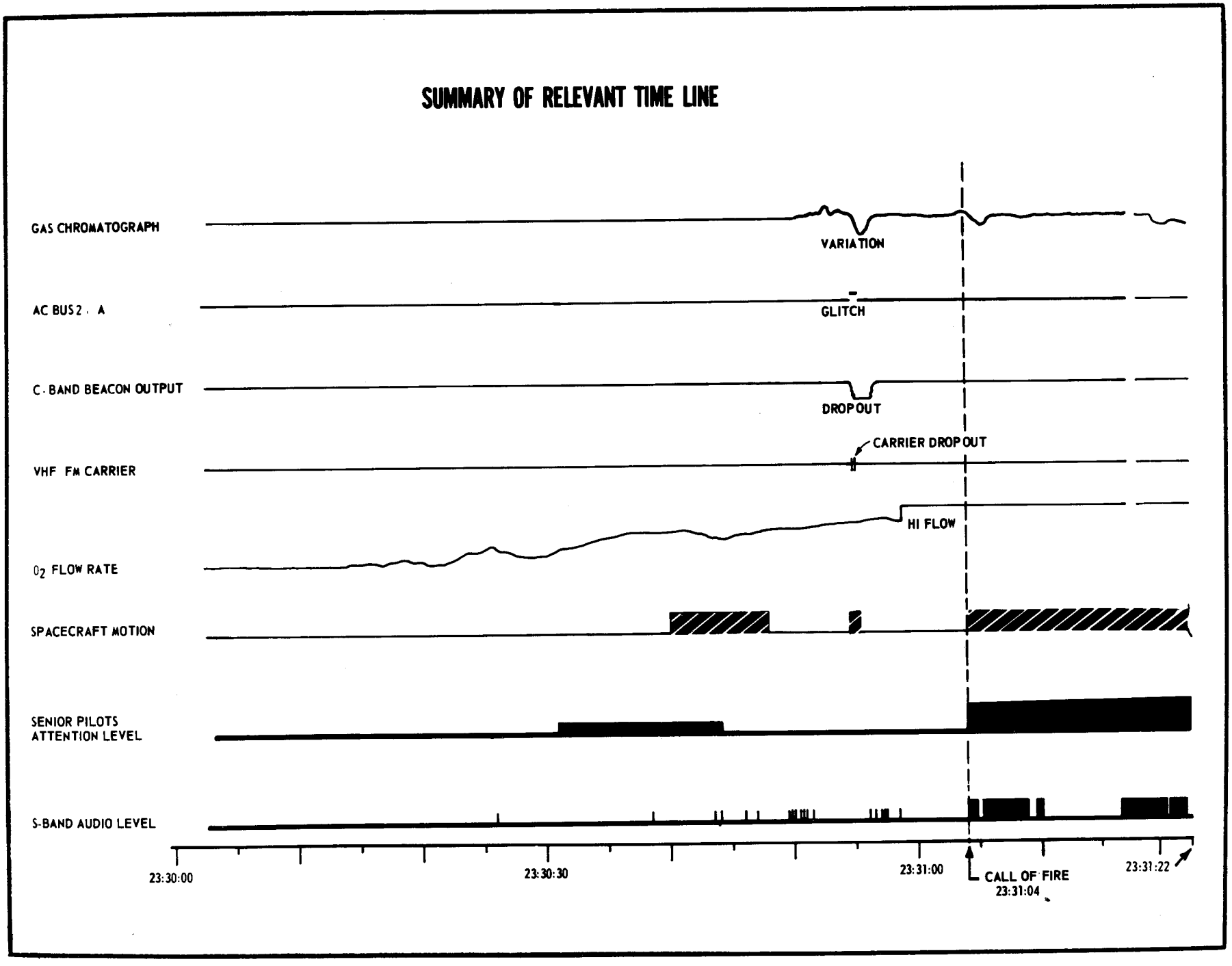
AFT BULKHEAD OF CREW COMPARTMENT



EXPOSED NON-METALLIC MATERIALS LOCATION – AFT BULKHEAD ADDED



WIRING ASSESSMENT


SUMMARY OF RELEVANT TIME LINE
GAS CHROMATOGRAPH
VARIATION
AC BUS 2 - A
GLITCH
C-BAND BEACON OUTPUT
DROPOUT
CARRIER DROPOUT
VHF FM CARRIER
HI FLOW
O_2 FLOW RATE
SPACECRAFT MOTION
SENIOR PILOTS ATTENTION LEVEL
S-BAND AUDIO LEVEL
23:30:00
23:30:30
23:31:00
CALL OF FIRE 23:31:04
23:31:22

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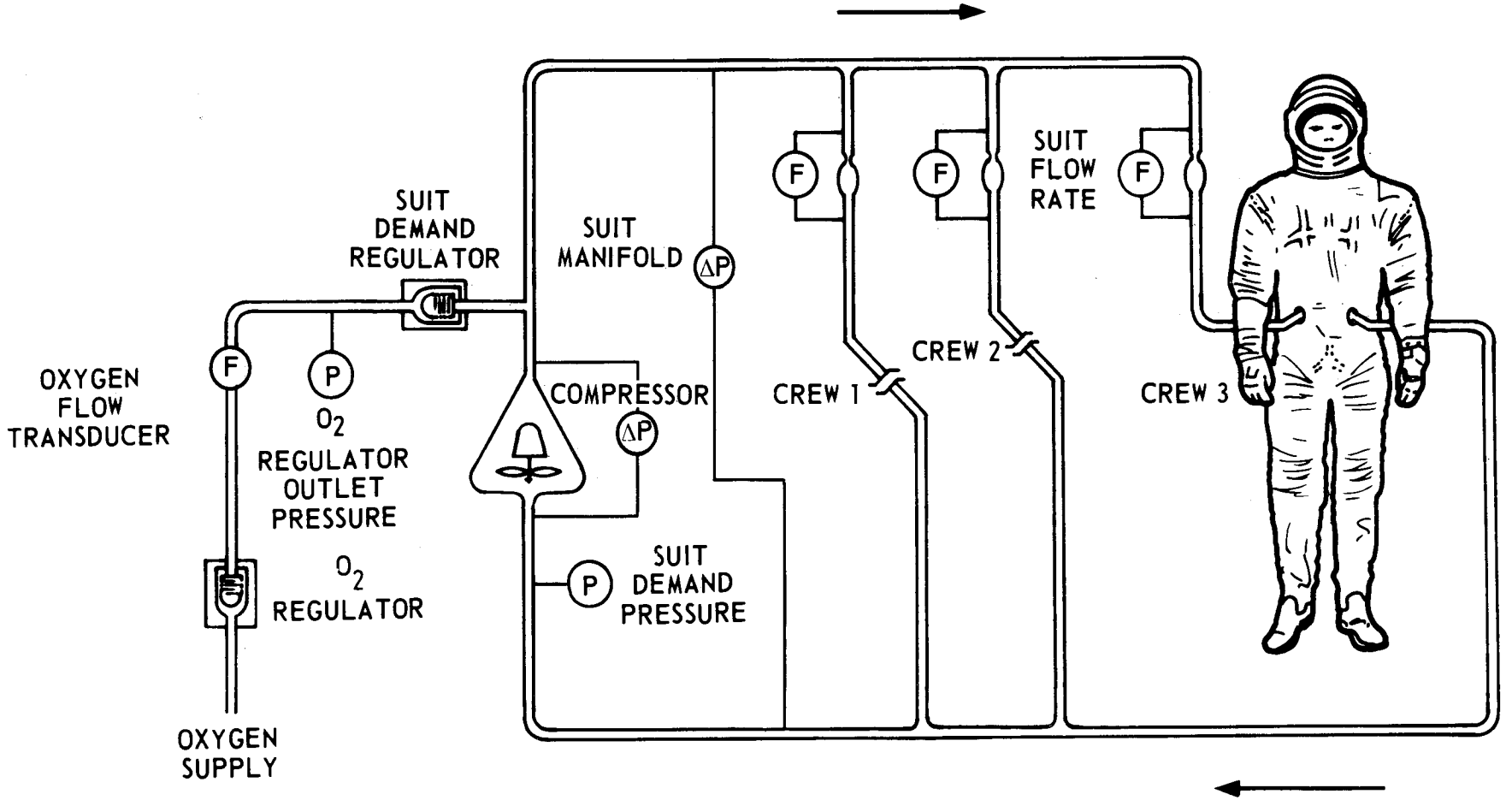
SUIT CIRCUIT SIMPLIFIED SCHEMATIC



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ENCLOSURE V-19

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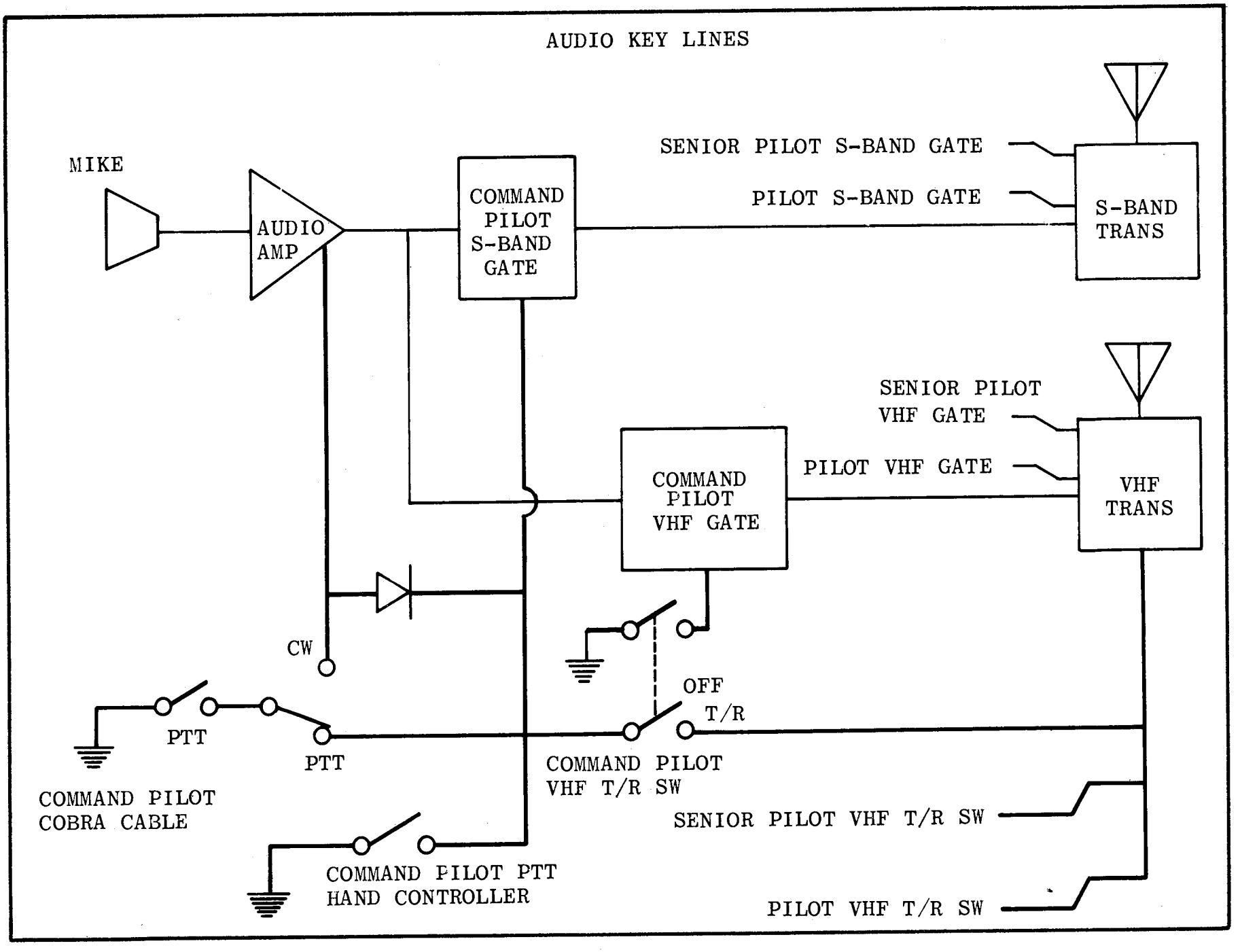
AUDIO KEY LINES
MIKE
AUDIO AMP
COMMAND PILOT S-BAND GATE
SENIOR PILOT S-BAND GATE
PILOT S-BAND GATE
S-BAND TRANS
SENIOR PILOT VHF GATE
PILOT VHF GATE
COMMAND PILOT VHF GATE
VHF TRANS
CW
OFF
T/R
PTT
PTT
COMMAND PILOT COBRA CABLE
COMMAND PILOT VHF T/R SW
SENIOR PILOT VHF T/R SW
COMMAND PILOT PTT HAND CONTROLLER
PILOT VHF T/R SW

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PART VI

FINDINGS, DETERMINATIONS AND RECOMMENDATIONS

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Part VI

BOARD FINDINGS, DETERMINATIONS AND RECOMMENDATIONS

In this Review, the Board adhered to the principle that reliability of the Command Module and the entire system involved in its operation is a requirement common to both safety and mission success. Once the Command Module has left the earth's environment the occupants are totally dependent upon it for their safety. It follows that protection from fire as a hazard involves much more than quick egress. The latter has merit only during test periods on earth when the Command Module is being readied for its mission and not during the mission itself. The risk of fire must be faced; however, that risk is only one factor pertaining to the reliability of the Command Module that must received adequate consideration. Design features and operating procedures that are intended to reduce the fire risk must not introduce other serious risks to mission success and safety.

1. FINDING:

a. There was a momentary power failure at 23:30:55 GMT.

b. Evidence of several arcs was found in the post fire investigation.

c. No single ignition source of the fire was conclusively identified.

DETERMINATION:

The most probable initiator was an electrical arc in the sector between the −Y and +Z spacecraft axes. The exact location best fitting the total available information is near the floor in the lower forward section of the left-hand equipment bay where Environmental Control System (ECS) instrumentation power wiring leads into the area between the Environmental Control Unit (ECU) and the oxygen panel. No evidence was discovered that suggested sabotage.

2. FINDING:

a. The Command Module contained many types and classes of combustible material in areas contiguous to possible igntion sources.

b. The test was conducted with a 16.7 pounds per square inch absolute, 100 percent oxygen atmosphere.

DETERMINATION:

The test conditions were extremely hazardous.

RECOMMENDATION:

The amount and location of combustible materials in the Command Module must be severely restricted and controlled.

3. FINDING:

a. The rapid spread of fire caused an increase in pressure and temperature which resulted in rupture of the Command Module and creation of a toxic atmosphere. Death of the crew was from asphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns.

b. Non-uniform distribution of carboxyhemoglobin was found by autopsy.

DETERMINATION:

Autopsy data leads to the medical opinion that unconsciousness occurred rapidly and that death followed soon thereafter.

4. FINDING:

Due to internal pressure, the Command Module inner hatch could not be opened prior to rupture of the Command Module.

DETERMINATION:

The crew was never capable of effecting emergency egress because of the pressurization before rupture and their loss of consciousness soon after rupture.

RECOMMENDATION:

The time required for egress of the crew be reduced and the operations necessary for egress be simplified.

5. FINDING:

Those organizations responsible for the planning, conduct and safety of this test failed to identify it as being hazardous. Contingency preparations to permit escape or rescue of the crew from an internal Command Module fire were not made.

a. No procedures for this type of emergency had been established either for the crew or for the spacecraft pad work team.

b. The emergency equipment located in the White Room and on the spacecraft work levels was not

designed for the smoke condition resulting from a fire of this nature.

c. Emergency fire, rescue and medical teams were not in attendance.

d. Both the spacecraft work levels and the umbilical tower access arm contain features such as steps, sliding doors and sharp turns in the egress paths which hinder emergency operations.

DETERMINATION:

Adequate safety precautions were neither established nor observed for this test.

RECOMMENDATIONS:

a. Management continually monitor the safety of all test operations and assure the adequacy of emergency procedures.

b. All emergency equipment (breathing apparatus, protective clothing, deluge systems, access arm, etc.) be reviewed for adequacy

c. Personnel training and practice for emergency procedures be given on a regular basis and reviewed prior to the conduct of a hazardous operation.

d. Service structures and umbilical towers be modified to facilitate emergency operations.

6. FINDING:

Frequent interruptions and failures had been experienced in the overall communication system during the operations preceding the accident.

DETERMINATION:

The overall communication system was unsatisfactory.

RECOMMENDATIONS:

a. The Ground Communication System be improved to assure reliable communications between all test elements as soon as possible and before the next manned flight.

b. A detailed design review be conducted on the entire spacecraft communication system.

7. FINDING:

a. Revisions to the Operational Checkout Procedure for the test were issued at 5:30 pm EST January 26, 1967 (209 pages) and 10:00 am EST January 27, 1967 (4 pages).

b. Differences existed between the Ground Test Procedures and the In-Flight Check Lists.

DETERMINATION:

Neither the revision nor the differences contributed to the accident. The late issuance of the revision, however, prevented test personnel from becoming adequately familiar with the test procedure prior to its use.

RECOMMENDATIONS:

a. Test Procedures and Pilot's Checklists that represent the actual Command Module configuration be published in final form and reviewed early enough to permit adequate preparation and participation of all test organization .

b. Timely distribution of test procedures and major changes be made a constraint to the beginning of any test.

8. FINDING:

The fire in Command Module 012 was subsequently simulated closely by a test fire in a full-scale mock-up.

DETERMINATION:

Full-scale mock-up fire tests can be used to give a realistic appraisal of fire risks in flight-configured spacecraft.

RECOMMENDATION:

Full-scale mock-ups in flight configuration be tested to determine the risk of fire.

9. FINDING:

The Command Module Environmental Control System design provides a pure oxygen atmosphere.

DETERMINATION:

This atmosphere presents severe fire hazards if the amount and location of combustibles in the Command Module are not restricted and controlled.

RECOMMENDATIONS:

a. The fire safety of the reconfigured Command Module be established by full-scale mock-up tests.

b. Studies of the use of a diluent gas be continued with particular reference to assessing the problems of gas detection and control and the risk of additional operations that would be required in the use of a two gas atmosphere.

10. FINDING:

Deficiencies existed in Command Module design, workmanship and quality control, such as:

a. Components of the Environmental Control System installed in Command Module 012 had a history of many removals and of technical difficulties including regulator failures, line failures and Environmental Control Unit failures. The design and installation features of the Environmental Control Unit makes removal or repair difficult.

b. Coolant leakage at solder joints has been a chronic problem.

c. The coolant is both corrosive and combustible.

d. Deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring.

e. No vibration test was made of a complete flight-configured spacecraft.

f. Spacecraft design and operating procedures currently require the disconnecting of electrical connections while powered.

g. No design features for fire protection were incorporated.

DETERMINATION:

These deficiencies created an unnecessarily hazardous condition and their continuation would imperil any future Apollo operations.

RECOMMENDATIONS:

a. An in-depth review of all elements, components and assemblies of the Environmental Control System be conducted to assure its functional and structural integrity and to minimize its contribution to fire risk.

b. Present design of soldered joints in plumbing be modified to increase integrity or the joints be replaced with a more structurally reliable configuration.

c. Deleterious effects of coolant leakage and spillage be eliminated.

d. Review of specifications be conducted, 3-dimensional jigs be used in manufacture of wire bundles and rigid inspection at all stages of wiring design, manufacture and installation be enforced.

e. Vibration tests be conducted of a flight-configured spacecraft.

f. The necessity for electrical connections or disconnections with power on within the crew compartment be eliminated.

g. Investigation be made of the most effective means of controlling and extinguishing a spacecraft fire. Auxiliary breathing oxygen and crew protection from smoke and toxic fumes be provided.

11. FINDING:

An examination of operating practices showed the following examples of problem areas:

a. The number of the open items at the time of shipment of the Command Module 012 was not known. There were 113 significant Engineering Orders not accomplished at the time Command Module 012 was delivered to NASA; 623 Engineering Orders were released subsequent to delivery. Of these, 22 were recent releases which were not recorded in configuration records at the time of the accident.

b. Established requirements were not followed with regard to the pre-test constraints list. The list was not completed and signed by designated contractor and NASA personnel prior to the test, even though oral agreement to proceed was reached.

c. Formulation of and changes to pre-launch test requirements for the Apollo spacecraft program were unresponsive to changing conditions.

d. Non-certified equipment items were installed in the Command Module at time of test.

e. Discrepancies existed between NAA and NASA MSC specifications regarding inclusion and positioning of flammable materials.

f. The test specification was released in August 1966 and was not updated to include accumulated changes from release date to date of the test.

DETERMINATION:

Problems of program management and relationships between Centers and with the contractor have led in some cases to insufficient response to changing program requirements.

RECOMMENDATION:

Every effort must be made to insure the maximum clarification and understanding of the responsibilities of all the organizations involved, the objective being a fully coordinated and efficient program.

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U. S. GOVERNMENT PRINTING OFFICE : 1967 O - 261-101

DRA

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-TM-X-70218) REPORT OF APOLLO 204 REVIEW BOARD TO THE ADMINISTRATOR. APPENDIX A: BOARD MINUTES (NASA) 121 p

Unclas
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APPENDIX A

(NASA-TM-84101) REPORT OF APOLLO 204 REVIEW BOARD TO THE ADMINISTRATOR. APPENDIX A: BOARD MINUTES (NASA) 121 p

N82-72197

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APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

APPENDIX A

BOARD MINUTES

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APPENDIX A

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

February 8, 1967

IN REPLY REFER TO Chairman, Apollo 204 Review Board

TO: DISTRIBUTION

SUBJECT: Transcripts of Review Board Sessions

1. During the first days of the sessions of the Apollo 204 Review Board, the Board heard discussion, suggestions, extemporaneous remarks by Board members, Advisory Group members and technical experts engaged in studies relevant to the review, and accounts, to be verified, from two on-the-scene witnesses and one individual who was observing the monitors in the blockhouse.

2. In the free and open discussion, in many cases the identity of the speakers was not established and the remarks were not clearly related to the subject under discussion. The result is that the transcript of the proceedings of the first days (other than eye witness accounts) is valuable primarily as background material that provides a useful source for identifying potential review action.

3. In view of the foregoing, the minutes of the Review Board meetings on January 28, 29, and 30 will be utilized only as reference material with limited distribution, with the exception of identifiable eye witness accounts which will be appropriately incorporated in the final report.

Dr. Floyd L. Thompson

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CHAIRMAN: I want to make a statement regarding procedure. The meeting is now convened. We are having trouble in wording proceedings of this board. One of the main difficulties is the lack of identity of the speakers. We need less conversation and more statements as far as the record is concerned, with identification of the speakers. In certain cases where we do get into a period of discussion, perhaps the best thing to do is to put it off the record and then come back on the record at such time as we reach an understanding that permits progress with the development of a record. If this is going to be embarrassing to the speaker, remember that it is necessary to require identity. The first subject that we're going to deal with this morning is the finishing up of the business we were dealing with last night...relative to procedures for this assembly.

SIMPKINSON: Before I start reading this plan, I would like to say that this was written quite late last evening and I had hoped to bring in a typewritten copy, I will get it, but I am interested in moving on here and I would like to go ahead and read what I have here. There are no copies at this time. Is that all right?

CHAIRMAN: Go ahead.

SIMPKINSON: This is a debris removal plan which encompasses at the board's request a method for removing a couch or the couches. This will be in detailed steps so I will just read it rather fast and if there are any questions, break in.

One of the first things we need is to provide good fixed incandescent lighting within the spacecraft. It is very difficult to see in there now. We don't want flourescent because it is bad for color. We will provide a hand held pre-focused spot which a person can move and get good shadows and good lighting on particular things of interest. Then, if we divide each couch in half and have all interested parties examine the top half of the center seat and pick up one layer of debris and place it in a bag, we would immediately photograph all single significant finds. At the minimum, we would photograph after each layer is uncovered. Interested parties would then inspect each significant find at least once per layer and photograph anything of significance. We will repeat this process until the top half of the center seat is cleaned of loose articles. We will then carefully vacuum the cleaned portion using a clean filter at the business end of a vacuum hose, carefully remove the filter with the debris that is caught, and place it in a bag with the picked-up articles and seal the bag. We would mark it for location such as "center couch, top half." Repeat this with both halves of all three couches until we have each completely picked up, free of loose particles and the seats vacuumed. We will repeat this for the leg supports. This is too detailed...I will just read it. I think it is better this way. Remove one leg support and mark the location. Check the underside for additional debris, inspect and photograph and then remove particles by hand and place in a separate bag for the bottom half of the leg support. If you didn't catch it now, we did the top half and put these in six bags; one for each leg support. We will turn them over and put them in separate bags. Mark that as the bottom part and then, as with the seats, we will inspect and photograph any particles as we uncover layers. They will always be photographed until we get down to the bottom, which we will vacuum and put in with the bag of particles. We will seal these bags using a clean filter each

time. We will repeat this procedure for each of the remaining five leg supports, one at a time. We will then transport all the bags of debris and the leg supports and place them on a prepared floor. I'm not prepared at this time to say exactly how it will be prepared, but it will be on a concrete floor in a building. It is in the Pyrotechnic Installation Building which is not in use at the present time and is practically a white room. It will have clean benches installed if necessary, to work with the debris in the bags. We are going to have a floor that I hope is white, smooth, and new, and has no speckles on it to hide anything we might drop. We started painting it this morning. We are painting a double size bulkhead on the floor.

FAGET: Double scale?

SIMPKINSON: Double scale, right, bulkhead.

FAGET: Do you think that is big enough?

CHAIRMAN: I just made a statement, Max, we're trying to establish a record now that will be intelligible and it requires identification. As I said earlier, I think we are going to have to depend on statements rather than conversation. If you want to say something, get it in the record with identification. Go ahead.

SIMPKINSON: The question from Mr. Faget was, "Do we think that it is big enough." We talked about this and felt that is about as big as we can use in this room. With the time we have available, I think we ought to get started. I believe this will allow us to lay out a pattern on the floor of the office with walk-ways in between. I think double scale – that's a 24 foot circle – is pretty big. Outside of that, we must eventually lay a second circle representing the walls of the spacecraft. I think it is big enough. The building is probably 300 ft. by 100 ft. I can't be specific, I haven't been there for some time. We will lay down the couch material which will be to the side of the circle, a second floor, so to speak. We plan to lay it over to the side with a dash line in the big circle representing where the couches were. Then to the side of this, we will have the debris from the couches placed for inspection, and left in the bags. I feel that we must do something specific with that debris. I don't want to just scatter it out as if it were on the seat again for everybody to look at. I think that we need definite tasks to come up with plans to be approved by you people, to process this debris. Now this means that we have the couches clean and we have the debris laid out under proper control. To go on here, the parts like the leg pans, can be taken out of the bag so people can look them over. They are large parts, and can't be lost or moved. Incidentally, only authorized personnel would be allowed in the area. Now we have clean couches. Our next thought varies somewhat between ourselves, however, I think I have the consensus that "complete inspection will now be made of the bulkhead area." Complete as possible by laying on the couches and leaning over so that overall photos will be taken. Also, specific area close-ups will be taken of areas of interest pointed out by anyone, but most assuredly, those the fire experts would determine. A technician will then be sent in to remove the couches, where they would have to stand on the floor. I know that some people in here would prefer, and I'm one of them, that we didn't have to stand on this floor. But we don't see any way in the world after working it for two days not to have to get on the floor. So we're asking that the technicians point out to us...

CHAIRMAN: Interruption...the Chair. There is a question from Mr. Mathews.

MATHEWS: What do we do to verify the structural integrity of that floor?

SIMPKINSON: Mr. Jeffs has brought in the men who practically melted the metal down to make this thing and I think they will be of great help to us. We have looked at it with the best people we have. We cannot guarantee it. I believe the most important thing we want to look at in here if flame patterns: I could be wrong. Maybe the spread in the pressure shell is more important – exactly how it is split. That is way over to the right and down front (+Y, -Z). I don't think we'll have to get near it. It is in a honeycombed structure. This kind of thing doesn't tear very easily and it only has to move an inch and a half, it is my understanding, and you're standing on a heat shield. So again, I can't guarantee the integrity; however, there is no problem of safety in my opinion. I don't think we'll destroy any evidence that's worthwhile, and I don't know how in the world to get those couches out without getting on the floor. And no one else does at this point. I know it hasn't been answered yet.

CHAIRMAN: Open for questions.

JEFFS: Mr. Chairman, I have a suggestion, and that would be the following: Prior to the couch removal, we consider a quick explanation of the fracture by the fracture experts who are now on site. From two points of view, one from further damage point of view, the other a safety point of view, and that it be carefully monitored and then followed by a floor clean-up and item photography for position recording and identification, prior to moving off with the couch removal TPS.

CHAIRMAN: Were there further questions?

WHITE: White here. I wonder if consideration should be given to some sort of a walkway, suspended from the sill of the hatch and from a solid point on the opposite side of the spacecraft, grill work or something of this sort (other voices) just above the floor!

CHAIRMAN: (Off the record at this point.)

Off the record discussion.

CHAIRMAN: After discussion, a point of decision was reached. I'll turn it over to Dr. Faget to summarize the decision that has been arrived at on the basis of this discussion. Dr. Faget.

FAGET: The disassembly of the vehicle should proceed to the point where the legs, supports, and head supports are removed from the couch, the couch is cleaned up, and at that point a piece of plywood or other suitable cover will be put on top of the couches that remain. At this point, other tasks will be allowed to be carried out within the vehicle.

CHAIRMAN: Is there agreement with that assessment or does anyone wish to make an addition to it?

BAXTER: I assume these other tasks, will be defined and criticized.

SIMPKINSON That is correct, we will come back with a plan.

WHITE: I guess that it is also assumed that this task takes place after the one we discussed last night for removal of the LES.

SIMPKINSON: That is correct.

CHAIRMAN: We will now go off the record for a continuation of a discussion of future plans.

(Off the record discussion.)

CHAIRMAN: After further discussion, a point of agreement was reached which will be summarized by Mr. Geer. Mr. Geer.

GEER: The TPS2, we'll call it, which covers the removal of the dust and bag from the couch and the placement of the plywood on the couch for a matter of ingress-egress, is a basis for TPS2.

SIMPKINSON: Point of order, Mr. Chairman...We had better avoid numbering TPS's as they already have numbers.

(Off the record discussion.)

CHAIRMAN: I will now attempt to summarize the situation just developed by the discussion relating to the planning of further removal of articles from the spacecraft. A plan for removal of couches will go beyond that agreed upon involving the plywood covered couch and will be developed in detail and brought back to the board before action is taken on the removal.

(Off the record discussion.)

CHAIRMAN: In a further discussion with Mr. Simpkinson, it was agreed that further planning for removal of articles from the vicinity of the spacecraft is underway and will be brought back to the board for approval. Also, as regards the disposal or further disposition of certain exhibits, it was agreed that Dr. Van Dolah would work with Dr. Kelly in arranging for the proper action relative to space suits for exhibit purposes. Also, it was agreed with Mr. Simpkinson who said that he would proceed with certain other actions regarding release of impounded objects. These will later be handled through appropriate panels which are not yet formed. Yesterday I received a memorandum for the Apollo 204 Review Board, signed by Dr. Seamans, which constitutes a written authorization and confirmation of the constitution of this board, and the responsibilities that have been assigned to it. Up until now, we've been operating on verbal instructions, directives, and notes. Each member of the board is being furnished a copy of this statement. I call your attention to the change in title from that I gave you earlier stated in the draft left here by Dr. Seamans last Sunday. If you read this document, you will realize, I think, that this board has extremely broad and serious responsibilities. We are concerned with a matter that involves broad public interests to a degree that is not always associated with accident investigations.

DR. LONG: A small point. One of the items from Dr. Seamans' letter says that the final reports will not be released without his approval. I ask only that, or rather I suggest to you, that perhaps you may wish to ask whether that means it will, in fact, be classified because this rather sounds as if it is or likely to be unclassified

and ultimately released after his approval, and it seems to me the question remains of interest to us.

CHAIRMAN: I think that we'll have to fall back on the decision of the Administrator as to how he desires to handle it. That's what this statement says to me and at this time we cannot clarify beyond the statement given here. Just what will happen on that is a matter that will be decided by the Administrator and I certainly am not in a position to go beyond that. I don't know that we will gain anything by discussing that point any further at this time, although we agree that the statement made by Dr. Long is an important one.

YARDLEY: Mr. Chairman. The thing I think that we have to decide right now, especially when we're getting ready to say – print a hundred documents of 20 some odd pages which give some idea of what the board is doing, – is what sort of temporary classification we want to establish for this sort of thing. We have about 100 people involved on these panels and they're going to be generating data. We have to give them some guidance as to what they should put on their data to restrict its distribution. We need a temporary classification of some sort.

CHAIRMAN: We're getting involved in a matter that's not entirely clear as to all the details involved. We're using "treatment as confidential" as a guide to handle material at this time. We need to clarify the detailed procedures involved, but we are not prepared to do it at this time.

(Off the record discussion.)

CHAIRMAN: The Chair is asking for a report from Mr. Williams, regarding the activities of the ad hoc working group that he has headed relative to implementation of the plan for putting into work status all the panels that are proposed by the plan discussed in earlier meetings. I'll ask Mr. Williams to make a report.

WILLIAMS: We have gone over it and corrected several areas, typographical errors and so forth. The plan was completed last night and distributed for review by various people. Corrected sheets are in typing now. Is this correct?

YARDLEY: That's correct.

WILLIAMS: It shouldn't be distributed until we get the special cover that identifies the need for special handling. Who is going to take the action required to devise the special cover?

CHAIRMAN: I will.

(Off the record discussion.)

CHAIRMAN: Relative to the question of the special cover, a discussion just entailed about how to handle all this material in a discreet manner appropriate to the purpose of this entire investigation. The current plan that I think we will agree upon is that a special cover and identification of all material relative to this investigation will be worked out without using the formal classification machinery that is not applicable in this case. I will take on this subject as an action item so that we may release this material as quickly as possible.

(Off the record discussion.)

CHAIRMAN: Discussion resulted in an understanding that the material required would be in hand so as to permit the working group to meet at about 3 o'clock.

We have just learned that there is another reported accident at Brooks Air Force Base in a pressure cabin simulating space operations. Col. Strang will make the the necessary follow up for the board regarding the relationship of that accident to our investigation, as well as taking care of any appropriate action on the other incident he reported.

I would like to ask Mr. Williams to go back to the subject that we interrupted regarding the action of his working group relative to recommendations to the board.

WILLIAMS: We suggested that the group, of which I am chairman, get together and call in the panel chairmen and let the board explain to them and put down on paper a work statement what we expect to come out of their activity and let them in turn go down and get in contact with their panel personnel and start appropriate action.

CHAIRMAN: I am asking for verification. You mean the Chairmen will come before the board?

WILLIAMS: That's correct.

VOICE: Before the board or before the working group?

WILLIAMS: No, not the Review Board, before the working group.

CHAIRMAN: You are referring just to operation of your group.

WILLIAMS: That's right.

CHAIRMAN: Let me ask Mr. Williams. Do you think that the action of your group in preparation of the proposed work statements and the comments that you have just received, puts you in a position to proceed with the implementation of the plan under your group's direction, subject only to some minor corrections from board members that will be taken up with you individually?

WILLIAMS: This is correct. We have a board member as a contact for each panel chairman. If there are changes necessary after we implement this system, then the board members can take it up with the working group.

CHAIRMAN: Does the board agree that we can implement this action by assigning this working group the responsibility for going ahead in accordance with our understanding as was provided by these papers that we have had a chance to review. The consensus is yes.

WILLIAMS: Then I propose that the group that was just appointed meet in my office and we'll set up a meeting with the panel chairmen.

CHAIRMAN: Proceed with that understanding.

WILLIAMS: We'll try to get the board monitors and the panel chairmen together.

FAGET: I think you ought to consider a little bit of time between the time our group meets with these people. It would seem that the panel members ought to have a little time to look at the assignments.

YARDLEY: This is just an introductory meeting.

CHAIRMAN: Let me interrupt again. I think our understanding is good enough so that we can consider this issue closed at this point and turn over to the custody of this group for action all these and other matters that can be taken up privately until we reach the stage where the board needs to consider the whole thing again.

(Off the record discussion.)

CHAIRMAN: In summation of the results of the foregoing discussion, Mr. Yardley will make a statement regarding an additional panel that is being put into the action plan. Mr. Yardley.

YARDLEY: We have added Panel #20 which is entitled "Safety of Investigation Operations," with the task of taking the responsibility for reviewing all operations performed during the investigation to assure that all personnel safety requirements are adequately maintained. John Atkins of KSC is Chairman. Lt. Col. Baxter is proposed as the board monitor.

CHAIRMAN: The board agrees with the addition of this panel. The board now plans to adjourn. I am going to ask the members to make themselves available for a possible meet- at some other time today and I would like to at this time establish the time. I'll go off the record for a moment.

(Off the record discussion.)

CHAIRMAN: We will now adjourn until 3:30 this afternoon.

SECOND SESSION:

CHAIR: The system spacecraft data work that is going on is under the direction of Dr. Joe Shea. Presentation will be by Mr. Abbey, but first of all, let me call your attention to the sheet of paper that our secretary has up there, which is the means by which this work will be designated, at least to start off with. Read the title please.

SWIEDA: "For the Use of Apollo 204 Board Investigation Only."

CHAIRMAN: Thank you. Do you want to say anything further on it?

We have a substantial quantity that will be available in the secretary pool area and I will distribute these here.

Could I ask a question of the secretary? What progress are you making in getting transcripts of some of the witness statements and so on? I think a number of us are beginning to feel a little rusty that we haven't seen some of these things to go over firsthand.

SWIEDA: At the present time I believe we have a 20-hour lag in transcription. We have all of Saturday's and Sunday's transcribed at this point. I am not certain about the status of Monday's events.

CHAIRMAN: And distribution lags the transcription by how much?

SWIEDA: The distribution of this material...the mode for this distribution has not been developed yet. A procedure is in process now and will be presented to the chairman today or early tomorrow morning.

YARDLEY: It might be appropriate to tell everybody when they are going to get the printed copies of this task definition. I think we have a little slip in that, haven't we?

CHAIRMAN: We are on the record now. Do you want to report on the status of that?

SWIEDA: I can report on that, sir. We are in the process. We got a lot of material typed. It is ready to go to the printing plant and with your approval, we will do this... send it over to the printing plant and have it ready in the morning. We have to print up some 4000 sheets of paper, collate them, and staple them together.

WILLIAMS: We have some changes to make in some of the names. Are you typing the mats now?

SWIEDA: The mats have been completed.

WILLIAMS: Have you started printing it?

SWIEDA: No sir.

WILLIAMS: Well, we would like to hold the mats. As we reviewed each one of these panels, there were some name changes.

YARDLEY: Can you get that in so they can go ahead with it?

CHAIRMAN: If we are going to get in a discussion of this matter, let's go off the record.

(Off the record discussion.)

CHAIRMAN: The work statements will be signed out for printing very shortly after the meeting. We asked Dr. Joe Shea, Director, Apollo Spacecraft Program Office, here...to present his discussion of a program that we have under way.

SHEA: Perhaps it would be of interest to the board to do two things. I will try to do it very quickly. One is to tell you what we are doing in the overall program, in effect, independent of this investigation and problem; and secondly, the things that we are doing specifically associated with this investigation here, and some of the actions that we have taken to hopefully make the problem of the board a bit simpler in terms of the availability of information and things like that. I would like to preface the first part of the discussion by saying that we have a very large program which is in existence. We've got 150,000 people all over the country that up until last Friday at 6:30 worked on going to the moon. We can't send them all on vacation. We can't stop the program. And, we are worried about this mass confusion in the overall organization. So we have had them make a series of programmatic decisions as to what we intend to do. Obviously, the board recommendations can change this plan but let me tell you what we are doing now so that if you hear anything coming back you will understand. We have had a series of missions planned. The next missions which were coming up in sequence. The

mission called 501 which was a Block I command service module unmanned flight on top of the Saturn V. It was intended to be a heat shield test primarily. It's the time when we were going to qualify the heat shield at lunar return speed. We really see no inter-action of the problem that we have here with that activity except possible for the method of closing out the unmanned spacecraft. That spacecraft is stored down at the VAB at the present time and we said go ahead with that and get ready to fly that mission in 2nd Quarter 1967. The first of the lunar modules which was also intended to be an unmanned mission is in the latter stages of checkout at Grumman. It was intended to fly on Saturn IB-206. It would be again an unmanned mission. Its primary purpose was not to test environmental systems but rather to test things related to the propulsion system and what we considered up to that time to be the safety of flight items. We are delivering the spacecraft. We would expect to bring it down here. We would expect to start the checkout process down here with a target date of that mission by 2nd Quarter 1967. Now the first perturbation in the program plan comes with the next scheduled mission. It was to be a mission called 258 and was going to be the first of the manned Block II command service modules and a LEM lunar module. The mission involved launching the CSM into earth orbit, launching the LEM on the second one, joining the two of them together. The CSM comes in to rendezvous and then going on with simulation for the lunar mission. We feel that in light of the fact that we have not achieved the 204 objectives and because the dual mission is a somewhat complex mission, we can't imagine coming back without a tremendous reconcentration on this first flight -- that that next mission will be a CSM mission only. The only spacecraft we have to do it on that we think makes any sense at all is the first Block I spacecraft called 101. Excuse me, Block II spacecraft the number is 101 and it's in checkout at Downey and is presently due to be delivered around the end of March and we always have uncertainty in our delivery dates so that might stretch out to be sometime in April. We have not introduced any changes at the present time under the checkout procedure or into the spacecraft. We would expect obviously to have to contain any design changes in the overall system but we are still targeting at this point in time for a launch of that spacecraft around the first part of August. Whether that happens or not of course there's a lot of things behind this. There is one more Block I spacecraft and that's to get delivered out of Downey. That's the spacecraft for 502. It's also an unmanned version 502 being a repeat mission of 501. We are proceeding with that.

The first combined mission and if this turns out to be the program plan, would occur some ten weeks after this 101 mission and that would be the 102 spacecraft and LEM 2 and whether that flies on Saturn V or a dual launch on Saturn IB really is a function of when we fly it and where the Saturn V is at that point in time since it's been having some difficulties. This then is an operating plan which represents essentially no perturbation in activities that are going on at the present time. In addition, we got two ground test spacecraft, a thermo-vacuum spacecraft, 2TV-1, a command service module that goes into one of our chambers at Houston. A second spacecraft LEM test article which goes into another chamber at Houston. We are proceeding with those with the intent of getting them into the Chamber in the unmanned and manned altitude testing essentially on the schedules we had before. In addition, we are doing things like reconfiguring the Mission Control Center all the block II's and LEM's – and the trainer down here for example, which had been held in the Block I configuration because of the mission that we were doing – we need to get the scheduled time for the conversion to Block II so we are in the process of breaking that down and converting it to

Block II. So, my point is, the program is going on as usual. Whatever comes out of here and I think that's just what we have to do. We talked to our people in Houston and told them this and told them that we don't want them to do too much volunteering and going off by themselves but to compensate for the problem, we and the board have. We have a series of directed actions going on and we'll tell them anything that needs to get done. Similarly, we are calling in all the contractors Friday at Houston to give them a similar briefing. To tell them at least right now that the program continues and they have no contractual authorization to do anything but what they were supposed to do as of last week and to keep stability on the overall program. I guess I can't emphasize the importance I feel for ultimately getting to the moon. Alright, now let me talk more specifically about things associated with the boards activities and the kind of staff we think can be helpful. We have directed that Spacecraft 14, which is a sister spacecraft to 12, be brought here, because at one time in the program, we had two spacecraft flights of block one that were essentially the same. One was going to be 204 and the other 205. For a number of reasons, we cancelled the 205 flight just before the spacecraft was to have been delivered. Three days from delivery, we had to use the service module for something else, but the command module was built. Later the command module was put in bonded storage. There were minor configurational differences, but extremely minor, in the context of what we are talking about here between those spacecraft. There always are in an involving problem. Rather than try to bring 14 up to the 12 configuration, a lot of people fooling around with it at Downey and so on, we said, "Ship the spacecraft down here; bring with it the configurational records so we can identify differences." And our suggestion is, and I believe this may have been accepted already, that any work done inside 12 – dissasembly, taking things apart, and so on – be done first by the technicians in 14, so that you completely review in 14 every tool you are going to use, every step that is going to be done. If they are going to remove a panel, they remove that panel in there, have them look in, have them understand it. Take pictures in 14, so you are working from a data basis before you go playing around with the evidence upstairs. We would request that you stop short of burning the cables, or scraping wire, or that sort of thing. But I think this will be a tremendously valuable tool, because even if you are talking about trained technicians, they have never been inside that spacecraft down here enough to really know what the guts of it look like. Because, hopefully, we haven't had to get in there all that often.

WILLAIMS: Is that true of removing the seats of 12?

SHEA: I think not. I think that is a sufficiently straightforward operation that we all understand, and I think it's more of a question...

VOICE: And a different configuration somewhat relative to the results of the fire.

SHEA: Well, the fire completely changed the configuration in and around the seat area.

(Off the record discussion.)

CHAIRMAN: The discussion involved the question as to the influence the accident has had on procedures that are planned for the future, so Dr. Shea will now give a statement that answers that question. Dr. Shea.

SHEA: As nearly as we can see, the area of procedure that would be affected by the

accident relates to the operation of the spacecraft cabin in a pure oxygen environment either at 5 psi or at ambient pressure. Because of that concern, we have issued instructions to our contractors to do no such testing either in spacecraft checkout operations, spacecraft test operations or any of our breadboard and subsystem operations throughout the entire program. At this point in time, that direction is not holding up anything on the program, as far as the in-line production spacecraft is concerned. It is slowing down a few qualification tests which are not critical in line of scheduling and in light of the magnitude of the problem that we face.

CHAIRMAN: Thank you.

SHEA: I talked about Spacecraft 14. We have in Houston, another spacecraft called 008 which was used in the thermo vacuum testing at Houston. We have pulled it out of the thermo vacuum chamber but had made arrangements for that spacecraft to be in electrical configuration and probably powered up during the 204 mission. There are again some minor configurational differences between that spacecraft and Spacecraft 12. In addition, the environmental control system had been removed from that spacecraft and put into our environmental control system breadboard in chambers in the crew systems division at Houston. We have brought Spacecraft 8 on line, or will have it on line, within the next couple of days; and it is the place in which we can do electrical testing of systems in order to investigate problems. And we just point out that this is a facility, then, which is available. If you want to know if touching a particular wire to a particular point will cause a particular phenomenon, we believe that that can be reproduced with almost complete fidelity in that 8 spacecraft, and we are doing some tests of that kind ourselves.

This is a facility available to the board for additional investigation. This is also, then, the environmental control system breadboard which I mentioned, which is at Houston, and it is a configuration available for any testing that may be appropriate, as far as the environmental control system itself is concerned. We have, as you know, an extensive materials program going and also a series of special tests on possible, I'd say, non-electrical related causes of the failure. That's being run at Houston under the control of Mr. Joseph Kotawchik who heads the structures and mechanics division at Houston. The materials investigation, by and large, has been directed by the board, and we are also looking at some experiments in spontaneous combustion electrostatic discharge phenomena. We also have had for some time a zero G airplane series of experiments on combustion phenomena at zero G as distinct from 5 psi (corrected) or from 16 psi, and that's going to be very important, as you decide what the risks are upstairs. These would be the risks on the ground. These are two different problems. That program...

(Interrupted by a question)

CHAIRMAN: Is there a question?

YARDLEY: The question was – I wanted a clarification of whether the zero G tests were zero G and 5 psi as opposed to the ground test of one G and 16.

SHEA: That is what we have been running. We can modify the experiment to any atmosphere and pressure at zero G. One other thing that we are doing which may or

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may not be a help – that is we are doing it partially for ourselves and partially for the board. We are trying to take one of our mock-ups which is now a non-flight type spacecraft and put into it, or be sure it is up-to-date with all of the material locations which might be involved in flame and flame transmission. I would picture that we finally would be able to tag that with things like nominal combustion temperatures, propagation rates, with the materials and so on. And this would be a kind of a tool that the flame propagation people, the rest of the board, could have as a visual mock-up of what the thing was as you begin to piece this together. I have given an assignment to one of my people to bring this into being. I don't know how soon we will have it, but it will go now.

(Interrupted by a question)

CHAIRMAN: Identify yourself please.

PHILLIPS: Sam Phillips. Are you setting that up in Houston?

SHEA: I can't give you the location yet. We'll set it up wherever it is convenient to get it done; and it will be a command module mock-up, so it will be transportable. One of your problems here is that your nominal drawings, your nominal spacecraft configuration, I think, involved primarily the stuff that is tied in, in the as-designed condition. There is more dynamism in the stowage, particularly in a test like the one we are running up there where you were not in a final stowage configuration. So what we are going to try to do is get this mock-up into the configuration as we assume it was or as we can document it was in this test, and this is different from anything you will see on any individual drawing. We are bringing down for the Board's help as much visual material as we can about the spacecraft itself. Many of you are familiar with it, some of you aren't, so we have a set of transparencies for examples which is a mult-layered sheet of drawings of both the command module and service module which you can strip off the various layers and be able to look at it in depth, and get a feel for what the spacecraft is like. In addition, I have a mockup in my office that's about this big, and this is high, which can also be similarly disassembled, and it's not going to be anything like a one-to-one representation of the spacecraft. But if you want to get a feel for what the inter-structure is and how the heat shield goes on and what is in the service module and all that kind of stuff, this is a pretty good way of getting a first whack at education on what the system is. We will also send down the instructional books and our manuals, and this type of thing, so there is as much sort of background data, descriptive data available as we think we will be using. We are going back through all of the files at Houston.

LONG: Let me just check if I got that for sure. Are you going to attempt in this mock-up to ultimately duplicate as much as you can in the spacecraft?

SHEA: I've discussed, Dr. Long, two mock-ups. One is just a – a sort of – it's the big kid's model of the spacecraft, except it's valuable. In the earlier one, we are going to duplicate, full scale, the interior of the cabin, all of the materials that may be pertinent to the flame problem, in the configuration we believe the spacecraft was at the time of the incident. I should mention that, in addition to all of these things, we would expect to ultimately reproduce the entire incident – probably in a flame mock-up that we have at Houston. We have a boiler plate of the spacecraft with which we can do complete flame studies. We can outfit it with the things we think are pertinent and reproduce the phenomena in a mock-up at

Houston, and I think that would be one of the certifications that would finally demonstrate that we knew what happened for sure. We are going to collect data at Houston, not now so much related to the, – let's say the data files of the spacecraft and the kind of things that you have already got going in your various panels, but there is a long history of why we were doing what we were doing. It involves decisions that go back to the first time the Mercury Program was laid down. These things have been looked at, discussed, reviewed, second guessed, re-reviewed through a period of about six or seven years, longer than that, and so we're doing a complete data search of our files on everything related to pure oxygen, to purging on the ground, to flammability, hatches, questions of escape, couches, suits, emergency procedures. Again, we're to get that file available because that's kind of the background of when you go into – how come it was that way, and what were the traits that you thought were important coming up to this point in time. We're also doing things like PASC reviews and all that sort of stuff to be sure that everything that anybody's ever said about it is in the file, and that, we'll then organize those files ourselves and any of that information that is obviously available to the Board. As far as design is concerned, we have started a series of design review activities under the control of the Program Office and the Engineering Development people at Houston. These will be tied in to the design review board or design review panel that you've already constituted, but we've got these started over the weekend. The first and probably most obvious is to re-look at the question of the pure oxygen purge on the pad. I don't know how many of you realize why we were doing that, – it's primarily a medical requirement that the crew be completely de-nitrogenated before they go into orbit in order to prevent any possibility of the "bends", nitrogen bubbles coming out of the blood, after you get up there. It turns out that at one time back in the Mercury Program, very early before any flight, the cabin was not so purged -- the guys were just in the pure oxygen suit loop and there developed a leak between the ambient air cabin and the suit loop and the leak interacted in such a way that the guy was consuming oxygen, and the lithium hydroxide cannisters were removing the CO_2, and the concentration of nitrogen was just developing and increasing, and test subject passed out very gradually and very gently but we knew it. He didn't die but that was one of the earlier traumatic instances in the program, and from there on it has been a standard procedure to purge at 16 PSI. I would point out that that would represent a specific, a kind of general reaction to a specific problem. I think one of our difficulties as we review this entire process is going to be what are our general reactions to this specific problems and we've got to have a continuing balance of trades, we've got to know what the risks are when we change and these design reviews are intended to emphasize not just what the design impact is, but what the entire "risk balance" is to the best of our understanding. Because it's kind of in the real world anytime you jump from one thing to something else, you're buying a set of problems that may take you six or seven, eight or ten years to find. All right, in addition to examining the pure O_2 purge, we're also examining the hatch, the questions of hatch design and escape and so on. As you probably know, the Block I hatch has been considered not proper for EVA, and we had a new hatch designed in Block II after we had reviewed the EVA procedures in Block II. We had already had for about six or eight weeks, a Block II re-review going because the program has not been satisfied with the hatch or with the couch arrangements and struts or that type of thing. We're intensifying that effort and that's part of the feed-in here associated with redesign. We're obviously re-examining materials criteria and the impact of re-designing materials or changing materials of cabins, and we are examining that impact of the two gas system introducted at this stage and to the overall program.

In addition to all of those things, I formed a committee out of Houston; it may or may not be something the Board is interested in, but the communications actually all during that day, and you've heard some of the tapes and so on, and communications left a fair amount to be desired. We've set up a committee to examine the entire communication problem. We had had some troubles in the spacecraft. We had thought the spacecraft troubles were solved; the tapes are very noisy and we're going to go through the entire communication system down here to see if we can understand where the transmissions got bad, and I don't think, again, this had anything to do with the accident, but it really, it's partially a clean-up that we have to do anyhow, but partially we need to understand this. There were for the Board's information, which you probably know, records taken at Mission Control. Those records had, for a while been impounded. I asked yesterday that we at least go through the same process there that we've been going through here, which is to take that data and reconcile it. There are some differences in the data, as at least initially analyzed from the records. We've tried to examine all the data here, and be sure that what we were doing was right, and it's one of those funny things where the mission control data bears, in certain instances, a very strong family resemblance to the data here, but then every once in awhile it's a different event in there. And we're going through a major review of those data and a reconciliation of those data with what we see here. Most of us feel that the problem is really one of the distance between here and there and the methods of data processing used over there and so on. But we want to leave no possibility for an anomaly measured someplace and not a second place.

LONG: This is Long. Question! Are there any other places besides these two where significant bits of data were accumulated in real time that might also need reconciliation?

SHEA: There is, of course, the data recorder at Goddard, and I think that's already been brought into the, – over – at least the Goddard station down here, I believe that's already been taken into the loop. There may be some recorded at North American, I don't know for sure. But we will check that sir, and see.

BAXTER: Question. You say that we are going through the data! Is this here now? Has this all been involved with the central data bank?

SHEA: It's not been in here, I've asked..., the Mission Control people at Houston are doing the data processing at the present time. The computers over there are set up to do it and so on. We'll bring the data down here when the Board desires. I think it really should be processed at home there, because that's the place that knows it best just as we've left essentially all the data here for processing because this is the place that knows it best. An independent check! It may do absolutely nothing but I've got an individual assigned to make the reconciliation between the data and determine if there's anything significant there or not. Lastly, we are generating at Houston a PAO plan. Some of you have been involved with the program and you know what the publicity pressure is like, others, I think, are going to be a little bit surprised by the amplification of the inconsequentials that's associated with the program at the time that, particularly, where there's an information vacuum, and the Board is intended, I think, to control the release of all information. We're trying to give you at least the ability to tap our background of experience here, and what the reporters are like and what they might resonate on and what they might not resonate on. And we will have a way of making that available to the Board as well. Lastly, I've moved down here and

will stay here to be available to the Board for either specific actions or if you want to talk about the background of whatever we know about something and so on and if I don't know it, I think I know who does know it, so that over and above the activity going on in the panels, if there's anything I can do for any of you, I'll be around.

LONG: Question. One small point. You mentioned that you were putting together in very complete fashion, the record of flammability studies, experiments, and so on, as they bore on development of decisions the development of this spacecraft, and that these records would be at Houston. Is there a mechanism whereby somewhat similar to some thing Baxter mentioned a moment ago, we could automatically have it understood that these will be made available in duplicate here?

SHEA: Yes sir, there I'd suggest that you give us time to complete the assembly and a kind of bibliography of this thing, because you know what government files are like, they just go on and on. We need to get this stuff pulled out; we need to understand it, and then, about all we are doing is collating now, and then the process of synthesizing from that, the description of what really went on is the process that we will make all the information available to the Board and any file material can be brought down here.

LONG: Question. Are you implicitly suggesting that it might be a good thing if you supplied with some of these large files a librarian to work with us to..?

SHEA: I believe we probably need a librarian, we probably need a language translator, and we probably need somebody who is at least familiar with some of the things that never get written down on paper but are part of the background of why these things happen. I think it is important none of us are trying to be protective or anything but there is just so much that never gets explicitly written down that I think you ought to, as you read things and so on, have somebody available to answer questions and explain. We will try to have such people available if that is what the Board decides.

CHAIRMAN: Thank you, Dr. Shea. Are you proposing a question, Mr. Faget, – you are still on the record now.

FAGET: This is in the form of a remark which I would like put on the record. The story Dr. Shea told about Mercury he got from me and it is wrong in one slight detail because I told it to him wrongly and that was that the introduction of nitrogen into the suit was through a GSE piece of equipment and that analysis showed that it could just as well have been introduced in the cabin and that is the only detail of the story that was wrong.

SHEA: I didn't check the data source.

CHAIRMAN: I want to make an observation relative to the impact of the questions and answers between Dr. Long and Dr. Shea. I have asked the Secretariat to follow up on this matter of assembly of material and in a form that people can make use of here on sort of a library basis. This may require some implementation to carry out the intentions of that discussion and may require action here. Question?

BAXTER: I might suggest that we have done this, the Air Force has done this on other programs as when you have an area of very technical investigation by a particular

Center or group you might ask that they come in with a summary rather than all of their files and work, and tell you what they have found out. It's just a suggestion.

CHAIRMAN: This seems to finish this part of our agenda for this afternoon. I would like to go off the record at this moment.

(Off the Record Discussion)

CHAIRMAN: The next item to be reported on will be the status of the work at the pad relative to the removal plan that was discussed early this morning. Mr. Simpkinson will report on it.

SIMPKINSON: By way of explanation for the change in this, I would like to offer that we are faced with operations we haven't performed before and the planning is proceeding, we are being very cautious in our planning – I think this is the wise way to go. In order to be safe out there, which we certainly want to do, we had certain operations to go through and those were reported earlier. The schedule which now has come out which is tentative and hopefully meaningful, is that we will have the hatch cleaned. I'll explain that there is some debris that got into the little latch mechanisms. We will clean up the hatch by 6:00 p.m. This is some debris that we have checked with the fire people and they have seen the hatch. It got in there in the ensuing days and we are bagging it and holding it. We are going to have the hatch installed by 7:00 p.m. We will have the white room disconnected by 9:00 p.m. We are presently building stands to get to the LES which we do not have. A plan is being put together right now which will be ready at the same time of 9:00 p.m. tonight, by TPS, to move certain equipment to put these stands in bolt holes that exist on the thing. We have got to do this to get to it. I plan to come back to the Board with that TPS before we move any of this GSE. Some of it is connected to the spacecraft. We may have to change our plans again if the Board does not concur with this. If we continue and the Board agrees with our moving plan, we get the stands up, we will have the boost cover off by midnight. We plan to have two hours of photography because this is a new area and it takes quite a while to cover that size, to get all of the flame patterns damage, and so on and we plan two hours for photography. Of course, photography will be taken throughout the operation. The stands that we have built will then be installed by 4:00 a.m. We'll set up the stands, prepare the LES for removal. We raise and hoist it by 7:00 a.m. tomorrow morning. We will have the launch escape system off by 1:00 p.m. tomorrow. We will have the forward heat shield off then by 9:00 p.m. and by way of explanation this takes chipping out a lot of hard epoxy to the hex holes in top of hex bolts in order to wrench them – many of them. Then by 7:00 a.m. the following morning we will have all the pyros shorted. We are then ready to remove the debris from the couches as discussed earlier. We will be in a configuration to allow the first entry on the clean couches for a look at the structure and the heat patterns and the systems by 7:00 a.m., Thursday morning. That, Mr. Chairman, is our present schedule which I have a lot of faith in that we can meet.

CHAIRMAN: Thank you. Other comments? I'll ask Mr. Donnelly, I think you want to say something about the work. Did you want to make some statement.

DONNELLY: No, I want you to make a statement, Dr. Thompson, that you have directed us to take the ordnance off the launch vehicle because that is the first configuration

change they have made to the launch pad and vehicle since the accident.

CHAIRMAN: I don't know whether they heard that but I directed Mr. Donnelly to comply with the requirements and proceed with the removal of the ordnance from the launch vehicle. That accounts for part of the delay in this program. There are several other factors involved. In accordance with our request, Dr. Shea has prepared for consideration the draft of a statement that intends to express our intentions for a policy that will be the basis for implementation of a plan for control of data and documents.

SHEA: This is a policy for the control of data and documents relative to the AS-204 Review. Original copies of all specifications, inspection data, test procedures, test data drawings, etc. Relative to all parts, sub-systems, modules, in space vehicle AS-204 and associated GSE shall be impounded. Access to these data, shall not be restricted for normal program uses. Original copies of all inspection data, test procedures, test data, tapes, etc., relative to AS-204 and associated GSE from 0600, January 27, 1967, on, no matter where recorded, as well as all duplicates of such data shall be impounded. Access to such data, or duplicates of such data, will be restricted to authorized personnel associated with the AS-204 Review Board. For purposes of this instruction, impounding means assuring security of such data from alteration or destruction. No release of any information of this type to public sources shall be made without specific approval of the Review Board.

CHAIRMAN: The intention of this proposed action is to establish a procedure that will allow work to progress wherein it is now hampered by the general impoundment of all material, records, and data that pertains to this vehicle. We are confronted with the necessity for a policy that will permit work to progress in an orderly manner. I would like to ask the Board members whether or not having heard the statement do they consider this is an adequate statement of policy to guide the implementation of action under task 15.

(Off the Record Discussion)

CHAIRMAN: Does anyone have any further comments, or should we proceed? I hear no one objecting to this. I think that we should adopt this as a policy statement for guidance, and I would like to ask that the Secretary prepare a sheet report on that for each member of the Board for tomorrow, so we can have another look at it and see if tomorrow it looks as good as it does today, so that we don't have to modify it. It is possible that, further consideration of it, we will have to find some amendment necessary. This meeting will now adjourn subject to reconvening tomorrow at noon. I want to restrict this meeting to just the Board members. That meeting will be at 12:00.

The meeting is adjourned.

CHAIRMAN: At this point I would like to distribute to the membership a statement concerning policy for control and release of documents. The title of this release is Policy of Control of Data Documents Relative to AS-204 Review. We will have, in accordance with our plans as of yesterday, a report at this time on working progress on the pad. The report was prepared under cognizance of Mr. Faget who will ask for appropriate members to make their report. In the Executive Session this morning, it was agreed that a suitable format which we will follow for operations of this Board, will require a progress statement each morning that will bring the board up to date on activities of the previous time period. Also, it was agreed that there will be an Executive Session of the Board at 4:00 p.m. each day. We will try to formulate activities around those two basic elements of agenda planning for meetings of this Board. I would now like to ask Max Faget to start off with the report of progress for this morning's session by either presenting himself or by appropriate speakers for such a report.

FAGET: This morning's report will follow a form that we think we will continue with if it proves practical. It consists of three parts, the first will be the scheduled activity accomplished in pad 34 area, and other areas having to do with the disassembly of the spacecraft, and the investigation of the actual article. We will also review the anticipated scheduled and authorized scheduled activity that will take place during the next twenty-four hours. The second part will consist of a number of items that need Board approval in carrying out future activity on pad 34, and other locations in this investigation. The third part of the report will consist of the progress that has been made in analysis and in anticipated work that will be carried out in the conceivable future. Mr. Simpkinson will give us the status at the pad.

SIMPKINSON: Essentially we are on the schedule that was recorded yesterday at noon but I have provided 15 copies of this schedule which was completed yesterday on one phase and where we are today. For your information, we are presently removing the Launch Escape System, and plan to be through essentially on this schedule and continue on it the rest of the day until 7:00 in the morning as reported, when we would be ready to go into the spacecraft and perform the TPS according to the plan agreed to yesterday. This TPS will be ready for approval at 3:00 this afternoon by the Board, and we will have to arrange some schedule for this Board to agree to it. As per schedule, we spent about two hours with a number of members and the advisors to the Board, particularly the fire propagation advisors. We had a very good look at it last night. We may have gained quite a bit by looking at that. Other than that, we have nothing new to report. We have a couple of problems that need Board attention in particular. We have here antenna hats which were on the opposite side of the hatch which we need to remove in the next hour, or we will be holding up work. This is a scimitar which is a combination S-band. VHF hat used to pull off the signal not normally on the spacecraft in flight, it is nearly always on for test, it has no hard connection to to the spacecraft, it is taped on, and has a coax cable connected to it for purposes of signal take off. We have decided that proper photographs be taken, proper inspection, proper photographs after removal. We would like to set it aside. This would require no disconnection of connectors we feel that are not in our realm, because of C-band may be a suspect here. We would like a decision from the Board, almost immediately, on whether we can go ahead with the plan I just gave you. Remove it and set it aside with the proper photographic inspection coverage.

CHAIRMAN: I would like to interrupt at this point, and ask Dr. Van Dolah whether he has any comments on the inspection that was made last night. For the information of the Board members here who do not already know it, the status of Dr. Long and that of Dr. Van Dolah has changed. Dr. Long has become a consultant to the Board because he is unable to spend the time required as a Board member, in view of his duties at Cornell. Dr. Van Dolah has now been assigned the position of membership on the Board, and I would like to ask him at this time if he has any comments that he ought to make or wishes to make regarding the observations made last night.

VAN DOLAH: Yes, as was already noted in the statements, a number of us, all of those associated with the origin and propagation of the fire visited the spacecraft and spent about two hours examining it after the boost protective cover on one side had been removed, and after the air supply duct has been removed from the opposite side. We were able to see quite a lot that was impossible to see previously, and were able to gain considerable insight into the nature of the fire. This is all very preliminary and much more needs to be done.

SIMPKINSON: I have the daily schedules and pad progress report. I have one more item I would like to place in the record and get a decision from the Board at your convenience. We have a problem in that our special TPS written for this work has been misconstrued by some to be necessary to work on hardware that is associated with Spacecraft 012, but was never on it, and has been impounded. We would like a decision some time during the day so that we can complete and pass out our ground reules of operation within our pad complex work, and how we can control this work with TPS's. We need a decision as to what hardware should be under our control. We have this suggestion. All hardware, both spacecraft and GSE facilities that is now attached or has been connected or installed at any time since initiation of testing of the spacecraft at KSC. This is about the time you will recall, that we should do our altitude chamber run here. All other hardware would return to normal control by standard Apollo operating procedures that are in existence. We would like the decision sometime today, so that we can get our ground rules out to many of the people, inspectors, and so on. It is very difficult holding meetings and every time we change shifts to give temporary ground rules out. Could we do this sometime today.

(Off the record discussion.)

CHAIRMAN: It is clear from the question with which we were just presented and the ensuing discussion that we are confronted with an unresolved problem of retaining proper supervision and control of these operations while at the same time, allowing work to progress in an orderly and expeditious manner. I would like to ask Max Faget for a comment on that.

FAGET: We will give this problem some consideration because it has a lot of implications and prepare a procedure that will bring here in written form for discussion by the Board, which I think will take care of all this concerned.

CHAIRMAN: Thank you. Max Faget is now going to continue with his presentation of a progress report.

FAGET: Next we would like to ask Dr. Lanzkron who has been receiving the various requests for work out on the pad and other places that have come under the control

FAGET: of this Board to speak. He is going to make some specific recommendations on what should be done in the future.

LANZKRON: I basically handed out a list of items that require attention of the Board. It falls into two categories: those that directly affect the spacecraft, and those that do not affect the spacecraft. I will cover first the items that do not affect the spacecraft. We would like to remove from the pad to the MSOB the Beckman gas analyzer is not connected to the spacecraft at this point. It was used to check the gases in the spacecraft. We would like to move on this very fast, because probably most of the gas has escaped out of the analyzer. We would like to take it to the lab for immediate analysis. We would like to remove this item #I.

JEFFS: Interruption. I presume Rolf and you also intend, of course, to calibrate the analyzer.

LANZKRON: Yes. There will be a detailed TPS written on how to handle the evaluation of this data and how to control it. But we need immediate allowances to remove the hardware from the pad to the laboratory for analysis.

VAN DOLAH: Physically, where is it now?

(Off the record discussion.)

CHAIRMAN: The discussion of Item #I has led to the conclusion that the Board should insist that in analysis we are assured that outside organizations are involved and in the certification of the processes involved in this analysis. This is in line with a policy that was agreed upon in the Executive Session this morning to insure that the Board is properly monitoring the action. I am asking Mr. Geer to assume the responsibility for the Board of monitoring the action on the analysis in a manner that conforms with this policy.

LANZKRON: Item #2. Remove samples from the different K bottles - which are the bottles which contain the oxygen - and the test set-up, for the same kind of analysis.

CHAIRMAN: The Board requires that the comment made relative to Item #I apply also to Item #2. So, proceed with the discussion or with the presentation of the plan.

LANZKRON: Item #3. The removal of the signal generator from a piece of GSE. This specific piece of GSE is a piece of communication GSE, which is used to receive data from the spacecraft during transmission. It is not used as the primary mode of reception; it is that reception which is used here in this building only. It is not used as part of the GOSS net, which is used as an official form of communication from the spacecraft. The signal generator, let us say, remove from the impounded condition it is in, in the GSE C-14-442 as a complete unit.

WILLIAMS: Can we get the advisability of this from communications experts when they arrive? I think this is under the same thing . . .

CHAIRMAN: A few minutes ago, we had an unresolved item that needs to be cleared up for action at the Pad regarding the C-band antenna coupler and we deferred action on that until we had some expert advice on that from someone who is to be brought here. I understand that the gentleman is here now, and will resume the discus-

CHAIRMAN: sion of that item based on the presentation or respond to questions. Are you prepared to make a statement on that or just respond to questions. I don't have your name. . .

STELGES: Bill Stelges.

CHAIRMAN: Are you prepared to respond to questions or make a presentation?

STELGES: I understand the question is whether it is acceptable for us to remove the antenna hat off the coupler.

(Off the record discussion.)

CHAIRMAN: On the basis of the discussion, that is the clarification obtained from it, the Board approves the action to proceed with the removal plan for the C-band antenna coupler.

SIMPKINSON: Does this give us permission then, Mr. Chairman, to remove the VHF antenna hat which they have already stated is not a problem. We have had no known anomalies in the C-band as well as the scimitar.

CHAIRMAN: We are still on the record here. Is there any reason to interpret this request otherwise than for both, for the removal of both antenna hats? (pause) This does approve the removal of both antenna hats. The discussion of the proposal for Item #3 has brought out the need for much broader action to release equipment from its impounded state. In taking this action, the Board also will ask Mr. Williams to take the necessary action to bring before the Board a plan for broadening the scope of the requested approval to include the many other items that ought to be examined to permit the orderly release of impounded equipment. So, if Mr. Williams will take into his area of responsibility, we will await a report from him at some future date.

WHITE: Mr. Chairman, I think we should also add to that statement the requirement that we record the configuration of the communications GSE in the MSOB before it is removed from impoundment.

CHAIRMAN: Very good. We will continue with the tests, or with discussion of the tests to be done, or hardware to be removed by Dr. Lanzkron.

LANZKRON: Item #4. On the SLO platform verify storage of GN GSE Cable S. You remember the meeting of two nights ago it was discussed that it's not coherent that the GSE cable was removed from the spacecraft. The cable in the spacecraft which was seen visually was not the GSE cable - we have been able to identify that much. But we want to assure ourselves that the cable was removed and is stored right now in a specific area stated.

CHAIRMAN: Is there discussion?

(Off the record discussion.)

CHAIRMAN: On the basis of this discussion, Item 4, as proposed, is approved for action, so we may continue with the presentation.

LANZKRON: Item #5. Six out of 18 lithium spare hydroxide canisters which are located here at KSC are required in Downey. We would like to move these to Downey. We will also come up with a general plan to allow us to remove other such things out of impoundment.

(Off the record discussion.)

CHAIRMAN: With reference to Item 5, the discussion has revealed the necessity for imposition of a constraint in the release of the canisters to insure that one or more canisters of the lot that are identified as from the same lot as are in the spacecraft be retained, in their current status.

(Off the record discussion.)

CHAIRMAN: By this action we approve the release of all others of the 18 mentioned.

(Off the record discussion.)

CHAIRMAN: I wish to amend the statement made previously about the number of canisters to be retained to say three rather than one or more.

(Off the record discussion.)

CHAIRMAN: We will resume a discussion on items for approval, regarding tests to be done or hardware to be removed. Now going to those in the spacecraft, Dr. Lanzkron, will you please proceed.

LANZKRON: Should we call each one of these pictures a different number or would you like to take the total category of photographs as one item?

(Off the record discussion.)

CHAIRMAN: It is clear from the discussion that at this time, it is necessary to take action that will permit an orderly coordination of the many tasks that are being performed. In particular, we must give attention to the problem of getting Board approval on items that are in a category that requires such action in order to insure an orderly process and proper coordination between all the task groups that are now active. In order to meet the requirements imposed on us by the situation. I'm going to establish at this time a committee[1] that will deal with this coordination task, that is, the coordination task required for an orderly presentation of matters to the Board for their approval. This committee will be chaired by Mr. J. Williams. The other members of this committee are Max Faget, C. Matthews, J. Yardley, and D. Jeffs.

As a responsibility of this committee, the Board is asking that in the daily reports of progress to this Board, that it present an over-view of the entire scope of the activities of the various panels in a form appropriate to the purpose of the Board's meetings. In effect, this means that it should be broad enough to be suitable for the meeting but should not get into great detail. The responsibility for working out the actual format and type of report to be made will be left to the chairman of the committee.

(FOOTNOTE) 1. This is the body which was functioning earlier as a working group in the task of organizing the working panels.

(Off the record discussion.)

CHAIRMAN: The problem of photography has been resolved by Board approval of the plan as specified in the list submitted and with the understanding that additional photographs required by certain of the Board members or task groups needed to supplement photography in the areas of their particular responsibility can be arranged for through the systems already set up without requiring future Board action.

(Off the record discussion.)

LANZKRON: Last Item, Item 7, is the MDAS, Medical Data Acquisition system removal. We would like to remove it for correlation of data as associated with the flight PCM and the central timing equipment and the actual time records on the recorder.

(Off the record discussion.)

CHAIRMAN: The discussion of this item has shown the need to defer approval of this item at this time subject to consideration at a later date. The suggestion has been made and endorsed by the Board that in removal of items from the spacecraft, the location from which the article was removed be identified by some unobtrusive indication that identifies the area and is indexed to a record that permits the inspection from other sources, of what was in fact, removed from that area. The responsibility for insuring that this procedure is followed is assigned to Mr. Geer. In continuation of Faget's report, he will now continue.

FAGET: The third part is a summary of the analysis work of today and some speculation of where it's going in the future.

MARDEL: This is sort of a conclusion of the activities of the (DATA) analysis activity from yesterday. The first item, we should have a complete time line being typed. I'm not sure the time line is available right at this moment.

Just say more detailed time lines; has more data than any presented so far. There were no new data anomalies disclosed from the last 24 hours. In other words, the new time line even though it has more detail is still basically the same as the time lines of a day or so ago. A second item; we need data on cabin temperatures and two cabin pressure measurement systems response times to determine a more real-time of the actual increase in temperature and pressure. The data should be available from qualification or other test data. This list was requested from North American yesterday, and additional testing may be required at North American to obtain the statements.

The configuration of the battery manifold pressure measurement system must be determined to determine the response time. Remember the battery compartment manifold pressure measurement wasn't connected to the manifold, it was laying loose on the floor and it should have been bagged or should have had a dust cap over the pressure ports. We'd have to know what the configuration was and actually run a special test in this case to determine the response time. We don't know at this time what the exact configuration was.

We've requested this morning that the configuration committee provide this data. Item 4, the required data on the over and under voltage samples for the inverters on Spacecraft 012. This is required for correlation with the buss 2 inverter difficulty and the caution warning system. We've requested the information from

MARDEL: North American yesterday, we received most of the information this morning, but right now, we're still trying to correlate serial numbers with inverter positions with busses. We will have this cleared up by this evening, we ought to be able to report on it tomorrow morning. Five, we say a special test will be required on the gas chromatograph electrical connectors and the associate circuitry. We requested North American to configure a harness and connector to the exact Spacecraft 012 configuration yesterday. I have no idea right now, how long it will take to make up these connectors. Item 6, we requested North American to run a quick test on a connector and harness similar to that of Spacecraft 012 of the gas chromatograph system. We're trying to get some feel as to what happened when the connector is exposed to flame.

In a power on and a power off condition. -- We've requested the test yesterday and it may be run today or tonight.

That North American reduce and analyze at Downey, the home plant in California with the following restrictions:

a. That a closed area be provided for all data storage and analysis activity.

b. That the area be closed with limited access to personnel.

c. That a tape copy be provided with the voice track fully wiped out and all data after 23:31:05 wiped out, with a restriction that the medical data playback be prohibited.

d. We request permission to have this tape copy made here at KSC and released to North American Aviation at KSC for hand-carry to Downey.

I request permission to have a tape copy made as per the previous restrictions as stated and released to NAA-KSC for hand-carry to Downey.

Item #8, circuit breaker status for the gas chromatograph must be determined from the procedure and crew check list. We need this to determine if the connector was hot. We will request this of the procedure committee immediately. Now, if you have a little bit of information on it, the procedure said that the circuit breaker should be closed which would make it hot. -- The final switch set before crew ingress. A special check was made and the circuit breaker was closed, which made the connector hot. We had to check the crew check list out to find out if any change was made in that. After the incident, this particular circuit breaker was found open. So we've got one more check with the crew check list after ingress.

Item #9, we need to analytically determine all the failure modes for the oxygen flow measurement system. We need the failure modes that could result in a high oxygen flow rate. This has been requested of North American this afternoon. What we are trying to do here is validate our data. We believe that the data is truly representative of a high oxygen flow or could the measurement system have failed at this point.

Item #10, we have to determine the status of the water glycol, water reservoir valves. I believe we are talking about 3 valve positions to correlate with the water glycol pressure data. This has been requested for a couple of days. We'll go to the proper committee right after the meeting.

MARDEL: Item #11, Item 11 was scratched out and is back in.. Request that a consultant be provided for clarification of voice data to determine what is actually stated by the crew at the time of the difficulty and we have a specific recommendation for a person.

CHAIRMAN: The Board does not agree with the need for this request at this time. Continue with the request item.

MARDEL: We request a special playback of the gas chromatographs of the inverter the C-band data for the last hours and various switch set up to see what the data looks like. This has been requested from the Events Committee and they should be available this afternoon.

We modified the request in the last hour, that based on the fact that during close out before crew ingress the circuit breaker was closed. It was not changed from that point on. Crew ingress through the incident - complete data.

CHAIRMAN: Does this complete your report?

MARDEL: Yes, sir.

(Off the record discussion.)

CHAIRMAN: One comment on the report just made. There was considerable discussion by the Board of the restraint imposed on release of data represented by Item 7C. The Board does not object to the release of this data as proposed but considers it necessary that consideration should be given to the necessity for this restraint and will expect to here from this matter on the subject of reports.

(Off the record discussion.)

CHAIRMAN: Col. Strang is prepared to make a preliminary report on the area of his responsibility.

COL. STRANG: First of all, gentlemen, as we look at it now, there will be three reports: a preliminary report, an intermediate report, which is further down the road, maybe two or three months, based on the feedback of the analysis. (When I use these figures, I'm just taking a guess). Then the final report, which is after all research accomplishments and analyses are completed; unless we are kept in session until the final report. Then, we will have only one report. But in this report, this is what we will have to have -- I submit it to the Board for its evaluation, revision, and/or acceptance.

The authoritative document, this would be the document from Dr. Seamans, that established the Board and would include any other documents that come to us, from now on until the completion of the report that may change the Board's composition. That is Section One. Section Two will be a narrative of the accident.

This will be a two to three page paper to include the period of time up to the accident itself. Number three should be on the investigation and analysis -- This is developed from the time of the accident, right after the fire in other words, through the entire time the Board was in session. In this section we would also include the finalized recommendations. Section Four, a Life Sciences Report,

STRANG: This will be the autopsy, report of death, the report of injuries, a general statement made by the doctor and of anything else in the area of this concern; for example, gas masks, etc. Section Five is Board proceedings.

I would like to take a minute here to tell you what this consists of. We have here a tape being made daily which is being developed into a typewritten report afterwards. This will not become a part of the report itself because there are going to be many, many pages of proceedings. We would put this in the file of the accident; the file would be those backup data and everything else in support of the accident investigation. Where this would be located at NASA, I don't know. The Air Force's, is at Norton AFB in the Inspector General's Safety Office. At NASA, because of the decentralization of safety, it is conceivable that it would remain here at KSC. The second part that we're confronted with here daily are notes that are being taken by the court reporter of important happenings, such as the fact that perhaps we will be visited by some Congressmen -- this would be an important happening. Or important things that are made a matter of record here that Dr. Thompson, the Chairman of the Board, elects to put into the daily log. It definitely should become part of the Board proceedings. Now, there is a third item or a sub of what I just discussed and that is a list of actions that take place in the Executive Board sessions. This will be contained in a book separate from what I discussed. Whether or not this is ever put into the Board Report is entirely up to the Board and Chairman. The sixth section is the Damage Report. In the Air Force, for example, we list the cost of the total damages to the vehicle and I am sure that NASA wants to make that information available -- damage to the vehicle, the equipment, etc.

Section Seven is the Task Group (Panel) Report. This report concerns each and every Task Panel. For example, if we were running around 18 Task Panels, we would have a report from each one of these. The overall report from a Task Panel is broken down to at least five subheadings -- we have the work statements, the proceedings, the findings, the recommendations, and supporting data.

This last item would just have a reference in this Task Panel Report to the effect that the backup data for specimens of some hardware are contained at certain locations. Reports from the Task Panels are part of the basic report itself. Now what I plan to do is come up with a written paper by tomorrow to present to each of you, and each Task Panel, a procedure so that we can help build towards this right now instead of waiting until the end because it gets real bulky and real hard to control.

In some cases you'll find that you have to leave picture numbers blank because the day will come when we have to select maybe a hundred out of a thousand photographs. You will have to number these. You'll have to refer to them accordingly. Are there any questions?

(Off the record discussion.)

CHAIRMAN: There was considerable discussion of this report by Col. Strang. The Board, I believe, feels that the outline presented represents a very good statement of a plan that will be at least at this time, in our view of the situation at this time a workable and satisfactory approach to the problem of making a final report.

CHAIRMAN: The meeting is adjourned.

CHAIRMAN: The meeting is now in session. We are privileged to have with us, today, Dr. Seamans, Deputy Administrator, and Dr. Gilruth, Director, Manned Spacecraft Center. I would like to make a few announcements of actions that have been taken since our last meeting. There have been revisions of the tasks that were organized to implement our investigation. There has been a need to change the status of one of our members, because of problems regarding the association of contractors and Government workers. In accordance with the requirements of a situation that we find ourselves in, Mr. Jeffs is no longer a member. He will act as a consultant. I hope that it will turn out that these changes will in no way impair the very good working relationships that have been developed without respect to who anyone is working for, when they are working for a common purpose. Another matter that I would like to announce is that I am asking Col. Strang in my absence, to serve as the Acting Chairman. Another announcement perhaps is a repetition of what I said before, and maybe it is not. The format that we worked out is that the Mission Briefing Room will now be classified as a briefing and hearing room for Board activities. In addition, there is also a Board room at which executive meetings of the Board will take place, rather than here. This room can remain available for other uses that may be appropriate, because of the displays and equipment in here. This morning we have as an agenda, reports of events since our last meeting. To start off, however, I'd like to ask Col. Strang to tell us a little bit about some events that he knows of that are relevant to this, our meeting here, if he'd care to at this time. Col. Strang.

STRANG: Yes, sir. I just received a call from the Executive Officer in Gen. Houston's office. He had been notified by Col. Floyd, Air Force Legislative Liaison Office, to the effect that we're going to have a visit, Friday afternoon at approximately 1430, by two Congressmen. I have the names and all, but it's in a paper being developed upstairs, sir. They expect to proceed from Patrick Air Force Base, right after arrival at 1430, out to the launch complex, where they would like to talk to the authorities in reference to the investigation and conduct of what's going on. They will depart Patrick at noon Saturday, and go to Houston, where they will continue their investigation Saturday night and Sunday morning, then to Brooks Air Force Base, where they will then do a little investigation where the Air Force just had an accident, and then proceed back to Washington. I might bring up that one of the deceased at Brooks Air Force Base is a constituant of one of the Congressmen, from New York. I have all the facts and figures on this - they will be available in a couple of minutes and I'll present them to you.

CHAIRMAN: Thank you, Col.

(Off the record discussion.)

STRANG: I just received a second progress report from Brooks Air Force Base.

CHAIRMAN: Just a minute, Col. Strang, just one comment.

SEAMANS: We were advised yesterday afternoon, by the Armed Services Committee that the Chairman, Chairman Rivers, had designated these two Congressmen to come here

and to go to Houston as well as Brooks Air Force Base to investigate the accidents that occurred both here and at Brooks, but we were aware of this and a little later on we'll discuss with our Chairman exactly what arrangements should be made for the Congressmen while they're here.

CHAIRMAN: Thank you, Dr. Seamans. Col. Strang, you want to continue with your report?

STRANG: Yes, Sir. The second item I have is that I have received the number two progress report from Brooks Air Force Base where the Air Force is conducting an accident investigation. This is on a recent incident where two airmen were killed in an altitude chamber. I have a written report on this, and I'll pass it out to the Board members for their information. We have established, in line with this, a tie with persons on the Board there. We have concurrence from the Chief of Staff of of the Air Force to get this information as it occurs. It will have some bearing possibly. That's all I have, sir.

CHAIRMAN: Thank you, Col. Strang. In addition to the tie we have with the Brooks incident, we also have established another tie that relates to the problem of having what is learned here made applicable to other national programs. A new Board representative has arrived today -- Mr. Collins who will serve in a liaison capacity here to take advantage of the findings that are developing, and their application to the Air Force MOL Program. We will now continue the progress reports.

CHAIRMAN: In case there are planning groups or other groups that need witness statements, before they go out, we have the initial document on the witness statement, I passed it out to all the Board members. Second, what distribution, what kind of control on distribution has the Chairman considered on these witness statements? I would consider out of all our documents they are the most sensitive right at the moment. We can certainly make them available to whoever needs them. In the witness statement of work in response to the charter, for the panel, which describes how we are going to operate. That's all I have, sir.

CHAIRMAN: The Chair, you are asking for instructions and guidance on the classification?

BAXTER: No, sir, not classification, the distribution.

CHAIRMAN: Well, we'll try to develop something on that, and see that you get the necessary information. We will give Lt. Col. Baxter an instruction that the distribution of the information for which he requested guidance will be controlled in the following manner: it will be available to the Board members as they require and with the restraint that they can pass it on to the Task Chairman. Any further distribution is to be restricted except by specific request to the Board member who will have the authority to permit additional distribution if necessary.

CHAIRMAN: We have received a report of preliminary findings of the Apollo 204 data and related material dated 1 February 1967, developed by the Apollo Spacecraft Programs Office. This report is being distributed to the membership, here today. I will now ask Dr. Faget to report on developments of the last day.

FAGET: I would first like to ask Mr. Simpkinson to report the status of the work out on the pad and the predicted schedule of work the next day.

SIMPKINSON: Mr. Chairman, we had some slow-up of the activity and yesterday I reported we

were essentially on schedule. This morning we are several hours behind. At the moment we are safing the pyros in the forward heat shield and this is the reason for the delay. I think you should know that. The same team that is required to remove the launch escape system is required to remove the pyros, and they needed three or four hours sleep between these two operations. We didn't lose this time. We took advantage of it to do other things out there. Our reported schedule did drop back somewhat. There are 20 copies for the Board as of the day's projected schedule. We planned to start safing the pyros at six o'clock this morning and plan to be through by two o'clock this afternoon and we covered up the forward heat shield after that to protect it and removing the hatch some time between two and three o'clock. You schedule shows at three o'clock to start TPS's or work orders as they are available. We do have one approved which cleans the debris from the couches and it is a 30 page document to be very very carefully done and will take considerable time. We are projecting about two days to do that, but we have really no basis to put this on. It's going to be very slow and cautious. We don't believe we can hurry this operation any way. We will be starting about three, we will have Five Panel with us, we'll have anyone that is required. That's our schedule for today -- our activities. The other TPS that we will work in conjunction with this is the one which you approved yesterday to remove the the non-attached, non-connected hardware so that we can have a better place to work now. I do need some guidance for this two-thirty meeting if I could have it.

CHAIRMAN: Thank you, Mr. Simpkinson.

(Off the record discussion.)

FAGET: The next part of this morning's report will be from Dr. Lanzkron who has a number of action items that he would like to put before the Board.

CHAIRMAN: As suggested yesterday, the Board came up with the general policy for removing hardward that is not associated or connected with the accident. These are numbered in continuation of the action item of yesterday and we start with number 8. Basically this is GSE, STE and facility equipment on Launch Complex 34. All equipment of this type not utilized for checkout or servicing of Spacecraft 012 on Pad 34 should be released for normal operation. This equipment is not required for this investigation but is required by other Cape operations. Are you asking the Chair a question, Dr. Lanzkron?

LANZKRON: I am asking for approval of the Board for this action. Item 9 -- all equipment of this type utilized prior to Plugs-In and removed prior to Plugs-In but are still in the complex area should be statused in terms of configuration and released for removal from the complex area.

Item 10 -- all equipment of this type used during Plugs-In or later will require Board approval. Item 11 – GSE STE facilities equipment outside of Launch Complex 34. All equipment of this type utilized in buildup prior to the arrival on Launch Complex 34 of Spacecraft 012 should be released for further use. Item 12 – all servicing equipment of this type utilized prior to arrival at Launch Complex 34 should be checked for configuration status and fluid samples for future reference. Equipment then should be released for further usage. Item 13 – all BME of this type utilized on spacecraft hardware prior to completion of the chamrun should be released for use. Suit BME should remain under Board cognizance.

Item 14 – spares which are utilized in Spacecraft 012 should stay impounded. Spares that did not see the spacecraft should be dispositioned as follows: Items of large quantity production, more than 50, maintain 3 of same lot. Small production, maintain 1 of same lot. Item 16 – GSE spares. All spares should be released except those used to service oxygen and water glycol. Non-flight hardware and non-GSE. Item 17 – equipment of that category not utilized after chamber test should be released except for communication equipment which will be controlled by the Board. Item 18 – equipment in above category utilized during chamber run should be base line in terms of configuration and released for use except the communications equipment which will be controlled by the Board. Item 19 – lab supplies. Any item used on Spacecraft 012 should have set aside adequate quantities allowing for lab analysis. The rest should be released for use. Item 20 – new equipment. Any equipment whose equivalent has not been used on Spacecraft 012, but is now in areas which aren't controlled by the Board will be released for use. Item 21 – IMCC, Houston, Not utilized, but for monitoring should be released for further use on other things. Item 22 – the UCP checklist schematics, both flight and non-flight, being utilized by the crew at the time of the incident should be removed for reconstitution. The removal should be careful, photographs should be taken to establish condition of both. Provide photographs where technically possible showing the location and condition of these items as follows: only books to be removed now are those on the couches. I would like to add an item 23 which is not on this list. Since this Board makes available this room for access, who are the people who have access to this room?

(Off the record discussion.)

CHAIRMAN: It is understood by the Board, that all these recommended actions have been approved by the cognizant committee. The Board approves the recommended action but wishes to reiterate a matter that was brought up in a previous meeting, that where samples are required for analysis, that there be sufficient samples left to provide analysis by outside or independent groups. It is a general policy directive that there be enough for two outside analyses of this type. If there are certain conditions that make this impossible the appropriate action could be brought back to the Board for approval. In bringing that matter back to the Board it is requested that recommendations for appropriate action accompany it.

(Off the record discussion.)

CHAIRMAN: Dr. Kelly.

DR. KELLY: Room 106 at the PIB is set up as stated in Administrative Procedure No. 3. This is an Evaluation Room for the flight suits. Additional aids in this evaluation are needed such as the training suits and photographs. Security will be worked out between myself and Mr. Buckley and patterned after Administrative Procedure No. 3.

CHAIRMAN: Thank you, Dr. Kelly.

BORMAN: Spacecraft 14 arrived here at Cape Kennedy last night and is now in the MSOB. It is proposed that that spacecraft be relocated at PIB and that the work on that spacecraft be under the control of the same panel, the disassembly panel, that is now controlling the work out at Pad 34.

CHAIRMAN: Thank you. I would like to have a statement from the appropriate Board member

as to the intended use of the Spacecraft 014 in the immediate future.

BORMAN: Mr. Chairman, this is Col. Borman. Spacecraft 014 will be located in the PIB Building. It will be under the control of the Spacecraft Disassembly Panel and it will be administered in the same manner as Spacecraft 012. The immediate use will be to provide a "before" item and a comparison with Spacecraft 012. The immediate access should be for the fire people who are not familiar with the spacecraft and also systems experts from the Apollo Program Office who will need immediate access. This will not, of course, involve disturbing or removing any items. This is the immediate requirement. Further on we are going into detail disassembly of Spacecraft 012. It is proposed that the technicians perform the corresponding disassembly on Spacecraft 014 prior to proceeding on Spacecraft 012. We really have two separate utilizations, the initial one is for investigation and observation, the final one will be for disassembly.

FAGET: Mr. Chairman, I propose that we impound the checklist of the backup crew for use in the event that the checklists in the spacecraft were destroyed or partially destroyed. These checklists were updated and represent the best copy of the checklist used by the crew.

CHAIRMAN: Are there any comments contrary to that proposed action? (Pause) The Chair agrees that appropriate action. Dr. Kelly, with reference to your proposed action, this is approved to include the photographs and other material with the understanding that we have established before that they are in proper custody and available to those who have the need to know.

(Off the record discussion.)

CHAIRMAN: With reference to Dr. Kelly's item, the photographs in his custody should be handled in such a way that they are made available to those who have a need to know.

(Off the record discussion.)

STRANG: Gentlemen, in your box today I will place a format for the Task Group Report that we discussed lightly yesterday. Attached to it is a little philosophy as to why we need this information.

CHAIRMAN: Will the secretary take those documents that you all have and see that each one of the Board members gets a copy. The meeting is adjourned until tomorrow morning at 10:30.

CHAIRMAN: I think that at this time it may be appropriate to make a few remarks relative to accomplishments to date, in view of the fact that I believe we have reached a fairly important, or passed, perhaps, an important milestone in the progress of this review. The Spacecraft has now been made available for at least initial photography inside. The process of unlocking the paperwork and equipment – all those things involved in the impoundment – the impoundment action that took place has at least in considerable degree been accomplished. It has not been accomplished in full detail, but I think we can say it has been a relatively effective effort. I think we have accomplished this with sufficient care so that I feel that we are in command of the situation.

The inspection of the Spacecraft by photography at this stage is being controlled in the following manner: The Coordinating Subcommittee will establish priority and coordination for all tasks requiring access to the Spacecraft. In addition, the access to the Spacecraft will be controlled by a crew under the direction of Colonel Borman, who is a member of the Board.

I'd like to make a correction as to the status we have achieved in inspection of Spacecraft. It is not limited to photography – it actually applies to all activities of inspection of the Spacecraft.

(Off the record discussion)

CHAIRMAN: In the discussion that just took place, it appears necessary to point out that in obtaining statements from witnesses which is now in progress, that any information that people have, that should Board Members and other people associated with this Board have, that is in a category that belongs in this statement framework, they should bring it to the attention of Colonel Baxter of the stituation and let him take appropriate action.

We have just witnessed a film concerning fire hazard with conducting wires, and a record of and identification of that film which was supplied by Lockheed – Georgia Company and will be given to the Secretary for the record.

The title of the film is "Investigation Report, Aircraft Wire Harness Fires – Rev. #3." This film describes a phenomena called "Wet Wire Fires" which may be relevant to a possible source of ignition in the Apollo 204 Spacecraft. Three reports in this subject are in the possession of Colonel Strang and will be available to any interested task group.

Mr. Petrone, who had made a statement in a previous meeting, wishes to address himself to that previous record and make some remarks concerning it. Mr. Petrone.

PETRONE: Mr. Chairman, in my verbal report to the Board, late on Sunday, I said we had taken a sample upon a report by the Command Pilot, of an odor – a buttermilk type odor – in his loop. I reported that when we got the sample, a sample was taken from Ed White's loop. I'd like to amend that to state that on further investigation there were two samples taken; the one taken initially reported the butter-

milk odor. We find that upon later review that it was actually taken from Grissom's suit, and the sample taken White's suit was a normal sample. We would like to close out the environmental control system with a Beckman analyzer. It only tells you how much oxygen is present. I was requested to get the names of the people who physically did this job to Colonel Baxter and his group. so that the statements could be taken of what was connected physically to what suit to set the record straight.

CHAIRMAN: Thank you. Mr. Williams, do you have a report?

WILLIAMS: We have the three items that we reported on yesterday. The recommended Board be given by Dr. Lanzkron, summary of panel findings will be given by Mr. Mardel and the Disassembly Committee's report will be given by Colonel Borman. We We will have Dr. Lanzkron's report first.

LANZKRON: That's Action Item No. 25. It deals with the ACE Spacecraft Station Number I and computer control room. The feeling is mutual that it could be released for maintenance and normal work after documentation of the computer and control room configuration. Item 25 is releasing the ACE Spacecraft Station for other utilization after configuration inventory to assure that we know what the config- was at the time of the accident.

(Off the record discussion.)

CHAIRMAN: There being no objection, the Item 25 is approved as proposed and so you may proceed, Dr. Lanzkron.

LANZKRON: Item 26 – Authorization is requested for expedited issuance of request to the F.B.I. to insure maximum salvage of burned crew data book and other burned crew documents.

(Off the record discussion.)

CHAIRMAN: Item 26, on the basis of the discussion, is approved with one modification – the word "salvage" is changed to "reconstruction." And with the understanding that Colonel Borman will take steps to obtain the help from appropriate organizations in the process of meeting the requirements of maximum reconstruction indicated by this item.

LANZKRON: Item No. 27 – The S-Band, VHF Spacecraft official tapes should be released to Bell Labs to determine contents of tapes.

(Off the record discussion.)

CHAIRMAN: With reference to the last item, that is, Item No. 27, there was considerable discussion on how best to make use of the additional data hitherto not known to us, or not analyzed by us, to insure that we obtain the maximum value from it and run no undue risks in the process. The selection of the Bell Lab as a contractor takes into account a need for an outside, disinterested party of high quality with well established qualifications to make this analysis. However, in the process of getting an appropriate copy to them, we would like to charge the people who have custody of the tapes here to explore with Bell the problem of how best to

CHAIRMAN: insure that when they analyze the original that we retain the best possible copy in order to avoid all possible risks of losing the value of a very important record.

As a result of further discussion, an additional instruction is given regarding exploration of the manner in handling this tape. There will be an exploration of the problem of extracting the maximum information from tapes that may be in our possession and could possibly yield additional information of value to this review.

(Off the record discussion.)

CHAIRMAN: We are now prepared to hear a report from Mr. Mardel.

MARDEL: Item 1. The gas chromatograph powered sensor cable connector was exposed. A special check disclosed that the plastic bag of this connector was removed during close-out. This was a question raised in the Board Meeting on Wednesday. From statements received from two of the people, it was stated that during close-out, the plastic bag was removed. There is a standard practice that no open connector remain in the Spacecraft, that every electrical connector, every exposed plumbing line be covered. We will plan on a meeting with these people again, around noon, to try to determine why the plastic bag was taken off.

CHAIRMAN: With reference to Item 1, the discussion discloses that the Board will be very interested in a very careful and complete evaluation of the situation that surrounds and is associated with Item 1. So we may proceed, Mr. Mardel.

MARDEL: Item 2: A taped sequence of the events chart is complete. The chart you see on my right, the white board. This chart will be updated daily, each morning. And that contains the complete sequence of events from the data, versus time.

Item 3: The latest data indicates a rotational controller output transient at 22 hours, 30 minutes, 54.85 seconds. This is the same time that the AC Bus 2 voltage changed. This data is preliminary, it is not validated . We will do some validation on it today, reporting on it tomorrow morning.

CHAIRMAN: We are receiving a progress report and I think we have to keep in mind that these item-by-item progress reports do not, in general, represent findings, nor is it intended to create the impression that this is all of the action that is intended. Mr. Mardel, continue.

MARDEL: Item 4: The Witness Statement Panel has received two statements that mention a peculiar odor near the Spacecraft, prior to the incident. We don't know the exact period of time when these statements were made. We will check this today, report on it again tomorrow, the same item.

Item 5: A GSE measurement, the hydrogen tank fan motor was found to vary at 23 hours, 26 minutes, 30.4 seconds. At the exact time of the previously recorded ground supply center variance. This measurement cable was not hooked up at the service Module and should not have to read anything. A check will be made to determine if it's an ACE Station noise problem. It's preliminary data, and we have to investigate it further.

Item 6: The gas chromatograph rate was found to vary a number of times in the

MARDEL: last one and one-half hours, before the fire. The significance and meaning is being studied. We looked at special playback last night, and going back from the first variance near the fire, the trace remains stable, and 35 minutes before the fire, it showed a variance. Going back through the total hour and a half trace, we had about 4 variances in the data. We are making additional playback today, going all the way back to the time of crew ingress and will review that data some time this evening, and will report on it again tomorrow. We are also making a special check on airframe 008 at Houston where we've got this connector in the Spacecraft and we'll move the connector around to try to determine if there is any variation from connector movement. This information should be available some time this evening. We'll be reporting on it tomorrow morning as well.

CHAIRMAN: Thank you, Mr. Mardel.

Colonel Borman, are you prepared to give a report?

BORMAN: The report from the Spacecraft Disassembly Committee. The debris is now off the couches. We are preparing to remove the leg rests and headrests. This should be completed by 1600. After 1600, we'll install the plywood covers over the couches and we will be ready for the fire experts to make the initial look within the interior of the cabin. We are planning also today to transport the hatches over to the PIB Building and we are now formulating the TPS' to continue on with the work as directed by the Board. I think that the rest of the day will be spent in examination and photographic evidence from the couch area. And that's all I have.

CHAIRMAN: Thank you. I wish to make further reference to an action we took earlier here about the responsibilities of the Panel Coordination Committee as to their activity in relation to setting up priorities for access to the vehicle. I would like to point out, particularly based on the previous discussion, that the panel should consider themselves as having a responsibility for reviewing the entire process, not only in regards to passing on priority, but perhaps questioning and suggesting items that should be included that may not have been proposed to them. And particularly this matter of the structural examination, as being essential part and parcel of the examination should be considered.

CHAIRMAN: In opening the meeting this morning there are certain things I would like to say regarding things that are underway. We are taking appropriate steps to be certain that offers of help from organizations, groups, or individuals to assist in this review are acknowledged by the Chairman, and that with the understanding that we are also taking appropriate action to follow up on these offers. This will include, particularly as regards many of the suggestions that are coming in from individuals that probably have very little to actually contribute other than their extreme interest in this review, an acknowledgement of their suggestion to this Board. We have one matter that I would particularly like to emphasize this morning. That is, we proceed here in establishing our course of action. We find it necessary to re-examine procedures, particularly those that relate to the control of, access to, and preservation of exhibits. This means that responsibilities of individuals may be modified and that everyone that has knowledge or custody of material relative to this review take appropriate action to insure that it will be placed in the designated areas.

In the discussion, it was brought out that the adherence to procedures or the development of procedures to adequately deal with the situation with which we are presented has many complexities that will require individual judgment to be applied at many levels. It is clear that there must be a very careful attention given to the implementation of procedures that will meet the broad requirements outlined, and at the same time permit a workable pattern that will permit this review to proceed in a direction that will yield a maximum result.

I will ask Mr. Williams to proceed now with the presentation of the reports of the Task Groups for the acts that have taken place in the last periods.

WILLIAMS: We'll call on two panels this morning. We do not have any tests to be done, or items to be removed at the present time, but we will have the Dissassembly Panel on the work schedule to be carried out. And also a report from the Integration Panel, which will bring us up to date on what has happened since the last report.

CHAIRMAN: In an action yesterday afternoon the Chair approved the removal of items from the spacecraft that went beyond the authorization that was on the record in the morning meeting, and I think the report that is now being made, the progress report, will reflect this action. I will ask Mr. Williams, in connection with his approval to itemize the extent of the approval as it now exists.

WILLIAMS: In executive session yesterday, we approved the installation of plywood covers for the couches. What was approved last night was inspection by the fire experts followed by another inspection by the spacecraft inspection groups. The third item was the Materials Panel inspection. The Materials Panel wanted to take a look at the inside of the spacecraft. We approved the inspection by the systems engineers, to see if they could see items out of place, an item that shouldn't have been there. After the inspection by these three groups, we authorized a series of photos of the interior. Once photos are taken, we then plan to remove the top hatch. The next item was to cut the cables from the translation controller. The next item was to tie back the cobra cables, install the platform under the couch, to be followed by the fire experts inspection from the platform, and then we are ready to remove the couches. Following the removal of couches, we want another inspection by the fire experts from the Z platform, a panoramic photography of the interior of the spacecraft and a detailed floor inspection and

sketch. Following that, we want to remove discrete pieces from the floor, install a false floor to protect the remaining pieces of evidence on the floor and then proceed with our inspection of the interior of the cabin. This is as far as the planning went last night.

CHAIRMAN: Thank you, Mr. Williams, I would like to ask Mr. Williams, at this time, to explain how far in time the current defined and approved plan takes them.

WILLIAMS: The current plan or approved plan should take about 3 or 4 days. We are in the process of working on an overall plan covering the remaining period of time.

CHAIRMAN: Let me ask you further, can you give us a notion where we will be at that time regarding our ability to inspect, and inspection of the spacecraft.

WILLIAMS: At the end of the approved plan, we will have the fire group inspecting the spacecraft and what we are working on now is to have the design people and subsystems specialists develop what testing should be done after this period of time. I think that we can have an overall plan by the next Board meeting, say Monday.

CHAIRMAN: I would like to discuss this a little more with the group under Mr. Williams after this meeting to see and get a little better idea of just how we are and have an overview of how far we go, how far our current planning takes us. I would also like to ask this group to address themselves to the overall planning of making their progress known so that the Board can be in a better position than it is now to understand the course of action when major milestones may be passed or reached.

Mr. Williams will proceed with the Progress Report.

WILLIAMS: I would like Mr. Simpkinson to give us the Progress Report on Complex 34.

SIMPKINSON: Mr. Chairman, our present schedule has been passed out to all of you, work fashion, and it contains the items that Mr. Williams repeated before in the record and just to briefly summarize with milestones here. For the record, we have just about finished, at this point in time, the inspection by the Quality Control Inspectors will be going into further inspection by engineers and specialists and taking some specialized photographs stereo-type. That will be completed by 1400, at 2 o'clock this afternoon, we hope. They'll be started at 2 o'clock this afternoon and be finished at 4 o'clock. After that, we'll do some minor work on the spacecraft including installing a platform underneath the couch which starts at 1800, and our fire experts will get underneath the couches on the Z-platform for an underneath type of inspection starting at 2000. At 2100, we will start the removal of the couches. This is planned on here as an eight hour task. This is an average time for a removal of this type but could take longer. Providing we get along all right with that, we start with some more inspections and further photographs from the Z-platform with the couches removed, revealing the entire inside. This will start at 0500 Sunday morning providing we meet our schedule. And then, a detailed floor inspection and sketch of the floor which will include the pointing out of certain discrete pieces by the inspection people to remove. This will all be completed by noon tomorrow, at which time we hope to install a false floor to protect the other floors as Mr. Williams pointed out. We have four hours on the schedule for that test, very flexible, it could take much more than that. And we have allotted eight hours at the end of this on the false floor with free access to the entire inside of the spacecraft on a "no touch" basis. All of

this inspection so far now will be on a "no touch" basis of what is not removed. We hope to finish that by Sunday night, midnight; however, I point out that's quite an optimistic schedule. In addition to the work in the spacecraft, the schedule includes last night's building the Z-platform and trying it in Spacecraft 014. It has worked out well. They are now, at this time, until they are ready to go in the spacecraft, going to practice removal of the couches from the Z-platform which is a difficult task that they have never tried before. We are writing out procedures for that. As you approved the other day, we also are cleaning levels 6, 7 and 8 of the gantry and hope to have that finished by tomorrow morning. A word on that -- this is proceeding according to an approval list of GSE facility and special test equipment that we've received yesterday. In order to get it out of the way up there, we are moving it to bonded storage in the PIB. Anything that is to be, has not been connected, is not connected, or was not connected during the test. Things that may have been connected prior to that we will move into the PIB, per your instructions to maintain control. And, I hope that meets the approval of the Board. That's the extent of my report for today.

CHAIRMAN: Thank you.

WILLIAMS: I would like Mr. Mardel to present the findings since the last Board meeting.

MARDEL: I'm not sure that I have anything for the record. I have no prepared statement; I'd like to talk on a number of things, prefer to speak off the record.

(Off the Record Discussion.)

CHAIRMAN: Mr. Mardel described many of the events and actions being taken off the record but because some of the things he wanted to say are in such a tentative or preliminary form they are not properly a part of the records at the time; however, for the record, I would like to have him, in outline, tell us what subjects he reviewed. Mr. Mardel.

MARDEL: We're showing special interest right now in the area of the translational controllers. This was brought about by examination of photographs. We've seen a hole, either burned out or blown out, at the translation controllers. The controller is located on the left side of the command module, and the controller is also associated with the communication system in that we had a push-to-talk switch on the controller. One of the actions we are taking now is to determine where all the translation controllers are and what their configuration is – trying to determine the exact spacecraft quality configuration for further tests. Another action was to try to determine what the condition is of the command pilot's suit on the left side right above the knees. In the area of the chromatograph connector, with respect to the plastic bag, we have a fairly conclusive story (from which we can conclude) that the bag was removed. The technician remembers removing the bag. Two of the technicians remember that in the area where the bags were removed, the only bag that had tape on it was the chromatograph connector bag. The bags were passed out to one man outside the command module; he passed these to the second man. The second man remembers bottling up the bags, and after bottling these up, finding tape in the bags and putting tape around the bottom; the tape that only had come from the connector bag. He then threw these in a trash can or towards a trash can. We went through the trash can last night; couldn't find it. We're going to make another search around the platform to see if we can find the bag. From all the statements we had so far, we are satisfied that the bag has

been removed. In the area of the elapsed time indicators, we received a report yesterday that we did have smoke in the command module 14 at Downey at North American. The smoke was attributed to a burning of an elapsed time indicator behind panel 13. Preliminary data available this morning indicates that we do have an elapsed time indicator of the same type installed on Spacecraft 12, behind panel 13. This elapsed time indicator, this particular one, was to be removed before the FRT, the Flight Readiness Test. An action was taken to survey what elapsed time indicators were installed in the spacecraft, which were to be left on, and the qualification status of each one of these timers. With respect to data reduction and data analysis, we have reduced all of the data at Houston, and completed an analysis. The analysis results will be available this weekend. We've also reduced the data at North American at Downey. The Analysis results will also be available this weekend. This weekend we will integrate the three analysis results. The one we have here, the one from Houston, and the one from Downey. And, Monday morning, we will have available, on the events chart, a fully integrated picture from the three different analyses. We, then, would be prepared, Monday, to give a complete briefing on what the events mean and what the status is.

Another item is to talk about a burnt-out blower in Spacecraft 8 in the second manned altitude run on Spacecraft 8 in Houston. We had a burnt-out blower in the waste management system. The blower motor in Spacecraft 12 is reported to have had some 25 hours of operating time. It's also been reported that the circuit breaker blew on Spacecraft 008, somewhat like it blew on Spacecraft 012. It's also reported that when the circuit breaker blew on Spacecraft 008, there was a pungent odor. The last item concerns the voice tapes. Information from the Bell Labs is that they do require the original tape. The original tapes will be handcarried, and by this evening we will have prepared a complete set of instructions for what has to be done to track all the data from this station. That's all that I have.

CHAIRMAN: Thank you, Mr. Mardel.

Board was called to order and the records show that the Board convened at 1150 hours this date by Col. Strang, Acting Chairman.

CHAIRMAN: There was discussion relative to Administrative Procedure No. 13 and it was recommended that the agenda inputs be provided to the Secretariat by 2000 hours in lieu of 1800 hours daily, due to the fact that the panel meetings take place at 1700 hours. Mr. Simpkinson, will you give us a run down, please, on the progress of your panel?

SIMPKINSON: It's been two days since we reported on the record of our progress at the pad. We have accomplished all of the scheduled items and are presently in a configuration where we have the command module completely empty as far as we planned. We have accomplished putting a plexiglass floor suspended from the original strut points in the top of the command module so that nothing is touching the floor. We have had inspection going on in this area by QC inspectors this morning. We have had the fire panel group in there for many hours and they are preparing their reports for the Board. We have had materials people in this morning and they just got out early this morning, about 8 o'clock, and I am sure they are preparing their reports. This afternoon, as soon as the inspection people get out, we will have the systems people back in for a second look. At that point in time we will be ready to proceed with the plans that have been given to us as of this morning with the spacecraft itself. In the P1B area we are removing the articles from bonded storage today, placing them on the tables for inspection by appropriate members of the team. However, this is a no-touch inspection and will require written paper to do anything physically with this hardware. That is our present situation, ready to proceed as the Board desires.

CHAIRMAN: Mr. Jeffs.

JEFFS: Mr. Jackson, Carl Jackson, of AiResearch, accompanied by Mr. Nate Nicollo and Mr. Spencer, also of AiResearch together with Mr. Stowall of North American and Mr. Jolly of North American are on site to date. They are surveying the spacecraft with the objective of coming up with a proposed further plan of action on the ECU and also other areas of the ECS. They are working with a member of the Integration Panel in development of that plan in consonance with the procedures that have been developed here by the Board and will present that plan when it is ready for the Board's further consideration.

CHAIRMAN: Thank you, Mr. Jeffs.

LANZKRON: If you would like to reopen Item #7, which was deferred the last time we brought it up in front of the Board. Item 7 reads that the MDAS, the medical data acquisition system removal; we would like to remove it. I would like to have approval of the Board.

CHAIRMAN: Off the record.

(Off the record discussion.)

LANZKRON: On Item 28, we would like to have authority to disassemble the panel, be free to remove equipment cover panels, and to open normal access doors, provided that pre-removal or pre-opening configuration is photographed and that the fire inspectors agree. Basically, there are a lot of compartments in the spacecraft which are used for storage of equipment, there is nothing electrically connected to them, but there will be a lot of new areas that we have not exposed as yet and would like to be able to open up these compartments which have no hardware behind them, connected functionally, and take a look at these areas.

CHAIRMAN: Let us show that the two items Dr. Lanzkron has just discussed have been approved as long as the Fire Panel and the Disassembly Panel Chairmen with their designated personnel are available and in the presence of the work.

MARDEL: Item 1, we completed a power status review. This is attached in your enclosure – the three page write-up plus the sketch, and since Saturday at the Board's request we have put in all the verifications from data and from the panel switch positions. Now, this write-up covers only the external and internal DC main and the internal DC main and the internal pyro busses. We are preparing a supplement to cover other miscellaneous power sources to the spacecraft such as the service module jettison controller batteries, Q-ball powers and Saturn instrument Q-ball heater power and so forth. We plan on having a supplement available either tomorrow or Wednesday, so there will be additional power data.

Item 2, we do now have a list of the elapsed time communicators installed in spacecraft of the type to be removed before flight. This listing is also enclosed immediately following the sketch. We now have verification that the unit that experienced the difficulty in Spacecraft 14 is the same kind of a unit that we had installed in Spacecraft 12. The difficulty in 14 was a shorted capacitor. The cause of the shorting was not and could not have been determined because of the changed condition of the capacitor. We still have not determined the qualification status of all these elapsed time indicators. It's being worked on today and should be available tomorrow.

Item 3, a squeeze bottle of cleaning fluid was found in Level 8 White Room. This bottle does have a tag on it. Work is under way to perform a chemical analysis to determine what the fluid is and we are also reviewing all of the inspection records to determine how this bottle was used that day.

On Item 4, before I talk about item 4, I would like to pick up a photograph and explain geographically in the spacecraft what I'll be talking about the remainder of the morning...I'll pass it around but I will be glad to explain everything here. We're concentrating on the left side of the spacecraft, here you have the ECU, The Environmental Control Unit; one thing I'll be talking about this morning. You'll notice two gold colored connectors on the Environmental Control Unit. These are transducers. The translation controller will be located at about this point. I'm talking about a screwdriver incident that occurred in a panel here and then the chromatograph connectors located close to this panel with the chromatograph installed. The connector would have been laying on the deck where the chromatograph is here. So I'll pass this around and then talk, and refer to the photograph somewhat.

The QC people that went into the spacecraft Saturday noted that two transducers were damaged in a study of the Environmental Control Unit. These are the two transducers with the gold colored connectors. It appears that the electrical connector end of the transducer was separated from the case by a quarter to a half inch as of from overpressure. These transducers will have to be examined to determine the cause of failure. At the present time we're reviewing the design to try to analytically determine the failure cause possibilities. We have a plan of action for a more detailed examination of the translation controller; however, we're putting this in a hold. This is not an official plan. A policy has to be worked out and is being prepared now on exactly how hardware will be disassembled, so I'd like to strike whatever I've got written on Item 5.

On Item 6, this is referring to the panel that I pointed out in the photograph. During trouble shooting, this panel had to be removed to look at the wiring in back of the panel. To try to remove the panel – the panel has four screws – the two sets of right hand screws cannot be removed because one of the harnesses is in the way. So what they did was unlace the harness, separate the harness, and insert the screwdriver through the harness to get at the screws on the panel. The technician had a difficult time removing the screws. Finally the QC man tried it, he drew an arc. At that point then the technician took the screwdriver and tried to remove the screws; he also drew an arc. Finally they removed the panel. They examined the wiring closely. They found wiring damage; they repaired the damage. We questioned the people in reinstallation of the panel. We wanted to know when the panel was reinstalled, how do we know we didn't have any damage. Was the power off the vehicle when the power was reinstalled, so that if you nicked the wire you wouldn't know it? And we still don't have complete information at this time on whether the wiring was examined after the panel was reinstalled. The panel was reinstalled on the first shift, and the technician transferred the work to the second shift. We had to call the second shift man in today to find out after the final close out, if the wiring was examined for any physical damage. Now this may have some significance in that some of the wiring in the stabilization control system and some of the wiring may be associated with the translation controller. We are also making a wire by wire check today to try to determine every wire in that panel, what its relationship is with the various subsystems. That is all I have in writing. I've got three items I would like to talk about. The chromatograph connectors we spoke about last week. We have conducted some testing on Spacecraft 8 at Houston. Some of the data from testing was brought in last night and a quick look at the data at about midnight disclosed that the variations in the chromatograph connector trace resemble very closely what we had during the incident when the connector was wiggled. Wiggle around and you get variations much similar to the test data. This will be studies in more detail today. All I want to point out is that it is of some significance that the variation of the data can be produced not only by fires, as reported from the North American testing last week, but also from a physical movement. We will try to have some plots here tomorrow to show the degree of correlation. We are also preparing today a complete history and configuration on the environmental control system water glycol – and what we have for power today we will have for the water glycol system tomorrow. Now the last item I have is that we did receive the analysis results from Houston over the weekend. We also received the analysis results from North American at Downey. The results were integrated with our data yesterday afternoon and evening. There is no additional data from Houston or Downey that contributes to the picture we have here. The Board has been updated this morning and the Board now represents a total integrated picture

of the three different sets of data, the one from here, the one from Houston, the one from Downey. And we are prepared anytime the Board desires to have Mr. Arabian come down and explain every item on the board and explain what it means, explain where we stand with the data. That is all that I have.

CHAIRMAN: Thank you Mr. Mardel.

BAXTER: Item 3, a cleaning problem. I saw two bottles while I was up at Level 8. I wonder if the other one has been identified.

(Off the record discussion.)

BAXTER: Mr. Mardel, just clarify how many bottles. You just mention a bottle...

MARDEL: Well, we are talking about one bottle, and as they tag with a number on it, it is very discretely identified by a number.

DR. LONG: Question: It's the only bottle in the White Room.

YARDLEY: Was this bottle in the White Room at all or was it outside the White Room on the gantry area?

MARDEL: I can't specifically tell where it was. What I will do is have inspection people make a sketch and have the sketch brought in before noon, exactly where the bottle was found.

CHAIRMAN: Right, thank you Mr. Mardel. For the purpose of the record let it be shown that Mr. Williams presented to each Board Member a copy of a proposed master plan display, and briefed the Board on it. It is hoped that each Board Member will use this proposed plan throughout the day, working with his panel chairmen as to any possible changes to the plan. The Board Members will present this to the chairman, Dr. Thompson, during an executive session this evening. Second item, let the record show that there are now ninety witness statements as of ten thirty a.m. 6 February 1967. Off the record.

(Off the record discussion.)

VAN DOLAH: Mr. Horeff has been in touch with the Civil Aeronautics Board and will shortly get confirmation of which investigator the CAB will make available to this Board. He is also getting information on the laboratories and investigators that the Civil Aeronautics Board makes use of in their investigations so that we can have additional expert assistance, if needed.

CHAIRMAN: Let the record show that Col. Baxter has accepted the responsibility to gather up the gas masks and provide for an analysis to be taken.

Let the record be corrected to show that Panel 13 will take charge of having the gas masks analyzed. The requirement to gather the gas masks and provide for analysis will be accomplished by Panel 11, in lieu of Col. Baxter or Panel 13.

The Board adjourned at 1203.

CHAIRMAN: With reference to the master planning schedule that was discussed yesterday, the Board has approved the preparation of this plan and it will be available for circulation to the various people involved. Later today, according to our current understanding, it will be made available to Board members, Panel Chairmen, and such others as have a need for this schedule.

In two actions, the Board approved many items of a removal schedule, one of those actions took place in a meeting yesterday afternoon, and one in an Executive Board meeting this morning. I would ask Mr. Williams to detail for this meeting, the items covered in those approvals. Mr. Williams.

WILLIAMS: Item 29 is to perform Launch Vehicles Spacecraft Interfacing Impedance Test to resolve engine 8 light anomaly. We need to make resistance measurements, a Q-ball power, and Q-ball heater wire.

Item 30: Remove MDAS, take to the PIB, call vendor technicians to come for disassembly and tape removal.

Item 31: Remove mechanical covers over the functional equipment for better inspection: (1) covers on data storage equipment records, (2) flight qualification records, (3) ECS CO_2 absorber panel, (4) cabin heat exchanger inlet screen, (5) heat exchanger access panel forward of inlet screen, (6) compartment D scientific door, (7) structural panel next to panel point 24, (8) G&N computer close-out panel.

Item 32: Disconnect batteries and measure bus resistance.

Item 33: Establish continuous ohmmeter resistance. Continuous bus resistance should be made during all subsequent operation. This item is restricted to DC at this time.

Item 34: Methodically depress all open circuit breakers on the DC system one at a time per detailed TPS to determine ground resistance of the bus resistance change.

Item 35: Make special inspection of all elapsed time indicated, of the type "to be removed before flight" to determine condition. Carefully inspect in place. Note any suspicious ones for further TPS action. One additional mechanical panel removal may be required in order to view the elapsed time indicators for the caution and warning system.

Item 36: Pick up gas chromotagraph plug and carefully examine and photograph from all sides.

Item 37: Carefully inspect wire harness which was involved in the screw driver spark incident.

Item 38: Remove parachutes and inspect the heat damage.

Item 39: Remove battery vent lines in batteries entry, labeling each location.

Item 40: Remove inverter terminal cover, place and examine for arcing.

Item 41: Measure resistance from each inverter terminal in the spacecraft ground without disconnect or wire cutting.

Item 42: This is the one we want to approve, but we don't watn to do it as yet. Remove circuit breaker panel bolts and carefully back out panel. Inspect and photograph for arcing.

Item 43: Remove cover on translation controller and inspect for evidence of explosion.

Item 44: Inspect cobra cable wires laying across translator controller for evidence of arcing.

Item 45: Record panel 101 and 105 switch positions.

Item 46: Read CVU's in place; taking care to avoid thumb wheels.

Item 47: Remove 02 panel and inspect.

Item 48: Remove $H2_0$ panel and inspect.

Item 49: Xray glycol reservoir to determine quantity.

Item 50: Xray water tank to determine quantity.

Item 51: Inspect CSM on umbilical guillotine area prior to removal, and

Item 52: Remove the water gun.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion.)

CHAIRMAN: I will now ask for the progress reports for today and I understand that Col. Borman is prepared to make the presentation of a report. Col. Borman.

BORMAN: We have removed the flight books. All the flight logs from the spacecraft were transported to the PIB. Unfortunately, due to weather, they could not go to Washington this morning. We have an airplane standing by tomorrow morning. They will be transported to the FBI tomorrow morning. The biomed recorder is removed in the PIB and is waiting for the technicians from Cook Electric before any further work is generated in that area. The lithium hydroxide panel has been removed and it is in the PIB. The panels covering the area for constant wear garment storage have been removed. The panels for food storage have all been opened and photographed. We have removed the mechanical covers over the functional equipment as authorized by the Board. This includes covers on data storage equipment, flight qualification recorder, the cabin heat exchanger inlet screen - we found that this had a hinge on it and rather than remove the hinge, we opened it and inspected it and closed it back up. The heat exchanger access panel forward of the inlet screen, the compartment D scientific door structural panel next to panel 24 in the G&N computer closeout panel have all been removed. The paperwork is now in process and work

is proceeding on the disconnect of the batteries, establishing the ohmmeter resistance readings that were requested. The circuit breaker testing is in work. We are also making a special inspection for all elapsed time indicators as authorized and the gas chromatograph plug inspection is going on at this time. There was a little misunderstanding on which wire harness (wire bundle) we wanted examined as far as the screw driver spark incident is concerned. That TPS is being rewritten so that we get the right wire bundle. Another progress item, sir, we have delivered the tapes to Bell Laboratories and I have a trip report from Mr. Cunningham that I would like to submit to the minutes.

CHAIRMAN: Thank you, Col. Borman. We will now open the meeting for discussion of this report, but go off the record.

(Off the Record Discussion.)

In the discussion, it was brought out that there is a need and possiblity of assigning priorities to areas within the vehicle to which we should direct our immediate attention since they are defined by the inspection to warrant such an assessment of priority.

(Off the Record Discussion)

CHAIRMAN: The discussion has just brought out the fact that there is work in front of us in planning systems removal and systems testing that is being properly coordinated with the committee. The Coordination Committee has general responsibility for the coordination of the investigation.

(Off the Record Discussion)

CHAIRMAN: With further reference to the matter just discussed, the importance of this action of a plan for removal and testing is that it brings in contractors in the operation to such an extent that we are at this point asking the Coordinating Committee to develop for the Board's consideration a plan that will properly inform the Board on the nature of this aspect of our program and bring to the Board's attention such items as are necessary for the Board's consideration or approval. We are prepared now to hear a report of the panel #5 which is coordinated by Dr. Van Dolah, and I will ask him in just a minute to make a report on the fire inspection.

VAN DOLAH: Yes. Mr. Pinkel will make the report.

PINKEL: This is Mr. Irving Pinkel reporting on the findings of Panel #5 called the Fire Panel. In exploring fire problems and our approach to the exploration, we recognize that our responsibilities are these: To plot the fire progress in order to assess the history of the fire and the possible site of the origin of the fire; to determine ignition source or sources through inspection of the accident actual site and related laboratory tests; to explore other fire hazards and recommend changes to reduce the hazards and prepare a final report in which we review all combustibles contained on the spacecraft during the operation leading to the accident and attempt to determine for each combustible, whether or not this combustible could have been the initial combustible. Now, in order to appreciate the situation in the space capsule, I have made this layout which attempts in two dimensions to show a three-dimensional arrangement. I used the Peeled

Banana technique. The floor, as you see, is essentially circular and represented by this circle which is approximately 12 feet in diameter. The vertical walls have been sliced at appropriate corners and layed flat so that moving from the center of the circle in any direction implies going upward from the floor once we reach the zone outside the circle which represents the floor. The coordinate system shown on this illustration has been accepted as standard for describing the orientation of the space capsule. +Z being in a direction away from the hatch if you look at the bottom of our figure -Z would be in a direction towards the center of the floor. +Y to the right as viewed from the hatch and -Y on the left. Now, the general arrangement of the space capsule going in a clockwise direction would be the environmental control unit and systems on the left in the forward portion; in other words, in the +Z idrection - that panel contains food lockers, places for experiments, navigational zones, assortment of electrical equipment, batteries. In the +Y direction, the panel on the right as we view the capsule through the hatch is a waste disposal area with medical equipment and other associated devices and the controls for the capsule. In the neighborhood of the hatch itself, the principal elements are rather massive cables which run along the wall directly beneath the hatch and appear to be the nerve center for much of the distribution of the electrical wiring in addition to the umbilical cords which join the capsule to the Service Module. Now, our first interest, of course, is with the initial distribution of combustible materials and I've diagrammed this on the opposite side.

(Refers to diagram)

Proceeding again in a clockwise direction, those items that are of interest to us in the fire and distribution of the combustibles are plotted here in the gross sense. On the left, in other words in the -Y direction, and on that panel on the left, we have a variety of combustibles - principal combustibles being portions of the glycol system, carbon in the filter canister to remove organic vapors from the atmosphere, pads of felt made out of plastic which are combustible, and contained in such canisters, and considerable insulation which I am told is silicone rubber, which covers much of the glycol system is quite extensive in this area. The fact that this is a foam, I think is important too, in our latest consideration of this matter. Now, an associated important feature of this system is the fact that we have oxygen carried at 900 lbs., water and glycol in aluminum tubing which lie close to the floor all in close proximity to each other. Along the +Z panels, the principal combustibles are plastic strips which go under the brand name of Velcro which are used to hold items of personal gear like pencils and so on, during Zero G flights to keep them from floating around; this is a hook-and-pile arrangement for holding these pieces of equipment. These are applied extensively with considerable exuberance, I expect, all through the panelling which appears in the Command Module. It appears that some of the wiring insulation in this area which, if not combustible, is melted quite readily by heat. I'm not sure that they're not combustible, but if they're not, they seem to be susceptible to heat damage, whereas the bulk of the wiring is Teflon, I am told and stands up to the fire and heat very well. That constitutes the description of the principal combustibles that are visible to the eye without removing any panel assemblies on the Z axis. Now, in the +Y direction, the cabinets there contain a variety of items having to do with bio-medics, I suppose, which are cased in what appears to be nylon. Now, in the -Z direction, which is the wall immediately above the hatch, I am told that an extensive nylon net was stretched across the entire width of the -Z wall which reaches from the level of the hatch to the floor. Now, for

the floor itself, the combustibles there appear to be in two classes, perhaps there are others they haven't discovered yet. The first is a mat made up of foam plastic which occupied a zone immediately below the hatch on the floor. I'm told its purpose was to receive the hatch and avoid damage during an egress exercise, and also, three helmet covers which I assume are made of nylon or a related material. That constitutes the bulk of the combustibles distributed on the permanent parts of the capsule. In regard to the couches, one must regard the suits and the equipment of the astronauts as being part of the combustibles in this system.

Now to discuss the distribution of fire and the probable direction. Let me say this, that in a fire-enclosed space where a succession of rather drastic events occur, the fire pattern goes through several histories each leaving its trace. The last phase of a fire, if it's an important phase, may overshadow all the earlier traces left by the earlier phases of the fire. However, we have this pattern developed which we have fair confidence in, from what we're able to observe. We believe first that in the -Y direction, the area covered by fire looks something like this (and I should change the color of the chalk - I'll do this in red or something that approximates it). The area of the fire....I'm talking about fire where a certain amount of the damage exists, substantial fire, in contrast to portions of the cabin which are licked by the flames and have only a soot deposit located thereon.

(Off the Record Discussion)

CHAIRMAN: Proceed, Mr. Pinkel.

PINKEL: Now for purposes of orientation, I provide a line which goes approximately half way up from the floor on each of the walls of the capsule which marks about the couch level (and I've shown this here). And you'lllnotice that most of the fire that we observe is below couch level along the walls. With certain notable exceptions, this is true. The principal notable exception is the zone near the environmental control unit and in a corner, the corner would be the YZ corner (in other words, a line with 45° to the axis), where the flames appear to have done meaningful damage above that level. In other words, that level being the level of the couch. Now the surprising thing is that there's very little damage above it. A typical picture of the underside of the couch just before the couch is moved shows it fairly clean and almost smudge free. However, above the couch, things were burned badly. Let me draw a pattern of the damage there and I'll show it this way - I've taken what would have been the couch area and now have reproduced it to the right - these are the three couches. I include only the outline of one suit on said couch. Now, the fire appears to take a pattern something like this, and this can only be considered approximate. This would be the zone of major damage, located here, now - crosshatch that area, with less damage in the X area. These must be regarded as very preliminary. I think that we should make a more dtailed examination of the debris taken from the couches to get a better feel for distribution but in a rough way since I was the one who removed this debris, I could get a fairly good rough estimate of what must have been the relative intensity of the fire.

(Off the Record Discussion)

CHAIRMAN: At that point, there was an interruption to discuss a plight regarding the contour outlines that were just drawn by Mr. Pinkel. The question being whether

he had considered that this outline might reflect somewhat different locations of the astronauts relative to the couches. His answer to that question was that it does possible reflect such a situation. So I'll ask Mr. Pinkel not to continue.

PINKEL: Thank you. Before proceeding, I'm reminded of another feature that I should have raised with regard to the distribution of combustibles. And that is, the point that considerable paper was in the cabin in the form of books and checklists and so on, during the incident. These were scattered about the cabin mostly at control panel locations and on the couches that the astronauts occupied.

Now we get the direction by observing the fire damage and the marks left by the fire, we have this impression - At first the fire was quite directional. In other words, there wasn't a general fire burning in the capsule, the kind of fire you would get if you had a homogenous mixture of fuel in air occupying the atmosphere of the cabin. These represented tongues of flames from local area of burning that took discreet paths responding to the expansion of the gas that occurred as the capsule deformed and broke. Starting at the environmental control unit and plotting the course here, we seemed to feel that the fire progressed in the general direction leading toward the hatch, so as one arm of the fire, staying largely below couch level, except in the area of the couch, a tunnel of flame seems to have approached the couch position so, and rise above the couch level. The progress of the fire, below couch level in the neighborhood of the hatch, was influenced by two major factors. First the availability of the nylon net which lay there to provide additional fuel to move the fire in the counterclockwise direction, the presence of the astronauts in that area, causing the flame to split and the presence of the couch supports which also seem to split the flame into several tongues.

(Off the Record Discussion)

CHAIRMAN: There was an interruption to permit some discussion of the presentation up to this point, with particular reference to obtaining a better understanding by the listeners as to the nature of the flame propagation that Mr. Pinkel was describing. It became to appear that he was describing progressive flame propagation through the media as contrasted to what might be called a very abrupt flame throughout the entire vessel. With that explanation, I will ask Mr. Pinkel to proceed.

PINKEL: Thank you, very much. Another path of the progress of the flame appears to be in this direction -- going clockwise from the environmental control unit, mostly below the couch level.

(Off the Record Discussion)

CHAIRMAN: After a brief interruption, we'll ask Mr. Pinkel to proceed.

PINKEL: We were discussing the propagation of the fire originating. We suppose for the purpose of our discussion, in the minus YZ corner and proceeding clockwise across the front panel containing the navigation equipment, the batteries and electronics. We have the impression that there were two main branches to the fire which proceeded in a clockwise direction. One which swept across the panel, and one which swept across the floor. I'll diagram these. The one across the panel below, again couch level, and the one that swept across the floor was in this direction. In the minus YZ corner, the flames did indeed reach fairly

high, so that in that corner, we see evidence of much heat applied to the metal structure high in that zone. We assume, or we suspect that the fire that I'm describing now was projected in this direction, clockwise direction, by streams of burning liquid in contrast to the fires I described earlier which represented the progress of fire along continuous paths of combustibles. The fire proceeding from the portion of combustibles to the next. We think we have a burning stream of combustibles presumably glycol. The high elevation, relatively in the capsule, reached by the flames in the $-YZ$ corner, we think resulted from the burning of glycol in that corner. The evidence for the fire direction on the floor is provided by the helmet covers on the floor which show zones of more intense burning in the 9 to 2 o'clock position on the helmets as contrasted with the zones from 3 to 7 o'clock, these being the results from 3 to 7 o'clock on the helmets as viewed from above, helmet covers, I should say, as viewed from above these zones appear to be in the lee of a fire which has some velocity so that the greatest heat transfer occurs at the leading edges of the helmet with respect to the fire progressing with some velocity and then we have as a result more charring in these zones than in zones which are in the lee of such movement of burning fluids.

Now we reach a point in the progress of the fire when the pressure in the capsule is large enough to cause failure of the floor. This is now another phase. This accelerates the displacement of the fire that I described earlier moving in a counterclockwise direction, starting from the environmental control unit and moving counterclockwise heading for a break, as we appreciate this now, in the floor which is at the perimeter of the floor to the right of the hatch occupying the 5 o'clock position, approximately. The fire issuing through that floor widened the initial crack by burning away the local material so that the crack has in this zone an appearance as shown. The failure of that floor is hard to observe with the capsule in its present configuration since the failure disappears under the cabinetry and so on, so its extent cannot be appreciated at this time. The movement of air of the cabin atmosphere through that hatch accelerates the velocity of the gases generated in the fire. There are other breaks in the floor which may have modified the course or the movement of the fire. These are hard for us ... the effect of these breaks in the floor on such movement is difficult to assess at this time. We hope that with further removal of some of the panels which obscure our view, we'll get a better appreciation of these factors. Now, there were several explosions that occurred ... Oh, incidently, I should make this point which I think is important, the amount of combustibles required to raise the pressure within that capsule to the point where the floor will break is surprisingly small. It would be less than a pound. The heat released by less than a pound of material would account for the pressure rise which our structures people say would give us a floor fracture.

These then are the principal features of the fire as we see it. There appears to have been a flash fire which has little consequence to us in this study, we feel at this moment at least, in the tunnel above the capsule. This is the cylindrical portion of the capsule above the cabin. Characteristically, in most fires,,the combustible materials give off combustible vapors which do not burn where they are generated because locally the vapors are coming off at such a rate as to render the zone too rich to burn. These vapors then float to the higher regions of the capsule where they accumulate - now, that accumulation is starting from a condition which is too lean, in other words, pure atmosphere, and then a continuing accumulation of combustibles until you reach the lower combustible limit. Then, that is ignited as a flash fire in the volume of that space in the

atmosphere. It does very little damage; it is short-lived, and we see no evidence in that zone that the fire did any substantial damage. It did appear to have ignited the Velcro. This Velcro is, incidently, the plastic materials that are used to give a pseudo friction to stabilize the position of somebody crawling thru that tunnel. And that, then, constitutes the description of the fire as we see it now.

Now there were two explosions or two events, that could be assumed to be explosions which are really characteristic of such fires. In the course of a fire, you frequently have explosions. The temptation is always in investigation these things to attribute the fire to the explosion, or to the explosions that one secs. Generally, the reverse is more apt to be true. The explosions occur during the course of the fire. One explosion appears to have happened in the oxygen purification system here, which contains carbon as an absorbent of organic vapors. It also contains a felt made of plastic which could be a polyurethane; the felt ignites easily. This was determined in the experiments that were run last night by Dr. Carhart. Their intimate contact with a pure oxygen atmosphere he feels would give their burning an almost explosive quality. The rate of propagation of fire would be great enough so that locally you could raise the pressure sufficiently to damage the rather substantial structure associated with the containment of these, carbon dioxide absorption capsules. Whether the carbon also in the canister was involved in that explosion seems to be problematical. The felt appears to have been the principal one to have given the pressure rise - it shows the distortion here.

We are anxious to get to these devices, these carbon dioxide absorption devices, which we suspect were involved in one explosion. The second explosion appears on the controller on the left couch. A corner of the control box is gone. It's not clear whether it is gone because an explosion occurred within the box that ripped off the corner - and that's a strange place for the box to have a failure. The corner is not the place you generally will find a failure. However, that corner is gone and it's a substantial corner. It's not just a flick - it's a substantial piece. There is some evidence on examination that seems to indicate that corner may have been helped along the way by being struck by a projectile coming from other part of the cabin. Also, small explosions take place in fluid lines, if the fluid is trapped between two closed valves and sits in the fire, sooner or later these lines will burst. Some of these lines have this appearance of having burst. Water, one of the water lines, in particular. I think then this represents all that we observe now that we can speak about, except to say that the greatest fire damage to the floor and to systems occurs in the zone beneath the lithium hydroxide cannisters which purify the cabin atmosphere. The situation at the base of that zone near the floor and including the floor shows an extremely severe fire here, enough to melt aluminum and cause it to puddle on the floor as ingots, which is a rather unusual situation. It implies several things: First, the fire was hot, and another, and more important, of long duration. Meaning that it started first and burned for awhile to give this much heat transfer into fairly massive aluminum pieces. This would not be the case, even with a hot fire, which would appear there only momentarily. Remember now, we have only a limited budget of oxygen here. The oxygen in that capsule could probably burn materials of a weight, say between 12 lbs and 15 lbs, depending on their chemical compositions. And this is all the material that can be burned by the available oxygen. Much of that oxygen was lost when the floor broke and the gases expanded; flame and oxygen came out together. So, the total amoont that could have been burned in that capsule is perhaps no more than 12 lbs of nylon-like matcrials. In that case, the extensive

damage done here would account for much of the heat release in the whole system. We think, just guessing, that glycol was the principal combustible in this area, to have provided so much heat release.

CHAIRMAN: Thank you, Mr. Pinkel.

(Off the Record Discussion)

CHAIRMAN: Mr. Pinkel wishes to add an additional statement.

PINKEL: With reference to the damage done at the floor and of the Environmental Control System, and in the zone immediately above the floor location, I think its necessary to point out that in the location we are speaking of, we have a co-mingling of oxygen lines and glycol, water glycol lines. The oxygen lines carry 900 psi oxygen and 100 psi oxygen in aluminum tubes which are vulnerable to local fire. The releases of oxygen into that zone helped to continue the fire. One thing I should point out, that under these conditions, aluminum itself can be a combustible and represents some of the combustible distribution to be considered when you have a situation of this kind. So, in addition to glycol, aluminum itself. The zones in this area, or adjacent to this area, which were not quite so hot, show characteristic white powder on them which we assume, without a test, to be aluminum oxide. This concludes then this phase of my remarks.

CHAIRMAN: Thank you, Mr. Pinkel.

(Off the Record Discussion)

CHAIRMAN: I believe Dr. Faget has a progress report to give.

(Off the Record Discussion)

FAGET: I have nine items. I'll just read them out quickly. The review of the environmental control system, water glycol circuit has been completed and is attached. This is a review similar to the one we had on power and I have a copy for distribution for the people here so they can look at it. The preliminary report is attached on the history of the environmental control unit's installation and removals in water glycol leakages on Spacecraft 012. This report does not contain leakages at Downey, nor does it contain a history of leakages during gas tests. But what it does contain is a number of cases where we have leakages and I think a great number of people are interested. The plan for examination of translation controllers is attached. This is supplemental to an item that has been approved today. It shows in detail how we will examine the translation control. Approximately 95% of the Command Module switch positions has been verified per the procedure, crew check list, and voice data. A list of all elapsed time indicators permanently installed on Spacecraft 012 and not to be removed before flight, is attached. Yesterday we had those that were supposed to be removed before flight. These are the ones that aren't. A check was made on Spacecraft 014 to determine visibility of the caution and warning system elapsed time indicator and capacitor. The removal of an access panel disclosed clear visibility. This panel will be removed on Spacecraft 012. This is already an approved action. As you might remember, this particular item is of interest in that we had a previous case of the condensor in question having had a fire in it. A simulation of the screwdriver incident reported yesterday has been

completed on Spacecraft 014 and the findings are attached. A review of the oxygen system is in work and should be available tomorrow. And this will be a report similar to the one that we have now on the water glycol system and on the power system. As a matter of information, there has been an inquiry about the last item. Two fresh lithium hydroxide cannisters were installed in Spacecraft 012 on the date of the test, January 27, 1967- They were installed on that date.

That completes my report and we'll pass out the package.

CHAIRMAN: Thank you. This meeting is adjourned at 1:00 p.m.

CHAIRMAN: This meeting is now in session. I would like to advise that the system for recognition of suggestions and offers of help is now fully in operation which includes -- letters signed by me to all individuals and organizations who make such offers or suggestions.

The master planning schedule has been prepared and distributed to those who have a requirement for it.

Mr. Williams, I understand you are now ready to present the progress reports for the day.

WILLIAMS: Yes, I would like to call on Col. Borman first to give the work status.

BORMAN: Yes sir, last night we found that the action items that were approved by the Board yesterday were completed with the following exceptions.

The gas chromatograph plug that we were concerned about was found stuck to the floor of the spacecraft and could not be moved without undue prying so we left it in place, and we are calling a team out now to examine it before we go ahead any further. The elapsed time indicator, you remember, we were concerned about because one of the elapsed time indicators was similar to the part that had had a failure in Spacecraft 014. We removed the panel and we were able to view it yesterday and it appeared to be in good shape so that removes that possibility.

The hypergolic unit that we're having a problem with and seems to be a concerning, reoccurring item is being removed from the pad today.

We also got the inverter cover panels out last night and No. 1 inverter, from a cursory inspection by the people on the pad, appeared different, and we have members of the Fire Investigating Committee on now looking at this number one inverter. Today, we are going to remove the main parachutes so we can examine the temperature-sensitive paint located below them, and we have already examined the umbilical area and found nothing unusual there. So the main emphasis now is developing a plan for progressive disassembly of the environmental control unit. We are working on this and this will probably be the first major system that we remove from the spacecraft. Incidentally, I have taken action to have the executive secretary of our panel reference or "close the loop," on the Board action items so that you get back not only the final action and the parameters involved, but also a reference of the test procedure that was written to cover it – so, if you want any further detail you can go to that. This will be initiated tomorrow.

CHAIRMAN: Thank you.

Mr. Williams, you have another report to give?

WILLIAMS: Yes, I have the report presenting additional removals which is a continuation from yesterday. It's Item 53. What we would like to do is propose a total interface check for the launch vehicle-spacecraft. Yesterday we verified certain key wires to the cue ball and the malfunction of the No. 8 engine light. This is a continuation of that, to verify the whole interface between the launch vehicle and spacecraft.

Item 54 is to determine the position of the direct O_2 valve. We would like to determine what position the valve is presently in.

Item 55 is a DC circuit breaker check in combinations, this is, after the inspection that was already approved.

Item 56 is the examination of Panel 150 and repositioned in the spacecraft. This is to verify if shorting behind this panel caused the fire.

Item 57 is to remove the pyro batteries behind the panel.

Item 58 is to disconnect the service module jettison controller batteries. We would like to remove the active power source from the service module.

Item 59 is to inspect ECU wiring-nondestructive. It is a routine check and inspection.

Item 60 is to remove mechanical cover on C15-1852 Junction box. We want to inspect the wiring where the screwdriver incident occurred, take the panel off and look at it.

Item 61 is to remove the X003 Recorder from the Launch Complex 34 and transport to S/C 017 at the VAB. Now this was the recorder that was used during the plugs-in test about two days prior to incident. It was disconnected during the plugs-out test, and we would like to verify configuration prior to transfer to S/C 017. It is a piece of GSE. The reason is to support the checkout Spacecraft 017.

Item 62 is to remove the cobra cable from the command module. What we are primarily interested in there is to see if there is any indication of arcing between the wires laying on top of the translation controller.

Item 63 is not on the list -- we would like to add it. We will pick it up on the list tomorrow. It is to conduct a limited analysis on the rotational hand controller, the same way we did the translation hand controller.

CHAIRMAN: Thank you. The plan is approved as presented by Mr. Williams.

BORMAN: Sir, I have one item that I inadvertently missed, and I think it is significant in our work statement. We got the main batteries out -- the reentry batteries out and first inspection shows that they were not in bad condition. We could find one small hairline crack, but no evidence of explosion or heavy fire damage.

CHAIRMAN: Thank you. In the authority under which this Board was constituted by letter from Dr. Seamans, one item stated is this: (paragraph 6, item d): "The Chairman shall appoint or designate such representatives, consultants, experts, liaison officers, observers or other officials as required to support the activities of the Board. The Chairman shall define their duties and responsibilities as part of the Board's records." We have arrived at definitions regarding these categories that apply to the Advisory Group.

A Representative - An individual representing a major element of NASA or other government agency having programs and activities associated with the Apollo Program, who participates in general meetings of the Board.

Consultants - Individuals who serve as an advisor to the Apollo 204 Review Board. It is the responsibility of the consultant to give his views or opinions on problems or questions presented by the Board or Panels. Consultants will,as appropriate recommend to the Board or cognizant Panels courses of investigation action to be undertaken in the field of their competence.

Liaison - An individual representing an activity having a recognized interest in the Apollo 204 Review, who attends general meetings of the Board for the purpose of familiarizing himself with the current status of the Apollo 204 Review. Liaison personnel are empowered to coordinate with the Panel Chairman or Board members as appropriate, in areas of interest, to acquire data that is of interest to the activity represented by the Liaison individual.

At this point we are going beyond the scope of the directive I previously referred to:

Panel Chairman - An individual designated by the Board to serve as a Manager to direct and coordinate the activities of the Panel to which appointed in accordance with a statement of work prescribed for the Panel by the Board. The Panel Chairman reports directly to the appropriate Board Monitor. Panel Chairmen will report to the Board when required on a progress of work and obtain Board approval of work plans.

Observer - An individual who attends general meetings of the Board for the purpose of familiarizing himself with the current status of the Apollo 204 Review, particularly in the area of his expertise and responsibility. Observers are empowered to enter restricted areas upon approval in order to be able to assist the Board or Panels. They shall also be prepared to submit to the Board, either orally or in writing such reports and recommendations as the Board may require.

One additional definition that we are applying to the procedures is that of Secretariat.

The Secretariat provides administrative, secretarial, clerical and other supporting services to the Board and Advisory Group.

Representatives, consultants and individuals serving in a liaison capacity will receive letters from the Board that confirm their relationship with the Advisory Group.

Dr. Faget has a project report to present.

FAGET: As reported earlier, there were nine instances of indicated high 0_2 flow rate during the test prior to the incident. Of these, six were of sufficient duration to trigger the master caution alarm switch. The master caution alarm was delayed for 15 seconds prior to giving a high 0_2 flow indication. The first high 0_2 flow which occurred at 2145 Zebra did not trigger the alarm in 15 seconds; it took 27 seconds. This could be indicative of either:

a. Some type of intermittent condition in the 0_2 sensor and/or a time delay device, or

b. The flow leaving the high flow condition during the data sampling intervals. The data sampling rate is only once every second. Of added interest the time delay device is attached to the junction panel, where the screwdriver incident occurred. The last instance of high O_2 flow indication, approximately 4 seconds before the fire call had a rather steep slope. In reviewing the nine instances of high O_2, only two others indicated this type of steep slope. One was at 2319 Zebra (Zebra - Zulu Mean Greenwich Mean Time) when the command pilot opened the space plate, the other was at 2323 Zebra and the voice recording did not reveal anything out of the ordinary at this second time.

Item 2. A review of all available data discloses that the C-band transponder dropout and the VHF-FM interruption at 233054.7 Zebra was caused by an AC power interruption. It cannot be concluded at this time whether AC power interruption was caused by AC power or DC power glitch (a malfunction detected over a very small period of time in the electrical or electronic systems). A playback of the MDS recorder should help to clarify this situation.

Item 3. The elapsed time indicator and capacitor for the warning systems on Spacecraft 012 was examined and found to be satisfactory yesterday. This was the same indicator that was burned on Spacecraft 014.

Item 4. The medical tape recorder will be opened late today or early tomorrow. TPS's are in preparation fro removal of tape and the strip-out of data at the KSC facility. A test tape is being prepared to verify the reduction and strip-out of data at this facility. Cook Electric, the recorder manufacturer, and 3-M, the tape manufacturer, have each a tape expert enroute to inspect recorder and tape prior to removal.

Item 5. During inspection of spacecraft inverters this morning, visual inspection of inverter 2 and 3 indicated they were in good shape; however, inverter #1 looked suspicious. Systems engineers and fire board panel people have been requested to inspect this inverter immediately.

Item 6. The chromatograph connector cannot be lifted from the floor. It is stuck. Another TPS is being prepared for its removal. This is the chromatograph connector that we were suspicious about earlier in the investigation. That ends the report.

CHAIRMAN: Thank you.

Col. Baxter, do you have any progress report in the operation of your panel?

BAXTER: Yes, sir. Very briefly, we followed a priority along these lines. Eye-witnesses first. That is, people who actually saw flame or fire, or heard something at the command module. Other witnesses, who were remote, but had a view through television; people who heard things; and lastly, a general category of other. Now, in this other category, we have quite a number of people. We have had in all categories approximately 100 statements as of this morning. We have been promised approximately 150 other statements which will probably be of primary interest to the procedures panel, inasmuch as these people neither heard nor observed anything, but were simply stating what they did during the test in question. That's all I have, sir.

CHAIRMAN: Thank you.

Off the record discussion.

CHAIRMAN: Mr. Williams has an additional item of action taken by the Board in approving an additional panel. Mr. Williams.

WILLIAMS: This is Panel 21, Service Module Disposition. We discussed it yesterday at the meeting, and it was approved at the Executive Session last night. The task description is, "This task involves the planning and execution of necessary service module activity beginning at the time of Board approval for Command Module demate. This task will be performed by appropriate Apollo line organizational elements in accordance with a Board approved plan which identifies the Board requirements for documentation control of this activity."

CHAIRMAN: Thank you, Mr. Williams. This action reflects a suggestion made in the morning meeting yesterday, resulting in the action taken later on by the Executive Board in the afternoon.

The meeting was adjourned at 11:31.

CHAIRMAN: The February 9 general meeting is now in session. First, I would like to point out that we have felt the need to establish our own letterhead for the use of the Review Board and its panels. The nature of our responsibilities is such that it was inappropriate to use other letterheads. We have formed our own letterheads. All correspondence going out of here from the Board will be on this letterhead. It says National Aeronautics and Space Administration, Apollo 204 Review Board.

In action of the Executive Session yesterday afternoon the Board approved a standardized diagram for use by all Board Members and Panels. The diagram is designated the "Apollo 204 Orientation Drawing." It is to be used to depict exact locations of equipment or activities referenced in documents and reports. The drawing is on exhibit here in this room.

(Off the Record Discussion.)

CHAIRMAN: Copies of this drawing will be distributed today to all the Panel Members and Board Members and others who have a need for this drawing.

In yesterday's general meeting it was brought up that there was a need for the development of workable procedures for an effective program for testing systems and components as they are moved from the spacecraft to the plants of prime contractors investigating them. As a result of the discussion, an ad hoc committee meeting was called to meet with Mr. Malley, Counsel to the Board, at 1:00 PM to prepare recommendations for the Board on this matter. That panel prepared a proposed method of handling this problem which was presented in the Executive Session of the Board in the afternoon meeting. The Board approved in principal a method of classifying material so that the intent and requirement for rigid controls, and proper control by the Board, of certain material could be followed, but that other material could be handled in such a way that we could have a workable arrangement that would not impede our progress in the entire program. The classifications of material that were developed are as follows:

A. Highly relevant material under rigid control.

B. Relevant materials subject to normal program procedures.

C. Material released from Board jurisdiction.

Category A material which must be sent off site for testing, analysis or other reasons to satisfy requirements of the review will be accompanied by representatives or a witness designated by the Board. Appropriate quality control and contractor personnel must also accompany the Board representative.

Category B material sent off site need not be accompanied by a Board-appointed representative.

Category C requires no further comment since it will be released from Board jurisdiction.

(Off the record discussion.)

CHAIRMAN: We'll call on Mr. Williams now for a progress report.

WILLIAMS: Col. Borman will give the work progress on the pad.

BORMAN: Yesterday we completed all the outstanding TPS's and these included removing the main parachute and several other inspection items. I have a copy of this I'll submit for the official record. Today, we have a rather light load on the spacecraft. As of this time we have some TPS's that have been authorized that are in preparation and these will be worked as soon as they are completed. The main one will be electrical resistance check and continuity checks in mapping of damaged wiring. That was the extent of the activity yesterday and for today, sir.

CHAIRMAN: Thank you, Col. Borman. Will you please continue, Mr. Williams.

WILLIAMS: First item I will pass on is the one that was approved yesterday – analysis of rotation hand controller in the same way that we did the translation hand controller.

Item 64: Is to remove stowed crew systems equipment from the spacecraft. The reason for removing loose equipment is to eliminate damage, primarily, – here it's the cameras and the wire bundles that were not connected with the spacecraft wiring at the time of the incident. We feel it's satisfactory time to remove them now and place them in the PIB building.

As you recall we had an item yesterday to inspect the command-module, service-module, umbilical guillotine and what we're interested in here is to inspect it and see if there is any way we would dislodge evidence. The inspection shows that we can use action Item 65 to remove the guillotine. What we're primarily interested in is to remove the pyro device.

Now Item 66 we're getting into disconnecting plugs. I'd like to discuss Items 66 and 70 at the same time. To measure continuity and pin-to-pin check of all wires through the fly-away umbilical, if there's no visual evidence of fire damage. This is the main umbilical that goes into the spacecraft. We discussed this for about an hour this morning, the pros and cons, and I feel that by removing this and the inspection of it, we can ring into the spacecraft and find out more information on the wire bundles in the spacecraft. It will be removal of GSE umbilicals from the spacecraft.

PETRONE: You're not proposing removal – you're just saying check?

WILLIAMS: No, check involves removal.

PETRONE: You've got to disconnect the umbilical?

WILLIAMS: That's right.

PETRONE: You cannot make it through the interface?

WILLIAMS: No, that's why I'm highlighting this one point. I'm assuming that we could discuss it during the discussion period.

Item 67: Is continuity and pin-to-pin check of all wires, the service module, GSE access connector. There's nothing tied on to the wire bundle now. It's a GSE plug; there's no removal of any wire bundle.

Item 68: Is in the same category as continuity and pin-to-pin check of all wires terminating at RCSC, GSE-connector. This is ringing into the spacecraft without removal of wire bundles.

Item 69: Is the continuity and pin-to-pin check of all wires in the tower disconnects to establish the configuration of it.

Item 70: Is in the same category as 66, continuity and pin-to-pin check of all wires to the command-module/service-module umbilical if there is no visual evidence of fire damage in the area. The reason is to establish configuration.

Item 71: Is to determine the configuration of sequential systems using GSE connectors. This is to establish the configuration.

Item 72: Is to determine the configuration of spacecraft wiring associated with the event inputs of the "Caution Warning" system. There is a plug with about 8 resistors in it that we want to remove that was a flight team. It was to change the scaling factor on certain measurements of "Caution - Warning." The mod was put in the plug at the GSE point. We discussed this one also. What we want to do is ring out the "Caution - Warning" system through this GSE plug.

Item 73: We had a preliminary meeting on the ECU removal and analysis yesterday and I don't think we'll be able to give the Board a presentation on what we expect to do on this before tomorrow afternoon. I would like to check with the people again today and if it's satisfactory I would like to give the Board a presentation of the ECU plan sometime tomorrow afternoon.

Items 73 to 77: Were preliminary plans leading up to getting more visibility into the ECU.

Item 73: Is the removal of the 0_2 valve panel.

Item 74: Is inspect the CO_2 absorber element; analysis is the charcoal absorber for traces of possible early combustion products and source materials.

Item 75: Is remove the water valve panel for additional visibility required after 0_2 panel removal.

Item 76: Is a chemical analysis of selected ash material from the spacecraft.

Item 77: Is to remove 17 screws from the Lithium hydroxide access panel to obtain access.

Item 78: Is to remove the octopus and corba cables from the command module. Reason is to prevent further damage to cabling during command module work and troubleshoot the communication keying problem encountered during the test.

Item 79: Is the release of non-accident associated miscellaneous materials from

levels 6, 7, and 8.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion:)

CHAIRMAN: The discussion has brought out the need for clarification of certain items relative to the fact that they do involve the disconnection of certain of the equipment. I would like to ask Mr. Williams to comment on a plan to provide this clarification. Mr. Williams.

WILLIAMS: Yes, sir, we'll modify our list for the record and point out the item numbers that require the disconnection of flight bundles. Primarily items 66, 70, and 72.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion:)

CHAIRMAN: I would like to ask Mr. Yardley if he can clarify the actual intent of the phrase "establish configuration" which appears in many of the items that we're discussing.

YARDLEY: The real intent is to establish the damage configuration to the electrical system. We would take the information that we obtained by unplugging these items and measuring and compare them to the previous information before the accident. The differences would define the damage configuration. We would then take this damage and go further into the spacecraft looking for potential ignition sources.

CHAIRMAN: Thank you, Mr. Yardley.

(Off the record discussion:)

CHAIRMAN: The list of items presented by Mr. Williams is approved subject to the condition, that the clarification of certain items previously mentioned will be provided in the final listing; and further that with reference to Item 79, that clarification of the manner in which this item is to be administered will be provided the Board in Executive Session this afternoon at which time they will be in a position to take action on that item.

(Off the record discussion:)

CHAIRMAN: Dr. Faget will continue with a progress report.

FAGET: The item for the day concerns a power glitch. All the deductions concern the AC Bus 2 glitch at approximately 23:30:55, point to the problem being associated with an AC source rather than a DC source. Because AC Bus 2 is fed from DC Bus B and because DC Bus B feeds the Biomed recorder, it is quite possible that the tape from this recorder will help validate the deduction. One possible explanation for the AC glitch would be if the crew had the telecommunications on AC Bus 1 instead of AC Bus 2, - switching from AC 1 to 2 at this time would produce the results indicated by the data. The records are carefully being reviewed from crew ingress to the time of the incident, to determine if any switching to AC Bus 1 had occurred earlier.

A structures assigument report has been passed out. This consists of a list of all structural damage from a thorough inspection. No discussion or analysis as to the possible cause, other than that implied in the description of the damage is included. Two main categories are listed: first, damage of major significance. Damage in this area is classified into a number of categories such as metal, where primary failure is cracking; metal where primary failure is due to melting and so forth. Damage of minor insignificance includes such things as cracked glass, melted plastic, and things of that nature.

(Off the record discussion:)

FAGET: Starting with today, we plan to prepare a Board action summary sheet, which will be passed out daily. I haven't got them here at this time, they are being reproduced and will be put in the boxes for the various Board Members and others who get this type of material. This summary sheet lists the Board actions by number; the description of the Board action; the reason for the action; the date at which the Board approved the action; the TPS number that resulted from that action; the summary of the results of the TPS's work; and whether or nor the action is completed or still open. In today's listing I have all of the Board action numbers from 0026 to 0062. We weren't keeping quite as good a record prior to 0026, but we will have those from 0001 to 0025 tomorrow. As I said earlier, these sheets will be updated daily and the updated sheets will be passed out at the meeting.

CHAIRMAN: Thank you, Mr. Faget.

(Off the record discussion:)

CHAIRMAN: The Chair wishes to point out that the standardized drawing that was referred to earlier is actually on exhibit here for the members of this meeting to look at. I think it was pointed out earlier that it will be distributed to all those who have a need for it, – that is copies of it will be distributed this afternoon.

(Meeting adjourned at 11:43)

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CHAIRMAN: In the first part of the Executive Session activities yesterday we met with the Panels, not only the Chairmen but also the membership to hear a brief report of their activities up to now. Each Chairman presented a brief statement supported by a written statement that he provided the Board. This review is considered by the Board to have been very successful in accomplishing the purpose of getting an overall view of the actions of the Panels up to now. So we are very grateful for the effort that all the Board Monitors, the Panel Chairmen and the Panel Members did in making this review possible. With reference to work schedules for this weekend, the current plan is that there will not be formal meetings, either of the General Meeting or the Executive Sessions, Saturday and Sunday. The pacing items in this investigation are the work at Complex 34 and the PIB. It is the understanding of the Board at this time that the approved plan for work at these activities, which will be further supplemented by the Executive Session this afternoon, will cover this entire period to the extent that formal meetings will not be required. There will be people on hand, including the Chairman, to handle emergency questions that may arise.

In order to obtain a proper understanding and assessment of the manning requirements to carry out the program that is in progress, we will place on the agenda for next Tuesday's General Meeting a report from each of the Board Members, (the Board Monitors) of an assessment of the manning requirements for the Panels for which they are responsible. This will provide us with an assessment of the manning requirements to execute the program as we have laid it out in our plans that were developed a few days ago.

I will now ask Mr. Williams if he is ready with the progress report for today. Mr. Williams?

WILLIAMS: I would like to call on Colonel Borman first concerning the work at the Pad.

BORMAN: The Spacecraft now is being worked on the TPS 049, which is the electrical continuity check. We estimate two plus days to complete this. We also have some TPS's in preparation, ready to start Monday morning. First priority will be to X-ray the glycol tanks. We have approval for three people on the Spacecraft and we will be removing the cobra cables. We will also be removing some of the GSE from around the Spacecraft. The work now is going into the detail pin-to-pin and pin-to-ground electrical continuity checks that we approved two days ago.

CHAIRMAN: Thank you, Colonel Borman. Mr. Williams, will you continue the report?

WILLIAMS: The Phase A Removal and Test Plans were approved last night at the Executive Session, Items 0079 and 0080. Item 0079 is, release the GSE to support electrical test. This GSE includes 6 TPS's.

CHAIRMAN: To interrupt a moment. For the benefit of the people here, the Chair would like to remind you that we left as unfinished business yesterday, clarification of certain items in Mr. Williams' report, and particularly Item 0079, which was taken off in the Board Executive Session yesterday afternoon. Approval was given subject to the understanding that it will be discussed here this morning

in the General Session. This, I take it, is the action that Mr. Williams is now covering. Mr. Williams?

WILLIAMS: That is correct. Item 0079, release of GSE to support electrical test. This GSE includes 6 TPS's. Launch Complex 34 TPS 5562561. GSE is as follows: One Breakout box X00-076, three battery sub-unit cables, one support test equipment cable and one milliohmmeter. Reason is, this GSE is required to support electrical test. Item 0080 is to perform translation control electrical operation verification. This includes checking the installation resistance and push-to-talk function. The reason is to check the electrical function and translation hand control which includes the talk leads. Item 0081 is removal of aluminum wickets that cover switches in the SCS main display console. Both sides of SCS direction. These wickets were in the line of the fracture of the translation hand controller. Reason: to examine and determine if melting or fracture were the mode of failure. Item 0084 is to remove a metal chip located in ECU demand regulator, left-hand equipment bay. Reason: to perform metalurgical analyses of metal chip which may aid to find thermo profile. Item 0085 is to perform electrical check of rotation hand controller. Previous work on the Rotation Controller 0063 was to perform mechanical inspection. This is to check functions from the Controller to the appropriate SCS in the J-box stub. Check function from pin-to-ground. This needs to be accomplished prior to seat removal. The reason is the continuity check. Item 0085 to perform translation controller pin-to-pin to vehicle ground point continuity check. Previous work, 0043, was mechanical inspection. Reason is to verify the Translation Controller to the Spacecraft interface. Item 0087 is to measure continuity of push-to-talk function on the SCMD cobra cable. Reason is to verify interfaces. Item 0088 is a portion of the hand control, both translation and rotational wiring which is attached to the right-hand couch and couch supports struts. In order to complete couch removal, this wiring was cut in two places. The continuity test needs to be run on the wiring on the couch to the SCS junction box on the couch. This equipment is located in the PIB. Reason is to verify continuity.

CHAIRMAN: Thank you, Mr. Williams.

WILLIAMS: I would like to add that we will have an overall Removal Plan available around four o'clock this afternoon on the removal and various test and removal of ECS. And from this, rather than do it in individual items, we would like to present to the Board the overall plan and then break it down at that particular time and get approval for removal and test on that phase.

CHAIRMAN: Are you preparing that for the Executive Session this afternoon?

WILLIAMS: Yes, so we can present it at the Executive Session.

CHAIRMAN: Thank you, Mr. Williams. Dr. Faget will continue with the progress report.

FAGET: There are several handouts that have been given out already. The first one, the one we started with yesterday, which is a summary report of Action Items, and includes at this time number 0026 through 0080, I had hoped that we would have the 0 to 0025 Items included but I think we need more time to research the records and get this straightened out. We have every reason to believethat we will have them in this form sometime next week. The next handout is the Integration Analysis status report. It looks much like the other one but deals with a different thing. It deals with the investigation of each and

FAGET: every item under consideration and we have them listed by description, status and conclusions. Each finding has a particular number assigned to it. As the Board saw yesterday in the Action Center, we have these displayed on a large board on the wall inside the room. Accompanying our status report, there is another report that goes with it. These are the conclusions and the findings. If you look at the first report I talked about, wherever you see a conclusion marked with an "X", that means that's a closed out item, and we will have conclusion. For instance, #6 VHF-FM video drops out for thirty milliseconds at 233054. It's an indication that the investigation is completed and the action in this case says it did not cause the incident. And we have a little paragraph on that particular conclusion here. In the event that anyone is interested in knowing more about the conclusion that what is contained in this paragraph, we have a complete file on each one of these findings in the Status Support Room and you are welcome to go up there and look at the folder. Of course, we cannot let the folder leave the room. At this time we have nothing in the conclusion column under the title "May have contributed to the incident". We have one more handout that's being passed out to the Board today. It is a summary description of the ECS oxygen system that was prepared by Frank Samonski and is in five parts as indicated on the cover sheet. Oxygen system description, the cyclic accumulator operation description, oxygen system schematic, oxygen system characteristics and a tabular summary of anomalies and associated notes. Monday or Tuesday we hope to have a written status similar to the oxygen description on the Communications System status at and prior to the time of the incident. That concludes my report.

CHAIRMAN: Thank you Dr. Faget. This meeting is adjourned at 11:16 a.m.

CHAIRMAN: At the start of this general meeting, we have just witnessed a photographic study, completed at Houston at the Manned Spacecraft Center, a photographic study obtained with Vehicle No. 8 which shows what can be seen through the hatch window with the television monitor with various degrees of external and internal lighting. The record of this study will be available for correlation with eye witness accounts.

Dr. Seamans spent most of Friday here and one item of business that was agreed upon is that at the earliest possible date date he wishes to obtain significant information and tentative findings. The subject of flame propagation. I'll ask Dr. Van Dolah for verification of the understanding the understanding that we have, that it may be possible to make such a reporting to Dr. Seamans by Wednesday of this week. Dr. Van Dolah, do you have any comments?

VAN DOLAH: yes sir, Mr. Chairman. This we agreed to prepare, and will have it in your hands late today or tomorrow.

CHAIRMAN: Thank you, Dr. Van Dolah.

Also, we have tentative plans for a meeting of this Board with the Deputy Administrator and such others as may be required for review of our progress, a review of the activities of the panels for guidance of the Apollo Program. This meeting will tentatively be held February 22nd or 23rd, 1967, here at the Cape. This understanding; however, is tentative and will be confirmed at a later date.

We are obtaining considerable help from a few people that reported to assist the activities of the panels. One from Langley Research Center, representing the Life Support Program activities there and 7 from Marshall Space Flight Center from various activities there. I will ask Mr. Geer if he can briefly outline the activities or assignments that these people will be engaged in here - Mr. Geer.

GEER: Mr. Chairman. Mr. Key from Marshall has been working Panel #2 and Mr. Krupnick from Marshall, Panel #5. Mr. Brooks from Marshall is Panel #7, Mr. Rio from Marshall, Panel #8, and Mr. Hypes, Langley, who is interested in the life support area, we assigned him to Panel #9, and Mr. Haley, Marshall, is Panel #18, Mr. Glass from Marshall, Panel #18, and Mr. Cole, Marshall, Panel #18. That's all.

CHAIRMAN: Thank you, Mr. Geer.

In a meeting with the panel members on February 9, 1967, Mr. Jeffs brought up the question about names on panel reports. The Board has decided that Panel reports will be signed by the Panel Chairman only. The administrative procedure involved in putting that matter into our system will be developed by Panel #15. As regards the concern that may have underlied Mr. Jeffs' suggestion that we need assurance that the Chairman of panels are not withholding an important minority opinion from proper considerations, we are asking that the Board monitors will assume the responsibility for assuring that minority views are given proper consideration and that serious differences that are not resolved are brought to the attention of the Board.

I would like to ask Mr. Geer whether the Panel #15 work in developing administrative procedure to deal with the control and release of material for testing and analysis has been prepared and distributed. Mr. Geer.

GEER: Mr. Chairman, the Procedure #11 has been developed and has been distributed, this morning. And this procedure actually covers all the material related to this incident and we have broken it down actually into the three categories; Category A is this material is considered highly relevant and is to be maintained under rigid Board control. Category B is that material which would fall under normal program procedures. Category C is material released from Board jurisdiction. The procedure by which this material will be handled is spelled out in Administrative Procedure #11. And, it should be remembered that all categories, all spacecraft and GSE and all material related to this incident falls in Category A before it is degraded to B or C and does come directly under the control of this Board. Thank you.

CHAIRMAN: Thank you, Mr. Geer.

I will now ask Mr. Williams for a presentation of report of progress. Mr. Williams.

WILLIAMS: Col. Borman, will you give the Pad report.

BORMAN: Within the past 24 hours TPS 89, 63, 65, 66, 82 and 90 have been closed-out. These include making GSE continuity checks, removing the water panel, removing the oxygen panel, removing a selected metal chip and photographing it, removing panel C15 and 1A52, and also removing a CO2 sensor. On the pad now, we are working TPS's that include checking the continuity of the launch escape system, we are testing the 02 system, we are planning to remove the 1 lb. oxygen bottle and we are going to attempt to drain any water glycol that may remain in the system. The X-ray of the tanks has been completed and we are attempting to see if there is any valuable data on that. A great deal of the work now is being done outside the command module and we do have an opportunity now for people to investigate the inside if there are any valid requests.

CHAIRMAN: Thank you, Col. Borman. Will you please continue, Mr. Williams.

WILLIAMS: Yes, sir. We only have two additional Board items. One would be taken care of by this administrative procedure, but we would like to get an okay now. In order to determine the cause of communication problems encountered in the AS-204 plugs out test, it is requested the following equipment be released from impoundment. Some of it has already been released, some hasn't. I think the one that hasn't is the astronaut astro-communicators console A48 KS panel and the MSTC test conductor panel, the OIS RF located in ACE Station #1, ACE Station tape recorder voice channel, and the MOLC S-Band and VHF voice tape recorder during reported communications problem approximately 30 minutes prior to the incident. Reason is intended to simulate, as close as possible, configuration of total voice communication system involved in the test with particular emphasis placed on OIS channels Black 2, 3, 4, and associated off-site circuits. Item 0109, the cameras that were on board the spacecraft were located over at the PIB and was removed by another action item. It appears that the lenses are off, but we would like to develop the film in the camera. Cameras have already been removed from the spacecraft and the reason is there

is a possibility some of the crew activities were filmed during the plugs-out test. I think we're at a point now where we can have tomorrow, a detailed electrical review like we had of the ECS system, a removal and an investigation. It should be ready some time tonight. We'll review it and maybe we can shoot for tomorrow afternoon the electrical sequences.

(Off the record discussion)

CHAIRMAN: The items proposed by Mr. Williams are approved. I understand that Dr. Faget has a report to make. Dr. Faget.

FAGET: My report today consists of the results from Board action items. This is the report that will be prepared daily. Today's report also includes the first twenty-five Board actions. These were not included in the previous reports.

CHAIRMAN: This meeting is adjourned at 11:39.

CHAIRMAN: The meeting is now in session. The plans for obtaining panel reports and the subsequent action to coordinate these reports and prepare them for presentation to Dr. Seamans so that they will constitute an assessment of significant information and tentative findings is fairly well planned. The meeting with Dr. Seamans will occur on the afternoon of February 22 here. This meeting with Dr. Seamans will be preceded by a report, that has been prepared from all this assessment, before the board here on the afternoon of the 21st. At that meeting Dr. Mueller and members of his staff are being invited to sit in and discuss the report with us.

The period from 5:00 PM, Friday of this week until the afternoon of Tuesday February (22) will be utilized to coordinate and finalize the draft summaries presented by the panels into the form of the presentation that we are preparing to make to Dr. Seamans on Wednesday, February 22nd.

In the executive session yesterday, the Board approved a suggestion by Dr. Faget that it would be appropriate to have suit experts participate in the action of this review for the purpose of helping to assess the significance of the suit damage and also to provide a useful information regarding future suit designs.

I'd like to ask Dr. Faget whether the action that was approved has reached a status that people are really on their way to participate in that.

FAGET: Two people from the MSC Crew Systems Division will spend a day here Thursday. They will ask for one or two people from the David Clark Company to accompany them. I don't know about the David Clark people, but I do know the MSC people will be here Thursday.

CHAIRMAN: Thank you, Dr. Faget.

BORMAN: We're now entering a period of reduced activity within the spacecraft. The overall plan is to prepare TPS' to clear up the work prior to moving the spacecraft on Friday. We have now in work a TPS to remove the surge tank and we're also draining the water glycol. This is currently in work. Plans for the day are to initiate the TPS to check the vacuum on the cold plates, water glycol cold plates, and also to inspect wiring that might be moved during the move to do the ring-out on the command and and service modules umbilicals. These hopefully will be completed tomorrow. We'll use Thursday to clean up the spacecraft and we'll move it on Friday.

CHAIRMAN: Thank you, Colonel Borman.

Will you proceed, Mr. Williams.

WILLIAMS: Yes, sir. We have developed the overall electrical plan similar in nature as we developed the ECU removal plan last week and would like to present this to the Board, possibly three o'clock this afternoon. And from this approval of the electrical plan we'll start sequencing the other systems into it for Phase C operation back in the PIB Building.

CHAIRMAN: Thank you.

WILLIAMS: If that's all right with the Board at three o'clock, we'd like to set it up.

CHAIRMAN: This is an action that you wish to bring before the Board at three?

WILLIAMS: Right.

CHAIRMAN: For approval.

WILLIAMS: For approval of the electrical and sequential test plant.

CHAIRMAN: We will be prepared to take that action at three o'clock, as recommended by Mr. Williams.

WILLIAMS: I have item 113 of about five items today to inspect the spacecraft 012 service module and record damage.

WILLIAMS: The reason is to determine the general condition of the service module and give a description of any specific damage.

Item 114 is inspect the main display console DSKY and wiring harness, will require removal of an access plate. There are no cables being broken below the DSKY. Reasons to determine the general condition of main display console and DSKY -- its wiring harness.

Item 115 to make pin-to-pin resistance check and the GN and GSE access connective. Reason is to determine further the extent of the damage to the spacecraft wiring harness. There is no cabling hooked up to this GSE connector at this time.

Item 116 -- Remove the gas chromatograph Hughes connector from spacecraft and perform lab. analysis. Reason is connector was uncapped throughout the test and analysis needs to be made of this connector to determine if it could be an ignition source.

Item 117 is to remove the CO2 absorber cannister from the aft bulk-head in bront of the ECU. Reason for this is the CO2 absorber cannister must be removed prior to the ECU removal.

There is another item here that was passed out, of change in the categories from A to C on a lot of material on the pad and also the PIB.

My suggestion is thaa the Board review it for the remainder of the day and possibly make a decision on its disposition at the executive board meeting this afternoon at 4 o'clock.

CHAIRMAN: Thank you.

(Off the record discussion)

CHAIRMAN: After discussion, it is agreed that items 113 to items 117 recommended by Mr. Williams are approved. His recommendation that the Executive Session this afternoon review the recommendations for change of status, classification of material is also approved.

The progress report will be continued with Dr. Faget making a report.

FAGET: The daily progress reports on summary of board actions and the status of the analysis is hereby submitted. At this time, we still have nothing in the conclusion column that would be listed as "may have contributed to the incident".

CHAIRMAN: Thank you. Just wish to comment on the request that was made Friday for board members to come in with an assessment of the manning requirements for the activities of the panels with which they are associated. The review of that problem shows that the manning requirements supplemented by actions of the last several days seem to leave only one area that we need address ourselves to and that is in the area of assembly of report under Colonel Strang. He needs some additional help and we will take up with him the problem of getting additional help.

This meeting is adjourned at 11:46.

CHAIRMAN: The first portion of the meeting this morning was spent in a general discussion of the communications system as outlined to us by personnel who are handling this part of the review. With reference to the item discussed yesterday concerning the integrated electrical sequencial test plan which was to be discussed with the board at 3 PM, I wish to report that that meeting was held, and as a result of that meeting certain of the detailed items involved in the overall plan were approved and will be reported in a progress report today. In addition the overall plan was approved in principle as a basis for planning the detailed items which will be submitted to the board for approval.

Col. Borman has just presented for consideration by the board a list of items ov items of material proposed for release from Category A to Category C. These items are listed on 59 pages. The discussion brought out the need for certain revisions of the proposals and the final action on this entire list will be taken this afternoon in the Executive Session of the Board.

I will now ask Mr. Williams if he is ready with the progress reports.

WILLIAMS: Yes, Col. Borman do you want to give the status report?

BORMAN: Yes, the spacecraft work is again preceding rather slowly, we were not able to to remove the surge tank and we are going to have to wait till we get the environmental control unit out before we remove the surge tank. This is a difficult operation, - they made a special tool but they still could not get it out, so that we will have to delay that until we remove the ECU.

The continuity check and the umbilicals are proceeding. We have a plan now to demate the spacecraft from the service module and that also is proceeding. The leak check of the water glycol system, we have a TPS for that and that is in work right now on the spacecraft. In attempting to drain the water glycol out of the spacecraft, they were only to get about one quart out of the system and this may be due to the we don't know how much is still left in the reservoir, but to date we have only been able to get one quart out of the system. The plan for today is to start cleaning up there on the Level 6 and 7 in preparation for movement on Friday and we're preceding with the approved TPS's.

CHAIRMAN: Thank you Col. Borman. Mr. Williams do you have other progress reports to present?

WILLIAMS: Yes, we reviewed the electrical plan yesterday afternoon at 3 o'clock and the proposed board actions are listed here as the results of the tentative approval. I would propose rather than read them all off the three pages that you could consider them during the rest of the day and approve them.

CHAIRMAN: Mr. Williams has just presented to the board for proposed board action items 118 to 138. These items will be taken up for final action in the executive session this afternoon.

Col. Borman has just submitted for approval of the Board an additional four pages of items for material release and the items are approved as recommended, subject to the understanding that the complete list of items that he submitted for

approval today, including the previous 59 pages, will be brought to the Board tomorrow with the continuous numbering system that will identify the items.

With further reference to the proposed list of actions submitted by for board approval by Mr. Williams, items 118 to 138, these items will be submitted tomorrow morning at the general meeting for action rather than to the executive session this afternoon.

In continuation of the progress reports we are waiting for a report from Dr. Faget.

FAGET: First, I have the status of the analysis. We're submitting that today on a new form which includes a little bit more information. We have 92 items listed. Of these seventeen have been completed. Three other item numbers have been marked void as work has been dropped or grouped into other catagories, however, we expect to use these numbers on new work in the future. At present there are still no items upon which work is completed that falls into the category, "May have contributed to the incident". We also are submitting conclusion summary sheets from seven recently closed out items. I would like to propose that instead of bringing the analysis up to date every day like we have been doing, that we do this in the future just on Fridays and Tuesdays because of the large amount of work involved. I will bring in each day the conclusion summary sheets on those that have reached a conclusion. I alsoopropose that we do the same thing on the summary status of the board approved action. These also will be submitted just on Fridays and Tuesdays. This will eliminate a lot of reproduction of the same material every day. I also have a summary "write up" on the use of liquid material and solvents used in spacecraft 012 for such uses as cleaning, painting and bonding during January 1967. This summary was prepared by Panel 6 (Historical Data) and has been submitted to Panel 18 as a matter of record.

I thought the board would be interested in it. In addition to the oral report which you have heard, there is a written summary on the communications systems submitted today. That concludes my report.

CHAIRMAN: Thank you Dr. Faget, Dr. Faget made a proposal for simplifying the form of reporting progress and presenting action items that would result in a large reduction in the paper work and the discussion has brought out an agreement that this is a desirable action. The understanding is that the reporting forms will be simplified by having a complete summarization twice a week with each day a presentation of pertinent items that are of interest to the Board and should be brought to the Board's attention during the intervening period.

The meeting is adjourned at 12:52.

CHAIRMAN: In yesterday's meeting, you will recall that we agreed that an up-dated material release record will be distributed in this morning's meeting. I will ask Col. Borman if he has taken that action. Col. Borman.

BORMAN: Yes, sir. We have transcribed 35 of the items that were approved by the Board yesterday. We have them in the permanent material release record and this will be kept as a permanent record for the Board. Other items that we approve will be added sequentially.

CHAIRMAN: In yesterday's morning meeting a list of proposed action items were presented by Mr. Williams, Items 118 to 138. It was agreed that more time was required for review of these items, that the action would be deferred for consideration at this morning's meeting so that we will get the benefit of advice of more people who had a chance to see the proposed items. I will ask Mr. Williams now if the list that has been circulated here this morning is the same list that we had yesterday or for any comments regarding any changes or additions that we should consider at this time.

WILLIAMS: Yes, it is the same list with the correction as mentioned yesterday on Item 120. Panel 150, a loose piece of equipment, should be removed and we will remove it after we get the Command Module back to the PIB and wiring checked to establish wiring configuration. That is the only change on the lists at this time.

(Off the record discussion.)

CHAIRMAN: In the discussion of the items previously referred to by Mr. Williams, it appears that they are probably satisfactory. In addition, he has presented Items 139 thru 143 for consideration. Item 143 is an urgent item as regards the need for early approval. In the light of the discussion, Item 143 is approved at this time, all remaining items I think will be approved in the Executive Session this afternoon unless we learn something that will bring up the need for some modification between now and then. Mr. Williams, are you prepared now to proceed with your progress report for the day?

WILLIAMS: Yes, sir. I think we covered the items previously to action items, and the plan that we have now is to get an overall schedule for Phase C and D by Monday. That's a completely integrated schedule of all systems that should carry the rest of the work in the Command Module, ECS, communications, instrumentation, etc., on one Master Plan and we're shooting to have this by either Sunday or Monday.

CHAIRMAN: Thank you, Mr. Williams. Do you have anything else to report? Do other members of your Committee have items to report?

WILLIAMS: Col. Borman has a work report.

BORMAN: Yes sir. We are proceeding with disconnecting the inverters, continuity check of the cabin fan, and, of course, work is going on in preparation for the spacecraft move. The indications are that the spacecraft will be moved at noon tomorrow and go directly to the PIB building. All the work that's posted today is in direct support of the move.

CHAIRMAN: Col. Borman, you have a recommendation about work shifts. I'd like to ask you to state what that request is.

BORMAN: Yes sir, after the spacecraft is moved to the PIB building, I request that we be allowed to go on a two shift, 6-day a week operation, with the understanding that the technicians will be on call in the event the workload increases. The basis for this request is the fact that we are not able to program enough work in to keep the people busy 24 hours a day at this stage of the operation.

CHAIRMAN: The recommendation made by Col. Borman is approved. In continuation of the progress reports we will now hear from Dr. Faget.

FAGET: I have two items that have been closed out by Panel 18, Integration Analysis Panel. These are Items 15 and 52, one has to do with the inertial guidance system, it has been concluded that the changes in the readings of the inertial guidance system are associated with the increase and subsequent decrease of the pressure of the Command Module prior to and subsequent to the ruptured pressure vessel. The other has to do with the investigation of a waste management system blower that failed on a test of Spacecraft 008. It has been concluded that this failure is not connected with the instruments on Spacecraft 012. That ends the report.

CHAIRMAN: Thank you, Dr. Faget.
This meeting is adjourned at 11:21.

CHAIRMAN: The panel meeting is now in session at 10:44. In the Executive Session yesterday the Board approved items 118 thru 142 that were discussed in the morning meeting. The morning meeting you will recall approved 143 because of the urgent nature. In addition, one other item was added in the Executive Session, 144. It was urgent and it was approved and will be added to the list of approved items available for all parties concerned.

Mr. Williams has additional items to present for discussion this morning, for consideration of this body: Mr. Williams.

WILLIAMS: Item 144, approved last night at the Executive Session, was the removal of the TV container that was laying on the floor of the spacecraft. The reason for removing it was that we did not want it laying loose on the floor during the move of the spacecraft from the pad to the PIB.

Item 145 is to remove panel 24, it requires the removal of screws and disconnection of wires. The reason we want to remove this panel is that it represents a constraint on the removal of the ECU. We have to remove the panel to get at the bolts to remove the ECU.

Item 146 is demate the Service Module SLA combination from the launch vehicle. Required to remove the Service Module SLA combination from the launch complex and move it over to the MSOB Building.

Item 147 is analyze the contents of squeeze bottles located in white room at the time of the accident. The reason is several instances of odors both in the spacecraft and on the work platform were reported.

CHAIRMAN: After consideration of these items there seems to be no objection or comment. They will be brought to the Executive Session this afternoon for approval.

Col. Borman, you have a request concerning the approval of items previously discussed. Will you state the request, please?

BORMAN: Yes, sir. These are items we discussed on the 15th regarding items that are located now in the PIB and will be disposed of in accordace with the Board's wishes. We have now categorized and itemized every item and I would like to have items 36 through 55 noted as approved by the Board in accordance with the decisions that were reached on the 15th.

(Off the record discussion.)

CHAIRMAN: Thank you, Col. Borman. Are there any further comments? If there are no further comments, the recommendation made by Col. Borman is approved.

In yesterday's Executive Session, the Board approved a general plan for the disassembly procedures that will place the responsibility for the execution of the individual steps in the hands of the Coordinating Committee, or the Chairman of the Coordinating Committee and I'll ask Mr. Williams to discuss that procedure.

WILLIAMS: The procedures will be, that the Board will appoint a government witness to witness disassembly of the ECS system. This man will be responsible for the disassembly and assure that it is carried out along the guidelines that are approved by the Board. The disassembly will be performed at KSC in the Life Support Building Test Cell. Paper work used will be the normal TPS paperwork that requires the normal signatures of the Integration Committee, the Fire Group, and a Board member of the PCC group. At the end of each major disassembly, such as the oxygen panel, a test report will be written. The plan will show the various routes that may be yaken during the disassembly. An attempt will be made at a functional check first. If this fails we will go directly to disassembly, a report will be written covering disassembly and malfunction of individual components. The plan as stated could start work around the 20th of February and end up the latter part of March, about the 20th.

CHAIRMAN: Thank you, Mr. Williams. The plan that was discussed by Mr. Williams will require that the steps taken by reported at regular intervals to the Board and significant findings as soon as they occur. The intervals of reporting will be not less than a week, probably twice a week would be more appropriate.

A problem of access to the PIB has arisen because of the large number of people that have a need to be in there and the requirement that not too many be there at any one time. This is being worked on and I think satisfactory solutions seem to be in hand but there will be further detailed consideration given this problem and an administrative procedure distributed to cover the plan that actually is worked out.

In yesterday's general meeting it was agreed that we would obtain a report from Dr. Faget regarding additional testing items that resulted from the anomaly review of the preceding day and I would like to have Dr. Faget report of those items at this time.

FAGET: Specifically, we plan to do the following: We will use spacecraft 2 TVI which is a special spacecraft for test in the space environment simulation laboratory at Houston. The following test will be made to further pursue the oxygen system anomalies, that is, the high 02 flow rate just prior to the fire alarm and the suit flow drop to zero and back to normal shortly after that time. We will investigate the following: leaks in pressure suits, the effect of cabin pressure rise with the face plate open, and the effect of physical force to restrict the flow of oxygen within the suit. All these tests will be made with the hatch open with air in the cabin; however, for the first and third of these tests we will require 02 in the suit loop. In pursuit of the gimbal motion anomaly we will analyze all the date we can get our hands on from a number of different system tests to associate particular crew action with gimbal motion, i.e., such things as throwing switches, egress and movement within the cabin. We will use spacecraft 008 in Houston to associate possible effects on the chromatograph channel with various things such as crew motion within the spacecraft. The verification of glycol data in continuing. This is awaiting further strip-out of temperature parameters from the records to determine total enthalpy change within the system. This is the complete report at this time.

CHAIRMAN: Thank you, Dr. Faget. Another action item discussed in yesterday's general meeting pertained to an assessment of the activities people external to the spacecraft during the period of the incident. Col. Baxter has undertaken to get

information on that, and I think he is prepared to report at this time. Col. Baxter.

BAXTER: Yes Sir. As of late last night we checked all the crew people that were on the third shift. None had any memory or recollection of having touched or leaned up against the capsule or Service Module, Command Module or Service Module in the 15 minutes preceding the incident, except one individual, we were following up this morning, who had been adjusting some N2O4 lines for clearance from the umbilical, standing on a ladder down at the Serice Module, and we will follow up on that. But this is the only possible adjustment or movement or contact with either Command Module or Service Module near the time of the incident.

CHAIRMAN: Thank you, Col. Baxter. Are there progress reports that are to be made now, Mr. Williams, Col. Borman?

WILLIAMS: Yes, mine is on the record already. I believe Col. Borman can give you a status report of the spacecraft.

BORMAN: Yes, Sir. The spacecraft is still on schedule as far as the move goes. We plan to start hoisting it at noon today and it should be in the PIB building at 1600.

Everything has been checked out and so far, it is going according to schedule.

CHAIRMAN: Thank you, Col. Borman. Is there anything further, Dr. Faget?

FAGET: The status of the analysis items under investigation by Integration Analysis Panel is submitted with their interim report. To summarize, 92 items were listed. Of these investigated, 24 have been completed and one item has been closed. Five other item numbers have been marked void as work had been dropped or regrouped into other categories. Action item number 20 - momentary interruption of the VHF-FM and S-Band data has now been reopened to allow the investigation of post-test motor switches. At present, there are still no items upon which work is completed that fall into the category "May have contributed to the incident". On the status of Board actions, the Board Action Status Summary is also submitted today. There are a total of 144 Board Actions. Of these, 49 have been closed and 95 remain open. Of those remaining open, 48 are still awaiting the TPS's will be completed after the Command Module has been transported to the PIB. Of the 47 Board actions in work, many of the TPS's have been completed but the summary is yet to be submitted. That completes the report.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion.)

CHAIRMAN: Further efforts in the test described by Dr. Faget involved the use of oxygen atmosphere for suit experiments; the concern over testing with osyben prompted considerable discussion. The matter is being resolved in this manner by the Board, that the testing which will be done at MSC will be subject to the approval of the Director, Manned Spacecraft Center who has the responsibilith and authority to approve such programs as may be required.

Col. Borman has submitted for approval by the Board a material release item

number 56 - ECU 02 Flow Rate Transducer - the requested action is approved.

The Panel reports have been submitted by the Panels in preaparation for the review that is in progress for presentation to Dr. Seamans next week. The Board will review these reports and ask that Panel Chairman meet with the Board this afternoon in this room at 4:00.

The meeting is adjourned at 11:35 a.m.

CHAIRMAN: This meeting is now in session. The primary purpose of the meeting this morning is to discuss the preparation of material for the interim report to be made to the Deputy Administrator next week. Yesterday we received draft statements from the Panel Chairman. Copies of all those draft statements which constitute working papers for the purpose of supporting the preparation of the report for the Deputy Administrator will be made available to all panels. There will be a folder such as this prepared for each panel. The distribution will be controlled. These are controlled working papers. Any other use or the disclosure to other people will be arranged for as necessary by the Board.

In the discussion of the designation of these as working papers, the significant point to keep in mind is that at this stage they do not constitute the opinions in any manner of the Board. They are simply working papers that have been submitted for the purpose of preparation of the report that we are now working on.

In the executive session this morning, we approved two items that were presented for approval by Mr. Williams.

Will you describe those items, Mr. Williams?

WILLIAMS: Yes, sir. Item 48 is remove the CM aft heat shield. And the reason for this is, need to provide better visibility ot the CM external aft structure. We are noting going to remove the heat shield this weekend or the early part of next week, but what we are going to do is take the necessary steps now that we are in the alignment stand to drill out the ablative plugs. The second item is remove the crew compartment heat shield. This is needed to provide better access and visibility to CM external structure. We are not going to remove the heat shield this weekend or next week. The present plan is to remove the ECU starting Monday. We want to remove the ECU before we drop the heat shield and we have to generate TPS' to shore up the flooring when we drop the heat shield. All we are going to do this weekend is to take the necessary steps to remove the ablative plugs, to get at the bolts.

CHAIRMAN: Thank you, Mr. Williams. The discussion of the steps being taken to prepare the report for the Deputy Administrator and the other items of business have been completed.

CHAIRMAN: This meeting is adjourned at 11 a.m.

CHAIRMAN: This meeting is now in session on February 20, 1967, at 10:38. Over the weekend there were several meetings concerned with the preparation for the meeting with Dr. Seamans on Wednesday. There was an Executive Session at 8:00 A.M. on Saturday; another Executive Session at 3:00 P.M. Sunday, February 19, 1967; and, other informal meetings, primarily concerned with the preparation for the meeting with Dr. Seamans on Wednesday, next.

There will be an Executive Session this afternoon at 3:00 P.M. in the Board Room concerned primarily with the continued review of the material being prepared for presentation to Dr. Seamans on Wednesday. Any other matters that arise or require Board action will also be considered at that time.

I would like to have a progress report of the work at the Pad and at the PIB and I will ask Col. Borman to report on that.

BORMAN: As you know the spacecraft is now in the PIB and we are preparing to remove the Environmental Control Unit. We are putting in the structure that has been designed to assist in the removal. We are also doing resistance checks on the electrical cabling that have been approved by the Board and we hope to get into the removal of the ECU at 1300 today. The GSE is being disconnected from the Service Module and we are preparing the service module for removal.

CHAIRMAN: When will that be done?

BORMAN: The preparation should be completed at 1600 today and we will move it tomorrow or Wednesday.

CHAIRMAN: Thank you, Col. Borman. Is there anything to report on the PIB? Do you have a report on that?

BORMAN: Yes, sir. All the activity that I referred on the spacecraft is, of course, occurring in the PIB. The spacecraft was removed to the PIB, as you know, Friday, and we are now in a weight and balance jig. We have also done some work in preparation for removing the heat shield, but we are constraining the heat shield removal until we have the Environmental Control Unit out of the spacecraft because of the weight involved.

CHAIRMAN: Thank you. I would like to ask Mr. Geer as to what arrangements have been made for a proper disposition here at Kennedy for the Service Module. Mr. Geer.

GEER: The Service Module will be moved to the MSO Building on Tuesday. A specified area has been set up for the S/M and will be under security control.

CHAIRMAN: Thank you, Mr. Geer.

(Off the record discussion.)

CHAIRMAN: The discussion has just brought out the need for a definite planning of the complete release of material at the Pad following removal of the Service Module. We will attempt to have a study made that can be reported to this Board within the next two days.

I will ask Mr. Williams if he has a progress report to present to us at this time? Mr. Williams?

WILLIAMS: Yes, sir. We have two action items that came up when the meeting started and the first action item is the removal of personal effects, materials from the couches to Room 106 of the PIB Building. I think we have approved the inventory of the items and so forth, and we now have a TPS to actually physically remove the items from the couches to the PIB, to Room 106. That's action item 150. 151 is to move the hand-controller wire bundle that hampers the removal of the ECU. We want to "ring" the wire bundle out with the push-to-talk circuit before movement, it's in the way of removing the ECU. We checked with the fire people and they have no objection.

(Off the record discussion.)

CHAIRMAN: The items just proposed by Mr. Williams have been carefully considered by parties interested and are approved.

I understand that Mr. Williams is prepared to designate the person who will represent the Board in the operation of removing the ECU. Mr. Williams can you report on that?

WILLIAMS: Yes, sir. We would like to nominate Mr. Doug Hampton from KSC to be the Board witness on the ECU component testing.

CHAIRMAN: Very well.

This meeting is adjourned at 11:03.

CHAIRMAN: This meeting is now in session at 10:54. I will ask Mr. Williams for a progress report. Mr. Williams.

WILLIAMS: The report presented yesterday, the CM equipment removal plan has been reviewed by MSC, KSC and North American personnel. They feel that this is the way to go on the removal of the equipment inside the Command Module. The action item today is No. 152, a demate of the Service Module from the SLA here in the MSO Building when the Service Module -SLA is removed from the pad. Reason is to allow better access. Status of Board action as of February 20th is as follows: The total Board actions are 151, closed Board actions 61, open Board actions need TPS's 37, in work 53. Most of these Board actions requiring TPS's will be completed after looking inside the S/C and will be completed after the Command Module is transported to the PIB. Of the 53 Board actions in work, many of the TPS's have been completed but lack TPS summaries. That is all I have for today.

CHAIRMAN: Thank you, Mr. Williams. The Command Module equipment removal plan presented by Mr. Williams has been thoroughly reviewed by all interested parties and is now approved by the Board.

Col. Borman has submitted for consideration a list of 14 items, for consideration of release, and a list of material to be released. These items will be considered and action by the Board will be taken in a subsequent meeting. These items are unnumbered at the present time.

CHAIRMAN: Col. Borman has some proposed urgent action items that he would like to present to the Board. Col. Borman.

BORMAN: Yes, sir. I would like to have action on items 69-72 in our material release record. The items are Log Books from the Unified S-Band station, an air duct used on Spacecraft 012 to supply circulating air that is now needed for Spacecraft 017, and two mounting racks for GSE that have previously been released. These are items 69-72.

CHAIRMAN: Is there any discussion of these items? There being no discussion, these items are approved. Col. Borman will continue with a progress report.

BORMAN: Yes, sir. The ECU removal continues in progress. It's now estimated to be completed at 1700. We're continuing to resistance check the cabling in the spacecraft in coordination with the ECU removal. The Service Module and the SLA should be removed today from the launch pad at the MSOB.

CHAIRMAN: Thank you Col. Borman. I will ask Dr. Faget for a progress report.

FAGET: We're submitting our status and analysis end of the items under investigation by the Investigation Analysis Panel, 93 items now are listed. Of these, investigation on 26 items has been completed. Four items have been marked void as work has been dropped or regrouped in other categories.

At present, there is still no items which we are to complete according to the category "May have contributed to the incident." There are also a number of

conclusions from some of the investigation that have been under way. The write up sheets are submitted on these items.

(Off the record discussion.)

CHAIRMAN: Dr. Faget during an off the record discussion, did note some of the progress that is being made in the testing that is proceeding at MSC with particular reference to a better understanding of glycol. He will be prepared with a more detailed report later, probably by tomorrow.

This meeting is adjourned at 11:30.

CHAIRMAN: This meeting is now in session at 10:40.

With reference to attendance at the meeting this afternoon, it is clear that many of the Panel Chairmen are not really required at the meeting. The Board members are being asked to review the list of Panel Chairmen to determine which ones can be excused and to advise the secretary of the results of that survey.

We have just discussed the problem of filing and material that must be retained by the Board, with reference to selecting what material must be retained in the file and what can be actually released. Col. Strang will prepare some comments concerning this problem for consideration of the Board within the next few days.

Col. Borman has submitted the list of items that were discussed yesterday for consideration by the Board as suitable for material release. The items have been considered by the appropriate people, certain amendments have been made. They have been numbered from 73 to 86 and they are now approved.

Col. Borman has a request for an additional number of items for release and I'll ask him to describe those items.

BORMAN: Yes, sir. We would like to have released the normal operational land lines that connect the ACE in the MSOB with the launch pad. And also, various and sundry items or pieces of test equipment that were located in trailers on Pad 34, but that were not in any way connected to the spacecraft or had anything to do with the test. These would be items number 87 through 103.

CHAIRMAN: These items have been considered by the Board and the request is approved.

Mr. Williams has some proposed action items. Mr. Williams.

WILLIAMS: The plan that was approved yesterday on total equipment removal plan, right hand lower equipment bay and main display console panel, has been assigned a0tion item 153.

Item 154 is to photograph the remains of suits, connectors and personal effects. Filming to be directed by Dr. Kelley or his designee. Films to be processed as restricted data; all negatives and prints to be returned to Dr. Kelly. 155 is remove from all three suits - cobra cable adapter, bio-medical harness, suits side communications harness, helmet side communications harness and signal conditions. Reason: released to determine fire damage and evidence of arcing. Item 156 - Following 155, determine electrical continuity both of released equipment, separately and in series.

Item 157 is perform chemical analysis of residue collected from various locations in all three suits.

CHAIRMAN: The items proposed by Mr. Williams for Board action, items 153 to 157, have been reviewed by the Board and are approved. Dr. Faget has a report of progress in some special tests that are underway. Dr. Faget.

FAGET: This hand-out I have today is a memorandum from Dr. Downs of Manned

Spacecraft Center. The subject is "Some Investigations on Potential Hazards of Spillage of Glycol Water RS89A Coolant that was used in Spacecraft 012." I'll have additional information on the same subject, hopefully tomorrow.

CHAIRMAN: Thank you.

Several days ago we asked the Panel Chairmen to supply figures as to how many people were directly involved in the tasks for which they had responsibility. A summation of the reports obtained from that survey show a total of 600 government and 900 industry personnel. This number, in the opinion of the Board, is probably a minimal number in that it accounts for the direct support and certainly, in all cases, there are more people involved than those represented by this count.

Meeting adjourned at 11:31.

CHAIRMAN: This meeting is now in session at 10:43. As a matter of record I will point out that because of the interim report to the Administrator and the deliberate break of the sequence of meetings over the weekend there has been a period of several days in which there has been no regular session. There have been certain special meetings and executive meetings throughout this period. The meeting on the 24th was at 10:30; it was a special meeting chaired by Col. Strang to take up with the Panel Chairmen the problem of getting reports finished and organizing the business of the panels. This meeting was followed by an action taken in the executive meeting on February 25th at which a release was made that I signed, directed to all Panel Chairmen, firming the agreements made at that special meeting as to when they expected to have their reports finished. The one thing that we need to keep in mind, at this time, is that having set this machinery in motion we have reached the stage where the Panel work has been completed and we need a finished report that can be accepted by the Board. The Panel Reports must be acceptable to the Board before the Panels can be dismissed. The completion of reports is something that we must pay attention to from now on.

I will ask Col. Borman to describe the items 104 to 122 which were approved by the Board in the Executive Session at the meeting on the afternoon of February 23. Col. Borman.

BORMAN: Yes, sir. Item 104 was the approval to release bulk spares, spacecraft spares, nuts, bolts, wires and so on, that have been impounded, as needed in support of the other Spacecraft 017. Remaining items of 105 through 122 were items that are associated with the service structure. They were located on levels 6, 7 and 8, during the test, but were not in any connected with the incident. They have all been inspected and returned upon the approval of 105 through 122, to normal use.

CHAIRMAN: Thank you, Col. Borman. I've asked Col. Borman to continue with the description of Borman to continue with the description of Action Items that were taken up at the meeting on February 24th.

BORMAN: Yes, sir. We have 123 which releases a tool bag which was located on level 7. The contents were recorded and returned to the owner, and Action Item 124 was the release of Launch Complex 34; all areas below the adjustable level 5, not to include the spacecraft GSE. This was checked, all the areas were inventoried, walked down and released.

CHAIRMAN: Thank you, Col. Borman. I'll ask Mr. Williams for a discussion of other items that were approved in the meeting of the 24th, Items 158 and 162.

WILLIAMS: Yes sir, Action Item 158 was the overall plan for the action for the stabilization control system tests that would be performed on the system after it was removed from the spacecraft.

Item 159 was to conduct the test on the Spacecraft 012 pressure hatch, the reason was to find out why a wrench that was used could not be inserted in the hatch as far as it should go.

Item 160 was approval to conduct low level continuity test on all equipment removed from the Spacecraft 012. The reason, so that continuity tests can be conducted on all removed equipment as soon as possible after removal.

Item 161 was approval to conduct non-destructive laboratory inspections and analyses of all equipment removed from Spacecraft 012. The reason is that laboratory analysis and tests can be conducted on all equipment as soon as possible after removal from the Spacecraft.

Item 162 was to conduct inspections and functional test on Spacecraft 012 cobra cables and the reason is to determine a possible ignition source.

CHAIRMAN: Thank you, Mr. Williams. I would like to ask Mr. Williams to continue a discussion of Action Items that have been approved, Action Item 163, it was an urgent item that came up on February 27. Will you continue, Mr. Williams?

WILLIAMS: Yes, the action items I am formally presenting to the Board today is 163, 164, and 165.

Action Item 163 is the Service Module Investigation Plan; we passed it out this morning for all members of the Board to review. It looks like it is about the best detailed plan we have had so far. The reason is to investigate the service module used during Spacecraft 012 accident to determine if it was related to the cause of the fire.

Action Item 164 is to conduct G&N computer investigation and the reasonis to possibly obtain additional data from the erasable memory.

Action Item 165 is to conduct test on the MDAS recorder from Spacecraft 012, and the reason, to determine if installed recorder was DC glitch sensitive similar with those found with test article.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion)

CHAIRMAN: Following a discussion of the items that were presented Mr. Williams it appears that they are satisfactory and that they are hereby approved by the Board. I would like to refer back to the series of meetings last week at which the Board participated in the presentations to the DEPUTY Administrator here at KSC and then Friday in a meeting with the Administrator in Washington. At the later meeting I participated along with Dr. Van Dolah and Col. Borman. We made a presentation of significant information and tentative findings and I think I can say that perhaps an important milestone has been passed in that we have been able to give the Administrator the benefit of a great deal of significant information of value in directing the course of action that must be taken in the Apollo Program from here on out.

(Off the record discussion)

CHAIRMAN: We have just had an extensive discussion of the steps in the problems that we face in completing the Apollo 204 Review, so that we can have a definite completion date that is supported by a workable plan. We have already gone on record as stating that the final report will be available near the end of this

month. The planning necessary to bring this about will be discussed in the Executive Meeting this afternoon. It appears from consideration of the business appropriate to the general meetings that we can dispense with the General Meeting tomorrow. The next meeting will be held at 10:30 Friday, March 3rd and then there will be another one Monday at 10:30, March 6th. I'll ask Mr. Williams for a report of progress or presentation of Action Items that must be considered by the Board. Mr. Williams.

WILLIAMS: Yes, we passed out this morning an Amendment to Action Item 153; it is to pick up additional items on the lower equipment bay removal list and the right hand equipment bay, and the ECU. The first phase of the ECU inspection is completed, various X-rays were taken, and the ECU was moved over to the Launch Support Building last night for disassembly.

CHAIRMAN: The Action Item proposed by Mr. Williams will be considered in the Executive Meeting this afternoon. Col. Borman has some action items proposed for consideration. Col. Borman.

BORMAN: Yes, sir, I would like to have the Board's approval to change categories from A to C for the following items. Number 127 is a pressure test stand that was used to reduce the pressure between the K bottles and the Service Module entrance. It was not located in the White Room; it was on the southeast corner of 8A. The constraint prior to release is none. This equipment has been sampled and no unusual amounts of contaminants were found. Analysis is in the hands of Panel 16. Item 128, I'd like to release the entire voice operational intercom system that was used for the 204 Plugs-Out Test. The intercom system has been thoroughly documented by the voice communication Panel, a group of Panel 9, and a test was run on it last week. These circuits are needed for other tests.

Finally, there is Item 129, a protective pressure unit to maintain a pressure on the service propulsion tanks. The Service Module, as you know, has been removed from the gantry and there is no reason to believe that there is any connection between this and the incident.

(Off the record discussion)

CHAIRMAN: After consideration of the recommended action just proposed by Col. Borman, the Board approves the release of the change of category of these items, as recommended. Dr. Faget has a progress report. Dr. Faget.

FAGET: I have a report summary of the status analysis up to March 1st. There are six new items that have been added, and three items have been closed since February 24th. A summary of the closed items is attached. To this date, there are 104 items listed of which 66 remain open, 37 are closed, and one marked void. There are still no items which were closed that fall into the categroy "could have contributed to the accident".

(Off the record discussion and film)

CHAIRMAN: Thank you, Dr. Faget. Dr. Faget has just shown a film of a test that was made at MSC in the boilerplate model to investigate the flame propagation with materials that were installed to simulate those that were in the 204 vehicle It appears from the results of this test that MSC has made considerable progress in developing a tool with which to conduct flammability test and one that will

be very valuable in qualifying materials that will be ultimately used in the Spacecraft.

CHAIRMAN: This meeting is adjourned at 11:59.

CHAIRMAN: This meeting is now in session at 10:35. We've asked the Panel Chairmen to meet with us today so that we can discuss the preparation of Panel Reports. Before we get into that matter I will ask for a report of action items that were taken in the last two Executive Sessions on the afternoon of Wednesday, March 1 and Thursday afternoon, March 2. I'll ask Mr. Williams if he will describe the action items that were taken up at the meeting. Mr. Williams.

WILLIAMS: Yes, does the Secretary have the Action Item Numbers? We modified Action Item 153 and what we did was include Revision 1 which picked up several other panels that were in the lower equipment bay and also in the right hand equipment bay; it is part of the disassembly plan of the internal parts of the spacecraft.

Action Item 166 was, "remove and analyze non-functional equipment and debris from the Command Module floor", and the reason to investigate relative positions of equipment, and possibly determine the time that the equipment arrived there.

Action Item 167 was remove the floor of the Gas Chromatograph Compartment. The reasons, to investigate the harnesses located under this floor.

168 - ECS Phase C and D Test and Disassembly Plan. The reason, to investigate and analyze all components of the ECS subsystem.

And Action Item 169 was a plan of action - the interior lighting flood lights and the reason is to investigate and analyze all components of the interior lighting subsystem.

CHAIRMAN: Thank you, Mr. Williams. I would like to ask Col. Borman for an assessment of the Disassembly Plan as to when he thinks that it will be completed. Col. Borman.

BORMAN: Yes, sir, the Chairman of Panel 4, Mr. Simpkinson, assured me that by next Friday we should be essentially complete with the disassembly of the Spacecraft. We would like to have permission to operate a three-shift operation when we start removing the heat shield, but unless there are some unforeseen holdups we should essentially have the Spacecraft dismantled by next Friday.

CHAIRMAN: Thank you, Col. Borman.

(Off the record discussion and reports from the panel chairmen.)

CHAIRMAN: We have just listened to a report of the Chairmen of the Panels as to the progress that they have made and their expectation of meeting the dates that were agreed upon last week. The summation shows that the Panels arerating in accord with the schedules that were agreed upon and the entire effort supports the objective of providing the Board with Panel Reports that will permit the completion of a Board Report near the end of this month.

Col. Borman has a report to make.

BORMAN: Yes sir, we have just received the first interim report back from the FBI on the work that they have been doing on the flight logs and other flight books that were in the spacecraft. I would like to turn this into the Secretary for future reference.

CHAIRMAN: Thank you, Col. Borman.

(Off the record discussion)

CHAIRMAN: In a discussion, it appears that a new schedule of General Meetings will meet the requirements for the future. These meetings will be held on Monday, Wednesday and Friday. The schedule for Executive Meetings will not be altered by this change in meeting schedules, in other words, Executive meetings will continue to be held at 4 o'clock each day.

CHAIRMAN: This meeting is adjourned at 11:33.

CHAIRMAN: This meeting is in session at 10:43.

(Off the record discussion)

CHAIRMAN: We will have a report by Mr. Mardel on data analysis this morning. Mr. Mardel.

MARDEL: The most significant thing we found over the weekend, Friday evening, in inspecting the wiring in the vicinity of the junction box in the lower left hand equipment bay, we did find an indication of an arc in a wire. We then went back to the cover plate and found a like-indication that lined up fairly well, within an eighth of an inch on the cover plate itself. We're saying now that in the area where we think the fire initiated, we do have an arc indication. I'll bring down photographs to go through it in more detail. At the present time, we are going to take the cover plate and go through a metallurgical analysis to try to determine if the arc occurred when the cover plate was cold or when the cover plate was hot. We'll try to find out was it an initiator, or was it an effect from the fire. At the same time we're cutting away the gas chromatograph compartment shelf, inspecting the wiring beneath the shelf. We'll also unlace the wiring and try to identify exactly which wire it was that shorted to the cover plate. We'll try to find out what it carries. So we'll have more information on this later today. Now, if I could, I would like to bring some photographs down showing the detail.

CHAIRMAN: Thank you, Mr. Mardel.

(Off the record discussion)

CHAIRMAN: We'll have a status report from Mr. Simpkinson regarding the disassembly; also, I understand he has some proposed Board Action Items. Mr. Simpkinson.

SIMPKINSON: That is correct. We proceeded with the disassembly along a schedule that we've all had. We've nearly reached the end of that; however, there were several items added, many items, and in taking a relook at the schedule Saturday, we felt that it would be more advantageous to remove the heat shields, both the aft shield and the crew compartment heat shield, as soon as we could get to them. So I have here a schedule for the Board's approval, to go ahead and do that, which, step by step, uncovers a gas chromatograph area for inspection and then removes Panel 150, a C15/1A52 Junction Box, and a waste menagement Panel 202, unclamps some ECU lines, inspects the floor area, and supports the aft bulkhead, or the floor, from the top of the Command Module, and then removes some excess items from the floor that have to be removed in order to use this support, and then prepares for and removes the aft head shield. We will then move the entire Command Module, with the aft heat shield removed, over to the impounded area, and then remove the aft heat shield. This schedule is prepared here for, unfortunately, two 8-hour shifts and I have just talked to the crew and they'll start tomorrow morning with 24-hour coverage, which would advance this about a day and a half. In other words, we would be in a posture to continue with normal disassembly work of the added items about March 10th. So we would essentially complete the job of disassembly required to take off the aft heat shield and do that, and take off the crew compartment heat shield

and be ready to continue Friday, March 10th, if that meets with your approval.

CHAIRMAN: Thank you. We will now have a discussion of the proposed schedule.

(Off the record discussion.)

CHAIRMAN: The discussion ha brought out the understanding that the proposed action items are a revision of the plan that was approved last Friday. It does appear desireable to go ahead with this revision because it will permit the aft heat shield to be removed at an earlier date than would otherwise be possible, the removal of the aft heat shield is of great interest to the Board. According to the plan that is proposed, the aft heat shield probably will be an interruption of further work on the interior of the spacecraft starting Wednesday and lasting about three days. The advantages of this proposed revision are such, that the action is approved at this time.

(Off the record discussion)

CHAIRMAN: Mr. Simpkinson has some proposed Action Items that he now wishes to submit to the Board for consideration.

SIMPKINSON: Item 170 - Remove the Command Module aft bulkhead, which is the floor. The reason: For metallurgical evaluation required to define the origin, mode, and sequence of failure in the Command Module primary structure; Item 171 - Move the SLA-5 which was involved in the accident from the integrated test stand to storage area, in the MSO High Bay. This item is self-elplanatory. We have completely exonerated the SLA-5 from the incident. 172 - Conduct an S-band voice tape evaluation by Mr. Michael Luce of NASA-MSC; the reason: we feel we would like to have a second look by a different party of the last few minutes of the voice tape. Item 173 - Conduct an S-band voice tape evaluation by an outside agency, probably Civil Aeronautics Board for the same reason. In other words, we fell we would like our own evaluation by MSC, as well as two outside agencies. Item 174 - Perform metallurgical analysis on the LEB junction box cover-plate arcing spot, and an analysis of the nylon edging grommet and its adhesive cement. The reason: to determine if the arc occurred when the metal cover was cold or hot, and if the grommet or its adhesive could have propa. gated the flame. Item 175 - Unlace the wire bundle leading from LEB junction box. Identify and remove the wire that appears to have caused the arc spot on the cover plate and perform a metallurgical analysis of the wire. The reason: to determine the metal flow content and to conclusively establish that arc did occure. Item 176 - Remove connector connecting Command Pilot suit with PGA cable. This is to isolate locwtion of shorts in PGA and bio-med and communication harness assemblies. Item 177 - Remove portion of wires of Command Pilot's bio-med harness, the communication harness, conduct a metallurgical analysis, recheck remaining portions for shorts. The reason: to isolate the location of shorts and to establish temperatures that wires were subjected to. That completes the eight items for action for the Board as of today.

CHAIRMAN: Thank you, Mr. Simpkinson. We'll go off the record for discussion of these items.

(Off the record discussion)

CHAIRMAN: After discussion of the items just proposed by Mr. Simpkinson, it is noted that one word should be changed in Item 176, changing the word "remove" to

"disconnect". The items are in urgent need of approval in order that work may progress and the discussion discloses no reason why they cannot be approved at this time. They are, there approved.

(Off the record discussion)

CHAIRMAN: Mr. Simpkinson has another item regarding the classification of material and he wishes to ask for the approval of it.

SIMPKINSON: This is item 0147 of the material release record. It is a switching console part number G16-850130. It is located at the MSOB sequential lab. Room 3412. It normally is located there, and was impounded there. Its purpose is to connect one of three identical transmission lines from the Spacecraft to the RF System Checkout Unit. This is merely a piece of switch gear that is impounded. We feel there is no constraint and would like it to go from Category A to Category C.

CHAIRMAN: Thank you, Mr. Simpkinson.

(Off the record discussion)

CHAIRMAN: The requested action is approved.

(Off the record discussion)

CHAIRMAN: We have a report of action taken by the newly constituted Screening Committee that is screening the items associated with the Command Module to determine whether they should be in Category A or B. Mr. Sasseen has a report to make on the action to date.

(Off the record discussion)

CHAIRMAN: Mr. Sassees will proceed with the report.

SASSEEN: Per your instruction we formed a screening committee for the purposes of categorizing the Command Module equipment, in either Category A or Category B as was defined earlier. I'm going to be the Chairman and the Panel will be co-chaired by Mr. Don Mayhue from MSC and Mr. Dave Levine from North American. We categorized the spacecraft into its 16 subsystems.
We've had 39 people assigned to support this effort. They will arrive this evening, and we will hold a formation meeting tomorrow. Instructions have been written to define this operation and the charter of the group. They have been incorporated into Administrative Procedure 5C. I believe you all reviewed this instruction Thursday afternoon and approved it. In addition, we've developed forms to allow each subsystem to log every one of its parts and we've developed a form to permit justifying the reclassification of each of these parts. All of this was also incorporated into the Administrative Procedure 5C. We have, in addition, two lists of discrepancies and open items that we are going to use to essentially restrain hardware from being transferred from A to B. The first of these lists was published by Panel 8 and given to us. The second of these lists is currently being made up and it will include all all open discrepancies and interim discrepancies on equipment that was experienced during this particular test. I believe that's the status.

CHAIRMAN: Thank you Mr. Sasseen.

(Off the record discussion)

CHAIRMAN: During the weekend, several of the Board members were active in reviewing the transcripts and other material in preparation for its inclusion in the final report. In accordance with the work schedules that have been set up, there was no action of the disassembly people on Sunday.

CHAIRMAN: This meeting is adjourned at 11:26 am.

CHAIRMAN: This meeting is now in session at 10:41 a.m. I would like Col. Borman to report on the disassembly of the heat shields. Col. Borman.

BORMAN: Yes, sir. The aft heat shield was removed last night and confirmed that the crack, the eruption in the structure was about two-thirds of the way around the aft bulkhead, not completely around. The work that now is in process leading to the removal of the forward heat shield and we hope to have this accomplished by tomorrow.

CHAIRMAN: Thank you, Col. Borman.

(Off the record discussion)

CHAIRMAN: Before the Executive Board Meeting yesterday afternoon, the Board and some of the personnel interested in fire hazard witnessed the film from MSC covering Test Number 2 from the Mockup Flame Propagation Series of tests that are underway at MSC. The Board feels that the procedures being followed constitute a valid one for permitting studies of flame propgation as applied to an assessment of the hazards that will be very useful in qualibying the materials that are used in the future.

(Off the record discussion)

CHAIRMAN: I'll ask Dr. Faget to report further on the item discussed by Mr. Mardel in Monday's meeting regarding the LEB junction box cover plate as it relates to possible source of ignition.

FAGET: The cover plate has been delivered to the Malfunction Analysis Branch and is awaiting analysis there. A section of the wire that presumably made contact with this cover plate will also be removed from the spacecraft, and when it arrives at the laboratory, a metallurgical analysis will be made to ascertain that the arcing did indeed take place. And, if possible, the exact nature of the arcing will be determined. Also, I think we would like an analysis of the molten material along the bottom of the plate. This will ascertain that the chaffing strip was indeed nylon as opposed to, perhaps, teflon. An effort has been completed to determine the function of the wire in question. This wire is a DC power line that goes from the stability control system in the command module up to the plus yaw thrusters on the service module. This wire is normally powered with 28 volts through a 20 amp circuit breaker. I think that is about all we can say at this time. Further analysis and work is underway.

VAN DOLAH: Can you verify the buss?

FAGET: This should be on buss A but we cannot verify that it is indeed on buss A. There is some question.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

We have just learned of some further information about the circuit, Mr. Levine,

will you make a statement regarding that?

LEVINE: The circuit breaker that was in the circuit from the DC power supposedly, buss A, was supposed to have been in the closed circuit condition, circuit breaker physically in, and was found after the incident to be in that position.

CHAIRMAN: Thank you, Mr. Levine.

(Off the record discussion)

CHAIRMAN: I would like to acknowledge the receipt, from Mr. J.J. Williams of a status of Board actions dated March 7, and made available to all the Board Members.

(Off the record discussion)

I would like to now have Col. Borman present a proposed Board action for discussion.

BORMAN: This is Board Action No. 178. It's an attempt to streamline the procedures required for removing samples for analysis from the spacecraft. It gives approval from removal of samples based upon the discretion of the systems engineers, electrical systems engineers, and the Fire Panel involved. I think it would help greatly in expediting the work of the investigation.

CHAIRMAN: Thank you, Col. Borman. This item has been previously discussed by the Board Members and in the light of that discussion, this Action Item No. 178 is approved.

(Off the record discussion)

CHAIRMAN: Dr. Faget has a progress report to make.

FAGET: The summary of the status of the analysis of items under investigation along with a complete summary of all items considered closed are included in this week's submittal. Only one new Item, No. 34, arcing noted on junction box cover plate and this is discussed earlier today by myself. As of this date, 104 items are listed of which 59 remain open. There's still no items in which the analysis have been completed that fall in the category of having contributed to the incident.

There is also submitted at this time a special report on the investigation of the AS-204 main batteries and pyrotechnic batteries. This report has a cover sheet and a great number of pages of substantiating data.

(Off the record discussion)

CHAIRMAN: There has been some discussion of the battery report that Dr. Faget was making and some clarification of that report that I would like to have Dr. Faget summarize at this time.

FAGET: There are two Items to summarize, first on page 9 of Appendix A of the report, paragraph 7. Reference is made to arcing that was indicated on the lugs of the negative terminal of battery B. Subsequent to the writing of this report, the spacecraft discrepancy reports have been examined and discrepancy report 0248

on September 23, 1966, indicates that an arc was indeed drawn on the terminal lug. The other item of interest has to do with discussion of hydrogen that may be vented from the batteries. The re-entry and recovery batteries are all vented overboard through a manifold. The pyrotechnic batteries are not vented except through a relief valve. Tests have been carried out to determine the amount of time required for battery hydrogen to accumulate sufficiently to open the relief valve. It would be a matter of several days, even at elevated battery temperature. Therefore the 60 CC of hydrogen gas which could be expelled in one venting is a very remote possibility for the Plugs-Out Test.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

This meeting is adjourned at 11:21.

CHAIRMAN: This meeting is now in session at 10:36 a.m. I am asking the Board Members to advise the Secretary regarding any requirements for secretarial support during the week-end to support the activities of Panels. I would like to have the Board Monitors find out from their Panels what the requirements are.

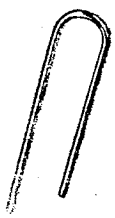
(Off the record discussion)

CHAIRMAN: We have asked Mr. Sasseen to report on the activities of the Screening Committee. I think you are prepared to report--are you, Mr. Sasseen?

SASSEEN: We have reviewed items with eleven different sub-systems groups, each of these one at a time and I'll tell you about where we stand. The Sabilization Control System people broke their subsystem into 14 different packages, we will recommend all of these items be Category B. The Structures people broke their entire assembly into 18 items; we will recommand all these also be Category B. The Earth Landing System people broke their assembly into 5 items; this is also complete except we are having the two antennas under the forward deck verified by the Communications people; we will recommand all these 5 items also be Category B. Pyrotechnic people broke their assembly into 14 different items; it looks like it will all also be Category B. We expect to treat the Launch Escape System as one assembly and recommend to you that it be placed in Category C. We still have the optical portion of this to be verified. The Guidance and Navigation people have 16 items. We reviewed 8 of them since the other 8 are still in the spacecraft. Three of them are completed to our satisfaction and the other 5, of course, require another review. The Reaction Control System people have a total of 12 items; they will also be recommended Category B; but their material still needs a rewrite. We talked to the Controls and Displays people, the Instrumentation people, the Communications people, and the Power people; we reviewed all their items, we sent them all back for a rewrite, and we expect to have this completed by Tuesday. The Environmental Control System people we talked to this morning; they are not in very good shape, as most of their components need a considerable amount of testing, so in all probability by next week we will not recommend any of their equipment go to Category B. Of the items that will probably remain in Category A, ECS stuff, there is an S-band Power Amplifier, I believe, that has a little more investigation because of a hole in it. The VHF AM transmitter with its keying problem will probably have to stay there, the Audio Center with the hot mike. There is another device which you probably haven't talked about, called a Circuit Interrupter, that, in essence, breaks the Command Module from the Service Module at the time of in-flight separation. It's not really part of harnessing, but it's buried so deeply in the harnessing that you can't take it out without a physical disassembly. Chances are that we will recommend this remain in Category A and be treated like the rest of the harnessing in the spacecraft. By next Tuesday or Wednesday, we should have a large composite MRR of most all of these items for you. This is basically where we stand.

CHAIRMAN: Thank you, Mr. Sasseen.

(Off the record discussion)



CHAIRMAN: We have discussed the report that Mr. Sasseen made, and we are very appreciative of the work that they have accomplished to date; they made very good progress in carrying out the responsibilities that were assigned to them, and it appears from the progress that has been made that by the middle of next week at our General Meeting on Wednesday, we can expect a report that will be close to a final report of the actions that this Committee has taken in preparing recommendations to the Board for the proper classification of materials of the Command Module.

(Off the record discussion)

CHAIRMAN: There is a need to consider the reclassification of the heat shield, the aft heat shield, and the crew compartment heat shield which had been removed from the Command Module, to Category B. This action will reduce the necessary guard service. The discussion has shown that this action is appropriate. We, therefore, approve at this time the classification of those two items at Category B.

(Off the record discussion)

CHAIRMAN: Colonel Borman had some Action Items to present to the Board.

BORMAN: These are MRR items that were released in Executive Session and I would like to make a matter of record. No. 148 released the Launch Complex No. 34 back to operational status, Categroy C. This was completed in Executive Session on the 6th of March; 149 released the Q-ball on the top of the Launch Escape System and was completed on 7 March ; No. 150 released the Service Propulsion Engine Gimbal Locking Links on 7 March; 151 released the Pitch Electronic Control Assembly as spacecraft spare, it's needed for support of Spacecraft 17 that was completed on the 9th of March; 152, the Roll Electronic Control Assembly for the same reason, on the 9th of March; 153 was a tool box that was inventoried and the contents recorded, released on the 9th of March; 154, another tool box, released on the 9th of March with the same constraints.

CHAIRMAN: Thank you, Colonel Borman.

(Off the record discussion)

CHAIRMAN: Dr. Van Dolah has an Action Item that he will describe concerning an action that was taken in the Executive Meeting yesterday afternoon.

VAN DOLAH: Action Item 179 calls for conducting low level continuity checks on all harnesses and equipment remaining on Spacecraft 12. This is to facilitate spacecraft electrical ring-out; it was approved in Executive Session on the 9th of March.

CHAIRMAN: Thank you, Dr. Van Dolah.

(Off the record discussion)

CHAIRMAN: I ask Colonel Borman for a report on disassembly progress.

BORMAN: The forward or the crew compartment heat shield has been removed, and the component disassembly and removal is proceeding. We now have a schedule that shows the entire spacecraft disassembly process completed by 18 March.

This may slip because of some further wire ring-out that we are doing while the spacecraft is in its present configuration.

CHAIRMAN: Thank you, Colonel Borman.

(Off the record discussion)

CHAIRMAN: In the Executive Session yesterday afternoon, an item concerning the handling of the wire bundles during disassembly was discussed and I would like to have Dr. Faget to comment on that.

FAGET: Now that the systems are in the final stages of removal from the spacecraft, the only significant rema ining hardware that could have contributed or been associated with the fire remaining in the spacecraft are the wire bundles themselves and the water-glycol plumbing and cold plates. This morning we have instituted an effort to determine the best plan for investigating these two items. Hopefully we will be able to remove the wire harnesses from the spacecraft in a way that will both optimize the inspection of the wiring as well as minimize any disturbance in the loss of evidence that might be in the wiring.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

CHAIRMAN: I would like to have Dr. Faget give a report on the test work in progress at MSC.

FAGET: There has been another mock-up test carried on at MSC which was completed Wednesday afternoon. This was test in which the boiler plate mock-up was filled with oxygen at a 5 psi pressure; unlike the previous test, the internal configuration was a flight configuration as opposed to the plugs-out configuration. The significant difference in combustibles was that the two large cushions were not in the spacecraft. Also, the nylon covers over the suit hoses were not present. With the exception of those two items, the combusitbles were just about the same. In this test the fire progressed much more slowly, the cabin relief valve lifted at 6 pis and the flow through the cabin relief valve was adequate to control the pressure in the capsule, it never exceeded 6½ psi and the fire went out after 5 or 6 minutes without consuming all of the combustibles. As a matter of fact, only the left side of the capsule was burned, and half of the left couch. We have a movie showing the progress of that fire and the damage that resulted, and I'd like to show it at this time.

CHAIRMAN: Thank you, Dr. Faget, we will proceed to show the movie that Dr. Faget just described.

(Off the record discussion and film)

CHAIRMAN: After viewing the film presented by Dr. Faget, it appears that the difference between the flame propagation, combustion process in this test as compared with the earlier test was well summarized by the statement made by Dr. Faget before showing the movie.

(Off the record discussion)

CHAIRMAN: In the Executive Session yesterday afternoon, the Board appointed Mr. Robert Bruce, who arrived from the Langley Research Center, as an Alternate Board Designated Agent for the ECS investigation.

(Off the record discussion)

CHAIRMAN: This meeting is adjourned at 11:33 a.m.

CHAIRMAN: This meeting is now in session at 19:41. The weekend has passed without formal meeting since Friday afternoon at the Executive Session. Considerable progress has been made in the acquisition and assessment of Panel Reports. Several have been received and distributed. I think it would be appropriate to ask Col. Strang for assessment of the activities of Panel 17. Col. Strang, do you have something to say about that?

STRANG: Yes sir. As of 11 March, six of the 21 Panels submitted their final reports. These are from Panels 2, 12, 13, 16, 19 and 20. The reports were reproduced and distributed to the Board members for individual study and Board review. That's all at this time.

CHAIRMAN: Thank you Col. Strang. I might add that we are acquiring some additional technical engineering support to assist in the editing of the Panel reports. We are expecting two people from Langley to report in tonight and I expect also one additional man from MSC. They will support activities from Panel 17.

(Off the record discussion)

CHAIRMAN: Mr. Malley has also acquired some additional help over the weekend. Mr. Malley, would you like to say something about that?

MALLEY: Mr. Robert Allnutt, the Assistant General Counsel for Patent Matters, NASA Headquarters, is here today to assist in the legal review of the Panel reports and to assist in the preparation of the Final Report particularly, with respect to the Findings - Determinations Section of the Final Report.

CHAIRMAN: Thank you, Mr. Malley.

(Off the record discussion)

CHAIRMAN: The Board is proceeding to review the Panel reports with the Chairmen and such others as they need, to assist them in the overall review with the Board, and the plans are this afternoon for a review of Panel 20 report at 1:30, and following that, we hope also to cover panel reports for Panels 12, 16 and 19.

(Off the record discussion)

CHAIRMAN: In the Executive Session Friday afternoon, action was taken on two items of material release. I would like to ask Mr. Simpkinson to describe those items and also to make a progress report on disassembly.

SIMPKINSON: The two items that were put up for material release record on Friday were 155 and 156. There were similar items, tool kits for the suit technicians that at the time of the incident were in the transfer van and not used. We required inventory prior to release and will release these items as soon as the inventories are completed. That is the report on material releases. As far as disassembly goes over the weekend: we worked Friday all day, until midnight, and Saturday and did get about two or three hours of electrical inspection of the harnessing that's left; quite a bit of that to go yet. Other than that, we removed a number of small items, toe plate and harness from the PCA's, a group of solenoids and we have no new things to report in the disassembly. We are

proceeding along our present schedule, which shows complete disassembly by the 18th; however, we may have to lengthen this somewhat due to the electrical checkout which we're putting in as we can.

(Off the record discussion)

CHAIRMAN: The discussion of the wire inspection program shows that considerable study and attention is underway, and that by Wednesday's general meeting, we can expect a fairly detailed program to be presented to the Board.

(Off the record discussion)

CHAIRMAN: I woule like to ask Mr. Williams to present a progress report.

WILLIAMS: This is a progress report on the dismantling of the ECU System. Saturday night, they completed the continuity check of the ECS ECU wiring harness and they disassembled, or removed the lithium hydroxide canister assembly. At the present time, they are running a leak check on the water glycol portion of the ECU. This should be completed sometime this morning and following the leak check, they'll start dismantling the various components on the ECU package itself.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion)

CHAIRMAN: Mr. Williams has an Action Item to propose.

WILLIAMS: We have a modification, the second revision to Action Item 153, which is the Command Module equipment removal plan. It was passed out this morning to the Board, and the items that were added to the basic plan is shown by two asterisks along side of the items in the plan.

(Off the record discussion)

CHAIRMAN: On the basis of the discussion, the item just proposed is approved at this time.

(Off the record discussion)

CHAIRMAN: Witness statements were distributed to Board Members and Panel members in accordance with the plan that was made for their use in pursuing the work on the review. We now require that all copies of these witness statements by returned to Panel 12. I would like to ask that all Board members and Board Monitors advise their panels to that effect.

(Off the record discussion)

CHAIRMAN: This meeting is adjourned at 11 o'clock.

CHAIRMAN: This meeting is in session at 10:37. I would like to ask that Panel Chairmen be present at the next meeting of this body, the General Meeting Friday morning; that is, all Panel Chairmen except hose who have already completed their responsibilities to the Board and whose reports have been accepted.

(Off the record discussion)

CHAIRMAN: I would like to ask Col. Borman to review the Material Release Items that have been accumulated during the last day or so.

BORMAN: Sir, I have Items 157 through 160; these include spare batteries, that were stored in the battery shop for release and for support of other programs, Item 161 was the Service Module which was approved for release to "C" category yesterday afternoon. That brings up up to date on all the records.

CHAIRMAN: Thank you, Col. Borman.

(Off the record discussion)

CHAIRMAN: I would like to ask Mr. Williams to make a report of the progress being made in the plan and execution of the disassembly.

WILLIAMS: The disassembly of the spacecraft is progressing along the following line: The primary interest now is in the electrical wiring harnesses, and we're using the second shift for the electrical people to inspect the wire harness in place, with permission to cut some of the structure away so they can get a better observation of the wire harnesses that go behind structure. The disassembly of the components are being taken care of on the first shift with the electrical inspection, the ring-out of the cables taken place on the second shift.

(Off the record discussion)

CHAIRMAN: Mr. Williams, are you prepared to make a distribution of the items up to date now which action has been taken.

WILLIAMS: Yes sir, we've passed out our status of the Board actions today, and the total Board actions so far, a total of 179. The closed items are 95; the open items are 84: TPS's completed, but need engineering analysis - 41; TPS's in work - 35, and we need TPS's on eight (8).

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion)

CHAIRMAN: I'll ask Dr. Faget to make a report of the progress of the Integration and Analysis Panel.

FAGET: The up-dated status of the analysis under investigation by Integration and Analysis Panel has been passed out this morning. Only one new item, Number 105, which is an investigation of a possible short in the suit wiring of the Command Pilot's suit, has been added to the investigation. Twenty items have been

closed since March 8th. As of this date, 105 items are listed of which 40 remain open and 65 have been closed. Integration Analysis summaries for the 20 newly closed items are attached. There is still no item for which analysis has been completed which fall into category "MAY HAVE CAUSED THE ACCIDENT". And, also, I am handing out a report this morning which is the result of the Mobility Evaluation Test results that was conducted on 28 February, Mock-Up Two.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

CHAIRMAN: I would like to have a report from Col. Strang, on the progress of Panel 17.

STRANG: In a special session on March 13, 1967, the Board reviewed and approved Final Panel Reports 12, 16, 19, and 20. In another special session March 14, 1967, the Board approved Final Report of Panel 21. The Final Report of Panel 13, previously reviewed, was approved by the Board Executive Session, March 14. All reports approved by the Board are being processed for final editing and printing. Panel 17 has received and distributed to the Board, Final Panel Reports 2 and 6 for individual study prior to Board review. At this time, for today's session, we have Final Panel Report 6, for review.

CHAIRMAN: Thank you, Col. Strang.

(Off the record discussion)

CHAIRMAN: After some discussion, we have rearranged the schedule for this afternoon to have Panel 5 report to the Board at 1:00 and, Panel 6 to come in later at around three o'clock.

(Off the record discussion)

CHAIRMAN: This meeting is adjourned at 10:55.

CHAIRMAN: This meeting is now in session at 10:36. I've asked the Panel Chairmen to meet with us this morning, because we wanted to review the situation relative to the preparation of the Panel Reports and their acceptance and coordination by the Board.

(Off the record discussion)

CHAIRMAN: The discussion of the Board with the Panel Chairmen was concerned with the problems that we now see in completing the Panel Reports and incorporating the substance of those reports into the Final Report of the Board.

(Off the record discussion)

CHAIRMAN: I'd like to ask Mr. Simpkinson to describe the status of the disassembly of the spacecraft.

SIMPKINSON: The spacecraft down at the PIB has been undergoing disassembly now for some time, and we are about at the stage of, I would say, and we are about at the stage of, I would say, more than 90 percent complete with that phase of the investigation. To sum it up, we have a total of about 40 more tasks left out of several hundred that we have already worked and these 40 consist of about 20 more removals of items that are very low, or practically no-suspect, nonfunctional panels and crew system components that were just in there with no connection to them. These final items are being removed to gain complete visibility of the inside of the spacecraft. The other 20 of the 40 tasks consist of TPS's (work orders) to run resistance checks and continuity checks of the harnesses. The remaining work out there at this point in time appears to consist of about five or six days which will be spent removing essentially these nonfunctional parts. Also, we're spending eight hours a day, as you know, with the electrical people going over the harnesses practically wire by wire looking for any indication of the origin of the fire. That's about where we stand at the moment.

CHAIRMAN: Thank you Mr. Simpkinson. I would like to ask Mr. Williams to report on the progress of the study of the ECU.

WILLIAMS: The ECU was completely taken apart by last Wednesday. The components of the ECU that will be disassembled in the Malfunction Investigation Lab are now in the bonded area in the MSOB Building. We should have an overall plan to show the various dates that we expected disassembly of the individual components of the ECU by Monday and we'll give a status of what we've found so far in the examination of the components in the plan at the Monday Board Meeting.

CHAIRMAN: Thank you Mr. Williams. Col. Borman has an action item to propose for the preparation by the Board.

BORMAN: Yes sir, I have five items that I would like to get released from Category "A" to Category "C". No. 162 the rate gyro assembly. 163 is an attitude gyro accelerometer assembly. 164 auxiliary electronic control assembly. 165 is a displays electronic control assembly. 166 is a gimbal position attitude set indicator. These items were stored in the warehouse or have arrived on the Cape since

the accident. They were not installed in the Spacecraft 012 at any time and they are required to support Spacecraft 017's operation.

CHAIRMAN: Thank you, Col. Borman.

(Off the record discussion)

CHAIRMAN: In view of the discussion among the recommended actions, these actions are approved. I will ask Mr. Sasseen to report on the activities of the and progress of the Screening Committee. Mr. Sasseen.

SASSEEN: The Screening Committee has reviewed to date 312 items of the Spacecraft equipment. I would recommend that 171 of these go into Categroy B. We have published a preliminary report in justifying each one of these items as describing the condition. We have 49 more items, some of which are still in the Spacecraft and should be removed by Wednesday. We expect to review these additional items and be finished by next Friday.

CHAIRMAN: Thank you, Mr. Sasseen. Mr. Williams has an action item to propose for consideration by the Board.

WILLIAMS: Action Item 180, approve or utilize the open TPS technique for A ction Item 160, which is "Conduct low level continuity tests on all equipment removed from the Spacecraft 012"; and Action Item 179, "Conduct low level continuity checks on all harnesses and equipment remaining in Spacecraft 012". This technique utilized on Action Item 178 which was, "Approval to remove small samples of material from Spacecraft 012 and send them to the Lab for analysis", has proven to be an effective time-saver in that a separate TPS properly signed and distribution was not required.

CHAIRMAN: Thank you, Mr. Williams. I am assured that this matter has been given sufficient consideration so that it can be approved at this time, so therefore, it is approved. This meeting is adjourned at 11:16.

CHAIRMAN: This meeting is now in session at 10:35 a.m. The weekend has been a busy one for the Board and Panel Members. I'd like to ask Colonel Strang to summarize the weekend activity on the report preparation.

STRANG: As of 19 March 1967, the Board has reviewed and accepted, subject to editorial corrections, the final reports of Panels 1, 8, 10, 12, 13, 14, 15, 16, 19, 20 and 21. Also, the Board has reviewed and accepted, except for the Findings and Determinations, the final reports of Panel 5. Panel 17 has received the final reports from Panels 3, 4 and 17. These reports were distributed for individual study for Board Members. That's all.

CHAIRMAN: Thank you, Colonel Strang. I would like to ask Colonel Borman for a report on Material Release Items. Colonel Borman.

BORMAN: Yes, sir, I have several items, they're Material Release Items Number 167 through Number 192. They were approved in the Executive Session on Sunday, that was yesterday, the 19th of March. I won't list them all specifically. They're generally miscellaneous items that were located in the area of the spacecraft during the incident but, all have been determined to have no-effect, or no-cause, or no-relation to the incident. They have all been released from Category "A" to Category "C".

CHAIRMAN: Thank you. Colonel Borman.

(Off the record discussion)

CHAIRMAN: I understand Mr. Williams has some action items to propose to the Board. Mr. Williams.

WILLIAMS: Yes, I have two action items. Item 181, utilize TPS technique to remove all debris from the aft bulkhead and vacuum, photograph and grid aft bulkhead prior to removal and vacuuming. No additional work will be accomplished under Board Action 0166. The reason is to allow inspection of the floor and better access with the Command Module. Action Item 182, return Inverter #2 to the vendor for detailed investigation. The reason, to investigate known anomalies associated with the inverter and determine their relationship, if any, to the accident.

CHAIRMAN: Thank you, Mr. Williams.

(Off the record discussion)

CHAIRMAN: I'd like to ask Dr. Van Dolah to comment on the first proposed action item just presented by Mr. Williams.

VAN DOLAH: An additional reason for this action item is to remove all of the debris, all material located on the floor, excluding of course, wire bundles. This material will be examined visually and thick sections of the material will be examined by X-ray and other techniques to insure that nothing unsuspected is in it.

CHAIRMAN: Thank you, Dr. Van Dolah.

(Off the record discussion)

CHAIRMAN: Mr. Sasseen of the Equipment Screening Committee has brought to the Board for consideration a proposed action item that pertains to AC Inverter No. 2. The proposal is that this item which is a Category "A" item of equipment be returned to clear up any suspicion that applies to an anomaly, or rather any relationship to the accident. The action item carries with it, the recommendation that Mr. E. E. Eastman of MSC, be designated as an agent of the Board for this action. I would like to have the Board consider this recommendation.

(Off the record discussion)

CHAIRMAN: It is the consensus that this action be approved. The proposal therefore is approved.

CHAIRMAN: I would like to have a progress report from Dr. Faget. Dr. Faget.

FAGET: The wiring on the Spacecraft 012 has been inspected. Inspection was completed this weekend. This inspection consisted of separating all wires from the bundles and inspecting visually each wire individually. The location of possible shorts and arcs in the wiring was noted. In addition, notation of fire damage and other anomalies in the wiring was made. A complete report on wiring inspection will be submitted at a later date.

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

CHAIRMAN: We departed from a normal schedule that we've been following recently and yesterday (Sunday, March 19) kept the PIB open for an investigation. I would like to ask Dr. Van Dolah to comment on the work that went on there yesterday. Dr. Van Dolah.

VAN DOLAH: The investigation concerned the question of the development of static electricity on a suited crewman. It was carried out in Spacecraft 014. The conditions were made as nearly similar to those that prevailed at the time of the accident as could be made. The air inside the cabin was very dry, and the suit loop was fed with dry air. A full report on the results will be presented.

CHAIRMAN: Thank you, Dr. Van Dolah. I would like to say that this afternoon the Board will meet with Dr. Gilruth, a group from the program staff at MSC, and the contractor to discuss joints in the spacecraft. This meeting will take place about 1:00 p.m.

(Off the record discussion)

CHAIRMAN: We have received a status report from Mr. Hampton and Mr. Bruce regarding the ECS review and examination that is underway. It appears that the subject of the status of this effort should be presented at the Executive Session this afternoon at 4 o'clock.

CHAIRMAN: This meeting is adjourned at 11:03.

CHAIRMAN: This meeting is in session at 10:41 a.m. The Board spent some time this morning in witnessing a demonstration of the operation of the hatches at the PIB to obtain a complete understanding of the operation of opening the hatches from the inside and from the outside. Following the demonstration of the hatch operation at the PIB, the Board went to the ACE Control Room to get first-hand knowledge of the operations that are carried on there. The Board has been spending most of its time in reviewing panel reports, and I'd like to ask Major Butler, in the absence of Colonel Strang, to report on the progress that has been made. Major Butler.

BUTLER: Yes sir, as of March 12, the Board has reviewed and accepted, subject to editorial changes, the final reports of Panels 1, 4, 5, 8, 10, 12, 13, 14, 15, 16, 17, 19, 20 and 21. The final reports from Panels 7 and11 have been distributed to the Board for individual study. Board review of these latter two reports is scheduled for today, starting with Panel 11 at 1:00 p.m. The final reports from Panels 15, 16, 17, 19 and 21 have been submitted for printing. The final reports from Panels 10, 13, 14 and 20 are presently being edited and should be submitted for printing later today or early tomorrow morning. Lastly, the final reports from Panels 1, 4, 5, 8 and 12 are being retyped and will be available for editing this afternoon or tomorrow morning.

CHAIRMAN: Thank you, Major Butler.

(Off the record discussion)

CHAIRMAN: Following Major Butler's report, discussions brought out that veri-typing required is posing a problem that is now being examined as to whether or not the facilities for typing are going to be able to keep pace with the requirements. This matter will be looked into after this meeting is adjourned. Colonel Borman.

BORMAN: Yes, sir. In the Executive Session last evening, we approved Items 194 through 199, which are miscellaneous items that were located on Level 8 of the gantry. They had no association with the spacecraft and were not physically connected to the spacecraft at the time of the accident.

CHAIRMAN: Thank you, Colonel Borman. We have additional progress reports this morning, I believe, or reports to be distributed. Mr. Williams, do you have reports to make or distribute this morning?

WILLIAMS: Yes, sir, I have distributed the status of the Board action items to date. There are no new action items to be presented to the Board today.

CHAIRMAN: Thank you, Mr. Williams. Dr. Faget has a report to make. Dr. Faget.

FAGET: An updated status of the analysis of the items under investigation by the Integration Analysis Panel is hereby submitted. No new items have been added. 13 items have been closed since March 15. As of this date, 105 items are listed, of which 27 remain open and 78 are closed. There are still no items upon which analysis has been completed that fall into the category, "may have caused the accident."

CHAIRMAN: Thank you, Dr. Faget.

(Off the record discussion)

CHAIRMAN: This meeting is adjourned at 10:56 a.m.

March 31, 1967

CHAIRMAN: This meeting is now in session at 10:33. I would like to ask Colonel Strang for a report on the progress of Panel Reports preparation. Colonel Strang.

STRANG: Reports from the following Panels have had printer's copies prepared and distributed to the Board for final review: 4, 10, 14, 16, 17, 19 and 21. Most of these Reports have been returned by Board Members for final editing and printing. The following Panel Reports are being processed for preparation of printer's copies as of this date: 3, 5, 7, 11 and possibly 6. Printer's copies of Panel Reports 1, 13, 15 and 20 are to be distributed to the Board today for their final individual review. Final draft copies of Panel Reports 2, 8, 7 and 12 are srill being individually reviewed by Board Members. After return of these Reports to Panel 17, they will be processed for preparation of printer's copies and subsequently distributed to the Board for final review. The Final Report from Panel 18, is still undergoing rewrite by the Panel.

CHAIRMAN: Thank you, Colonel Strang. I would like to ask Dr. Faget for a report I believe he is prepared to make. Dr. Faget.

FAGET: I have the final status report. One new item has been added to the 105 items under investigation by the Integration and Analysis Panel since March 22, 1967. As of this date, 79 items have been formally closed and the remaining 27 are still undergoing the validation and determination process. Twenty-six of the remaining open investigation items are not significant with respect to being the potential ignition source. Ten cases of arced, shorted and/or suspicious looking wiring have been identified. From these 10 items, only one is considered a possible cause of the accident. The one possible cause is the wiring providing instrumentation power for some of the Environmental Control System. This wiring contains both DC bus A and DC bus B electrical power, and is located along the floor on the Command Pilot's side in the Command Module in the vicinity of the lithium hydroxide canisters. A special report has been submitted by the Environment Control System (ECS) Investigation Committee. Out of the 78 ECS components, 58 were categorized as non-fire initiators and 20 as a possible fire initiator by this committee. Conservative criteria was used in classifying components as non-initiators. Further investigation is in work to establish whether or not the remaining 20 items are, in fact, possible initiators.

(Off the record discussion)

CHAIRMAN: I would like to ask Colonel Borman to present items upon which he requires action.

BORMAN: Yes, sir. I have two MRR items that I would like to propose. Number 1 - we would like to remove from Category A to Category C all parts and equipment, excluding records, that were not physically attached to the Spacecraft at the time of the accident.

CHAIRMAN: I believe that this proposed action is a desirable one, acceptable to all the Board Members. That being the case, these recommendations are approved. Do you have something further to report on, Colonel Borman?

BORMAN: Yes, sir. We're taking steps to obtain a container from the Navy that will be located here at KSC in which we can store the Spacecraft. Work is in progress now to provide a proper storage place for all the items and equipment in the Spacecraft.

CHAIRMAN: Thank you, Colonel Borman.

(Off the record discussion)

CHAIRMAN: The screening committee, as reported in an earlier meeting by Mr. Sasseen, has presented the Board with the results of the screening of the parts, components and assemblies of the Spacecraft and their recommendations as to how they should be categorized. The Board accepts the Report of this committee as the basis for custody and for further analyses of these pacts, components and assemblies.

(Off the record discussion)

CHAIRMAN: We are now in the final stages of preparation on our Report to the Administrator and it is no longer necessary to adhere to the schedule of meetings that we have been following. There will be no further General Sessions or Executive Sessions until we recess, except on call of Chairman.

(Off the record discussion)

CHAIRMAN: This meeting is adjourned at 10:55.

CHAIRMAN: This General Session called this morning, March the 28th, is now in session at 10:30 a.m. This is a meeting that was postponed from Friday morning the 24th of March. On Friday morning Panel Report Reviews were in progress and it was determined that it would be unnecessary to interfere with that by having a General Session, a decision was made to postpone the meeting till this morning. During the weekend the Board was in recess, however, work continued in the preparation of Panel Reports.

(Off the record discussion)

CHAIRMAN: I'd like to ask Col. Strang to report on progress in preparation of these reports.

STRANG: Yes sir, Mr. Chairman, a follow-on review by the Board of the Final Reports from Panels 5, 7, 9 and 18 is required. The Panel 18 report will be available for Board Review at 9 a.m. March 29, 1967. Eleven Panel Reports have been submitted for varityping. After these Reports have been varityped, copies will be provided to each Board Member and Counsel, for individual review and corrections prior to the actual printing of the Report. Panels 2 and 7 have been requested to prepare a narrative of Spacecraft 012 test sequences and their objectives. This narrative should contain the significant events up to T-10 hold before the accident. Panels 3, 11 and 12 have been requested to prepare a narrative on the time-line of events from the start of the T-10 minute hold through the medical determination of death. Panel 18 has been requested to prepare a narrative on the investigation and analysis activities of the Board. This covers the period of time immediately after the determination of the cause of death through the completion of the Apollo 204 Board Review activities.

CHAIRMAN: Thank you Col. Strang.

(Off the record discussion)

CHAIRMAN: Mr. Sasseen is here this morning to report on the status of the Screening Committee's activities. Mr. Sasseen.

SASSEEN: The Screening Committee closed its books on the 24th of March; with a small regrouping, there are 300 items that were included, the regrouping was in crew systems. Of these we are recommending 238 items to be transferred to Category B and in addition there are 54 ECS items which will be covered in the ECS Committee's report and not ours. This leaves a total of eight items that we would recommend remain in Category A, I'll go over them here. (1) One of them is an instrumentation J-Box which is essentially a portion of the ship's harness. (2) The Statis Inverter #2 that was sent back to the vendor, (3) the kick plate, or cover plate for the Lower Equipment Bay Junction Box that had the arc on it. (4) There is a main display console panel #8 where a wire was apparently off the structure. (5) The Bio-Medical Octopus Cable, we don't intend to exonorate; (6) the Command Pilot's Cobra Cable is also remaining in Category A since there was not a positive investigation to say conclusively that there could be no arcing. (7) The Command Pilot's torso harness is in the same Category and thus for obvious reasons so is (8) the Velcro and debris traps in the Spacecraft. These 300 items did not include harnessing tubing or some of those small, permanently attached items.

CHAIRMAN: Thank you Mr. Sassen.

The Board will review this Report and determine whether it agrees with all the actions. I think we will be able to act on this within the next day or so. Thank you very much.

(Off the record discussion)

CHAIRMAN: I've been concerned that early in this Review we injected into the record a figure for the melting point of aluminum, 1400 degrees. I'm not quite certain how that figure originated. It is a surprisingly high figure for aluminum. In view of that fact we recently took action to determine what the actual melting point of the aluminum involved in the Spacecraft is. There is, of course, a wide range for melting points of aluminum. Samples were taken and tests run here at the laboratory. I'd like Mr. Geer to comment on where those samples were obtained from and what figures were obtained for a melting point.

GEER: The samples were taken from the tubing of the 900 pis oxygen system, the water-glycol system, and the 20 psi oxygen system. Tests were run on the 6061-T6 aluminum tubing and the melting point on all of them was found to be 1241°F.

CHAIRMAN: Thank you Mr. Geer.

CHAIRMAN: It is my understanding that that figure corresponds to the point where the aluminum actually becomes liquid.

(Off the record discussion)

CHAIRMAN: I'll ask Col. Borman to make a report on certain action items for material release and the disassembly program. Col. Borman.

BORMAN: Yes sir, we had Item 200 which was approved over the weekend, the couches from Spacecraft 014 were released to Category C to be sent to Houston. I have two other items, one is trash that was removed from the garbage cans in the White Room, the fire panel and interested parties have checked through the residue and they can find nothing relevant to the accident. We'd like that placed in Category C. The other is. Clean Room clothing that has been soiled from normal use and we'd like to return that back to the normal channels.

CHAIRMAN: Thank you Col. Borman

(Off the record discussion)

CHAIRMAN: The proposed recommended material release items are approved. Will you please continue with your report, Col. Borman?

BORMAN: Yes sir, we have essentially completely disassembled the Spacecraft, the visibility of the parts and all the areas of the structure is complete. As of today we have logged 1241 separate items through the Bond Room for display to interested parties. Of these 1241 items approximately 1000 came from the C/M directly.

CHAIRMAN: I'd like to ask Col. Borman at what time was disassembly completed? Col. Borman.

BORMAN: Yes sir, disassembly of the Spacecraft was completed on the 27th of March during the first shift.

CHAIRMAN: Thank you Col. Borman.

(Off the record discussion)

CHAIRMAN: This afternoon an exercise will be set up in the PIB to clarify the events associated with the actual opening of the hatches. Eye witnesses and other people who are concerned with recording the events will be on hand to clarify the record pertaining to that portion of the incident. Board Members are advised of this and are encouraged to attend if they can.

(Off the record discussion)

CHAIRMAN: In view of the way the General Session schedule has worked out it will be unnecessary to have a meeting tomorrow morning in accordance with the usual schedule. The next General Session will be held Friday morning at the usual time. This meeting is now adjourned at 11:13 a.m.

CHAIRMAN: This meeting is now in session at 10:33. I would like to ask Colonel Strang for a report on the progress of Panel Reports preparation. Colonel Strang.

STRANG: Reports from the following Panels have had printer's copies prepared and distributed to the Board for final review: 4, 10, 14, 16, 17, 19 and 21. Most of these Reports have been returned by Board Members for final editing and printing. The following Panel Reports are being processed for preparation of printer's copies as of this date: 3, 5, 7, 11 and possibly 6. Printer's copies of Panel Reports 1, 13, 15 and 20 are to be distributed to the Board today for their final individual review. Final draft copies of Panel Reports 2, 8, 7 and 12 are still being individually reviewed by Board Members. After return of these Reports to Panel 17, they will be processed for preparation of printer's copies and subsequently distributed to the Board for final review. The Final Report from Panel 18 is still undergoing rewrite by the Panel.

CHAIRMAN: Thank you, Colonel Strang. I would like to ask Dr. Faget for a report I believe he is prepared to make. Dr. Faget.

FAGET: I have the final status report. One new item has been added to the 105 items under investigation by the Integration and Analysis Panel since March 22, 1967. As of this date, 79 items have been formally closed and the remaining 27 are still undergoing the validation and determination process. Twenty-six of the remaining open investigation items are not significant with respect to being the potential ignition source. Ten cases of arced, shorted and/or suspicious looking wiring have been identified. From these 10 items, only one is considered a possible cause of the accident. The one possible cause is the wiring providing instrumentation power for some of the Environmental Control System. This wiring contains both DC bus A and DC bus B electrical power, and is located along the floor on the Command Pilot's side in the Command Module in the vicinity of the lithium hydroxide canisters. A special report has been submitted by the Environment Control System (ECS) Investigation Committee. Out of the 78 ECS components, 58 were categorized as non-fire initiators and 20 as a possible fire initiator by this committee. Conservative criteria was used in classifying components as non-initiators. Further investigation is in work to establish whether or not the remaining 20 items are, in fact, possible initiators.

(Off the record discussion.)

CHAIRMAN: I would like to ask Colonel Borman to present items upon which he requires action.

BORMAN: Yes, sir. I have two MRR items that I would like to propose. Number 1 - we would like to remove from Category A to Category C the complete Launch Escape System that was on Spacecraft 12 at the time of the accident. Secondly - I'd like approval for a general MRR that would release from Category A to Category C all parts and equipment, excluding records, that were not physically attached to the Spacecraft at the time of the accident.

CHAIRMAN: I believe that this proposed action is a desirable one, acceptable to all the Board Members. That being the case, these recommendations are approved. Do you have something further to report on, Colonel Borman?

BORMAN: Yes, sir. We're taking steps to obtain a container from the Navy that will be located here at KSC in which we can store the Spacecraft. Work is in

progress now to provide a proper storage place for all the items and equipment in the Spacecraft.

CHAIRMAN: Thank you, Colonel Borman.

(Off the record discussion.)

CHAIRMAN: The screening committee, as reported in an earlier meeting by Mr. Sasseen, has presented the Board with the results of the screening of the parts, components and assemblies of the Spacecraft and their recommendations as to how they should be categorized. The Board accepts the Report of this committee as the basis for custody and for further analyses of these parts, components and assemblies.

(Off the record discussion.)

CHAIRMAN: We are now in the final stages of preparation on our Report to the Administrator and it is no longer necessary to adhere to the schedule of meetings that we have been following. There will be no further General Sessions or Executive Sessions until we recess, except on call of Chairman.

(Off the record discussion.)

CHAIRMAN: This meeting is adjourned at 10:55.

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX B

DRR

APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

WITNESS STATEMENTS & RELEASES
APPENDIX B
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

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WITNESS STATEMENTS & RELEASES
APPENDIX B
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

APPENDIX B

WITNESS STATEMENTS AND RELEASES

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The presentation of witness statements is in order of importance to the incident as determined by the Task Panel 12 (Witness Statements).

INDEX OF WITNESSES
STATEMENTS ENCLOSED

Number	Name	Organization	Position	Location During Accident
1	Babbitt, Donald O.	NAA	Project Engineer, Pad Leader	Adjustable Level A8, Service Structure
2	Gleaves, James D.	NAA	Mechanical Lead Technician	Adjustable Level A8, Service Structure
3	Curatolo, Lewis	NAA	Project Engineer, Pad Leader	*Adjustable Level A8, Service Structure
4	Reece, L. D.	NAA	Systems Technician	Adjustable Level A8, Service Structure
5	Hagar, Richard A.	NAA	Systems Technician, (Electrician)	Adjustable Level A8, Service Structure
6	Bachand, Richard L.	NAA	Systems Technician	Adjustable Level A8, Service Structure
7	Clemmons, Stephen B.	NAA	Systems Technician	Adjustable Level A8, Service Structure
8	Cromer, James Earl	PAA	Elevator Technician	200-foot Level, Umbilical Tower
9	Pleasant, Joseph H.	NAA	Systems Technician	Adjustable Level A8, Service Structure
10	Davis, Bruce W.	NAA	Systems Technician	Adjustable Level A8, Service Structure
11	Hickenbottom, Friend Dale	NAA	Systems Technician	Adjustable Level A8, Service Structure
12	Hawkins, Jerry W.	NAA	Systems Technician	Adjustable Level A8, Service Structure
13	Brown, W. Donald	NAA	Mechanical Inspector	Command Module - Adjustable Level A8
14	Owens, Jessie L.	NAA	Systems Engineer	Adjustable Level A8, Service Structure
15	Hedlund, Robert C.	NAA	Systems Technician	Adjustable Level A8, Service Structure
16	Markovich, John E.	NASA	QC Inspector	Adjustable Level A8, Service Structure

* Left Adjustable Level A8 at 1730. Returned to relieve Babbitt at approximately 1838.

17	Stoeckl, Joseph L.	NASA	QC Inspector	Adjustable Level A8, Service Structure
18	Rogers, Henry H., Jr.	NASA	QC Inspector	Adjustable Level A8, Service Structure
19	Journey, Creed A.	NAA	Electrical Leadman	Adjustable Level A8, Service Structure
22	Schneider, William J.	NAA	GSE Technician	Adjustable Level A7, Service Structure
21	Howard, Dave E.	NAA	Systems Technician	Adjustable Level A7, Service Structure
22	Scott, J. C.	NAA	QC Inspector	Adjustable Level A7, Service Structure
23	Bass, Robert I.	NAA	Systems Technician	200 Foot Level, Umbilical Tower
24	McConnell, John C.	NAA	GSE Technician	Umbilical Tower - 190 Foot Level
25	Belt, Burt B.	NAA	GSE Leadman	Elevator, 2nd Level, Pad 34
26	Rackleff, George W.	NAA-Tulsa	Systems Technician	Adjustable Level A7, Service Structure
27	Williams, Samuel	NAA	GSE Technician	Adjustable Level A7, Service Structure
28	Rooker, Forrest R.	NAA	GSE Technician	Adjustable Level A7, Service Structure
29	Wingfield, William H.	NAA	GSE Electrical Technician	Adjustable Level A5
30	Nelson, Marvin L.	NASA	QC Inspector	Adjustable Level A7, Service Structure
31	Mitchell, Patrick E.	NASA	QC Inspector	Adjustable Level A7, Service Structure
32	Deaver, William C.	NAA	Electronic Technician	Adjustable Level A7, Service Structure
33	Medcalf, Willis M.	NAA	Mechanical Technician	Elevator (3rd level going up to A8) Complex 34
34	Foster, Robert C.	NAA	QC Inspector	Complex 34 Fuel Area
35	Chauvin, Clarence A.	NASA/KSC	Test Conductor	Acceptance Checkout Equipment, Room 1, MSO Bldg.

36	Schick, William H.	NASA/KSC (DLO)	Assistant Test Supervisor	Test Supervisor's Console LCC 34 Blockhouse
37	Propst, Gary W.	RCA	Technician, OTV, Control Racks	Communication Control Racks LC 34 Blockhouse
38	Caswell, Alan R.	RCA	Communications Controller	Communication Control Racks LC 34 Blockhouse
39	Slayton, Donald K.	NASA/MSC	Director of Flight Crew Operations	Astronaut Console – LCC 34
40	Cain, Daryl O.	NAA	Spacecraft Test Conductor (017)	Acceptance Checkout Equipment Room 2, MSO Bldg.
41	Jones, Donald R.	NASA/KSC	Chief, S-IVB, Electrical Systems	LC 34 Blockhouse, VIP Room
*42	Eybel, Charles G., Jr. and Rubio, Jose Manuel	GE	Technical Audio Monitors	CIF Building
43	Jorolan, Albert E.	NASA/KSC	LVO Measuring Instrumentation Engineer	LC 34 Blockhouse
44	West, LeRoy G.	NAA	Spacecraft Technician	LC 34, Level A-8 at Ingress
45	Burch, James A., Jr.	PAA	Fireman	Cape Kennedy Fire Station
46	Mooney, James C.	PAA	Asst. Chief, Fire Dept.	Cape Kennedy Fire Station

INDEX OF WITNESSES STATEMENTS IN GENERAL FILE

A. T.V. MONITORS

Name	Organization	Position	Location During Accident
Allen, Ernest E.	Chrysler	Supervisor	LC 34 Blockhouse
Anderson, Robert L. III	Chrysler	Technician	LC 34 Blockhouse
Barwick, Dean E.	NASA/KSC	Flight Crew Systems Engineer	LC 34 Blockhouse
Bishop, Charles M.	Chrysler	S-IB Events Display Console Monitor	LC 34 Blockhouse
Blasky, M.	Douglas	Associate Engineer Scientist	CIF Building Room 307
Blocker, R. D.	Douglas	S-IVB Stage Historian	LC 34 Blockhouse
Brinda, W.	Douglas	Engineer, Measuring Panel Monitor	LC 34 Blockhouse
Broadbent, Joseph W.	Chrysler	Console Operator	LC 34 Blockhouse
Brown, William O.	Chrysler	OIS Monitor	LC 34 Blockhouse
Brunais, Ellsworth G.	Chrysler	Flight Control Console Monitor	LC 34 Blockhouse
Bunyak, R. S.	Douglas	Propulsion Panel Monitor	LC 34 Blockhouse
Carothers, Dale	NASA/KSC	Spacecraft Test Conductor	ACE Control Room #1 MSO Bldg.
Cheesborough, Richard S.	NASA/KSC	ST-184-M Systems Engineer	CIF Building Room 307
Childers, Leonard H., Jr.	Chrysler	Monitor Swing Arm Panels	Complex 34 Trailer 1-048
Coleman, Gerald C.	Douglas	Branch Chief Development Engineer	LC 34 Blockhouse
Conely, F. E.	Douglas	S-IV B Test Conductor	LC 34 Blockhouse
Coonce, James M.	NASA/KSC	Operator Console A4	LC 34 Blockhouse
Dillon, James E.	Chrysler	ECS Technician	LC 34 Blockhouse

Donnelly, Paul C.	NASA/KSC	Launch Operations Manager	LC 34 Blockhouse
Eddy, Robert W.	Chrysler	Monitor, Firing Panels	LC 34 Blockhouse
Edson, William	NAA	Test Conductor	ACE Control Room 1 MSO
Elliott, John G.	Douglas	Supervisor, IB, Mechanics & Reliability	CIF Building
Eri, Donald G.	RCA	Manager RCA Operations LCC 34 and 37	LC 34
Gaskins, R. B.	NASA/KSC	Test Project Engineer (S/C 017)	Observation Room 2 MSO
Gay, Charles D.	NASA/KSC	Chief, Spacecraft Test Conductor	LC 34 Blockhouse
Gehres, Charles E.	Chrysler	Technician	LC 34 Blockhouse
Grant, Fred C.	Douglas	Associate Engineer Scientist	CIF Building Room 307
Gruene, Hans F. Dr.	NASA/KSC	Director, Launch Vehicle Operations	LC 34 Blockhouse
Harris, Robert V.	Chrysler	Technician	LC 34 Blockhouse
Hoenstine, T.V.	IBM	I.U. Measuring and Tracking Panel Operator	LC 34 Blockhouse
Jatulso, A. J.	Douglas	Electronics Supervisor	LC 34 Blockhouse
Jolly, Dennis M.	NAA	Environmental Control System Engineer	ACE Control Room 1 MSO
Jumpa, J. J.	GE/ASD	ACE Display Monitor	LC 34 Blockhouse
Kapryan, Walter J.	NASA/MSC	Assistant Apollo Program Manager	LC 34 Blockhouse
Kelley, James A.	NASA/KSC	Monitor TV Console	LC 34 Blockhouse
King, John W.	NASA/KSC	Chief Public Information	LC 34 Blockhouse
Kleinschmidt, C1L.	Douglas	Group Engineer - ORD/HYD	LC 34 Blockhouse
Kranzfelder, William J.	AC Electronics	Associate Project Engineer (G&N)	ACE Control Room 1 MSO
Kuznicki, Henry S.	NAA	Test Conductor	ACE Control Room 1 MSO

Lealman, Roy E.	NASA/KSC	Electrical Engineer	LC 34 Blockhouse
Lee, Chet M.	NASA Hqs.	Observer	LC 34 Blockhouse
Levetto, Mario J., Jr.	Chrysler	Technician ECS	LC 34 Blockhouse
Linsday, Thomas H. Jr.	NAA	Lead Engineer - Procedures	LC 34 Blockhouse
McDonald, Randolph D.	Chrysler	Technician	LC 34 Blockhouse
McCreary, Martin E.	NASA/KSC	SII Electrical Systems	LC 34 Blockhouse
McNally, Edward	Chrysler	Swing Arm Electrical Design Monitor	CIF Room 307
McNeely, Maurice L.	Douglas	Mechanical Engineer	LC 34 Blockhouse
Martin, Virgil M.	Chrysler	Technician	LC 34 Blockhouse
Mason, Lyman, H.	Chrysler	Electrical Monitor	CIF Room 307
Mercier, Alfred B.	Chrysler	Console Operator	LC 34 Blockhouse
Meyer, George C.	PAA	Pad Safety	LC 34 Blockhouse
Miller, K. J.	NASA/KSC	Electrical Engineer	OIS Monitor LC 34
Monshor, Raymond M.	Chrysler	Technician	LC 34 Blockhouse
Moser, Robert E.	NASA/KSC	Apollo/Saturn Test Manager	LC 34 Blockhouse
Neely, R. D.	Chrysler	Technician	Firing Room LC 34 Blockhouse
Nelson, Isaac H.	Chrysler	Water Control Panel Operator	LC 34 Blockhouse
Orman, Donald L.	NASA/KSC	Engineer, G&C	LC 34 Blockhouse
Page, George F.	NASA/KSC	Test Supervisor	LC 34 Blockhouse
Parker, Marion, J.	Chrysler	Fluid & Pneumatics Group Electrical Unit	CIF Room 208
Payne, Viron E.	NASA/KSC	Test Support Controller	LC 34 Blockhouse
Peacock, Max J.	Chrysler	S-IB Test Conductor	LC 34 Blockhouse
Perry, Earl M.	Chrysler	Monitor, Propellant Event Display Panel	LC 34 Blockhouse

Petrone, Rocco A.	NASA/KSC	Director of Launch Operations	LC 34 Blockhouse
Ragusa, James M.	NASA/KSC	Engineer (Egress Committee)	LC 34 Blockhouse
Rengers, William C.	Chrysler	Monitor, SIB Propellant Dispersion Panel	LC 34 Blockhouse
Rockwell, Richard G.	Chrysler	Procedure Coordinator	LC 34 Blockhouse
Roosa, Stuart A., Capt.	NASA/MSC	Astronaut	LC 34 Blockhouse
Sassard, Jack P.	FEC	Technician	LC 34 Blockhouse
Schiedel, Gerald F.	NASA/KSC	Test Conductor, Spacecraft 017	ACE Control Room 2 MSO
Scoville, Donald A.	NASA/KSC	Mechanical Systems Engineer	LC 34 Blockhouse
Siskind, Jay S.	NASA/KSC	Electrical Systems Engineer	LC 34 Blockhouse
Smith, George E.	Chrysler	Power Supply & Launch Sequence Panel Operator	LC 34 Blockhouse
Smith, Joe R.	NASA/KSC	Staff/Director of Information Systems	LC 34 Blockhouse
Smith, Wallace S.	Chrysler	Technician	LC 34 Blockhouse
Talone, John J.	NASA	Program Coordinator with MSFC	CIF Building Room 307
Terry, James F.	NASA/KSC	Guidance & Control Engineer	LC 34 Blockhouse
Toback, D.S.	IBM	Technician, Telemetry	LC 34 Blockhouse
Turner, Charles A.	General Electric	Egress Committee	LC 34 Blockhouse
Turner, John T.	NASA/KSC	Flight Comp. Systems Engineer	LC 34 Blockhouse
Weaver, Billy H.	Douglas	Test Planning and Evaluation	CIF Buidling Room 307
Williams, Michael F.	NAA	Flight Test Engineer	LC 34 Blockhouse
Wilson, Virgil C.	Chrysler	Console Supervisor	LC 34 Blockhouse
Yount, Lawrence H.	Chrysler	Manager, Launch Systems	LC 34 Blockhouse

B. AUDIO WITNESSES

Name	Organization	Position	Location During Accident
Barber, Chester E.	Chrysler	Technician	LC 34 Service Structure 1st Floor West Side
Branch, Robert B.	Chrysler	Acting SIOT	LC 34 OAT Room 152-foot Level
Crane, John D.	Douglas	Electronics Tech.	LC 34 116-foot Level
Daniher, Pete M.	Douglas	Vehicle Checkout Engineer	LC 34 Measuring Station
Eldridge, Robert T.	Chrysler	Technician	LC 34 116-foot Level
Gillespie, Dallas K.	Chrysler	Assistant SIOT	LC 34 OAT Room 152-foot Level
Ham, Edwin J.	Chrysler	Technician (SIOR Recorder Operator	LC 34 OAT Station 152-foot Level
Kelley, Dean W.	Chrysler	Technician	LC 34, 152-foot Level
Kelley, John E.	Chrysler	Technician Umbilical Eject Test	LC 34 88-foot Level
Kemppainen, Willard K.	NASA/KSC	Engineer (Egress Monitor)	LC 34 Blockhouse
Leckie, G.E.	IBM	Technician	LC 34 IU OAT Station
Lindemann, Vincent J.	Chrysler	Flight Control Recorder Operator	LC 34 Blockhouse
Martin, Obrey E.	Chrysler	Technician	LC 34, Support Bldg. Room 123
Matson, Claude D.	Chrysler	Technician	LC 34, 116-foot Level
Pendleton, Philip L.	Chrysler	Technician	LC 34 Blockhouse
Perkins, William J.	Chrysler	Technician	LC 34 Measuring Station
Rogers, Lyman F.	NASA/KSC	SI Quality Surveillance	LC 34 House Trailer
Roof, Jesse M., Jr.	Douglas	Engineer, GSE	LC 34 Level A-4 outside IU door
Schlict, Wilber G.	FEC	Technician	LC 34, AGCS Area

Tipton, Charles J.	Douglas	Electrical Technician	LC 34, Level A-4 Near forward interstage
Whitaker, Billy B.	Chrysler	Technician Monitor OIS	LC 34, AGCS Trailer 609
Whitehead, Claudius D. III	Chrysler	Technician RF &TM	LC 34

C. RELATED AREAS

Name	Organization	Position	Location During Accident
Aderhold, T.R.	FEC	Telemetry Technician	CIF Building Room 291
Anderson, Deal L.	Bendix	Engineering Specialist (0_2)	LC 34 Umbilical Tower 220-foot Level
Barnum, George V.	Douglas	Operations Engineer	LC 34, outside aft interstage of Launch Vehicle
Batts, Bruce H.	PAA	Crew Chief, Fire Dept.	PAA Fire Station
Beavan, Harry E.	PAA	Elevator Technician	LC 34, Ground Level Umbilical Tower
Bilbrey, H.F.	PAA	Sgt. Security Police	LC 34 Level A-4
Blankenship, James R.	PAA	Fireman	PAA Fire Station
Bohlmann, R.R.	NASA/KSC	Communications Engineer	ACE Control Room 1 MSO
Brandon, R.E.	NAA	Power and Sequential Engineer	ACE Control Room 1 MSO
Bruckner, H.P.	Bendix	Manager, Support Branch	Unknown
Cain, James L.	NASA/KSC	Q C Inspector	LC Q C Trailer
Caris, Robert D.	NAA	Technician	LC 34 1st Level
Colevell, William E.	NAA	Technician	Home
Creighton, Henry C.	NASA/KSC	Project Engineer	VIP Room of Control Room 1 MSO Building
Darnell, Burnard E.	PAA	Security Police	LC 34 Main Gate
Dawes, Benny L.	PAA	Fireman	PAA Fire Station
Dike, J.L.	Douglas	Propulsion Engineer	LC 34 inside SIVB Aft Interstage

Fannin, Lionel E.	NASA/KSC	Mechanical Engineer	LC Blockhouse Console 8A
Fultz, James D., Jr.	NAA	Spacecraft Technician	LC 34 Level A8 at Ingress
Gallagher, Martin E. Dr.	PAA	PAA Doctor	PAA Cape Dispensary
Goodwin, Gewin H.	NAA	Technician	LC 34 - Level 7
Gorman, George W.	Chrysler	Q C Inspector	LC 34 Level A4
Gornto, Jack P.	PAA	Asst. Chief Fire Department	PAA Fire Station
Guidry, Mark	NASA/KSC	Electrical Sequential Systems Engineer	ACE Control Room 1 MSO
Hanna, Paul R.	PAA	Fireman	PAA Fire Station
Hennigan, Thomas R.	PAA	Security Policeman	LC 34 Ground Level West Side
Hinton, J.H.	Bendix	Manager, Propellant Syst. Component Dept.	Laboratory
Hipp, W.L.	PAA	Chief, Fire Department	Home
Hughes, Maynard S.	PAA	Supervisor	LC 34, Umbilical Tower 70' Level
James, George H.	NASA/KSC	Q C Inspector	Ground Level of Launch Structure
Jennings, J.B.	Douglas	Engineer Scientist	LC 34 Inside Launch Vehicle aft interstage
Jones, Ronald H.	Chrysler	ECS Technician	LC 34 Service Structure ECS Room
Kincaid, Randal L.	Douglas	Electronic Technician	LC 34 Blockhouse
McMillan, Kenneth C.	PAA	Assistant Chief, Fire Dept.	PAA Fire Station
McMyler, William F.	Bendix	Navigation and Control Test	CIF Building Room 307
Mills, Edmund B., Jr.	Douglas	Electrical Leadman	LC 34 inside Launch Vehicle aft interstage
Minnich, William T., Jr.	NAA	Spacecraft Technician	LC 34 Level A8 at Ingress
Moody, Samuel P., Jr.	NAA	Environmental Control System Supervisor	Office MSO Building
Moore, Dan L.	Douglas	Missile Technician	LC 34 inside Launch Vehicle aft interstage

Neal, Cecil E.	PAA	Crew Chief, Fire Department	Enroute from LC 37 to Fire Station
Olson, R.D.	Douglas	Electronic Technician	LC 34 Inside Launch Vehicle aft interstage
Ostiguy, J.J.	NAA	Communication Engineer	ACE Control Room 1 MSO
Plomer, Milt J.	Douglas	Section Chief, Structural Mechanical	LC 34 Blockhouse
Pride, Jim	IBM	Measuring Technician	LC 34 Blockhouse
Rector, Murray M.	PAA	Fireman	Cruising run crew
Rink, Elmer B.	Bendix	Propellant Sampler	Home
Salyer, Walter D.	NASA/MSC	Suit Technician	LC 34 Trailer
Scarborough, Robert K.	PAA	Pad Safety	N/E Corner of LC 34 Pad Area
Schmyser, Clayton F.	Chrysler	Technician Leadman	LC 34 Service Structure 152-foot Level
Sheeley, Vester	NAA	Weight Engineer	LC 34 Level A8 at Ingress
Sutton, Cermon S.	NASA/KSC	Q C Inspector S-IB	Launch Complex 37
Vallin, Jose	NAA	Electrical Systems Engineer	Office MSO Building
Van Hooser, John C. Jr.	NASA/KSC	Technician-Biomed.	ACE Control Room 1 MSO
Vaughn, Charles M.	NASA/MSC	Engineer, RASPO/MSC	Location Unknown
Warner, Alonzo E.	NAA	Electrical Power Systems Engineer	ACE Control Room 1 MSO
Watts, Wilburn Virgil	Douglas	Inspector, Missile Field	LC 34 inside Launch Vehicle aft interstage
Wilde, Walter L.	Douglas	Electrical Technician	LC 34 inside Launch Vehicle aft interstage
Wisenbaker, Harvey M. Jr.	Chrysler	ECS Technician	LC 34 Service Structure ECS Room
Wright, Edward E. Jr.	NASA/KSC	Environmental Control Systems Engineer	ACE Control Room 1 MSO
Yon, Ted Jr.	NAA	Supervisor Mechanical Systems	White Room during Ingress

D. MISCELLANEOUS

Name	Organization	Position	Location During Accident
Abrams, Robert D.	Chrysler	Launch Operations Inspector	Complex 34 Launcher
Acuna, R.	Chrysler	Launch Operations Inspector	LH_2 Facility
Adams, John P.	Chrysler	Station Patching/ Oscillograph Monitor	Blockhouse 34, Floor 1
Adrian, Kenneth R.	Chrysler	Measuring System Engineer (RIME)	Blockhouse 34, Rack C-24
Albright, Charles G.	FEC	Technician	Blockhouse 34 2nd Floor EA Recorder 1
Allen, R. H.	PAA	Security Police	LC 34 Blockhouse
Allen, Ronald D.	Chrysler	Quality Surveillance	Complex 34, Vehicle Mech. Off.
Allshouse, Dennis W.	Chrysler	Structure RF Technician	Service Structure, RF Room
Alva, Martin	Chrysler	RF Unit Supervisor	Blockhouse 34, Floor 1
Arlotti, Elio	Bendix	Laboratory Technician	At Home
Arrington, H. M.	Bendix	Technician	At Home
Avery, Charles B.	Chrysler	Support Engineer	Complex 34, Support Bldg.
Ayling, William T.	Chrysler	Launch Branch Inspection Propellant Networks	Complex 34 Inspection Trailer
Baer, John D.	Chrysler	Launch Operations Inspector	Complex 34, PCD
Bailey, James A.	Douglas	Flight Control Engineer	LC 34 Blockhouse
Ball, George D.	NASA/KSC	Technician	At Home
Ball, Melvin B.	Chrysler	Magnetic Tape Recorder Operator	Blockhouse 34, GSE Station
Banks, Samuel B.	Chrysler	Trailing Wire Recorder Operator	Blockhouse 34 C-17

Barkdoll, Milton E.	Chrysler	Monitor Hydraulic Recorders on SIB	Blockhouse 34 Firing Room
Baron, Thomas Ronald	N/A		N/A
Barnes, Harold F.	NASA-KSC	Q C Inspector	LC 34 Blockhouse
Barrow, John M.	NASA/KSC	Q C Inspector	LC 34, LVO Quality Trailer 254
Bassett, Paul J.	Chrysler	Supporting Test MGSE	Service Structure 17' Level
Bauserman, C. R.	NAA	SPS Engineer	ACE Control 1 MSO
Bayless, D. A.	Douglas	Engineer Scientist	LC 34 Blockhouse
Beagley, Richard C.	Bendix	Systems Safety Supervisor	Left Complex for Dinner
Beale, W. David	NASA/KSC	Instrumentation Engineer	LC 34 Computer Room
Becker, Donald E.	Bendix	Chemist	Lab. Building H5-994
Bedsole, H. D.	NAA	Technician	LC 34 188-foot Level
Bell, C. H.	IBM	BUTM Oscillograph	Blockhouse 1st floor RF station
Bennett, John	Douglas	Branch Chief	LC 34 Operations Office
Benton, Edward G.	Bendix	Technician	South Center side of 4th adjustable level (34)
Benziger, Ernest T.	Chrysler	Launch Operations Inspector	Complex 34, ECS Bldg.
Bielling, R.	IBM	AGCS Stabilizer Panel Monitor	AGCS
Birch, Ken W.	Douglas	Associate Supervisor	LC 34, Operations Office
Bitterling, M. D.	Douglas	Group Engineer	LC 34 Blockhouse
Blocher, Richard H.	Bendix	Foreman	Bldg. 3-66220 (Cape)
Bolster, Donald T.	Chrysler	Work Order Control	Complex 34, Trailer 169
Bond, Raymond H.	Chrysler	Chrysler Test Office	Complex 34, Support Bldg.
Boot, Clifford O.	Chrysler	Group Leader, Technical Documentation Unit	Complex 34, Support Bldg.
Borland, Thomas	IBM	Mechanical Systems Technician	LC 34, Mechanical Trailer 641

Braun, James E.	Bendix	Quality Assurance Technician	Complex 34/37
Bouwsma, William J.	Chrysler	DEE-6	Blockhouse 34, Floor 2
Brecken, E. R.	Douglas	Engineer Hydraulics Panel Operator	LC 34 Blockhouse
Bryan, Frank	NASA/KSC	Electrical Engineer	LC 34 Blockhouse
Bretzius, Edward D.	Chrysler	Vehicle Measuring Unit Supervisor	Service Structure, Measuring Station
Brewer, Charles W.	PAA	Security Police	LC 34, 27-foot level of Service Structure
Brown, Donald L.	Chrysler	Field Technician in MSAU	Complex 34, Support Bldg.
Brown, Julius	Chrysler	Battery Attendant	Complex 34, AGCS
Bruce, David L.	Bendix	Propellant Sampler	At Home
Buchanan, D. E.	IBM	Stabilizer Panel Monitor	LC 34, Rack B57, Stabilizer
Bumgardner, Albert	NAA	Mechanical Technician	LC 34, Service Structure Elevator, bottom
Burke, Edwin L.	Chrysler	Engineer, S1B Airborne Networks	Service Structure, Floor 2
Burlington, D.	IBM	Technician	LC 34, AGCS
Burmeister, Gerald A.	Douglas	Propulsion Engineer	Umbilical Tower, 100-foot Level
Burns, Robert	FEC	Technician	At Home
Byers, Andy	Douglas	Mechanical Technician	LC 34, Umbilical Tower, 10th Level
Byrd, Herman C.	NAA	Technician	ACE Control Room 2, MSO Building
Byrd, William R.	Bendix	Systems Safety Supervisor	Complex 37
Call, John E.	Chrysler	Launch Crew Manager	Blockhouse 34, VIP Room
Carlson, Norman M.	NASA/KSC	SI Test Operations Branch Chief	LC 34, Blockhouse Firing Room, Console A-12
Carlson, R. D.	Douglas	Electronics Propulsion Coordinator	LC 34, Blockhouse, 4B Firing Room
Carnes, Thomas H.	Chrysler	AGCS Networks Engineer (AINW)	Blockhouse 34, Power Racks

Carnley, Macey H.	Chrysler	Special Systems	Complex 34, Support Bldg.
Carpenter, Warner H.	Chrysler	Q C Inspector	Service Structure, 152-foot Level
Cesare, Donald E.	Douglas	Lead Man Mechanic	LC 34, SS, 116-foot Level
Chaille, William N.	Bendix	Technician	At Home
Chaitoff, Milton	Chrysler	DRSC GSE Ground Station	Blockhouse 34, Floor 1
Chambers, Milton	NASA/KSC	Chief, Gyro and Stabilizer Systems Branch	CIF Building
Charvet, Andre John	Douglas	Technician	LC 34, SS, OAT Room
Clements, R. D.	NASA/KSC	Engineer	LC 34, Support Bldg., Room 129
Clifford, Harold S.	Douglas	Engineer Scientist	LC 34 Blockhouse
Cobrin, R.	IBM	Technician	LC 34, Stabilizer System B56
Collier, J. G.	FEC	Shift Supervisor	CIF Building, Room 297
Collins, William C.	Douglas	Electronics Technician	LC 34, SS, Measuring Station
Comptom, R. L.	IBM	Technician	LC 34, Ground Computer. AGCS
Conner, R. P.	Douglas	Associate Engineer	LC 34 Blockhouse
Conrad, Harold E.	Chrysler	Engineer	Complex 34, DEE-6
Cook, Ross L.	IBM	BUTM FM FM System Monitor	LC 34, BUTM FM/FM Monitor
Cooley, Dudley M.	Chrysler	Standby Relief Operator, Firing Room	Complex 34, Support Bldg.
Correll, Carl C.	Chrysler	Field Technician (Valve Lab)	Complex 34, Support Bldg.
Cortez, Romo V.	NASA/KSC	Telemetry Technician	LC 34, Blockhouse TM Ground Station
Cottingham, Robert R.	FEC	ECS Measuring Monitor	Blockhouse 34, Rack G54
Cressman, John H. P.	NASA/KSC	Q C Inspector	LC 34, Trailer 1-254
Crosswell, A. L.	NASA/KSC	Measuring Engineer	Service Structure Measuring Station

Cuchens, James K. Jr.	Bendix	Life Support Technician	South Center of 4th Adjustable Level (Complex 34)
Dahlgren, Richard S.	Douglas	Checkout Engineer	LC 34 Blockhouse
Dasse, H. D.	PAA	Security Police	Security Headquarters
Dean, John O.	Bendix	Propellant Mechanic	Spaceline Shop - Complex 34
Dearth, Alfred E.	Chrysler	Vehicle Inspection Supervisor	Complex 34
Demco, Alan	NASA/KSC	Instrumentation Technician	LC 34, Blockhouse, DDAS Ground Station
DiGiorgio, George R.	Chrysler	Pneumatics System Engineer GSE	Complex 34, AGCS
Dobbs, Bruce S.	Douglas	Group Engineer, Electronics	LC 34 Blockhouse
Drott, Art G.	Douglas	Engineer Scientist	LC 34 Blockhouse
Dryden, Guy	IBM	Technician	CIF Building, Room 307
DuPriest, W. R.	Bendix	Acting Foreman	At Home
Durnin, Chester W.	Chrysler	S1B Vehicle Instrumentation Measuring Engineer	Service Structure, Measuring Station
Dybevick, Lowell H.	Douglas	Associate Engineer/ Scientist	CIF Building
Ebbert, Carl S.	Chrysler	Launch Operations Inspector	Complex 34, Support Bldg.
Edgar, Lawrence A.	Chrysler	Simulated Propellant Loading, LOX System	Blockhouse 34, LOX Racks
Edlund, L. R.	Douglas	Engineer/Scientist	LC 34 Structural Mechanical Trailer
Elder, J.	IBM	Technician	LC 34, IU Doorway
Edmunds, Edward C., Jr.	Chrysler	ESE Measuring Unit Supervisor	Blockhouse 34, C-19
Ellis, W. P.	IBM	Technician	LC 34, Blockhouse 1st Floor, Ground Computer
Ely, George W.	NASA/KSC	Guidance and Control Technician	CIF Building, Room 307

Evans, Ralph M.	Chrysler	Launch Operations Inspector Unit Supervisor	Complex 34, Trailer 1-069
Evans, Raymond T., Jr.	NASA/KSC	Propulsion and Mechanical Technician	LC 34, Level A-4
Evitt, Johnnie E.	Bendix	Operator of 0_2 Conditioning System	At Home
Evjen, J.	IBM	Technician	LC 34, Blockhouse, 1st Floor, Ground Computer
Fairman, J. W.	NAA	Technician	LC 34, Level A-6
Fickey, Edsel W.	Bendix	Chief Chemist	At Home
Ford, Francis B.	Bendix	Quality Assurance Technician	At Home
Forknall, George	Bendix	High Pressure Mechanic	At Home
Foster, J. S.	PAA	Pad Safety Supervisor	At Home
Fox, Beecher, H.	Chrysler	Electrician	Complex 34, ECS Breaker Control Room
Fredlock, Armistead III	NASA/KSC	Telemetry Technician	LC 34, Blockhouse, DDAS Area
Freeze, Daniel S.	Douglas	Engineer/Scientist	LC 34 Douglas Electronics Trailer
Fritz, Richard J.	Douglas	AGCS Technician-Guidance Control System	LC 34 AGCS
Frost, J. C.	General Elec.	Quality Control Specialist	Operations Mobile Trailer Located South of the Blockhouse
Furr, Glynn R.	Chrysler	Operator & Monitor TM Receiving Equipment	Blockhouse 34, TM Checkout Station
Galasso, Vincent F.	Chrysler	Vehicle Networks Electrical	Service Structure, 27-foot Level
Gavazzi, Trent D.	Chrysler	Senior Systems Launch and Test Engineer	Service Structure, 27-foot Level
Gay, John B.	Chrysler	Launch Technician Field Supervisor	Complex 34, Support Bldg.
Gerard, Jerry	Douglas	Engineer/Scientist	LC 34, Douglas Electronics Trailer

Gibbons, Thomas D.	Chrysler	AGCS Networks Engineer (AINW)	Complex 34, Launcher
Gibson, John H.	Chrysler	Pull Trailing Wire Measurements Cable After Liftoff +5 Seconds	Complex 34, AGCS Bldg.
Givens, Charles	Bendix	Electronic Technician	Complex 37 Storage Battery
Glusing, W. H.	NASA/KSC	Instrumentation Engineer	ACE Control Room 1, MSO Building
Goard, Garnett D.	Bendix	Propellant Sampler	LAB Building H5-995
Goodwin, Gilbert D.	Chrysler	Monitor Al Engine Actuators During Hydraulic Runs	Service Structure
Gordon, Eleanor L.	PAA	PAA Nurse	PAA Cape Dispensary
Gorrell, Gene P.	Chrysler	Senior Systems Engineer, Launcher & Firing Accessories	Service Structure, 27-foot Level
Graboski, Diana L.	Chrysler	Systems Design Clerk	Complex 34, Support Bldg.
Graham, Ira F., Jr.	Chrysler	Engineer, S1B Airborne Networks	Service Structure, Level 2
Gray, Stanley D.	Chrysler	DEE-3	Blockhouse 34, Firing Room
Grenier, Frederick C.	Chrysler	Launch Operations Inspector	Complex 34, Trailer 1-069
Gustafson, Gary F.	IBM	Oscillograph Monitor, BUTM	LC 34, BUTM Oscillograph Monitor
Hacker, Ford	Chrysler	Field Technician Supervisor (MGSE)	Service Structure, 27-foot Level
Haefner, Gordon J.	Chrysler	Operate DRSC Monitor Tape Recorder	Blockhouse 34, Floor 1
Hanson, R. O.	Douglas	Electronics Technician	LC 34 Blockhouse
Harbaugh, Weldon R.	Chrysler	Unit Supervisor, Launcher & Firing Accessories	Service Structure, 27-foot Level
Harms, Eugene H.	Chrysler	LO_2 Systems Engineer	Blockhouse 34, Console 17
Harman, Joseph F.	Chrysler	Stock Man	Complex 34, Support Bldg.
Hartman, William L.	Chrysler	AGCS Power Technician	Blockhouse 34, Power Racks & PCD

Hawk, Larry A.	Chrysler	Technician/PCD	Blockhouse 34, PCD Area
Hayes, Oliver B.	PAA	Security Police	LC 34, Main Gate
Hayes, Raymond E.	PAA	Security Police	LC 34, Rest Room
Haynes, Bill L.	NASA/KSC	Electrical Systems Engineer	LC 34, Blockhouse
Hazelton, James T.	Chrysler	CITC Backup	Complex 34, Support Bldg.
Heinbaugh, James R.	Chrysler	LH_2 Technician	Blockhouse 34, LH_2 Facility
Heinmiller, Walter R.	FEC	ECS Technician	Complex 34, AGCS
Heins, Don	IBM	Backup Test Conductor	LC 34, Support Bldg, Room 117
Hennig, Robert L.	Chrysler	Measuring System Technician	Service Structure, Floor 2
Heuss, Edward E.	Douglas	Electronic Technician	LC 34 Blockhouse
Hillman, Harry E., Jr.	Chrysler	S1B Telemetry Monitor	Blockhouse 34, Floor 1
Hinkle, R. R.	IBM	Technician	LC 34, Vehicle Networks Office, 2nd Floor
Hoblitzell, Wm. Roy, Jr.	Bendix	Propellant Mechanic	Spacecraft Line Shop - Complex 34
Hoeweler, Harold H.	Chrysler	Field Technician	Service Structure, A-1 Level
Hogston, Wm. Charles	Bendix	Propellant Sampler	Complex 34/47
Hoisington, Robert E.	Chrysler	Monitor S1 Engine Movement During Test	Service Structure
Holland, D. L.	A.C. Electronics	Guidance & Navigation System Engineer	MSOB/ACE Control Room 1
Holmes, Earle C., Jr.	Chrysler	Technician, Propellant Tanking Computer	Complex 34, Support Bldg.
Hopfinger, James L.	NASA/KSC	Quality Control	Service Structure
Hopkins, Robert L.	Chrysler	LO_2 Technician	Complex 34, LOX Trailer
Hopper, U. E.	Bendix	Technician	At Home
Householder, LeRoy W.	Douglas	Electronics Engineer	LC 34 Blockhouse
Howard, J. Ron	Chrysler	Telemetry GSE Operations	Blockhouse 34, Floor 1

Howell, Harold V., Jr.	NAA	Technician	LC 34, Level A-6
Hubble, E. E.	NASA/KSC	Pneumatics Technician	LC 34, Trailer 148
Hughes, K. L.	Douglas	Technician	LC 34 Blockhouse
Hughes, W.	NASA/KSC	LOX Area Inspector	LC 34, LOX Trailer
Hunter, H. D.	NASA/KSC	IU Technician	LC-37
Hutchinson, Bertie O.	Chrysler	Recorder Monitor	Blockhouse 34, Firing Room -
Iniestra, P. O.	GE	ACE Monitor Equipment	LC 34 Blockhouse, 1st Floor
Jackson, Richard F.	Bendix	Special Pneumatics High Pressure Gas Mechanic	At Home
Jacobs, Thomas W.	Chrysler	Support S1B Telemetry Checkout	Complex 34, Trailer 2-045
Jensen, Gerald L.	Chrysler	Project Technician	Complex 34, Trailer 847
Jewell, W. O.	NASA/KSC	Electrical Technician	LC 34
Johnson, Frank O.	GE	Computer Maintenance Specialist	Computer Room 1, MSO Building
Johnson, French E.	NASA/KSC	Electrical Technician	LC 34, Blockhouse
Johnson, Robert W.	Chrysler	QC Surveillance	Service Structure, Measuring Station
Johnson, William A.	Douglas	Electronic Technician	LC 34, Service Structure 27' Level
Jones, C. W.	Chrysler	S1B Stage Electrical Networks Engineer	Service Structure, Floor 2
Jones, Lawrence D.	Bendix	Technician	Titusville Fishing Pier
Joslin, John J.	Chrysler	Monitoring ODOP Ground Station	Blockhouse 34, Floor 1
Joyner, A. L.	NAA	Instrumentation Engineer	ACE Control Room 1, MSO Building
Kaminski, Leonard T.	Chrysler	Launch Operations Group Supervisor	Complex 34, Trailer 1-069
Kammerude, Stanley D.	Chrysler	RP-1 Technician	Complex 34, RP-1
Karli, Richard O.	Douglas	Lead Engineer-SIVB	LC 34 Blockhouse
Keefe, John J.	Douglas	Associate Engineer/ Scientist	LC 34, Service Structure Aft Interstage

Keever, N.	IBM	Technician	LC 34, 124 Stabilizers, Rack B55
Kelley, Donald E.	Bendix	Supervisory Engineer, System Safety Support Department	At Home
Kenny, B.	IBM	Technician	LC 34, Blockhouse, 1st Floor
Kiernan, John	Bendix	Systems Safety Supervisor	At Home
King, John W.	FEC	Technician	CIF Building, Room 297, TM Station
King, Joseph J.	NASA/KSC	Planning Technician	LC 34, Blockhouse
Kirby, R. G.	IBM	Technician	CIF Building, Room 307
Kitchens, T. R.	IBM	IU Ground Electrician	LC 34
Koby, Raymond	Chrysler	Telemetry TRS-1 Station	Blockhouse 34
Koivu, Ray A.	Chrysler	GSE Mechanical Technician	Service Structure, A-1
Kubasko, James	NASA/KSC	Quality Surveillance	LC 34, Service Structure
Lambert, Walter A.	Chrysler	Turn-Off Circuit Breaker	Complex 34, AGCS Area
Lambert, William F.	Bendix	Propellant Mechanic	In Shop - Complex 34
Langston, Gerald R.	FEC	Technician	CIF Building, Datacore Module
Lane, R. E.	PAA	Security Police	Security Headquarters
Laudermilch, Ray H.	NASA/KSC	Telemetry Technician	LC 34, Blockhouse
Lee, Robert E.	NASA/KSC	Instrumentation Technician	LC 34, Office Trailer
Lemmon, Floyd C.	Chrysler	Pneumatics Control System Technician	Complex 34, PCD Area
Lewis, J. E.	IBM	IU Complex Manager	LC 34, 2nd Floor
Lewis, John D.	Bendix	System Safety Supervisor	Driving in Cocoa Beach, Fla.
Lewis, William K.	NASA/KSC	Technician	LC 34 Blockhouse
Lewis, Richard W.	Chrysler	Q C Inspector	Service Structure, A-1

Long, R. G.	NASA/KSC	Chief, Planning & Technical Support	LC 34 Blockhouse, VIP Room
Luke, Rodney C.	Douglas	Mechanic	LC 34, Umbilical Tower, 110-foot Level
Mack, C. J.	PAA	Security Police	At Home
Mahoney, Richard H.	Chrysler	Pneumatics Technician	Complex 34, PCD Area
Maki, Paul W.	Bendix	Propellant Mechanic	At Home
Malkemes, R. F.	Bendix	Senior Engineer, Special Pneumatics Facility, High Pressure Gas Dept.	220-foot Level of Complex 34, Umbilical Tower
Mann, Richard C.	Chrysler	Monitor S1B Telemetry Data	CIF Telemetry Station
Martin, John D.	Bendix	Quality Assurance Technician	Spacecraft Lines Office Complex 34
Martin, John D.	Chrysler	S1B RF/TM System Engineer	Blockhouse 34, Floor 1
McCarthy, Daniel J.	Bendix	Quality Assurance Technician	At Home
McEachern, Charles A.	NASA/KSC	Propulsion and Mechanical Technician	CIF, Room 307
McMechen, Margaret A.	PAA	PAA Nurse	At Home
McRae, Walter LeRoy	Bendix	Propellant Sampler	Driving in Cocoa Beach, Fla.
Meisch, John A.	Chrysler	Assisting Senior Engineer/Test Box	Service Structure, 27-foot Level
Mellott, Douglas W.	NASA/KSC	Guidance and Control Technician	CIF
Miner, James W.	Chrysler	Support Telemetry Checks	Service Structure, A-1
Merrill, K. R.	PAA	Chief, Security Police	At Home
Mook, Gerald L.	Douglas	Lead Engineer/Vehicle Systems	LC 34 Blockhouse
Moors, Dave	IBM	Technician	LC 34, RUBM, Rack C-7
Morrison, Joseph E.	Bendix	Propellant Sampler	Winter Garden, Florida
Muldoon, Raymond	Douglas	Missile Field Checkout Technician	LC 34 AGCS

Mullin, J. T., Jr.	NASA/KSC	Electrical Systems Engineer	LC 34
Munson, Harry G.	Douglas	Supervisor Manufacturing Operations	LC 34 Operations Room
Muys, Paul	RCA	Communications Technician	MSO Bldg. Room 4440
Nadeau, Robert T.	Chrysler	Technician, Vehicle Measuring Station	Service Structure
Nicholson, John L.	PAA	Security Police	Road at N.E. Corner of LC 34
Niedert, Myron A.	Douglas	Engineer	CIF Building, Room 307
Norvell, G. C.	Douglas	Structural Mechanical Engineer	CIF Building
Oberlin, Donald	Chrysler	S1B Hydraulic Pnl. Operator	Blockhouse 34, Rack 44
O'Brien, J. J.	IBM	Technician	LC 34, OAT Room 1521 Level
O'Hara, A. D.	NASA/KSC	LV & Test Ops. Mgr., Saturn 1B	LC 34 Blockhouse
Olsen, Stanley	Chrysler	Supervisor, S1B Vehicle Telemetry	Blockhouse 34, Floor 1
O'Neal, E. H.	Douglas	Mechanical Leadman	LC 34, Mechanical Trailer
Otto, William E.	Douglas	Associate Engineer	LC 34, Service Structure OAT Room, 152' Level
Overstreet, Clyde F.	NASA/KSC	Electrical Systems Engineer	LC 34, Blockhouse
Overton, T. L.	Douglas	Engineer Draftsman	LC 34, Service Structure, 114-foot Level
Parker, Sanford	Douglas	Missile Mechanic	LC 34, Service Structure, 116-foot Level
Payne, W. D.	Douglas	Inspector	LC 34 Blockhouse
Pearson, Charles A.	Bendix	Propellant Sampler	Lab Bldg. H5-995
Penovich, F. R.	NASA/KSC	Guidance & Control Technician	LC 34, Support Bldg.

Perry, William	IBM	Technician	LC 34, Blockhouse RUCP Console
Phyllis, Howard L., Jr.	Bendix	Propellant Sampler	At Home
Pigg, Robert W., Jr.	GE	Computer Maintenance Specialist	Computer Room 1, Bldg.
Pipher, Marvin	Douglas	Lead Engineer - TM & RF	LC 34 Blockhouse
Pirtle, James E.	Bendix	Lab Technician	Lab. Bldg. H5-995
Pittman, William E.	Chrysler	OAT Battery Room	Service Structure, 116-foot Level
Platt, Philip C.	Chrysler	Launch Operations Inspector	Complex 34, AGCS
Ploski, B. T.	IBM	Technician	CIF Building, Computer Room 231
Pomeroy, Norman O.	Chrysler	Lab Technician	Complex 34, Support Bldg.
Pornovets, Michael	Bendix	Propellant Sampler	At Home
Porter, Earl G.	FEC	Tape Recorder Operator	Operating Tape Recorder
Powers, Tim L.	Chrysler	LOX Technician	Complex 34, LOX Trailer
Puckett, Paul E.	Chrysler	Support GSE Operations	Service Structure, 17-foot Level
Rainey, C. R.	IBM	Technician	LC 34, Flight Control Rack B47
Raley, E. O.	NASA/KSC	Instrumentation Engineer	LC 34, Service Structure
Reynolds, E. A.	NASA/KSC	G & N Engineer	ACE Control Rm/MSOB
Ricci, P. A.	Douglas	Senior Engineer-Launch Operations	LC 34, Operations Office
Richards, Charles W.	Chrysler	Mechanical Support	Service Structure, 27-foot Level
Richards, Jerry L.	Bendix	Special Pneumatics, High Pressure Gas Mechanic	At Home
Richards, Ronald F.	Bendix	Technician	At Home
Richardson, F. G.	GE	Project Engineer	Unknown
Rickert, James D.	Chrysler	Monitor Umbilical Housing Eject	Service Structure, A-1
Riddle, Albert L., Jr.	PAA	Security Police	LC 34, Blockhouse

Ridlehoover, J. O.	Bendix	Safety & Security Supervisor	At Home
Ries, Edward E.	Chrysler	Digital Range Safety Ground Station	Blockhouse 34, Floor 1
Ritchie, A.	IBM	Technician	Theodelite Hut-124 Systems
Robelen, Kenneth F.	GE	Quality Control Specialist	MSO Building, ACE Stations 1 & 3
Roberts, Wayne Elton	FEC	Magnetic Tape Recorder Operator	CIF Building, Module II
Robinson, Wilbert L.	Bendix	Systems Safety Supervisor	At Home
Rogers, Perry M.	NASA/KSC	Measuring Branch Technician	LC 34, Blockhouse
Rouse, Carroll R.	NASA/KSC	Electrical Systems Engineer	LC 34, Blockhouse
Rowe, D. O.	NAA	Technician	LC 34, 100-foot Level S. E. of gantry
Ruch, Herbert E., Jr.	Bendix	Engineering Specialist	At Home
Rudasill, Charles H.	Bendix	Foreman	Complex 39A
Rush, Russell D.	Chrysler	LH_2 Technician	Complex 34, LH_2 Facility
Russell, Orlando L.	Chrysler	System Test & Launch Engr. Supv.	Complex 34, PCD Area
Ryder, Barry A.	Bendix	Propellant Sampler	At Home
Sales, Amos H.	Chrysler	Launch Operations Inspector	Complex 34, Liquid Oxygen Fac.
Sample, Carl W.	GE	Decommutation Maintenance Specialist	MSO Building, Computer Room 1
Samples, Robert E.	Bendix	Laboratory Supervisor, Gas Analysis Lab	At Home
Sanders, William M.	Chrysler	Technician, PREV	Blockhouse 34
Santos, Tomas	IBM	Technician	LC 34, Rack B-53 Computer Console
Sapp, L. A.	Douglas	Electronics Technician	LC 34, Service Structure, Forward Interstage
Satterfield, Walter D.	Chrysler	Field Technician	Complex 34, Valve Lab

Sawyer, Arthur L.	NASA/KSC	Electrical Systems Engineer	LC 34
Schlaefer, Bryant C.	Bendix	Propellant Mechanic	At Home
Schoultz, P. A.	NAA	Stabilization & Control	ACE Control Room 1. MSO Building
Shackelford, David A.	Chrysler	RF Technician	Service Structure, A-1
Shoaf, Joseph M.	Chrysler	Recorder Operator Monitor	Blockhouse 34, Firing Room
Secor, Ray L.	Douglas	Mechanical Technician	LC 34, Service Structure, 116-foot Level
Shockley, R. L.	Douglas	Electronics Test Technician	LC 34, Service Structure, 116-foot Level
Short, Jack	NASA/KSC	Q C Inspector	LC 34, Service Structure
Shramko, John Jr.	NASA/KSC	Guidance & Navigation Engineer	LC 34, Blockhouse
Shreves, Dolores C.	PAA	PAA Nurse	PAA Cape Dispensary
Sibley, L. F.	Douglas	Electronics Technician	LC 34 Blockhouse
Simon, Marion	Douglas	Chauffeur	Driver Complex 34, Service Structure, 116-foot Level
Simonelli, R. B.	Douglas	Electronics Engineer	LC 34, Service Structure
Skog, Roy E.	Bendix	Technician	At Home
Sonnenthal, William L.	Chrysler	Engineer	Service Structure, 17-foot Level
Spiller, Henry W.	Chrysler	Launch Operations Inspector	Service Structure, A-2
Solo, Dennis	IBM	Technician	LC 34, Rack B-51 Flight Computer
Staveland, Allen R.	Chrysler	Field Engineer	Complex 34, Support Bldg.
Stelly, J. N.	NASA/KSC	Stabilization & Control Systems Engineer	ACE Control Room 1, MSO Building
Stewart, David D.	Chrysler	SIFC S1B Flight Control Engineer	Service Structure
Stubbe, R. E.	Douglas	Associate Engineer Scientist	At Home

Sudimak, Basil	Bendix	HPG Mechanic	At Home
Szott, Ronald D.	Bendix	Propellant Sampler	At Home
Tatham, Steve	NASA/KSC	Standby Van Driver	MSO Building
Taylor, Edwin R.	GE	Test Operations Engr.	Office, MSO Building
Taylor, P.	IBM	Technician	LC 34, AGCS
Terry, Marvin E.	Chrysler	Senior LC 34 Meas. Sta. Engineer	Service Structure, Meas. Sta.
Theobald, P. O.	IBM	Manager, Measuring & Telemetry Systems	LC 34, Firing Room, Ground Networks Panel
Thawley, John H.	Chrysler	Field Technician	Service Structure, Floor 2
Theofrastou, Perry	IBM	Technician	LC 34, Blockhouse
Thibodeaux, Albert W.	Chrysler	Engineer, Airborne Networks	Service Structure
Thomas, J. L.	FEC	Technician	CIF Building, Module 2 Data Core
Thomas, Palmer S.	PAA	Security Police	LC 34, base of Service Structure
Thomason, James R.	Bendix	Technician	Main Gate of Complex 34
Thompson, Arthur L.	Chrysler	Monitor Hydraulic Recorders/S1B	Blockhouse 34, Firing Room
Thompson, John P.	Chrysler	Support S1B Telemetry Checks	Service Structure, A-1
Thomson, J. C.	NAA	Cryo/Fuel Cell Engineer	ACE Control Room 1, MSO Building
Titler, Philip S.	Chrysler	Air Conditioning Technician	Complex 34, ECS
Torrence, Bernard W.	NASA/KSC	Electronics Technician	
Townsend, Larry S.	Bendix	High Pressure Gas Mechanic	GOX Pad, Complex 34/37
Tribe, John	NAA	RCS Engineer	ACE Control Room 1, MSO Building
Tucker, S. S.	NASA/KSC	Instrumentation Systems Technician	LC 34, Blockhouse

Turner, Charles A.	NASA /KSC	Guidance & Navigation Systems Engineer	CIF Building
Turner, Clark C.	Chrysler	Launch Operations Inspector	Complex 34, PCD Area
Tussler, H. R.	Douglas	Engineer/Scientist	LC 34, Service Structure between A-2 & -4 Levels
Tutwiler, C. W.	Douglas	Section Chief, Saturn Electronics	LC 34 Blockhouse
Tzareff, Paul P.	Chrysler	Support Test Operations, MGSE	Service Structure, 17-foot Level
Van Skaik, Albert L.	Chrysler	RP-1 Technician	Complex 34, Trailer (RP-1)
Vozzola, D. B.	IBM	Measuring Systems Engineer	LC 34, Rack C5
Vreeland, Arthur E. Jr.	FEC	Technician	CIF Building, Data core Module 4
Wakefield, Lester S.	Chrysler	Valve Lab Inspection	Complex 34, Support Bldg.
Walden, Gerald B.	NASA/KSC	Vehicle Measuring Technician	LC 34, Service Structure
Walsh, James P.	Bendix	Propellant Sampler	Complex 34/37
Walters, John R.	Chrysler	Propellant Tanking Computer System	Complex 34, Support Bldg.
Walters, Jurd A.	Bendix	High Pressure Gas Mechanic	Complex 34, 0_2 Conditioning Console
Ware, Edward J.	Chrysler	Chemical Cleaning	Complex 34, Support Bldg.
Washburn, J. E.	IBM	Technician	LC 34, Rack B-52
Watson, James R.	Chrysler	AGCS Ground Networks	Complex 34, AGCS
Wegelin, Wendell	Chrysler	Quality Surveillance	Service Structure, A-1
West, Edward L.	NASA/KSC	Q C Inspector	At Home
Whiteside, C. A.	NASA/KSC	Guidance & Navigations Systems Engineer	CIF Building, Room 307
Whiting, Donald F.	NASA/KSC	Q C Inspector	ACE Control Room 1, MSO Building
Whitson, James T.	Chrysler	Support Plugs-Out Test	Complex 34

Whitt, William B.	Chrysler	Pneumatics System Engineer	Complex 34, AGCS
Williams, Arthur J.	Bendix	System Safety Supervisor	School PTA Dinner
Williams, Carl M.	Bendix	Technician	Main Gate, Complex 34
Williams, Terry A.	Bendix	Propellant Mechanic	At Home
Williamson, E. L.	Bendix	Supervisory Engineer, PSCL Dept., Analytical Laboratory	At Home
Wilson, Dwayne W.	Douglas	Missile Field Test Technician	LC 34, Service Structure, 116-foot Level
Wilson, James C. Jr.	Chrysler	Launch Oprs. Insp. Unit Supv.	Complex 34, Trailer 1-069
Winborn, J. E.	IBM	Technician	LC 34, Blockhouse 1st floor, Ground Computer
Wise, Harry E.	Douglas	Missile Mechanic	LC 34, Service Structure Structure, 116-foot Level
Woodson, Mason C.	Chrysler	S1B Vehicle Electrical Networks	Service Structure, Floor 2
Wright, Roger N.	Bendix	Laboratory Technician	At Home
Wybranowski, Edward W.	Chrysler	LH_2 Panel Operator	Complex 34, LH_2 Auto Load Panel
Yeary, James R.	Douglas	Associate Engineer Scientist	At Home
Young, W.	IBM	Technician	LC 34, Flight Control Room Rack B45

COMMON ABBREVIATIONS AND DEFINITIONS

ACE	Acceptance Checkout Equipment
AFET	Facility Electrical Technician – (CALL SIGN) (AGCS Room)
AGCS	Automatic Ground Control System
APDS	Power Distribution System – (CALL SIGN) (AGCS Room)
B/H, BH	Blockhouse
BPC	Boost Protective Cover
CAST	Astronauts Communications Console – (CALL SIGN)
CIF	Central Instrumentation Facility
C/M	Command Module of the Spacecraft
Comm	Communications and Radio Frequency
CPX	Complex
CSTC	Spacecraft Test Conductor – (CALL SIGN)
CVTS	Space Vehicle Test Supervisor – (CALL SIGN)
ECS	Environmental Control System
EDS	Emergency Detection System
G & N	Guidance and Navigation
GSE	Ground Support Equipment
IDR	Interim Deviation Report
INST	Instrumentation and Telemetry
LC	Launch Complex
LCC	Launch Control Center
LES	Launch Escape System
MILA	Merritt Island Launch Area (now Kennedy Space Center, KSC)
MRCS	Reaction Control System – (CALL SIGN)
NAA	North American Aviation, Inc.

NASA	National Aeronautics and Space Administration
OCP	Operational Checkout Procedure
OIS	Operational Intercommunications System
OTV	Operational Television
PA or P/A	Public Address System
PAA	Pan American World Airways, Inc.
P&S	Power and Sequential
PL or P/L	Pad Leader
PLSS	Portable Life Support System
QC	Quality Control
RCS	Reaction Control System
RF	Radio Frequency
S/C	Spacecraft
SCS	Stabilization and Control System
SCET	Command Module Electrical Technician (Service Structure) (CALL SIGN–A8)
SCMD	Command Pilot – (CALL SIGN)
SCMT	Command Module Mechanical Technician (Service Structure (CALL SIGN–A8)
SFDS	Fluid Distribution System (Service Structure) (CALL SIGN–A7)
SLA	Spacecraft/Lunar Module Adapter
S/M	Service Module
SPAD	Pad Leader – (CALL SIGN)
SPLT	Pilot – (CALL SIGN)
SPS	Service Propulsion System
SSET	Service Module Electrical Technician (Service Structure) (CALL SIGN–A7)
SSRP	Senior Pilot – (CALL SIGN)

STC	Spacecraft Test Conductor
T/C, TC, T.C	Test Conductor
TM	Telemetry
TPE	Test Project Engineer
T SUPER	Test Supervisor
UFET	Umbilical Tower Facility Electrical Technician
VOX	Voice Transmission
W/R	White Room

DONALD O. BABBITT
NAA
JANUARY 28, 1967

I was stationed at the Pad Leader's desk, verifying that per the procedure, support was ready for umbilical pull at T-0. The time period in here I can only estimate as 5 to 15 seconds. I heard on the head set (Channel Black-3) Mr. Chaffee say, "There is a fire in here," (or words to this effect). I ordered the mechanical lead man, Mr. Gleaves, to "Get them out of there" (meaning remove the hatches and get the crew out of the Command Module). I started to turn toward the Communications Box (on my left), when out of the corner of my eye, I saw flame come out from under the boost near the steam duct. I almost completed my turn when I was hit by a concussion or sheet of flame (I don't remember hearing an explosion) and was pushed toward the communication boxes. My next thoughts were to get out of there. (I never had time to notify the blockhouse). I went to the umbilical (White Room) arm, and went across it to the umbilical tower where I encountered three of the spacecraft mechanics and an elevator talker who had a head set. I told the talker to inform the test supervisor that we were on fire and that I need firemen, ambulances, and equipment. With the three mechanics (Messrs. Gleaves, Hawkins, and Clemmons) we grabbed the only CO_2 bottle available and went back to the White Room to try to remove the hatches. The smoke and heat was so intense that we could only spend a short time in the White Room (possibly 1-2 minutes). After several trips back and forth Mr. Gleaves almost passed out due to smoke inhalation so I ordered him to stay out, which he did but for only a short time.

After the smoke had cleared some, I could see that the Spacecraft Technicians and Quality Control (NASA and NAA) had been able to get back into level A-8 and were fighting fires with everything available, so I got some more men and continued as best we could (because of the smoke and heat) to remove the hatches. We attempted to both remove the inner hatch or lower the hatch down inside the Command Module. We were not successful in removing the inner hatch and could only lower the hatch about 75 to 80% of the way because of obstructions. I was at that time only able, again because of the smoke which was considerable, to observe only two of the flight crew but could not recognize who it was. The inner hatch was extremely hot and we could only handle it with the handles attached to the hatch. My observation at the time of hatch removal was that the flight crew were dead and that the destruction inside the Command Module was considerable. After informing the test supervisor of what I had observed (while adhering to security guidelines wherever possible) and continued to direct the crew in putting out the fires. I asked the senior Pan American firemen to specifically check the Launch Escape Motor for hot spots and general heat.

I was relieved by Mr. Curatolo, NAA 1st shift pad leader.

I proceeded down the umbilical tower elevator, met the two NASA doctors and briefed them on what they would find. I then proceeded to the Pan American Dispensary, with a short stop at the NAA Shop Trailer, for treatment and checkup. I was treated for smoke inhalation, flash burns, and eye irritation, and ordered to remain overnight.

I feel that the Spacecraft Crew (Technical, Mechanical, NAA Quality Control, and NASA Quality Control) performed commendably well in this emergency.

I feel that there should be a number of things taken care of immediately by safety from the standpoint of working crew and Equipment Safety.

/s/ Donald O. Babbitt

WILLIAMS: The Pad Leader is on the upper level by the spacecraft. He is more or less in charge of pad operations. He reports back to the blockhouse and who in turn reports back to the control room where the test is being run from. The test is run from the blockhouse and the control room is back here in this building. He was taking direction from the blockhouse or the North American project engineer who is back here. The activities up there fall under his responsibility.

PETRONE: Where would you want him to sit or speak from the microphone? Put him there next to you, Dr. Thompson.

THOMPSON: One thing I think we should say is that the statement that you make will remain in the same -- leave yourself in the same category in keeping all this testimony within the same restraints that have operated up to now. The fact that you have talked to us doesn't relieve you of that obligation.

BABBITT: I understand perfectly.

PETRONE: We cannot hear you.

BABBITT: I have a hoarseness because of smoke damage, so I ask if I can move a little closer. May I speak freely or .....

THOMPSON: Go ahead. Tell us what happened, to your observation.

BABBITT: Well, as the North American pad leader on the 2nd shift, I was stationed at the pad leader's desk. At the time of the incident I was verifying that we were ready at T minus zero for umbilical pull as per the procedures. This is a manual pull and we were checking to make sure all our lines were clear. At the time it had happened, I heard and I can almost definitely state that I believe it was Mr. Chaffee say something to the effect of fire in the command module, fire in the spacecraft, the term fire sticks to me more than anything else. I ordered my mechanical lead man, Mr. Gleeves, to proceed toward the hatch for removing the crew, and started to turn, I was facing the spacecraft. You gentlemen are familiar with the layout up there.

THOMPSON: We have been there.

BABBITT: You know where the pad leader's desk is?

THOMPSON: That the desk with the telephone on it?

BABBITT: Yes, sir.

THOMPSON: You were at the desk?

BABBITT: Yes, sir, I was facing the umbilical at the time.

PETRONE: Were you sitting down?

BABBITT: No, I was standing. I had started to turn toward the comm box to call the blockhouse either on normal comm line or page whichever was open. Out of the corner of my eye I believe I saw which was flame from under the boost protective cover in the area what could be the steam duct and continuing my turn. I never made it to the comm box because at that time more or less over my head I felt a pressure and heat and flame and I never made the call to the blockhouse. My next thoughts were to get out of there as quickly as I could. I proceeded out across the umbilical arm, the walkway there, to where I got to a telephone talker who was at the elevator of a crew standing by which would have been the normal emergency egress test and they had a man stationed there and told him to inform the blockhouse through his channels of what was taking place. I was preceeded out the umbilical arm by three of my mechanics, Mr. Gleeves, Mr. Hawkins and Mr. Clements. From that time on it was - we were spent as quickly as we could, but with the amount of smoke, removing the hatches. I probably could answer questions better than I could speak freely on this. If there is anything specific.

THOMPSON: Let me ask you one question about the full length of time involved between any untoward event and/or enveloping flames. How long a period of time do you think that full action?

BABBITT: I can only guess, sir, there would be a matter of at the most maybe two to three seconds and the time it would take me to turn approximately 90 degrees to the comm box.

LONG: Is this two to three seconds from when you heard Chaffee's voice until you personally felt .....

BABBITT: Yes, sir.

THOMPSON: That is, this means then that the first evidence you had there was anything untoward happening was that voice.

BABBITT: Yes, sir.

YARDLEY: And almost simultaneously you saw this flame coming --

BABBITT: As I was turning I saw it from under the boost cover.

YARDLEY: Two or three seconds after that you felt the big pressure?

BABBITT: Yes, sir. In seeing the flame under the boost cover we, also, having been out there and been at the spacecraft many times when we do a normal cabin pressure check to where the relief valve goes on the cabin, we hear the, I believe I heard and at the same time saw the flame - the normal noise that we hear with this cabin relief valve going with the steam duct. The noise is sort of hard to describe but it is something that we hear all the time and know what is taking place at that time.

MATHEWS: Were you turning --

BABBITT: To my left.

MATHEWS: To your left - but you saw the flames under the boost protective cover and not coming out of the RCS doors?

BABBITT: Right, I would attribute this to be in the area of the steam duct. It would be only speculation for me to say that maybe the command pilot had dumped the cabin or maybe the normal relief valve had dumped.

YARDLEY: You say you hear this relief valve all the time and are familiar with it.

BABBITT: When we are doing a cabin pressure check.

YARDLEY: In other words, it dumps normally at 5 psi differential.

BABBITT: Yes, sir, and its noise that most of us are familiar with having heard it a number of times, not only in the altitude chambers prior to the altitude runs there but also I heard it the same day.

FAGET: That was before you saw the fire or after?

BABBITT: It was before the main flame came. But we - I saw and I heard the venting sound and then as I say I continued my turn and a sheet of flame came towards me.

VOICE: Who did you instruct to go to the hatch opening?

BABBITT: My mechanical lead man, Mr. Gleeves, and as required he takes a crew with him. I understand it was Mr. Clements and Mr. Hawkins also.

THOMPSON: There is, I understand, an override on this relief, the pilot pressure relief that the pilot can use as an automatic relief of pressure, too.

BABBITT: Yes, sir.

VOICE: The pressure relief knot last night were not in the manual order.

YARDLEY: That would indicate that the pressure had built up in a very short time from 16 absolute to say 20?

VOICE: What is this steam tube?

BABBITT: There is a hole coming up it is a duct coming off the ECU -- coming out the side of the spacecraft, and we have a, with a boost cover on, would have a tube inserted in there - to vent this downward.

THOMPSON: There's one impression we got out there, that the flame shot out way over the desk.

BABBITT: Yes, sir.

THOMPSON: With the paper -- did you see that flame. Was it a jet of flame or can you describe it in anyway?

BABBITT: All I saw was flame coming overhead as I was almost turned toward the communications box. My back was more or less, toward the command module. I was turned maybe of a possible 90 degree turn there, we'll say 75 degrees, all I saw flame come overhead and felt the heat and concussion of it.

THOMPSON: The papers on the desk, though, were charred.

BABBITT: Yes, sir.

THOMPSON: The distance is, what do you think, 10 to 12 feet?

BABBITT: I would say it must be 12 feet.

THOMPSON: On a horizontal, on a level with only desk height.

BABBITT: Yes, sir.

THOMPSON: Our question was, it was a rather narrow confined area that got the full extension of the that flame?

BABBITT: As I understand it, I have not been out to the pad since this has happened, as I understand it, but I believe myself and several people who were very near there, the desk, were very lucky to get away.

THOMPSON: They were rather close to the desk despite the fact that the desk itself, the papers on the desk were burned?

BABBITT: Yes, sir.

MATHEWS: I think you have to be careful to assume that was a jet because there are a number of evidences around that are more direct that indicated it was pieces of flaming material that fell in the area.

BABBITT: Might I answer that. My white coat that I had on and my shirt that I had on which were - well, the white coat looked like it had been hit with material or something like this to burn holes in it. My white shirt looks like it would be residue from, the shirt that I had on looks like it would be the residue from the white coat, from being burned as such.

YARDLEY: Like a cigarette ash burn hole?

BABBITT: Yes, sir.

FAGET: There were a number of these holes?

BABBITT: Yes, sir. They were mostly on my right shoulder which as I say, I would be turning to the left. May I illustrate?

VOICE: Why don't you make us a sketch?

BABBITT: I think I can do it assuming the spacecraft is in front of me here and my comm boxes are over here, I was turning, the comm boxes are a little low, so

I was turning down towards those and it was more my right shoulder that was hit with it.

THOMPSON: Where are the desks in relation to where you were standing?

BABBITT: It would have been behind me.

VOICE: Do you have a feeling that this area round you was pretty well filled with flames.

BABBITT: Yes, sir, very much so. I had the feeling that if I stayed low, I could get out all right and I had the feeling, too, that the only direction that I had open to go from there was toward the umbilical arm. It just looked to me, although I honestly can't answer whether I even looked at the other direction - it looked to me that was the only area open for me to go towards.

FAGET: You had on a head set and a hard hat?

BABBITT: I had on a head set and a white hat.

FAGET: And you say you felt pressure on your head?

BABBITT: Yes, sir. I felt a pressure - not as a blast or anything, but a positive pressure to where I was forced toward the comm boxes or towards .... away from the spacecraft.

VOICE: Did this over-pressure last very long?

BABBITT: No, sir, it did not.

(Background discussion)

VOICE: Was the kind of pressure you felt the kind you would feel if someone opened a furnace door? Was it that combination?

BABBITT: Yes sir, more that or the pressure of someone gently but suddenly pushing you. It wasn't a hard pressure or anything of that sort but just a positive pressure.

WHITE: Have you ever lit a gasoline or something in a bottle or bottom of a can and thrown a match in it? Was it that type?

BABBITT: Yes, it was. (Looking at drawing) This would be the umbilical arm. I was standing looking at the umbilical arm, the pad leaders desk being here. I would be facing in this direction when I heard the words, "Fire" and I turned in this direction toward -- which would be the communications boxes, and as I say, the boxes are a little low so I had to bend over slightly to get to them. The umbilical arm being here, I went out this direction to the arm and then out here.

MATHEWS: In other words, you went out past the place where the flame was coming out thru the boost protective cover.

BABBITT: I think - that would be where the white room would be attached. That would be approximately here. The length of the white room here. I would be in this area here. The steam duct. It is, as you face the hatch, it's to the left and below the hatch.

VOICE: Where is the cabin vent valve?

BABBITT: It is right here.

VOICE: Does it come out through the steam duct?

BABBITT: This is what we call the steam duct. It vents through this duct.

PETRONE: The boost protective cover limits might be interesting. Where were the limits of the boost protective cover?

BABBITT: The -- it would be in this general area. I can see it from where I am.

YARDLEY: You didn't see it coming out the side, over there? Right behind the desk?

BABBITT: No, sir, I did not. The limits of the boost cover is the sections that we had on, would be approximately here and say over here.

YARDLEY: But you saw it over on this side?

BABBITT: We saw it here, underneath here, which would be in the general area of the steam duct.

VOICE: Was this the initial thing that you saw?

BABBITT: This was the initial thing that we saw. I saw it as I was turning, which an over pressure would cause the thing to vent.

MATHEWS: When did you hear that? Can you give us any estimate of time between that period and when you first heard the fire signal?

BABBITT: I heard the fire signals, well, you mean as to clock time.

MATHEWS: No, the estimate of how many seconds.
YARDLEY:

BABBITT: In relation to hearing the fire signal. The time it would take me to say to a man standing in front of me, "Get them out" and turn, like that. Whatever length of time that is.

YARDLEY: Was that valve sound a single sound or.....

BABBITT: Sort of a whooshing sound.

MATHEWS: Did it signal more than once?

BABBITT: All I heard was once.

PETRONE: Was there a definite click or just a whoosh?

BABBITT: There is a definite whoosh and a cutoff, in normal conditions.

VOICE: You used the phrase earlier when you were talking about this flame by the steam duct area. You used this phrase, "Seeing it out of the corner of your eye". Is there any doubt in your mind as to whether you saw a flame?

BABBITT: No, sir, there is not. There is no real doubt in my mind that I saw it. It's an outstanding feature of things that we normally see in there. There is something that was unusual, but I was still making my turn towards the communications box.

FAGET: When did you inhale the smoke to your knowledge?

BABBITT: After we had proceeded out on the umbilical arm. The - I talked to the telephone talker, to the talker at the top of the elevator. Then I proceeded back in with the three mechanics who were with me to get to the hatch if possible. We were in there - time is - it's hard to say how much time there was. I would say not more than 30 seconds. In there long enough to know and be able to tell that we could feel the hatch. We could see it up very close but the smoke was so thick that we couldn't stay in there very long. We went out, grabbed the only CO_2 bottle on the umbilical arm on that level, went back in again, spent a little longer in there, we got the boost cover hatch off. The tools were in the white room. We had placed them there for the emergency egress test anyway. So we knew where those were. It was just a single multipurpose tool. After taking that off, we left again. We made any number of trips in and out of there. I guess on possibly the third trip the smoke had cleared enough down on the deck below the umbilical arm to where I could see my head set and I stepped down and put it on and that's the first contact I had with the blockhouse, then. From that time on, we made a number of trips in and out. We did as we could as long as we could stay in there and then came out. We more or less went in as a group and came out as a group. As I was coming out I would report to the blockhouse, as best I could at the time. I know Mr. Page probably thought that there was something wrong that I kept yelling for people and equipment and things. At the time the smoke was so heavy that I couldn't see that there were people. My own spacecraft technicians, mechanics, NASA QC, NAA QC had gotten back into the level and were on the other side and were working on the fires in the area. We needed, at the time, we needed some sort of as I call it some sort of a battle lantern. These old Navy lanterns that you pick up. We couldn't see the hatches well enough to work very long. At one trip in we had to spend more than half of the time in there looking for the tool because as we came out we must have placed it in a little different position. As I was informed later on, it was about five minutes before we got the hatch off. I may very honestly have been possible 15 to 30 seconds late in reporting it to the blockhouse, because during that period of time we were trying to maneuver the inner hatch, to either take it out which has to be rotated to get it out or to get it down, to drop it down inside. We finally, I told them to drop it inside to place it in there as close as they could and then I reported it to the blockhouse that the hatches were off. Then I went back in and made my own observations on what I saw.

VOICE: Did you have to get special handling equipment to handle the inner hatch?

BABBITT: There are handles on the inner hatch which, fortunately, were hot, yes, but they could handled. The face of the hatch itself was extremely hot, but the handles were cool enough where we could handle it and could lower it or maneuver it.

VOICE: With your bare hands?

BABBITT: Yes, sir.

VOICE: What exactly was this fire indication at the steam vent? Was that the only part of the time you took off for the umbilical arm? Was that the only evidence of fire?

BABBITT: Prior to the main force, yes sir, that was the only impression that I had. As I say other than the call that I heard.

BAXTER: As to the - I'm interested in the sequence again. As to the time you heard the fire sounded by one of the individuals the time you saw the flame coming out of the vent the time you could tell it on the back of your neck. Could you give us this one time again?

BABBITT: Colonel, that's the thing I can't give you in time unless I timed it myself. Maybe one to two seconds. That's in the time it would take as I tried to illustrate to tell a man to get the crew out and start turning towards there. Seeing this but continuing to turn anyway one to two seconds, was all that I can say.

BAXTER: First time was the signal that you heard over the intercom?

BABBITT: Yes sir, the term fire, I couldn't tell you whether he said, in the Spacecraft, or in here or Command Module.

VOICE: Fire?

BABBITT: Right.

VOICE: Then the vent valve?

BABBITT: Then the vent valve.

VOICE: Then on the back of the neck?

BABBITT: Right, yes sir.

YARDLEY: Did you hear any other noise after the vent valve immediately preceeding this big rush of heat?

BABBITT: No sir, I don't remember hearing the pressure release, the main force. Maybe it was because I had my back to it. I didn't hear it.

LONG: Have you given all of this also on tape, has all this been recorded?

BABBITT: I have only spoken to my own management.

YARDLEY: Did you make a written statement?

BABBITT: Yes sir, I have.

LONG: The reason I'm interested is that the some of these sequences, events, that followed for plus 30 seconds would be interesting to look at but the problem is somewhat lengthy. Maybe it would be better if we have it in a statement. Is that available?

BABBITT: I have written a statement, yes sir. I may be able to amplify possible the first 30 seconds a little bit more if you wish me to in writing, but the first 30 seconds, it happened so fast, it's hard to explain it any better.

FAGET: I'd like to ask you some more questions. Now on the events when you first went into the white room.

BABBITT: After we had evacuated?

VOICE: The first time in and tell me when that was.

BABBITT: My very first time in the white room that day, was when.....

VOICE: No, no, after the fire.

BABBITT: O. K.

VOICE: How long after the fire when you first went in and I'd like to know about the condition about the smoke in the white room, what your impression where it was coming from and could you see in the window.

BABBITT: O. K. As we proceeded into - across the umbilical arm, there was billowing smoke coming out the level.

VOICE: Billowing smoke, what color?

BABBITT: It was a very dark gray. Seems to stick in my mind. It was a very heavy, thick smoke. As we proceeded in farther, knowing the umbilical arm as we spent quite a bit of time on it, the smoke was there we could see to a certain extent towards our feet and our hands. The hatch window -- I honestly don't remember looking at it.

VOICE: You didn't see any flames, is that it?

BABBITT: No sir, I don't believe I did, but I don't honestly remember looking in there.

VOICE: Can you recall seeing fire or lighting?

BABBITT: I did see fire in there, [illegible] fire that I saw primarily was from under-

neath, coming up under the hood of the white room outside the command module. We used the one fire extinguisher that we had to put out any small local fires in the white room of which they were only around the hood of the white room. Then as I say, the smoke was heavy and billowing enough to where we could only see in a small area we were trying to work in. We had to be pretty close to do that.

VOICE: That first moment you did not locate the tool.

BABBITT: Yes sir, we did locate the tool, because we had placed it in a specific spot. As I say, we had done preparations for the emergency egress teams that would have made a normal emergency egress test later on, so we knew where the tool was.

PETRONE: I've got a question I may pose to the Board to ask you.

BABBITT: Yes sir.

PETRONE: The white room quite large is up high. This area over the hatch is up fairly high and the boost protective cover is about right to the right of the shelter there's a gap in there now which has been blown out a couple of inches between the boost protective cover and the heat shield. You were standing here as you looked. Just where did you see the flame? Did you see it in this area or did you see something come up over the top?

BABBITT: Before all of this happened, the boost protective cover was laying not perfectly flat against the command module, but we will say within 1/4 to 3/8 of an inch from it. It was faired in as it would normally be. There was no large gap there. As I say I - it appeared to me to be more underneath the white room which is where the steam duct would be.

PETRONE: The steam duct is on this corner.

BABBITT: Yes, sir.

PETRONE: And roughly how far from the aft heat shield?

BABBITT: The steam duct itself is about, I'd say a foot above the aft heat shield.

PETRONE: Fairly low, then isn't it?

BABBITT: Right, but where I would see it would be below the aft heat shield because of the section of the boost protective cover that was on there. In fact we would see it to a certain extent almost down at the service module.

PETRONE: Looking from here, your line of sight would take you to here.

BABBITT: My line of sight being - my drawing isn't too well in scale. Standing here we can see this area underneath here, and it was underneath the hood of the white room.

PETRONE: You looked then underneath the hood when you first saw flame and what direction was it going?

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PETRONE: You looked then underneath the hood when you first saw flame and what direction was it going?

#14
J. C. MOONEY
PAA
JANUARY 27, 1967

At approximately 6:27 p.m., Eastern Standard Time, the Egress Team was preparing for the egress drill on Complex 34.

Upon receipt of the alarm via the radio from Pad Safety Office, Complex 34, I started to respond to the Complex in No. 250 vehicle. Before I reached the Dispensary, the Superintendent, Range Operations called on the radio and requested the Egress Team. I radioed the Station and requested all 3 units prepare to roll. I turned around and proceeded to the Station and parked No. 250 and entered No. 3 M113 which was ready to roll at that time. Time elapsed was about 2 minutes. We then proceeded to the Complex led by Egress member J. Blankenship in P-6 truck No. 16.

I called the S.R.O. on Fire Crash Net and advised him our 3 units were responding. Upon arrival at the south gate of the Complex, we again notified the S.R.O. of our location. We proceeded to the base of the umbilical tower and parked in our designated area. Egress members Blankenship, Crowl, and myself proceeded up the elevator to the 8th adjustable level. Upon arrival at the spacecraft, I met J. Blankenship coming back stating that we needed Scott Air Paks. They were ordered from below. I then met the Assistant Test Conductor from North American Aviation and asked him what condition existed. He stated the spacecraft was burning and he thought that we had 3 dead people in there. Upon approaching the spacecraft hatch we found it almost impossible to remain without breathing equipment, which had not arrived yet.

The hatches were removed and all 3 bodies could be observed through the hatch. They all appeared badly burned and no movement was visible. I then contacted the Test Conductor again and asked about the status of the spacecraft and the Launch Escape System. He informed me that they could not shut off spacecraft power since it was on internal power and that the Launch Escape System was armed. I instructed all my personnel to not to try to enter the spacecraft until our Pad Safety Officer and Spacecraft Test Conductor had assured us that all power was off and the Launch Escape System was disarmed.

We attempted to remove smoke and fumes from Environmental Chamber by disconnecting the A/C duct and using it to push the smoke out. Blankenship was notified to call Crash and have Chief Hipp notified.

We were told by Spacecraft Test Conductor and Astronaut Doctor to begin removal of astronauts, but found that power was still on and we moved back until Chief Hipp arrived. We then checked with Pad Safety Officer, Test Conductor, etc., and determined that we would wait until given permission to enter the spacecraft. It was given by the Doctor. Then Chief Hipp and we proceeded to remove Ed White from the spacecraft. He was wedged in under Gus Grissom and with his back to the east wall of the spacecraft lying on his left side. We removed White with a good deal of difficulty and took him to the ambulance waiting at the base of the base of the structure. We then went back to the spacecraft and removed Gus Grissom and placed him in an ambulance, returned to the spacecraft and removed Chaffee. Notified Pad Safety and Security that we had completed our assignment and were returning to Headquarters at 2:30 a.m., EST.

All persons involved performed their duties flawlessly and without any questions at any time. Many suggestions were made and tried; some with a great deal of success.

All members are to be congratulated for their tireless efforts. We were only deeply sorry that we could not do more for all involved.

BABBITT: It was more or less down, more or less down under the heat shield - boost protective cover.

PETRONE: And what color was it?

BABBITT: Oh, I would say a bright orange - it wasn't a yellow flame. It was more like a bright orange.

FAGET: This was after you felt the heat.

BABBITT: No, this was before.

FAGET: Before you felt the heat.

BABBITT: Yes, sir.

MATHEWS: You never saw the thing coming out other than ---

BABBITT: As I say, I did not see the main flame.

BORMAN: Prior to all this, you saw no smoke or smelled no odors whatsoever.

BABBITT: No sir, I might point out as I believe has been pointed out before. I came in my normal shift around 3:30. Mr. Cortolla the first shift pad leader remained on since he had started the -- he had put the crew in and had started the closeout. We normally do this rather than relieve and make a break in the middle of an operation like that. I was present when there was an odor detected coming out. We had a sensing port which we use to check the oxygen level in the spacecraft as a part of the cabin pressurization and this sensing port is right, very near the white room door and I ah - the other people working in there smelled this odor. This is the only unusual item that we ran into.

MATHEWS: That was the odor that Grissom alluded to.

BABBITT: I believe it is, yes, it was that - the odor that he mentioned was before I had come in to work, before I had come up to the white room, to that area.

VOICE: You smelled this how long before the fire broke out?

BABBITT: Oh, it was a good 2½ hours. The inner hatch was closed.

MATHEWS: What was the odor like?

BABBITT: It was sort of a pungent odor, an odor like, oh, not carbon tet or anything like that, a mixture of maybe ammonia and oh, just a - the way I can describe it is a strong potting compound odor, some of the commercial potting compounds.

MATHEWS: It was an oily odor, was it?

BABBITT: No sir, it wasn't.

MATHEWS: Was it a volatile material odor?

BABBITT: It didn't appear to be, no. It reminded me of a potting compound that we had been using earlier that we were all familiar with.

THOMPSON: Did it smell more like an overheated potting material?

BABBITT: No sir, this smelled like removing the cap from this potting compound in preparation to use it.

VOICE: How widespread was that odor?

BABBITT: As I say, we were right near the sensing port where we attach the Beckman analyzer and there was just a venting out there. That is right beside the hatch going into the white room. -- The wall on the right as you go in the door.

MATHEWS: Could you think a little bit more on what that odor would be like and give someone a note on what that odor was like?

BABBITT: Yes sir.

WHITE: That sensing port going into the suit loop or into the cabin?

BABBITT: It goes into the cabin. It comes out the same point of the hatch that we pressurize the cabin with.

YARDLEY: You were smelling what coming out of the Beckman?

BABBITT: Right.

YARDLEY: In other words, this was a sample of what was going through the Beckman into the exhaust, to the white room?

BABBITT: Right.

VOICE: And was this just a temporary whiff or did it persist for a long time?

BABBITT: No, with the Beckman analyzer, you repeatedly squeeze the bulb to get air samples, and we were getting it continuously while we were taking our samples.

YARDLEY: So when you sampled, you got it?

BABBITT: Right.

VOICE: Then it went away after a while.

BABBITT: It appeared to. After we had purged once more, it appeared to lessen.

VOICE: You repurged the cabin to get rid of it?

BABBITT: As I understand it, as I say, I was only observing it at the time because the other pad leader still had the control of things.

DONNELLY: It took them a long time to purge? Correct? You know nominal is 20 minutes and you were in there for at least an hour purging. Is that right, George, about an hour?

PAGE: Yes -- something to the effect of recalling - I think the numbers were that for the first 20 minutes they got 50%, then they purged again for 15 minutes. About 75% at that time they suspected the Beckman analyzer. They got another Beckman analyzer and did another purge -- (interrupted) (goes right into the continued typed sheet) -- and got 92%

PETRONE: I'd record that for the record that statement by George Page who is Test Supervisor.

LONG: Is that sequence of purging in itself unusual?

PETRONE: No, its been encountered before, it's longer than the nominal time.

DONNELLY: No, it's longer than what you set your sight for, but it has been encountered prior in an altitude chamber run. You can't say that it's something new.

VOICE: I think the real details on that could be better defined -- by others.

THOMPSON: Are there any other questions that you want to ask while he's here?

LONG: One thing I gather is that none of you was equipped with any kind of mask. That is not the procedure for this.

BABBITT: We had gas masks up there, yes sir, they were the standard, oh, I believe mining gas masks. I myself tried twice to use them, I had - because well, the first time, I pulled the tape off the bottom of one of them and tried it and it just sucked up tight at my face like I wasn't getting any air through it, so I tried another one and they had the telephone talker because I couldn't see too well, because the amount of smoke that I had been in -- had him pull the tape off it -- he hadn't been exposed to any smoke. I tried it and it didn't work either. I have heard the same comment from a couple of my mechanics also. We did have masks at work, yes, but the masks didn't work long enough for anyone to spend a long period of time in there. They, the men, said they'd get in there maybe spend possibly a minute or a minute and a half and they would start choking up, too.

MATHEWS: One thing I would have done, you may have stated, I think you did say you initially went into the white room and approached the hatch and thought there were flames in that area.

BABBITT: There, we saw, flames around the hood area of the white room.

MATHEWS: And how long a time was that between the first time, between the fire signal and that sighting.

BABBITT: Possibly 30 seconds. 30 - 45 seconds. As long as it would take me to go out of the to the umbilical arm and turn around and come back into the white room.

FAGET: How long once more, how long was it from the time you heard the relief valve and you felt to your right side was pressure.

BABBITT: Nearly simultaneously? or were

VOICE: No, they were not simultaneous. There was a delay between them, yes. I could speak in terms of two and three tenths of a second but the time isn't, I couldn't answer you really how long it was.

VOICE: What happened before that .... it was less than ....

VOICE: Yes sir, it was such a quick period of time that I couldn't tell you how long it was.

VOICE: Dr. Debus asked a question, would you like to answer?

VOICE: Yes sir.

DEBUS: This arrow indicates that you went this way....

VOICE: Yes sir.

DEBUS: and you gave the others order to tell the blockhouse....

VOICE: I gave, I went out the the talker at the umbilical tower elevator.

DEBUS: It is all the way....

VOICE: It is all the way out to the end.

DEBUS: Did you observe at that time anything back towards the white room.

BABBITT: Smoke and flames, that's all I could see.

DEBUS: You saw flames in the white room.

BABBITT: In the whole area there was random fires.

DEBUS: Including the platform enclosure?

VOICE: Inside, yes sir.

VOICE: Yes. Can you estimate how long it took for your departure to go back to the white room. There is a door I believe.

VOICE: Yes sir, there is. That door by the way was opened by the three mechanics who went out ahead of me.

VOICE: They went out here, opened the door and then went in?

VOICE: Yes sir.

DEBUS: Was there anybody in the white room at the time?

PETRONE: Which door, there are two doors there.

BABBITT: OK, there is a door this thing right here on the white room. There is also a door.....

DEBUS: Does that have an automatic closer?

VOICE: That door we have locked open as part of the procedure for the emergency egress which would have normally taken place.

VOICE: This door here opens inward?

VOICE: Yes.

VOICE: I came across up the three small steps and out this way through this door. This door was already open. As I understand it from my two mechanics, my three mechanics, they were approximately somewhere in this area when the main force went -- they went out this way. The door was already open when I went through it.

DEBUS: What do you describe as the main force?

BABBITT: The flame and heat that hit me at the largest part of it.

DEBUS: While you were still there?

BABBITT: Yes sir, while I was still up there.

VOICE: Where's the other door to the part of the white room that opens into the hatch? Is there one on the other side?

VOICE: There isn't a door as such, there's a large area.

PETRONE: There's another door....

VOICE: There's another door on this end....

DEBUS: that's always opened close it....

VOICE: No it is not, no.

PETRONE: For the test....

VOICE: For our normal operation we kept this door closed, then we could control the access to the white room and try and maintain white room conditions.

DEBUS: How was this door during the event?

VOICE: This door? Was closed.

VOICE: Was it locked?

VOICE: I believe it was, yes.

DEBUS: There was nobody else inside the enclosure?

VOICE: To my knowledge, no, Dr. When it happened, my only thoughts were to get out. The only way I could see out was across the umbilical.

VOICE: Where were your three mechanics that preceded you?

VOICE: They were, as I say, I had given the order to get them out.

VOICE: Yeah, but I mean where were they before this ever happened?

VOICE: Before this ever happened they were right near me because they were the same gentlemen who would be working on the umbilical pull at T minus zero.

VOICE: Was there anybody up there near the hatch?

VOICE: No sir, there was not.

DEBUS: So you felt that you could not get the astronauts out that flame sheet and therefore you went there. Then when did you decide you could try by now? Had it subsided?

VOICE: After it had subsided my thoughts are sort of confused to be honest with you as to which I really thought of first and get back in or to let the blockhouse know what was going on. After I told the telephone talker up here to notify the blockhouse, then the four of us proceeded back in here.

DEBUS: So by that time something had subsided

BABBITT: Yes sir, I would say this was possibly 30 to 45 seconds.

DEBUS: I see. So was there still flames visible in a flow out sheet? Or was there more localized?

BABBITT: No sir, more random fires, small fires. To be honest with you, we couldn't even see the smoke was thick enough where we couldn't initially see the fire in this area. I saw....

DEBUS: That area would be closed by the enclosure, this is outside the enclosure.

VOICE: This would be the main....

VOICE: Is that inside the enclosure?

VOICE: Yes sir, there is a large portion inside.

VOICES: Jumbled questions. Inside what enclosure?

VOICE: This would be the level 8 structure here and this portion is inside that structure.

DEBUS: When you went in and out you went out here to get some breath of fresh air.

VOICE: Yes sir.

VOICE: And back in through here.

VOICE: Yes sir. The period of time I was talking to Mr. Page, the test supervisor, I was approximately here. I found my headset was approximately here.

VOICE: Now on the headset, is your assumption you started out with the headset but dropped it on the way out?

VOICE: I have a feeling that I ran out from under my headset. I don't think I took it off first.

YARDLEY: Were you plugged in at the time?

VOICE: Yes sir.

VOICE: Where were your gas masks?

VOICE: The gas masks would have been in a box right here.

VOICE: You had to go back over and get them out.

VOICE: Yes, the.....

YARDLEY: How did you get around to there?

VOICE: Well, there was some down on the umbilical tower, there were some on the next level below and one of the men got some up to us.

VOICE: You didn't actually go down and.....

VOICE: We had about five of them, five or six.

VOICE: These were used yes by the crew other people who came back in. There was a problem with that, also, which I should point out in that when you went out the doors on these levels, on levels, six, seven and eight, they were the crash bar type doors. When you went out, you were locked out. One of my mechanics, Mr. Metcalf, went down as I understand it about four levels on the gantry, came across on the first level he could, and came back up the one side only where there is a door that is always unlocked from the outside, which would be our normal access, this is done for cleanliness, and security reasons. So, most of the crew until someone opened the doors was locked outside of the level 8.

VOICE: How many men were in the enclosure at the time started this and at various intervals.

VOICE: Up on this level I would have to estimate about 18 to 20 at the time. We have a normal spacecraft crew up here and QC plus we had GSE people also who were supporting us for the umbilical pull, down on level A7 but up on structures so they could support the umbilical from below to prevent damage was more GSE, mechanics and technicians.

VOICE: Do you know when the east door, Colonel Baxter, of the white room is open?

VOICE: No sir, I don't, it was much after I left.

VOICE: Which door is that, the one right there by....

VOICE: Within your crew, sir, is there any summary responsibility about the question of getting crew out in emergency removal crew, you speak of these 18 people, was this particular responsibility specifically yours or the three mechanics you had with you? Others that were presumed had orders to be involved at this time.....

VOICE: It was the responsibility of the mechanical lead man to take his direction from me and he had delegated, designated certain mechanics to be with him unless properly relieved in case we had some condition where we had to take the hatch off. We thought more in terms of test scrub or something like this. Most of our mechanics are experienced in handling the hatches anyway. But he picked two of his best men to work with this and they were staying right with it.

THOMPSON: I think I understand that the situation relative to what you, the first things you saw. The first thing in sequence, first was audible indication of trouble, the voice.

VOICE: Yes sir.

THOMPSON: Second, and with a very short period of time, maybe two seconds later, you saw flames on the far side.

VOICE: Yes sir.

THOMPSON: And from there on there were many, there was flame and smoke and all this other action and I don't believe that you said you ever got to see flame inside the, this capsule.

VOICE: Not to my knowledge. We, in the time that we spent in there I have to be very honest with you I don't think we specifically tried to look in there.

THOMPSON: I understood you. This does not mean there wasn't flame, it means as far as you're concerned your observation was flames is all identified with external sources.

VOICE: Yes sir. At the time I will say this, at the time that we did get the inner hatch open, we saw no flame then.

VOICE: Great deal of smoke inside.

VOICE: Yes sir, there was.

PETRONE: In fact, what was your, who reported this. Who was there when the hatch opened?

VOICE: I was.

PETRONE: What did you report, sir?

VOICE: Yes sir, I reported to the test supervisor the hatches were off.

PETRONE: Do you remember your words, can you describe for us what you saw and reported? In terms of smoke and visibility.

VOICE: I have to be honest with you gentlemen, when the hatch came off and I looked in, I believe Mr. Page will I may have been evasive on it, I tried to give the impression of what I saw, and there was a catastrophe, but knowing that the communications circuits are rather open, I tried not to compromise things, too. I think I got this impression across, but.....

PETRONE: I was wondering, the question of smoke billowing out, did more smoke come, was there still a pressure?

VOICE: No, there was no pressure. There was smoke in there, yes sir.

PETRONE: Did it billow out?

VOICE: Not necessarily.....BILLOW....It was more a layer, laying in there. Which, as we got the hatch off,

VOICE: Did you have a good deal of light when you looked at that point?

VOICE: No sir, it is not, even under normal conditions, unless we have lights inside the spacecraft. You can't see that well....in there. I wish Mr. Petrone, I could answer you really on what I did say because I don't remember.

PETRONE: I did hear you, I wanted the board to hear what you said.

VOICE: I said I tried to keep from compromising the situation but get my impression across.

VOICE: Some of the words you said were "I can't see much but I can feel....

PETRONE: I recall that. Since it's not possible to describe what it looked like.

VOICE: ----------

VOICE: Gentlemen, I appreciate the opportunity to speak to you. May I say one thing? I can't commend my crew - by my crew I speak of not only my mechanics and technicians but my QC people and NASA QC people enough for what they did. The effort they made towards the whole thing. That's really the only thing I wanted to say about it, the effort was - it was fantastic - they're highly trained and they showed it.

DONALD O. BABBITT

NAA

FEBRUARY 3, 1967

QUESTION: Would you identify yourself by name and organization?

ANSWER: My name is Donald Babbitt and I work for North American Aviation.

QUESTION: Mr. Babbitt, you are probably aware of the critical nature of the information which you have previously furnished and will furnish to this panel, and we ask that you do not discuss your observations or viewpoints with anyone other than Apollo Review Board members or members of panels or other designated personnel. Mr. Babbitt, we have your written statement and we would like to ask that you supplement this with whatever comments you would like to make to expand as you feel appropriate, from the time that you first were aware of the situation and till you were in the White Room and were able to get to the hatch or approximately that period of time.

ANSWER: As the North American Pad Leader, I was located at the Pad Leader's desk which is approximately 90 degrees to the right of the command module hatch on the south side of the gantry level 8. The first word that I received of any problem started the incident, was over the headset on Channel Black 3, I heard the words, "Fire in - it was either in the command module or in here -" The term "fire" stuck out more than anything else. I, in turn, gave word to my mechanical lead man, Mr. Gleaves, to get the crew out, and had started a turn to the left to change my Operations Intercommunications Systems (OIS) box, or to get on the Public Address (PA) system to notify the blockhouse. At that time I never completed my turn because I was hit with a force of flame or pressure, both flame and pressure, that forced me toward the comm. box and down slightly.... I was hit by the force of pressure and heat. My immediate reaction was to get out of there, to evacuate the area, which I did do, I never completed my move to the comm. box. My moves were toward the umbilical arm and out of the umbilical arm, out to the umbilical tower itself, and upon reaching clear air outside, I came upon a telephone talker who was at the umbilical tower elevator standing by for the - which would have been the normal emergency egress test, and told him to notify the blockhouse that we had a bad fire on the level near the command module, and then as I also came onto the umbilical arm, I met three of my mechanics, Mr. Gleaves, Mr. Clemmons, and Mr. Hawkins. After notifying the telephone talker at the elevator on the umbilical tower, the three of us with a CO_2 bottle, proceeded back into the White Room to attempt what we could in removing the hatches. The time period as I believe it from the time that I heard the words "Fire" from the audio OIS system till we went back into the white room, I can only estimate to be between two and twenty seconds. I have no way of knowing exactly how long this time would be. As we proceeded into the White Room, the smoke was extremely heavy. It appeared to me to be a heavy thick grey smoke, very billowing but very thick, we couldn't, as we went in the first time, see the hatches well to work, we worked as we could by feel on the boost cover hatch, we had to come out in approximately, I would say twice, to even finish the boost cover hatch and go back in after removing the boost cover hatch. The smoke started clearing some, but we - there was still a problem with staying in there. We made several trips in and out. We could see as we worked on the outer ablater hatch a little bit better. We could see where we were working, but

could not see the whole hatch itself, and knew the general area of the place for placing the tool for unlatching the hatch, and as we removed it, we got it outside the White Room and also, about that time, I had to change crews in working there, because Mr. Gleaves had come very close to passing out from smoke. I had to order him out. Mr. Hawkins was in not too good a shape and Mr. Clemmons was also the same way. As we came out with the outer ablater hatch I observed more people in the level A-8, the gantry level A-8, and I motioned for two more of them to come in and assist us in removing the hatch. When we went in for the inner hatch, we could see the hatch fairly well. We could see the whole hatch well enough to work on it, the handles on the hatch, on the outer side of it, were cool enough to hold on to but the face of the hatch itself was extremely hot. As we unlatched the inner hatch and we attempted to rotate it (you have to go down slightly and inward and rotate the hatch to take it all the way out) we were unable to do this, either due to the speed or confusion or obstructions, so I told them to drop the hatch straight down, meaning to put it down on the floor inside the command module near the wall so that we could clear it.

This terminates the statement of Mr. Babbitt.

DONALD O. BABBITT
NAA
FEBRUARY 8, 1967

QUESTION: This Statement consists of an additional statement furnished by Mr. Donald Babbitt who was Pad Leader on 34 during the incident. Mr. Babbitt, we've asked you to come in today to go into some detail with us on your observations when the inner hatch was finally removed. And, we are particularly concerned with the configuration of the flight crew members as well as you can recall.

ANSWER: When the inner hatch was first lowered, the only thing that I could observe was smoke inside. We could only feel the flight crew. We could not see them very well as I could tell. As the men working with me went out because they'd been in the smoke quite a while, I went back in, oh, approximately one minute or a minute and a half later; and all that I could observe was what appeared to be Mr. White laying on his back with his arms over his head, appeared to be reaching for the hatch or in something in that vicinity. I also observed what appeared to be Mr. Grissom laying with one of his arms through and appeared to be reaching in the direction of the hatch also. I went out again for a short bit and came back in maybe thirty seconds after that. I could see a little bit more. The smoke had cleared some more. All that I could really see was, oh maybe, to the waist of Mr. White. It appeared to me that they; I at first got the impression that they were off the seats and then I got the impression that no they were on the seats. It appeared that their suits were shredded. I could see bare skin. No one, at any time while I was in the White Room or up on Level A-8, touched the crew other than as I say when we first lowered the hatch and could feel in there to see what was near the hatch, if we could feel the crew at all. One of the firemen stepped in for just a very short period of time. I directed him not to bring any fire apparatus into the White Room and he stepped back out again. As I say, no one else from the time that I was up there, went in the White Room but myself. The crew appeared to me to be in their normal, in-flight position. I could only see what

appeared to be Mr. Grissom's left arm reaching through Mr. White's arm. I could not see his body that well, but it had the appearance of being in its satisfactory or its normal position. I did not observe Mr. Chaffee because I was a little bit too far to the right of the hatch and could not see him. Mr. White appeared to me to be as I say, laying in his normal boost position. I could not tell whether his head rest was up or down. In fact, I couldn't even see his features because of the, what appeared the smoke or soot blackened face plate on his helmet. My observations are based on the looking from the inside of the White Room as close as I could to the hood without stepping on the hood of the White Room. The hatch was lowered as far inside as we could lower it, and it was still sticking above the lower edge of the hatch frame about three to four inches.

This concludes the statement given by Mr. Babbitt.

JAMES D. GLEAVES
NAA
JANUARY 29, 1967

PETRONE: Are you ready for Mr. Gleaves?

THOMPSON: Who is the next?

PETRONE: Mr. Gleaves, mechanical lead technician.

THOMPSON: Where was he?

PETRONE: He was on the platform. Mr. Babbitt reported he would be the man in charge of the technicians.

THOMPSON: Mr. Gleaves, we are asking you to appear before us and give us your account what transcribed and with the understanding, however, that the same restrictions continue regarding holding all this information under restraints. So with that I think perhaps you could just go ahead and tell us about where you were and what you saw and then there will be a lot of questions probably.

GLEAVES: The last I remember we were waiting at ten minutes and we were holding for this communication problem and there were about four of us in the vicinity of the umbilical waiting to jettison the umbilical when it came time for us to do so. And Don Babbitt, the pad leader, turned up the monitor a little louder and during this communication problem we sent most of our guys down for coffee break and on this communication deal if I remember correctly they went from black 3 to black 2 or from black 4 to black 3 and the instant Mr. Babbitt flipped a switch as far as I can tell I believe it was Mr. Chaffee that hollered that we have a fire in the spacecraft. And immediately we ran to the white room. And as we started up the swing arm there was a loud shoooooo. Like maybe Grissom or one of them had dumped the cabin pressure. And as we entered the white room there was a big flash and we knew something was fixing to happen and we started back out. As we did so, the spacecraft exploded and fire and debris covered the whole right side. It appeared that the flames and all the debris came out the right side of the spacecraft. In the area of the rendezvous windows in this area. And it knocked us up against the orange door, which I might say opens the wrong direction. We had trouble getting out due to the smoke and fire in this area. But once we were out in the swing arm everything settled down in just a few seconds. I returned to the white room and the smoke, heat and flames were so bad at the hatch area that we just couldn't stay near the hatch. So we wouldn't....

VOICE: The three of you?

GLEAVES: No sir, I returned. Right. Then in the meantime a gentleman named L. D. Reece found the oxygen masks and was handing out the oxygen masks we had trouble locating the strip of tape on the bottom because they were painted the same color as the connector. And several times, one, two, three or four of us returned without masks and stayed as long as we could, then finally Babbitt and myself entered the white room after the fire had been extinguished by Jerry Hawkins and on all fours I crawled. I found the tool to remove the ablative hatch. I removed the ablative hatch and I didn't have a mask on at this time

and I just couldn't take it no longer so I returned out and gave the tool to Jerry Hawkins, Steve Clements and L. D. Reece. And they removed the ablative hatch and L. D. Reece threw it out on level A8 and then these guys, also they had masks on, they removed the inter hatch and it was so hot they just let it drop down under the couch. So they come back out and I in return went in and kicked the inner hatch and it sort of fell down under the couch. I pushed but it was still hot and inside the spacecraft was black and filled full of smoke. You couldn't see anything at all. So I returned to A8 and out of the white room and got a flashlight and went back in and tried to see inside the spacecraft but the heat was too great and the smoke was too bad so we returned out on A8 and we continued to go back in. And as far as I can remember it took maybe 10 or 15 minutes for any fireman or any help to get to us up on the swing arm.

THOMPSON: Is there any point here? Could you draw a sketch indicating the sequences?

BAXTER: Before you draw it, do you remember who the first assistance was other than you three mechanics?

GLEAVES: Do you mean from below?

BAXTER: Right.

GLEAVES: We had two of our guys I don't remember their names. Willie Medcalf and some other guy came up to help us on the swing arm. From below on A8 there was a NASA QC and a couple of North American QC with fire extinguishers fighting the fire in and around the hatches as they were coming out. This being the command module in the white room here the pad leaders desk was here we had an electrician sitting here talking to an engineer and if I remember right we had an electrician sitting here at the lead man's desk, the umbilical being here I was standing in this area. We had a man here sitting in a chair monitoring the 401 unit which was supplying GO_2 to the OP-1 on sector 1 and another one of the mechanics was standing here. And when Babbitt turned up, Babbitt was sitting in this area when he turned up the monitor, and they hollered there is a fire in the spacecraft, I immediately run and went in the white room with Mr. Hawkins and a QC in the same vicinity as we went up these two stairs we heard a loud shoooo like maybe they had dumped cabin pressure. And once we entered the white room there was a tremendous flash and maybe the reflection come out of the hatch, I don't know. But there was a tremendous flash and then smoke and we started running in this direction and as we did from what I could tell the fire and debris just covered this whole area, just one big boom, one big blast.

VOICE: Which door did you get caught in?

GLEAVES: This is the orange door that the astronauts enter from the swing arm. This door opens in this direction, it knocked us against this door and we had to unpile to get out. In fact, the smoke and all was real bad at this time.

VOICE: Was there any noise associated with the flash?

GLEAVES: Yes sir, it exploded just like a big bang.

VOICE: Did you see anything of the hatch regard to the hatch or to the hatch window?

GLEAVES: Well, as I entered the hatch, I mean as I entered the white room we saw this flash smoke and we thought it was going to blow or something bad was going to happen so we came out of the white room. And the instant we came into this area which is about three feet maybe from this door it exploded.

PETRONE: You were outside the white room?

GLEAVES: That is right. With the flash and a lot of smoke and then we run.

PETRONE: Was this direction of this explosion in the white room?

GLEAVES: No sir, it was from this direction. The white room fits up in this area and this is all open to the umbilical.

PETRONE: You identify this as coming from the direction other than the white room?

GLEAVES: Yes sir, it come out between the white room and the umbilical I would say in the neighborhood where the windows are that is where it seemed to be. In that area.

THOMPSON: Can you indicate how far around that exterior shield goes, the outside shield, the boost protective cover, how far around that that comes relative to your picture?

GLEAVES: Well, the night before we had installed the boost protective cover for this run on our shift. And the boost protective cover when maybe a foot on the other side of flyaway umbilical. It went from there around to the same location on the other side, which if I am not mistaken is CM8 the opening here and maybe 13 here was still open but it covered this area.

VOICE: Show me where the door is into the white room.

VOICE: Well, the door into the white room is a sliding door right here in two pieces.

VOICE: That is the one if you had continued to go into the hatch you would have gone?

VOICE: No sir, we were into the white room.

PETRONE: What was the position of the door?

VOICE: The door was in this position right here.

PETRONE: Open or closed?

VOICE: Well, half of it [illegible] open. These sliding doors We kicked it open. Yes sir.

PETRONE: How many people got into the white room?

GLEAVES: Myself and one guy behind us.

PETRONE: You were fully in?

GLEAVES: Yes sir.

FAGET: Did you have a chance to look into the hatch? You were looking in what direction? At the time you felt this explosion.

WITNESS: When we saw the explosion, we were on our way back out because we had seen the flash, the smoke, and we knew something was fixing to happen and we left.

FAGET: You saw the flash, it came from around the seal, in the white room?

WITNESS: The reflection appeared to come out... the hatch. There is a glass in the hatch, yes, sir.

THOMPSON: As I understand it, the point you're making is that you did not see flame directly, but you saw the whole area light up, reflecting a flash, is that right?

WITNESS: Yes, sir.

MATHEWS: Where were you, where did you say you thought that....? You say you thought the flash came from the window?

WITNESS: On all three hatches. There's a little window on the boost protective cover on the inner hatch. On the outer hatch it gets a little larger, and the one inside is a little larger than it is. But there is a direct view from there into the SC.

FAGET: But you didn't get a chance to look in it?

WITNESS: No, sir.

FAGET: Is that where the light looked like where it came from in there, or from around the hatch?

WITNESS: It just appeared that there was a big flash, and I couldn't tell whether it came out through the window or whether it was coming from elsewhere. But there was the whole area lit up.

FAGET: The whole area?

WITNESS: Yes, sir.

FAGET: Inside the white room?

WITNESS: Yes, sir.

YARDLEY: That wasn't the violent....as several seconds later when you got out of....

WITNESS: No, sir, that's right. [illegible] as we went up the steps. Like I say, we heard this whistle like maybe the [illegible] pressure and a change, maybe to try to get out. And as we entered the white room, there was a big flash, and then we turned and started to run, and as we did, it blew, and there was an explosion and a tremendous amount of flame and smoke.

BORMAN: Then now did you to that door that was closed?

WITNESS: Yes, sir.

BORMAN: Then you ran out?

WITNESS: Yes, sir.

VOICE: Which door did you run out?

WITNESS: We ran out this door here, we....

VOICE: Then out it again, anyway though you regrouped and....

WITNESS: Yes, sir. That's the only door we could get out.

VOICE: If you went out the other door, you couldn't get out that way because that was really burning? Out there?

WITNESS: In this area? Oh yes, the Pad Leader's desk was on fire, and there was debris and all, laying here on fire.

VOICE: Tell us about this explosion. Try to think of some analogies to describe what is sounded like, now that you think about it, was it a crack, was it a whoom as if you threw a match into a barrel of gasoline, what was the character of the noise?

WITNESS: I would say it was like maybe when you were a kid and you put a fire-cracker in a tin can and it exploded and you had the lid on it tied down and it blew the whole side out of the tin can with the flames shooting out.

BORMAN: The noise was like that firecracker?

WITNESS: Yes, sir.

BORMAN: It was a loud bang, a loud explosion? Pardon?

WITNESS: Bang? Yes, sir.

BORMAN: Would you review for us again what you were saying about the men up near those oxygen bottles, what they were doing up there?

WITNESS: In this area?

VOICE: Yes.

WITNESS: We had two GOg bottles sitting here on a bluge which is a ZOO 026-401 unit which we were feeding in oxygen to sector 1, to OF 1 that fed the fuel cells. We had a man....

BORMAN: This was being fed at the time of the fire?

WITNESS: Yes, sir. We had a man here whose prime job was to monitor that to make sure there was 750 psi remaining on this gauge at all times. Anytime it got low, this man changed the bottle. Then we had another man standing here with myself at the umbilical....I believe he was in this area, he was actually closer to the S/C than myself, but he was between me and the white room, and we were standing there waiting to pull the lanyards to jettison the flyway umbilical when

our time came up which was T-10 and holding.

BARTON: This GO_2 was being fed where now? Does that go into the umbilical into the service module?

WITNESS: This GO_2? No sir, it goes into sector 1 down on the service module.

VOICE: Is this what they call the pad pressure on the tank?

PETRONE: No,_____

WITNESS: Yes sir, it's in a test port no, it's ah, in a servicing port, fill port, right.... into....

VOICE: Into the cryo oxygen....that's right.

PETRONE: This isn't a typical engineering way to describe it. Your two bottles - you draw your oxygen for this test, directly from a bottle, fed into the system rather than the cryogenic system you normally draw your oxygen from the cryogenic tank, liquid oxygen, in the service module, as it boils off you feed it into the command module, into the surge tank which has been described to you a few times, in earlier discussions, into the surge tank into a set of regulators as you go into the environmental control system, cabin, of the suit loop. So this, for this test, we had no cryogenics aboard. It gives you the oxygen pressure you need to feed the O2 into the cabin.

VOICE: And at the same time is one feeding oxygen to the fuel cells?

PETRONE: Fuel cells were not active. They were bypassed - they were on - you will find that the power system was not running. We had other things. The fuel cells were not active.

THOMPSON: Well, I think it will be very important, in that, to know where they were bypassed because there are a number of parts of the system brought in even though the oxygen is being fed in from....

PETRONE: I am not sure that Mr. Grimes is the man to give you the details on the configuration, but we on the panel, Mr. Williams, is on....the final configuration of the bottles, the loops and where they're tied in.

WILLIAMS: This shows the 6th deck. The platform and the steps.

BAXTER: That's a point I made earlier, I wanted to be sure.

VOICE: Well, let me come back to...you ran out the door, you moved when Abbett came out the door or did you not wait for them? You went back by yourself?

WITNESS: Well, when Babbitt came out, he was screaming for someone to please get them out of there. And, we returned, not only myself, I returned first, but I came back out and at that time I was given a fire extinguisher, and I passed it to Jerry Hawkins, and he, in turn, went in and emptied it to extinguish the fire around the hatch. But, there was five of us out here, and we each took turns going in and out trying to do something.

VOICE: Did you have a gas mask?

WITNESS: At some times I had a gas mask, yes. Other times, no.

FAGET: At any time that you went in there, did you notice flames inside....

WITNESS: Inside the bird?

FAGET: Through the window, yes.

WITNESS: No sir, the smoke was so great that you just couldn't see anything. But there was definitely flames coming up outside like it was coming up from the next level around the hatch.

THOMPSON: I think you've answered this question, but I want to be sure I understand it. The point where you were just prior to your receiving a first indication that there was anything unusual about the whole thing, what was the first indication that you had that there was anything wrong? Where were you?

WITNESS: I was standing in the area of the umbilical.

THOMPSON: And what way were you looking at that time? Do you know which way you were facing?

WITNESS: Yes, I was talking to the pad leader, or I had been talking to the pad leader.

THOMPSON: And what was the first event that gave you an indication that there was something wrong?

WITNESS: When Mr. Babbitt switched on the communication. Like I say, it was either from Black 3 to Black 2 or from Black 4 to Black 3, I don't really remember which it was, but the minute he switched, it sounded as if it was Mr. Chaffee hollered, "We have a fire in the SC." And at that time, we all run in this direction toward the white room.

VOICE: Why did they switch it?

VOICE: They were having a communication problem.

VOICE: Well, why did they switch it at that particular time?

VOICE: Because as he monitors the different channels on his head set, when he follows the test, and when the blockhouse who it is says go from Black 3 to Black 2, he immediately switches.

VOICE: We assume that he switched over to this because the blockhouse had instructed him to.

VOICE: Well, because everyone on this channel was switching.

VOICE: Right, before they switched, they were talking to Mr. Grissom, and Mr. Grissom they told him he was very garbled; they were talking to Mr. White and he said he was a little better than Gus, but he was still garbled, and Mr. Chaffee, they told him that he was the best of all. That they could understand him more

plainly than any of the others. And when they asked them all to switch and that's when they started flipping channels, and that's when I'd say it was Mr. Chaffee hollered that we have a fire in the SC.

VOICE: How much switching action was both in the capsule and on the loop?

VOICE: Everyone on the loop everywhere was changing switches.

PETRONE: Do you know what the time was, of the switching?

WITNESS: No, I believe it was in the neighborhood of 6:30.

PETRONE: No, I meant were we switching within ten seconds.

WITNESS: We were at -10 minutes and holding for this communication problem.

PETRONE: Yes, I know that but, in relation to the fire or the flash or the glitch of the communications when was the last time there was direction to do switching?

WITNESS: At this, when they switched from Black 3 to Black 2 and someone screamed - Mr. Chaffee I think screamed, we have a fire in the SC, immediately I run and Mr. Babbitt throwed his headset down and was coming behind us at the same time.

DEBUS: Can you describe what Grissom said, it was garbled, could that have been a call of fire or something? Was that around the same time?

WITNESS: Pardon me?

DEBUS: You said that as you checked communications that Gus Grissom said something, that it was garbled.

WITNESS: Well, they were talking to them.

DEBUS: Right.

WITNESS: The astronauts. And they were checking this communications problem.

DEBUS: And when was it?

WITNESS: It was just prior to switching from Black 3 to Black 2 or from Black 4 to Black 3, whichever it was.

DEBUS: And then was that after the word fire?

WITNESS: That was before the word fire. A matter of maybe 30 seconds or a minute.

VOICE: You heard this through your headset?

WITNESS: No sir, I heard it through the monitor. I wasn't on the squawk box.

THOMPSON: Well, I think there's a point here that has been established and perhaps he should renew it. As I understand it the hold was on account of the communications problem.

WITNESS: That is affirmative, yes sir.

THOMPSON: It was on the ten-minute hold? Because of the communications problem? And then, is it correct that some change there decided that everybody switch to another channel because of that problem?

WITNESS: Right, they were switching trying to determine what the problem was. Whether it was inside the spacecraft or the blockhouse or just where.

THOMPSON: The communications problem.....

VOICE: They were switching around from different things.

BORMAN: Internal switching, internal SC controls.

WITNESS: Right.

PETRONE: Dr. Thompson, I think on this....

VOICE: They had done this prior on the C-band or S-band or something else.

PETRONE: You can get a communication engineer to relate how they, what they do in the SC vs. on the ground. Remember, we said we were on S-band communications. And, this configuration is very important, what channel they were on, what was being over the air, whether you were OIS or operations intercom system. What switching is done on the ground vs. what's in the SC. I think that's most important.

THOMPSON: Well, there's one point I would like to be clear on and that is the duration or the previous history of this problem, how long prior to this final switchover had that problem existed. Had it been, had it existed for two hours?

PETRONE: Yesterday, in our summary, when the astronauts in their suits got into their suits got into their SC, it was the first time you could make a communications check with the actual speaker system and so on. And, there had been a series of difficulties in being able to hear. Either due to the air rushing by the mike or due to other difficulties, there had been a series of let's go VHF, go hardline, OIS, or S-band, so this had been the entire time they were in there, at various times there were switches in communications being made.

THOMPSON: Well, in other words, there was nothing so unusual about having a problem in communications. Is that the point?

PETRONE: Yes, there is nothing unusual....

THOMPSON: We will develop in a subsequent.

PETRONE: At that particular time, that was nothing unique?

THOMPSON: We will develop the actual timing of this thing I think in subsequent review of the information.

VOICE: I guess it is a fair statement to make that the channel switching that this man did and the other man did, there's no physical connection between this man

between those systems and the spacecraft.

THOMPSON: Well, we will.

VOICE: Except they were switching at the same time.

VOICE: He said they were switching at the same time. Now that's the thing I think we'll have to, I don't think you would even know they were switching at the same time.

JEFF: I think we have apparently got just one point that seems somewhat important and that is to say whether because of the switching of communications one didn't hear the word "fire" for the first time.

VOICE: Yes, I think that will show up later.

THOMPSON: We will have a review of events, recorded events. It will clarify that to the extent it can be clarified. But Gleaves is not the man in the position to give us much. Information on that as far as I can see except to establish the purpose of the hold and the fact that it's been a problem.

VOICE: You were monitoring the crew panel....all this time?

PETRONE: Yes. I was on 1, 2, 3, and 4. I was on all the channels.

MATHEWS: Any garbled conversations that you couldn't identify the nature of the conversation?

PETRONE: No.

THOMPSON: Let's get back to any further questions that you want to ask now before we let Mr. Gleaves go.

VOICE: Mr. Gleaves: Did you go out the door before Mr. Babbitt?

GLEAVES: Yes sir.

VOICE: You did?

GLEAVES: Yes sir.

GLEAVES: In fact, Mr. Hawkins was first and I was behind him and who was behind me, I don't really remember. But I know he and I were the first two out this door.

BORMAN: I was going to ask: Can you give us your estimate of time between when you first heard the fire call and went into the White Room? How much time do you think that took? And between the time you decided to exit the White Room before this big explosion.

GLEAVES: I would say it was just a matter of just a few seconds.

BORMAN: There was two periods of a few seconds each then you would say?

GLEAVES: No, I would say from the time he hollered "there is a fire in the spacecraft"

and we started running until the time we headed for the door, was just a matter of seconds.

BORMAN: Yes, well, I was trying to break down the two periods; one you went in the White Room and then you saw this flash outside and decided we better get out of there.

GLEAVES: And we immediately, there was no hesitation, we immediately turned and ran out. In fact, I almost ran over Mr. Hawkins.

BORMAN: The first time was how many seconds would you guess to run that distance to get into the White Room before you decided to switch.

GLEAVES: Just a couple maybe three.

BORMAN: And then you started running out and got about to the door and this other thing happened....the Bang....Would you say that was "2-3" seconds? Was it almost that long between the flash and the other "boom"? Was it about as long as it took you to get out of there?

GLEAVES: No. When it flashed, then we remember smoke, then immediately it blew.

BORMAN: So there wasn't much time to....

VOICE: But he got all the way from the White Room out to the orange door in that length of time.

GLEAVES: No, we got almost to the white door which is maybe as far as here to the mike. And it's not that great a distance from there.

VOICE: You go through the white room door?

GLEAVES: Right.

FAGET: From the time you heard fire until the time you heard the bang.

GLEAVES: Pardon....

FAGET: From the time you heard fire until the time you heard the relief valve.

GLEAVES: I say it couldn't have been over 10 seconds at the most....or 15.

YARDLEY: You mean, it might have been on order of 10-15 seconds? But in the other period it was only one or two seconds.

GLEAVES: That's right.

BAXTER: Sir, back to the....we, I say we....there exists procedures for emergency egress. Pad egress. I know you can't think of everything, but do you have a procedure that would come close to meeting this kind of thing and did you or were you just reacting spontaneously or did you have pad egress procedure you were trying to do?

GLEAVES: No sir, we are well aware of how to get these hatches off. Then he hollered

"fire" and all we could think about was to get the hatches off.

BAXTER: Could you have used more help?

GLEAVES: No sir.

BAXTER: You couldn't physically get people in there?

GLEAVES: That's right. After the explosion we re-entered the White Room and the fire was too great and the heat and the smoke was too intense....you could not breathe in there. After we could not breathe....

VOICE: I believe they had more help during that period that they would have under a hazard egress condition.

BORMAN: I think there is one thing of significance here your job was in 10 minutes to get that hatch off.

PETRONE: No.

BORMAN: Were they going to pull the hatch?

PETRONE: We were going to plus three.

GLEAVES: The astronauts were going to pull it from inside and we were to assist them on the outside of catching the hatches as they came out.

PETRONE: In 10 minutes he was going to pull the umbilical when we picked up the count. The egress would have been practable at the end of the count planned at plus three hours.

VOICE: What were the words from the crew the first words you heard?

GLEAVES: When Babbitt switched channels, the first thing we heard was that one of them hollered, "We have a fire in the spacecraft".

VOICE: It wasn't just fire?

GLEAVES: No sir. "We have a fire in the spacecraft."

VOICE: That was actually the sentence?

GLEAVES: He may have hollered the word "fire" before Babbitt switched. And then he did say, "We have a fire in the spacecraft."

THOMPSON: You were not wearing a headset?

GLEAVES: No sir. I was listening to the monitor.

THOMPSON: Any further questions?

THOMPSON: Well, thank you, Mr. Gleaves.

JEFFS: Mr. Chairman. I know it is slight side point here to this. It came up. We talked about it. I know my people have been trying to work with that garbled transmission too. To see if we can get some information out of it. I presume the data team is also working with that and you will hear a report on that, later on. There might be something there we should try and see if we can't extract.

LEWIS CURATOLO
NAA
FEBRUARY 22, 1967

My assignment as Pad Leader on Spacecraft 012, I was responsible for 1st shift activities concerning Test and Operation of the Spacecraft and Ground Support Equipment at Launch Complex 34. The scheduled activity for January 27, 1967, was the performance of OCP-0021 (Plugs Out Test). Chronologically, to the best of my knowledge the events of the day were as follows:
Power was applied to the Spacecraft and Ground Support Equipment at approximately 0813. Normal power up procedures were followed. System power up began almost immediately after the Spacecraft, Ground Support Equipment power up. No major discrepancies were noted during the power up sequence.

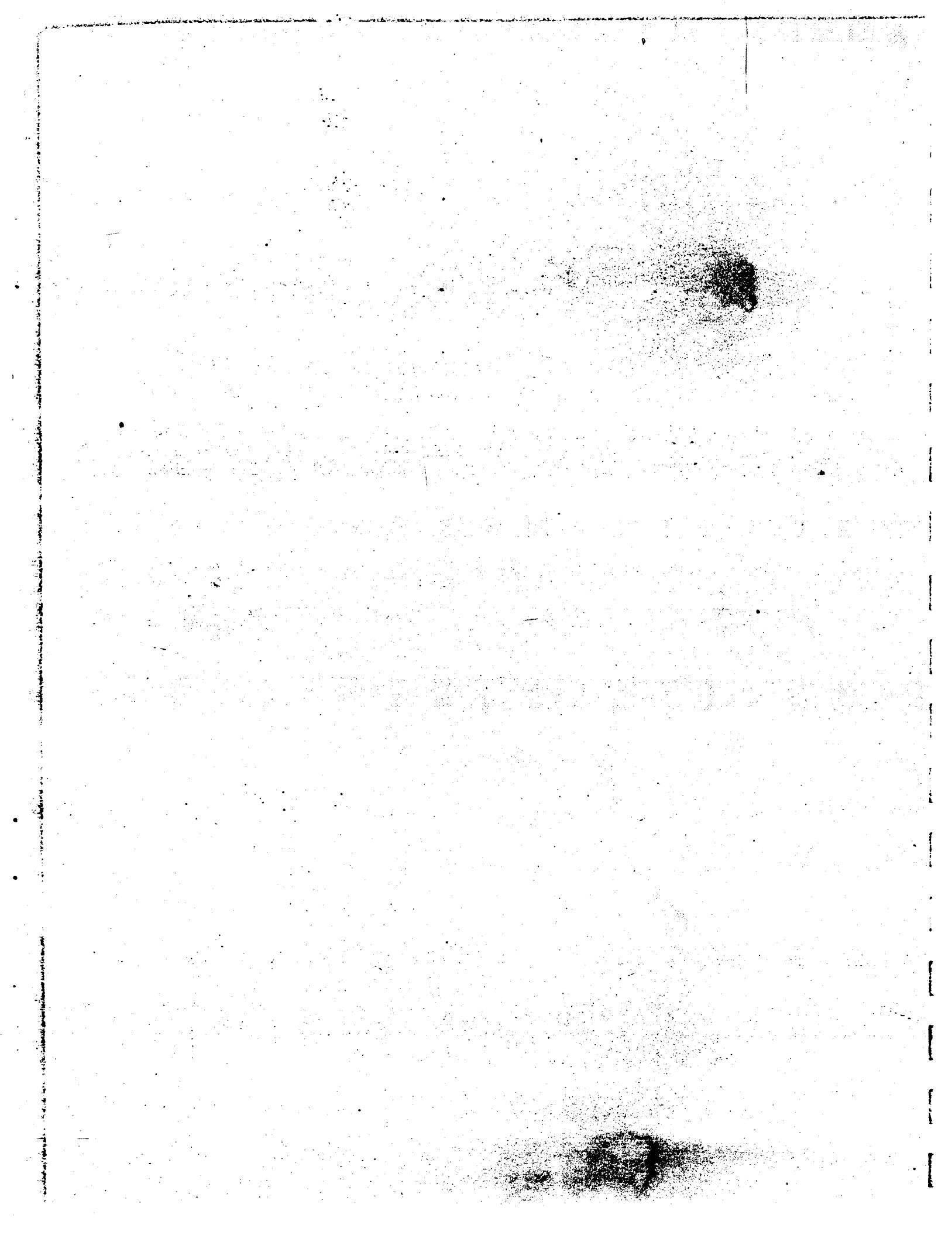
During the power up portion of the procedure we experienced many OIS communications problems. At approximately 1300 I notified the Test Conductor and Test Project Engineer that we were ready to perform Crew ingress. The Suit Technician and the Spacecraft Technician performed the pre-ingress layout of the cockpit and couches. This procedure consists of laying out the pilots seat and shoulder harnesses, and routing of the 0_2 umbilical hoses. I instructed the Spacecraft Technician to remove all foreign objects and materials from the Spacecraft interior. At this time the Technician handed out a number of plastic bags and some foam rubber mats, which we normally use for protecting wire bundles and Spacecraft honeycomb structure. During the pilots ingress I handed the Spacecraft Technician two pieces of foam rubber wrapped in velostat which were to be used for protection of the inner hatch during the scheduled emergency egress procedure.

After completion of the Crew ingress we proceeded with Hatch closeout, and Cabin purge, as directed by the Environmental Control System engineer and Test Project Engineer. During Cabin purge we detected a strong pungent odor which smelled like MEK. We reported this to the Environmental Control System engineer, and he directed us to do another purge because the 0_2 content inside the cabin was only 75%. We did another purge and pressurization and obtained a 92% reading on the analyzer. At this time we were directed to proceed with outer hatch and Boost Protective Cover closeout. We installed the outer crew hatch and started with the Boost Protective Cover installation but experienced some difficulty in getting the Boost Protective Cover to lock in, so I notified the Test Project Engineer and asked for an Interim Discrepancy Report. The Boost Protective Cover was left unlatched and we were instructed by the Test Supervisor and Test Conductor to clear the White Room. I followed the Test Conductor's instructions and at this point (1730) the 2nd shift Pad Leader (Don Babbitt) relieved me. After giving Mr. Babbitt a turnover on the next sequence of events I left the service structure and positioned myself in the Operations Trailer to monitor the "Liftoff" sequence of the procedure. This was my location at the time of the accident. Approximately 5 to 10 minutes after the accident I was instructed by the CVTS to go back to the A-8 level of the service structure to relieve Mr. Babbitt. Upon re-entering the A-8 level I observed that some areas of the Spacecraft exterior were still smoldering, and the Crew Hatch had been removed. I instructed the firemen to remove the shear panel from the White Room to allow the smoke to dissipate and allow the interior of the Spacecraft to cool. I entered the White Room and observed that the flood lights on the Crew Couches were still illuminated and the main display Console lights were still lit. I reported this condition to the Control Room and the blockhouse. I observed that the body of the Senior Pilot was wedged between the Crew Couches and the hatch bulkhead; the Command Pilot was positioned in the center couch with his body partially hanging over the center couch. The Pilot was in a reclining position in the Pilot's Couch.

I observed that the Command Pilot's leg pans were in the rest position, the Senior Pilot's leg pans were in the boost position, and the Pilot's leg pans were in the full down position.

I was relieved by Mr. J. Murphy at approximately 2100.

/s/ L. Curatolo



L.D. REECE

JANUARY 27 – 28, 1967

At the instant of first indication of a problem, I was on station at the cut-out in service tower directly above the fly away umbilical. I was standing on the side of the cut-out nearest the pad leader's desk. When the 10 minute hold was announced, I had moved around only slightly and had stayed pretty much in this area listening to the communications problem being discussed. I believe communications requested a test count from one of the crew so he could "Investigate Cross Reception Between Black 2 and Black 3."

A very few seconds later a seemingly calm voice said, "There is a fire in the C/M" or "There is an electrical fire in the C/M."

Turned toward the C/M intending to go into White Room and assist removing hatch. Immediate (1-2 sec.) there was a sheet of flame shooting out from C/M 17 access. Another 1 sec. I was inside White Room with one or two other persons, I don't know what happened the next 1-2 seconds, as I became scared and turned and ran across swing arm to elevator where several people were yelling and screaming that there was a fire and to help us.

A couple of seconds later some one got their wits and yelled, "Fire Extinguisher." Some else yelled, "Gas Masks." I got the extinguisher from hook west side of No.22 elevator door and carried it back to step down and handed it to Gleaves. Turned back got a couple of masks; put one on; gave one to someone and went back to White Room to open hatch. Smoke was so thick, very black, could not find tool or anything else. Went to level A-8, had nothing to use. Went back to swing arm outside door, then returned to White Room two more times trying to open hatch and leading Gleaves out as his mask didn't work and was blinded and choking. Last time inside Gleaves located tool, got B.P.C. cover off or partially off, left again, and I stayed and helped Hawkins remove outer hatch. I think I got scared again as I returned to swing arm, then went back to find hatch (inner) finally being pushed in. I could see nothing at all, but finally made out the left hand head floodlight very faintly. I was very highly excited at this time, and thinking I heard crew I leaned in as far as I could feeling around center couch. I felt no one, but still convinced I had heard them, I took mask off yelled several times to crew, felt around, then left mask on center couch and returned to swing arm.

I tried several gas masks after this, but all were broken or would not work. In meantime several men had been applying extinguishers, so as area got smoke cleared out, I gathered all Inspection Documents few at time and put on southeast elevator and called Inspection Trailer to meet me at ground level.

At critical time between hearing crew announce fire and going out swing arm, I just am not sure how many explosions occurred, possibly two.

/s/ L. D. Reece

RICHARD A. HAGAR
NAA
JANUARY 27, 1967

REPORT ON 012
I was monitoring the OCP on level 8 at the plus axis with Dale Hickenbottom. Dale told me there was a fire in the command module. I started for the White Room and had reached the +Z axis when I heard two loud pops. I stopped momentarily and at that time fire shot out of the command module at the +Y and -Y axis. The time elapsed couldn't have been more than a couple of seconds.

/s/ R. A. Hagar

JANUARY 27, 1967

SECOND STATEMENT
While monitoring the OCP I heard the report given "fire in the spacecraft." I was on level 8 at the +Y axis. I started for the White Room and as I reached the +Z axis I heard two loud pops, at this time fire blew out of -Y and +Y access panels. I went out on one of the elevator arms and at this time all of level 8 was on fire. I then proceeded to leave the tower.

/s/ Richard A. Hagar

JANUARY 28, 1967

Everything relating to this AS 204 plugs out test is classified in accordance with the mission failure plan. My name is Richard A. Hagar, my organization is North American Aviation, my position is spacecraft electrician, my supervisor is Carl Black; and my station call sign is SCO. On January 27, 1967, I was sitting at the -Y axis of the command module monitoring the OCP with Dale Hickenbottom, QC with North American. At approximately 6:30 there was a broadcast on the net that there was a fire in the command module. At this time I left my position - I was monitoring here, and walked to the +Z axis going towards the White Room. At this time I noted two loud pops, two loud bangs, and at this time fire shot out of +Z and the +Y and the -Y axis. Quite a bit of flame to be exact. At this time, noting the flame coming out I turned and went out onto one of the elevated platforms; however, I left the gantry. At this time, I reported to the tech trailer and reported to my supervisor, Carl Black, and stood by the trailer until approximately 11:30 when we went to the operations trailer for a short meeting where we wrote down our recollections of the OCP and the test and what had happened on the level, and then we were to come to the War Room for another meeting. At this time, Mr. Pearce asked Dick Bachand and myself to go into the command module after they had removed the astronauts and check through the switch positions and so forth to see if there was anything unusual and maybe out of place. At this time upon entering we went to the OCP up and around where they were testing at T-minus 15 minutes. Up to this point everything seemed good. The two main things that we did note, panel 150, the pyro panel, was out of position; it is normally mounted on the forward equipment bay in the right hand corner and it was approximately 8 inches forward of the equipment bay sitting on two brackets. It had not, from all appearances blown out since the mounting screws were laying right in front of it in a neat pile, and if they had of blown, why they would have stripped the screws and probably blown around the command module there. There were three circuit breakers engaged, they were Batt A power entry, Batt B power entry and Batt C power entry. The other circuit breakers on the panel were open. Starting after T-minus 15 minutes where we

would have picked up the count, which is T-plus 36, the only two things we checked into the sequence and fuel cell 3 on panel 18, fuel cell 3 to bus A was in the center position, and fuel cells 1 to bus B was in the center position. The other fuel cell switches on the busses were off, and you first step in sequence page 6, I don't recall the paragraph right now, but were to throw these to "ON" momentarily. It looked like this might have been done ahead of time, I don't know what bearing offhand, this is done but going on 9206 sequence 06 the battery relays busses were open and on the commander's panel 8, which would have been a few of his call-outs. The rate gyros were in the normal position and it looked generally pretty good. The test light or the abort light was hanging about half way out. It looked like there had been some flames shooting out beside it. But I believe that does it generally. This is all I have to relate concerning this test.

RICHARD A. BACHAND
NAA
JANUARY 27, 1967

At the time of this incident, I was standing about 10 feet from the outside between the +Z and +Y axis, level 8A, facing away from the C/M. When I heard the astronaut give the alarm over the headset of "Fire in here," I turned to look at the C/M. I heard a low burp, then a large whoosh, then a wall of flame from the side of the C/M jumped from floor-to-ceiling and a pressure and heat blast pushed me backward. I dropped my headset, turned, and ran to the exit on the northwest corner. I called the elevator which arrived in about 30 seconds and went down in it. This is all I remember of the incident at this time.

/s/ Richard L. Bachand
January 27, 1967

JANUARY 29, 1967

Everything related to this AS-204 plugs-out test is classified in accordance with the mission failure plan. My name is Richard L. Bachand, Tech Support Crew. My position is Spacecraft Mechanic Senior Electronic. My supervisor is Carl Black. My station call sign is SCET, which is the Command Module electronic tech. On January 27, 1967, I was part of the before-mentioned test. I was on the adjustable 8 level, Command Module level, between the +Y and +Z axes, approximately 10 feet from the Command Module. I was monitoring the command channel and active on green ten with MRCS (station call sign) at the time the alarm was given by the astronaut that there was a fire in the Command Module. I was facing away from the Command Module, and immediately I turned and looked at the Spacecraft; and I heard a small burp or thump which I didn't know exactly what it was at the time. I have been told since then that several others heard it and again find it is the Command Module pressure relief valve. Immediately following this, I'd say less than a second later, there was a large "woosh" and a wall of flame rose up between me and the Command Module. I'd say it was from floor-to-ceiling. Everywhere I looked there was flame. I dropped the headset, turned around, and ran for the exit which was on the northwest corner. I got out through the door, which locked behind me, and I'd say less than 30 seconds later, the elevator got there, and I went down on the elevator. This is all I have to relate concerning this test. My name is Richard Bachand.

STEPHEN B. CLEMMONS
NAA
JANUARY 27, 1967

1. First attempt to enter C/M via white room.
2. Went to get gas mask
3. Second attempt to enter C/M. Helped to remove B.P.C. access door and outer hatch to C/M.
4. Went to get another gas mask.
5. Helped to remove inner hatch.

JANUARY 27, 1967

After hearing the words, there's a fire in here, I turned toward the S/C and saw a white glow coming from the edge of the boost protective cover at the next opening as diagram shows.

Don Babbitt yelled, there's a fire inside and I ran toward the white room. Babbitt, Gleaves, Hawkins, L. D. Reece and myself tried to get in but by this time (10 seconds approx.) extreme heat and flames drove us out of the swing arm. We tried to find some gas masks but there was a little time required finding any. When we finally found some, one mask came off the hose and two could not be opened on port at bottom. By this time, the flames and smoke had subsided so that we could attempt to open the hatch. We finally removed the outer hatch and outer C/M cover, after some difficulty because of a binding condition on B.P.C. By this time our masks had been used up. All this occurred within 4 minutes or less. With fresh masks, we attempted to remove the inner cover. On opening the last hatch we were driven back by the heat and fumes/smoke. I saw no fire and the small florescent lights on the seat head rest area was still burning. Before leaving, I stuck my hand inside but I could feel nothing or see anything because of smoke/heat. I did not hear any sounds emitting from inside. By this time my gas mask was used up and the fireman arrived. All this took place no longer than six minutes after it started, or so it seems.

Then joined the other personnel putting the fire or remains out. There were not too many significant items except when it started. There seemed to be a loud venting of gases, then ignition which sounded like a gas jet being ignited. There was no loud explosion and the fire seem to come from all directions exiting from the command module access ports.

/s/ Stephen B. Clemmons

JAMES EARL CROMER
PAA
JANUARY 27, 1967

1215 - I went on station for the 220 foot level of umbilical tower for egress mode.

1245 - This was about the time the astronauts arrived. From this time until accident it was routine test on elevator which was in egress mode all this time.

About 1530 - During this time Bendix crew on 220 foot level changed crews on the unit on 220 foot level. I obtained permission from French Johnson for them to ride elevator. I was in Blue 3 on the head set and was monitoring Black 3 at this time. There was two sampling men which came up and took samples in the 8th level and then returned to the ground.

Accident - At the time of the accident, I was on 220 foot level standing beside elevator looking at White Room, there was a flash of fire which came out of the White Room door, the concussion blew the side doors open, personnel left 8th level onto the catwalks to get their breath. Personnel came from White Room and told me to tell someone that the spacecraft was on fire which I repeated over Blue 3. I asked for gas mask to be put on elevator 1 to the 8th level catwalks. I also reported the 8th level was on fire. I assisted the personnel on the 220 foot level with gas masks and the one fire bottle on 200 foot level. I asked that the elevator stay at 220 foot level which it did for quite some time. Personnel used all fire bottles that could be found. Personnel made repeated trips into the capsule, but had to return for air because of the gas and smoke. One made repeated trips in until one fellows put him and theirselves on elevator which I sent to the bottom to the ambulance. The elevator returned to the 220 foot level for stay-by. From this time on Harry and I controlled the elevator from top to bottom for personnel that was permitted to use the elevator. We stayed in this configuration until we secured the elevator at about 9:50 p.m. (the egress) at the bottom level. Which then we went to elevator 4 and put it on express from the 1st, 6th, and 8th levels.

JOSEPH H. PLEASANT
NAA
FEBRUARY 7, 1967

On Friday, January 27, 1967, at approximately 1830 hours, I was on Level A-8 of the structure standing near the stairs to the White Room. At that time, someone yelled, there's a fire in the Spacecraft; and about that second, there was a muffled explosion and fire shot out from around the bottom of the Command Module in several places. The Level immediately filled with smoke and some visible flame about the Spacecraft. The CO_2 bottles on that Level were being used by personnel to fight the fire. CO_2 bottles were brought from another levels to help. Every attempt was made to open the hatch for the astronauts' escape. There were no elevators available, so I climbed from Level 8 to Level 6 over the cat walks and then to A-5 where I went into a Douglas room and called the Fire Department; but they had already been notified.

At that time, someone was paging for the Tech Trailer to come up on headset. This was made several times. I went to the Tech Trailer by way of the stairs and reported in on headset but no answer. I immediately started with a head count of the GSE personnel and notifying higher level of supervision. When the first-aid trucks arrived, I sent five GSE technicians to the Dispensary which had been on station or or near Level A-8. Names as follows: B. Belt, A. Journey, J. McConnell, W. Wingfield and W. Schneider.

/s/ J. H. Pleasant

BRUCE W. DAVIS
NAA
JANUARY 27, 1967

I was standing at the umbilical on the adjustable 8 level at the time of the fire. Just previous to the fire I heard that the astronauts were having trouble with communications. They were instructed to change to Black 2 channel. At this time I heard someone say, "There is a fire in the cockpit." I turned around and after about one second I saw flames within the two open access panels in the command module near the umbilical. Someone said, "She's going to blow." Before I could turn around I heard a whoosh and flames shot out of the access panels. Someone shouted, "Clear the level." As I turned around and ran toward the south west door I felt a large breeze and felt the flames. Several of us got out the door and turned to look back through the window and all we could see was flames. Someone said the Launch Escape System is going to blow and some guys climbed down the beams to the next level. We looked back and someone said, "There's nobody alive in there." The elevator finally came up and we got on it and rode down to the bottom floor.

/s/ Bruce W. Davis

FRIEND D. HICKENBOTTOM
NAA
JANUARY 27, 1967

I was on level A-8, on a head set, monitoring the test, located on the south side of the tower, near the Quality Control desk.

I was facing east when I heard a report on the headset that there was a fire in the Command Module, this report I believe came from Chaffee, at that instant I looked northeast and saw a spurt of flame come from the area under the white room and heart a report that sounded like a small explosion followed by a louder, more distinct noise, and flames shot out of the openings of the Command Module.

At that time I left the headset and went to the phone which was located on the same level at the southeast corner of A-8.

I reported a fire in the Command Module on Complex 34, Level A-8 to the PAA Fire Department and waited for the indication that they understood me, which they did.

At this time I walked to the elevator on the southeast corner, called it and returned to the door where a fire extinguisher was, I took it and started to fight at the south side of the Command Module and continued until the firemen arrived.

Time was approximately 1820. crew reported fire, Fire Department called on way to get fire extinguisher, elevator arrived, (Rogers, NASA Quality Control, covered me with smock), ran out of extinguisher, flames are at all ports, up to 5 feet high near pad leader desk. Documents caught fire from objects blowing out near Pad Leader's desk. Got new fire extinguisher, flames are high again, flames secured on area near Quality Control desk, partially secured by the Pad Leader's desk. Fire Department arrived and finished the flames in the area near Pad Leader's desk. The area near the umbilical island was hard to put out.

The area had such dense smoke that it was not possible to determine where the major flame area was, but it was definitely on the north side near the umbilical and on around near the hatch. Flames were at times very near the base of the Launch Escape System (LES).

Hagar and I were discussing the jackets and other non-test related items, the count was at about 10 and we were having communications problems. This communications problem was not of such magnitude that it kept me from hearing the report from the astronaut that there was a fire in the cockpit.

/s/ Dale Hickenbottom

JERRY W. HAWKINS
NAA
JANUARY 27, 1967

I was located at the swing arm at the passway from level A8. Someone yelled fire, and I saw flame billow from the Spacecraft toward the pad leader's desk. The next thing, fire was showing up in many places; people were coming toward the swing arm; the area was rapidly filled with smoke and fire. We opened the swing arm exit and went to the umbilical tower to get gas masks and return to the white room, but fire and smoke was blinding. We ran back to the umbilical tower and found a fire extinguisher, returned to white room and put the fire out around the hatch area. My hose came off my gas mask, and I had to return to the swing arm. Gleaves, my lead man, came out a little later, how long I'm not sure, choking, and handed me his mask. He said "I got the B.P.C. hatch, get the others." I returned, and Clemmons and I removed the outer and inner hatches. We couldn't see inside, but leaned in and felt for the crew. The heat was tremendous, and I got ashes or soot on my hands, and all objects were too hot to touch. I was getting smoke in my mask at this time and left momentarily for fresh air and a flashlight - 10 - 15 seconds - returned to hatch with lite and there was nothing but what appeared to be a blanket of ashes across the crew couches, and no one could be made out anywhere in the C/M. The firemen arrived, and I left the white room to inform pad leader of condition inside C/M. Then helped Gleaves to umbilical elevator down and to medics.

/s/ Jerry W. Hawkins

W. DONALD BROWN

NAA

JANUARY 28, 1967

Was at Quality Control desk when Command Module access panel 10 seemed to ignite as a minor type explosion. During this period 2 wooshes (loud) of escaping gas were heard. The area L-8 became immediately full of smoke, grey. I went to L-7, top of Service Module (S/M), Sector I and II, were burning. Also quads A and B were on fire. Fire was coming from inside Sector I access from below the access (much grey smoke). I returned to Level-8 from Level-5 and smoke was still coming from under and left-hand side of BPC. Upon returning from L-6 with extinguisher was told to leave area. I do not recall any times (clock) of these events.

/s/ W. D. Brown

JESSIE L. OWENS

NAA

JANUARY 27, 1967

- Accident Report - Launch Complex 34, Level A-8
  Time: Approximately 6:30

My position was near the Pad Leader's desk (by the water cooler). Garbled communications, but intelligible enough to hear switch to Black 4 or Black 2 - then fire in Command Module - I turned, looked at the Pad Leader, looked back at the Command Module at the White Room P hatch area, heard what sounded like the cabin relief valve open and high velocity gas escaping. Within two seconds (I estimate) high velocity gas came out the access panel in the +Y direction from the G and N (Guidance and Navigation System). Immediately this gas burst into flame somewhat like lighting an acetylene torch. I turned to go to the White Room at the above noted instant but was met by a flame wall. I turned to exit through the northeast door to the elevator and my hair was singed in the back under my white cap (evidence of the height of the flame). I exited to the crosswalk but no elevator was available - turned back to into the A-8 area but flame and door being latching type from inside, I couldn't get in. I climbed out on the structure and down the beams to the stair area, went down the stairs and to the nearest trailer and phoned C. C. Stephens.

NOTE: The smoke I breathed was foul and of an irritating nature. The flame was orange.

/s/ Jessie Owens, NAA Supt.

(NASA-TM-84099) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C SECTION 1 (NASA) 440 p

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REPORT OF APOLLO 204 REVIEW BOARD

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(NAS-TM-X-70156) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C, SECTION 1 (NASA) 440 p

N74-72948

Unclas
00/99 16141

APPENDIX C

SECTION 1

(NASA-TM-X-70156) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C, SECTION 1 (NASA) 440 p LIMITED ACCESS

X75-71244

Unclas
00/98 06684

LIST OF EFFECTIVE PAGES

NOTE: The portion of the text affected by the current changes is indicated by a vertical line in the outer margins of the page.

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CHANGE INFORMATION

This handbook is subject to continuous change or revision, on a priority basis, to reflect current engineering or mission changes, or to improve content or arrangement. The content and the changes are accounted for by the above List of Effective Pages, and by the following means:

Record of Publication: The publication date of each basic issue and each change issue is listed on page B as a record of all editions.

Page Change Date: Each page in this handbook has space for entering a change date. The latest publication date will be entered in this space each time a page is changed from the basic issue.

*The asterisk indicates pages changed, added, or deleted by the current change.

Manuals will be distributed as directed by the NASA Apollo Program Office. All requests for manuals should be directed to the NASA Apollo Spacecraft Program Office at Houston, Texas.

RECORD OF PUBLICATION

This issue of the Apollo Operations Handbook, Spacecraft 012, dated 12 November 1966, constitutes a revision of the handbook, dated 16 September 1966. Subsequent changes may be issued to maintain information current with spacecraft configuration through completion of the mission. This record will reflect the publication date of any released changes.

LATE TECHNICAL CHANGES

The items listed below represent technical changes which have been approved too late for inclusion in the 12 November 1966 printing of the Apollo Operations Handbook.

Source	Description of Change	Section Affected
MCR A1735	Change S/M RCS fuel from blended hydrazine mixture to monomethylhydrazine	2.5
MCR 1591 REV 3.	Addition of inverter synchronizer power panel which provides circuit breakers for the control of power to the phase synchronizer unit.	2, 3
FEO M-53025 (10-13-66)	This is a nomenclature correction for the S-Band switch on the MDC panels No. 13, 23 and 26. This change is required due to wiring changes. The S-Band switch was marked "PTT", "OFF" and "VOX". The switch is now marked "OFF", "OFF" and "T/R".	2.8 and 3
MCR A1733 (10-11-66)	Modification of Crew Couch Lockouts. This MCR removes the lockout solenoid actuator and wire harness from the X-X axis strut lockout mechanism. Add an adapter to the lockout mechanism assembly to fix in the locked position. The switch on panel No. 9 and the wire harness assembly on the struts will be removed.	1, 2, 3

SYNOPSIS OF SIGNIFICANT CHANGES

This tabulation does not list all changes, additions, and/or deletions in the handbook. Its purpose is to assist the reader in determining the significant technical changes in each system.

PART I. TECHNICAL CHANGES

Handbook Section(s) Affected	Description	Handbook System(s) Affected
1	Updated lockout mechanisms on shock struts.	GEN
1	Updated forward hatch cover.	GEN
2	Revised RCSC circuit diagram to include entry battery backup power to pyro bus.	SEQ
2	H_2 purge line heater	EPS
2	Fuel cell H_2 and O_2 reactant shutoff valves holding voltage control	EPS
2	Cryogenic system response and operation	EPS
2	Revised, updated, and assembled end-to-end circuit and system diagrams. Added electrical power distribution diagrams and power requirements. Added operating ranges and panel references to measurement lists.	PROP
4	Added tabular data for color markings contained on indicator displays and updated art.	SPS, EPS and ECS
4	Added typical charts from MMDB to determine S/C consumable data.	RCS, SPS and EPS
4	Added data on S/C attitude controls.	RCS
4	Updated SPS Delta V and Engine Gimbal Angle charts.	SPS

FOREWORD

This handbook and its contents are restricted to the requirements for Spacecraft 012. It presents, in one document, descriptions of the spacecraft systems and equipment, and listings of the flight crew operational procedures necessary for the safe and efficient function of the spacecraft throughout its planned mission. This handbook is designed primarily for use by the flight crew, and secondarily for use by the mission flight controllers, flight planners, and trainer operators.

NASA comments or suggested changes to this handbook should be addressed to the Flight Planning Section, FCSD, MSC, Office Code CF 32, Telephone HU3-4271.

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SECTION 1

GENERAL INFORMATION

INTRODUCTION.

This section contains information relating to the Apollo spacecraft 012 configuration, and a description of the launch vehicle and booster used for the mission.

1.1 SPACECRAFT 012 CONFIGURATION.

Spacecraft 012 (figure 1-1) conforms to a Block I CSM configuration consisting of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft lunar excursion module adapter (SLA). This spacecraft, designed for an earth orbital mission, does not contain a lunar module (LM) within its adapter. (For a description of the launch vehicle used with spacecraft 012, refer to paragraph 1.2)

NOTE The Block I configuration missions for the Apollo program provide the following:

- Command module and service module development for earth orbital missions
- Demonstration of systems operational capabilities including all types of aborts, land and water recovery, Saturn IB and Saturn V operation and capability, and systems operation during earth orbit
- Development of qualified teams for checkout, launch, manned space flight network (MSFN), recovery, and flight analysis.

1.1.1 LES ASSEMBLY.

The LES assembly (figure 1-1) provides the means for separating the C/M from the launch vehicle during pad or suborbital aborts. This assembly consists of a Q-ball instrumentation assembly (nose cone), ballast compartment, canard surfaces, pitch control motor, tower jettison motor, launch escape motor, a structural skirt, an open-frame tower, and a boost protective cover (BPC). The structural skirt at the base of the housing, which encloses the rocket motors, is secured to the upper portion of the tower.

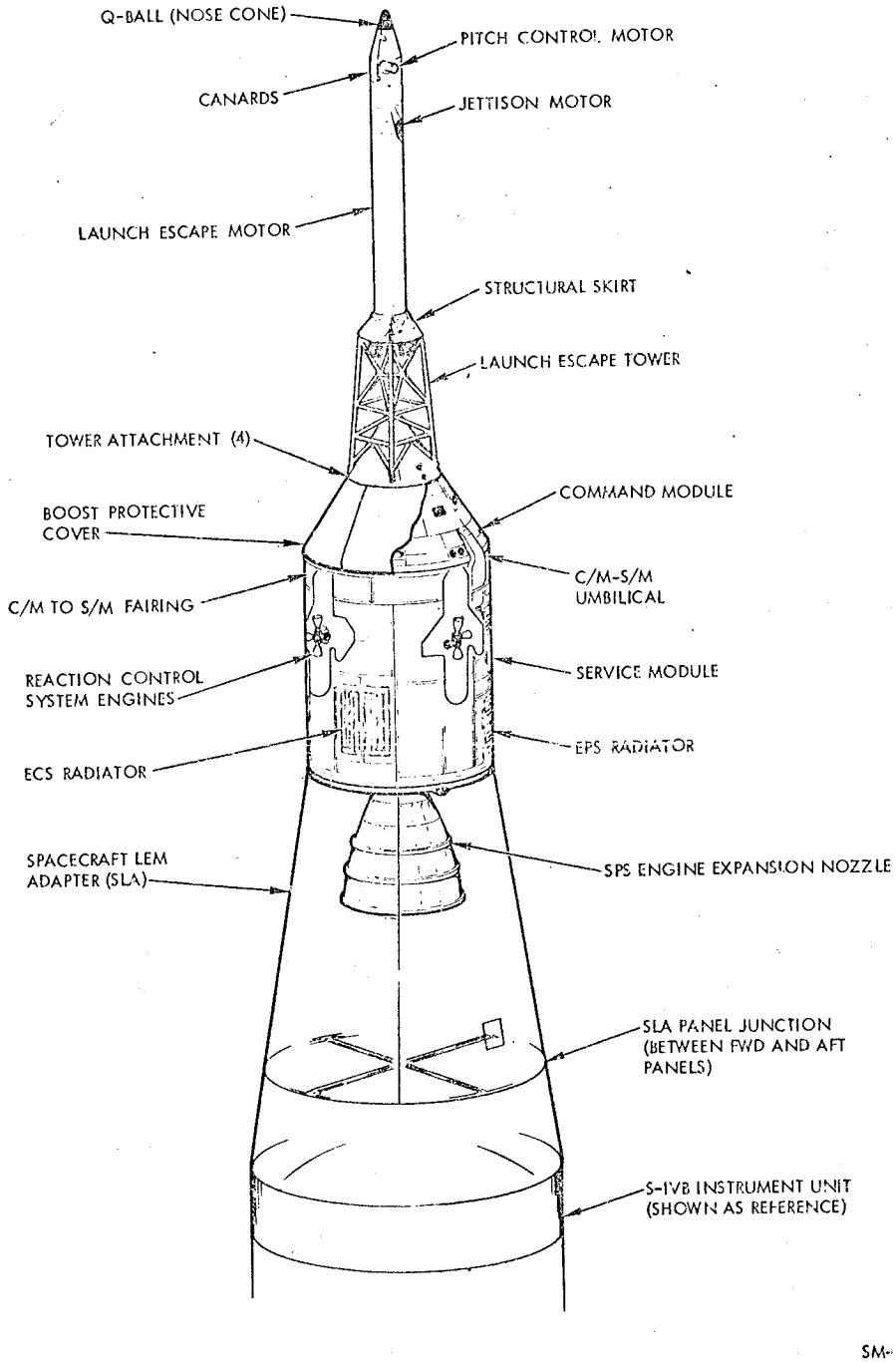


Figure 1-1. Spacecraft 012 Configuration (Sheet 1 of 2)

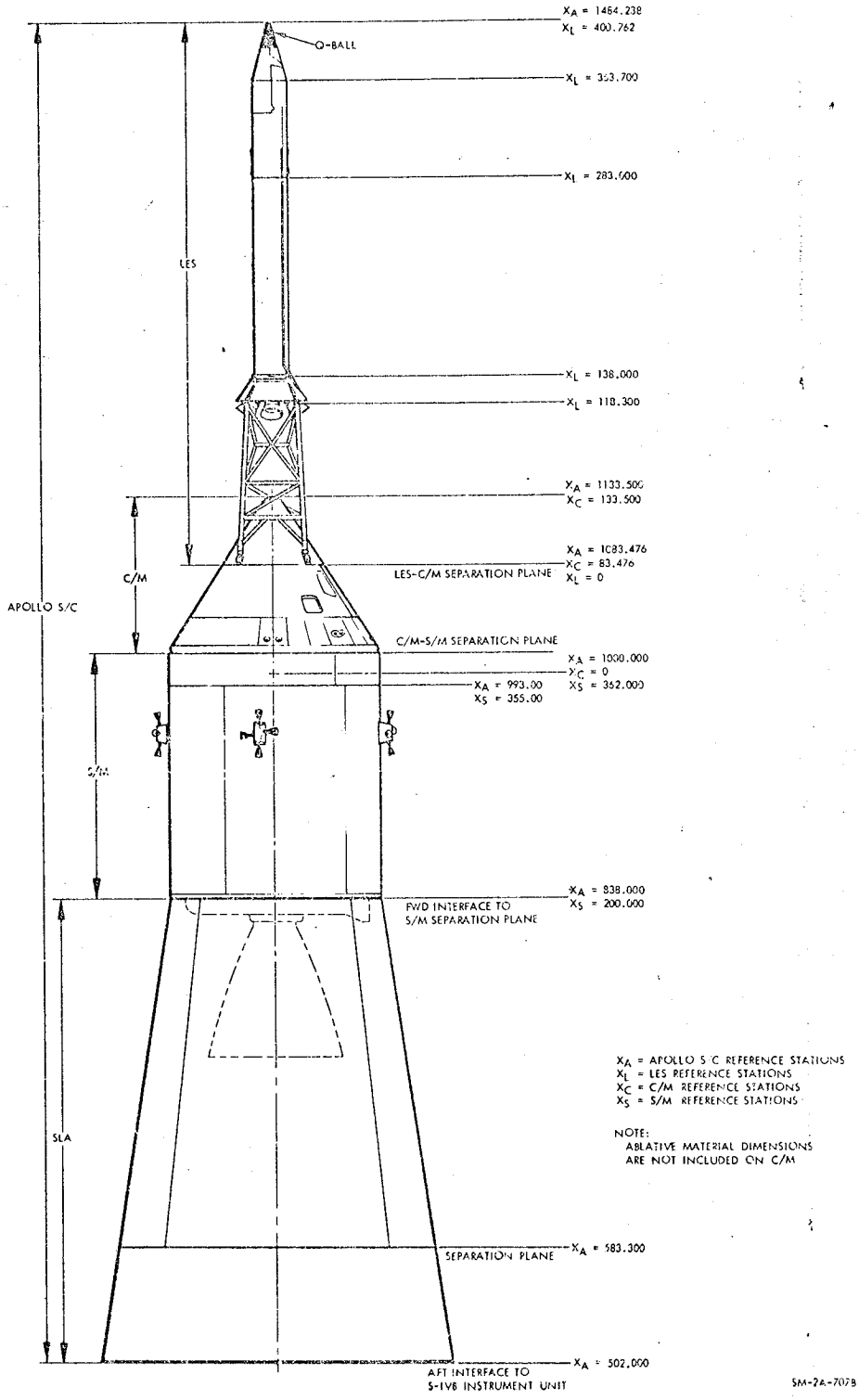


Figure 1-1. Spacecraft 012 Configuration (Sheet 2 of 2)

The BPC (figure 1-2) is attached to the lower end of the tower to protect the C/M from thermal heat during boost and from exhaust damage by the launch escape and tower jettison motors. Explosive nuts, one in each tower well leg, secure the tower to the C/M structure. (For additional information, refer to the sequential systems in section 2.)

1.1.2 COMMAND MODULE.

The C/M (figure 1-3) forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and conform of the crew. The module is an irregular-shaped, primary structure encompassed by three heat shields (coated with ablative material and joined or fastened to the primary structure) forming a conical-exterior shape. The C/M consists of a forward compartment, a crew compartment, and an aft compartment.

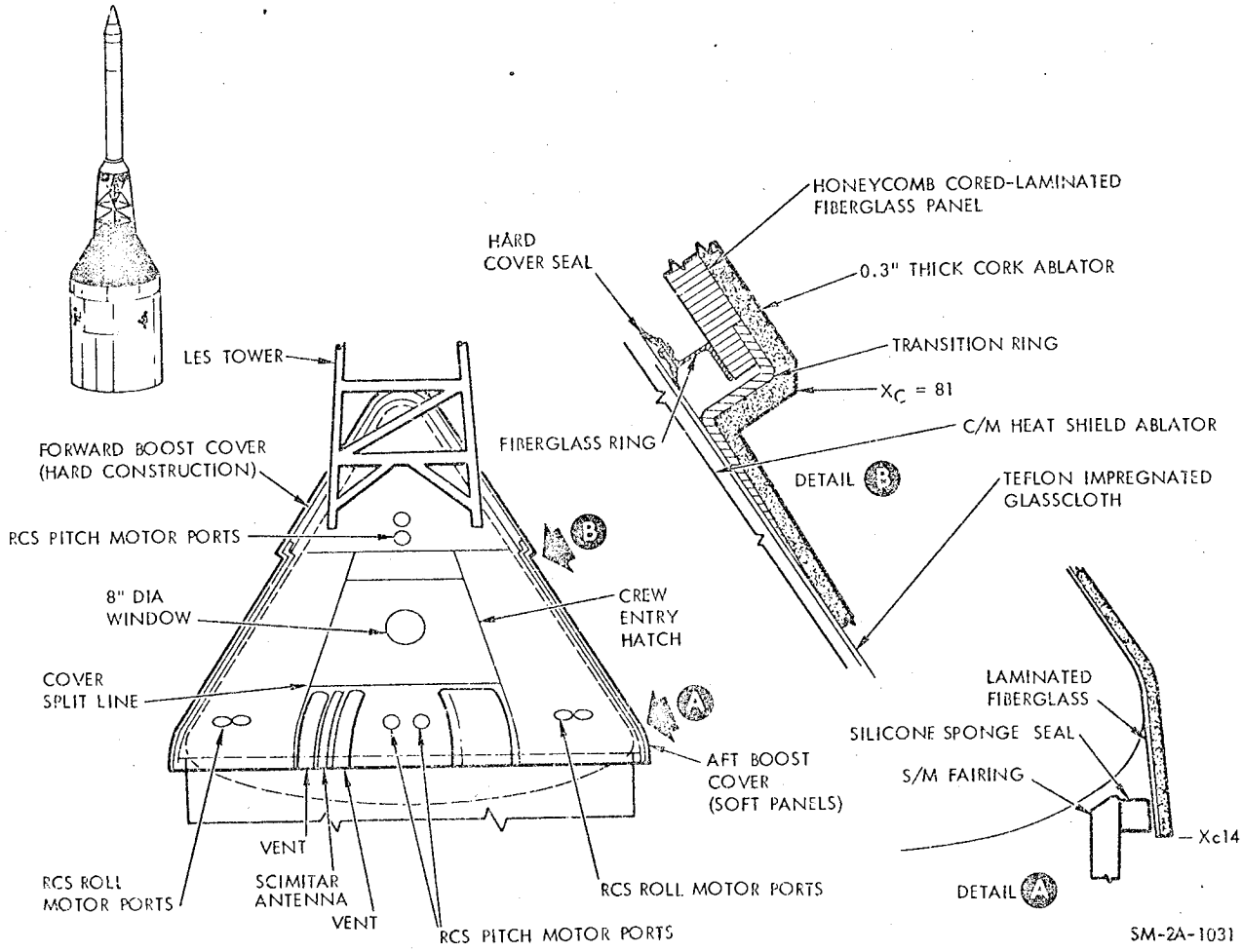


Figure 1-2. Boost Protective Cover

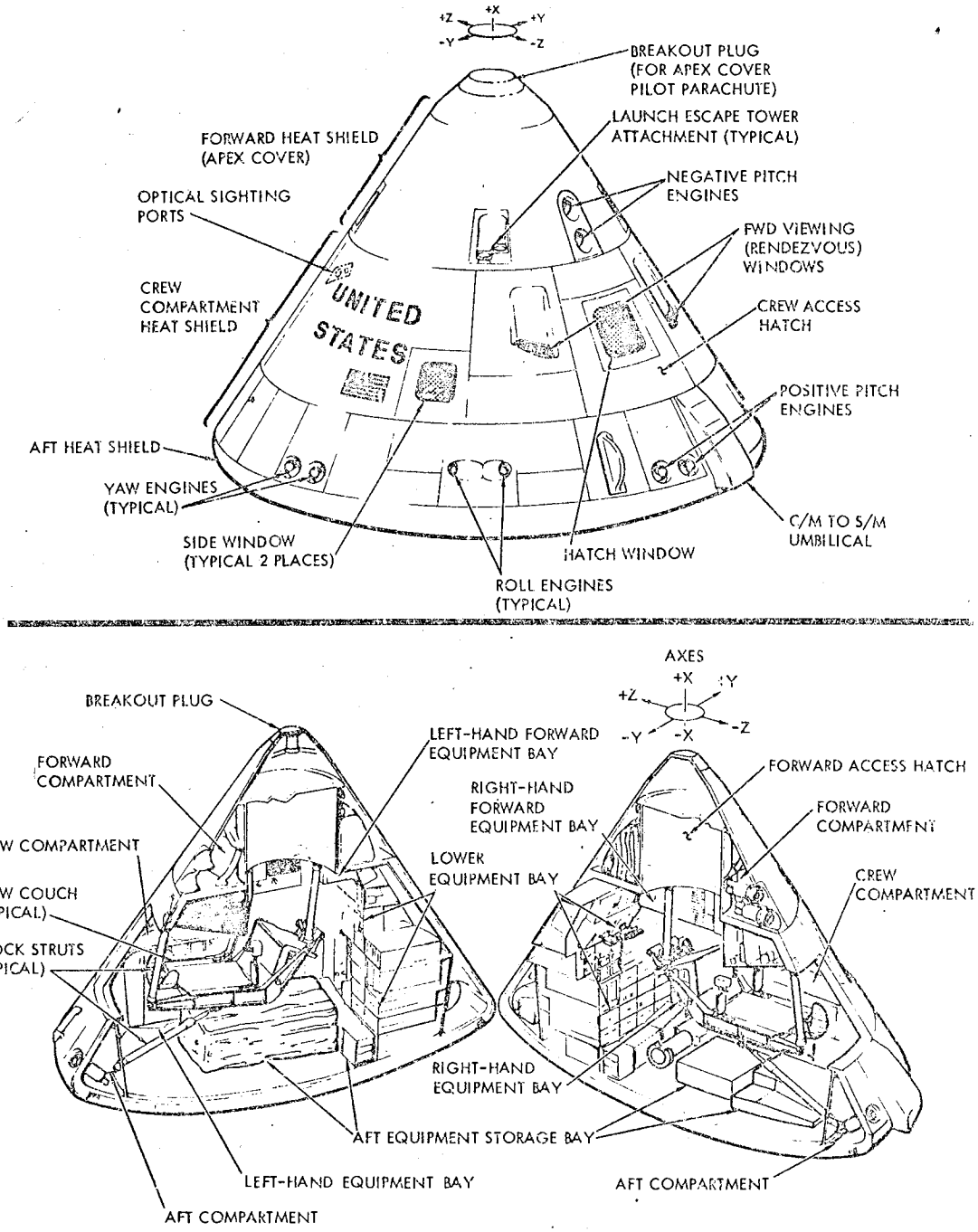


Figure 1-3. Spacecraft 012 Command Module

1.1.2.1 Forward Compartment.

The forward compartment (figure 1-3) is the area outside the forward access tunnel, forward of the crew compartment forward bulkhead and is covered by the forward heat shield. Four 90-degree segments around the perimeter of the tunnel contain the recovery equipment, two negative-pitch reaction control system engines, and the forward heat shield release mechanism. Most of the equipment in the forward compartment consists of earth landing (recovery) system components.

The forward heat shield, or apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. It contains four recessed fittings which permit the launch escape tower to be attached to the C/M inner structure. Jettison thrusters separate the apex cover from the C/M after entry or after the launch escape assembly is separated during an abort. (For additional information, refer to the sequential systems in section 2.)

1.1.2.2 Crew Compartment.

The crew compartment or inner structure (figure 1-3) is a sealed cabin with pressurization maintained by the environmental control system (ECS). The compartment, protected by a heat shield, contains controls and displays for operation of the spacecraft and spacecraft systems; contains mechanical adjustments for the crew couches, restraint harness assemblies, hatch covers, window shades, etc.; and is provided with crew equipment, food and water, waste management provisions, survival equipment, and scientific experiments equipment. Access hatches, observation windows, and equipment bays are attached as part of the compartment structure.

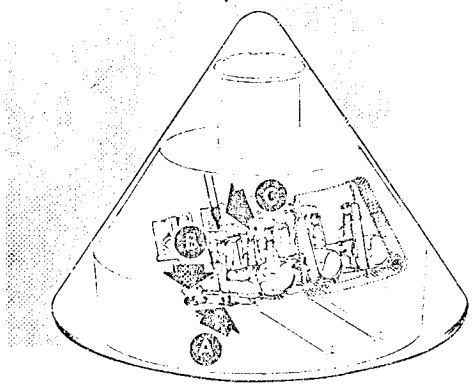
The crew compartment heat shield, like the apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. This heat shield, or outer structure, contains the S/C umbilical connector outlet, ablative plugs, and a copper heat sink for the optical sighting ports in the lower equipment bay, two side observation windows, two forward viewing windows, and the outer cover for the side access hatch which also contains an observation window.

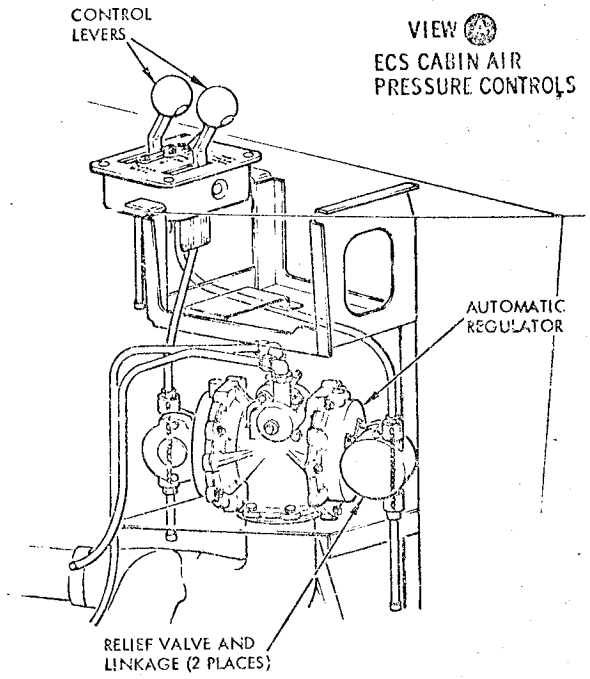
1.1.2.3 S/C Controls and Displays.

Information relating to controls and displays for operation of the spacecraft and its systems is provided in section 3.

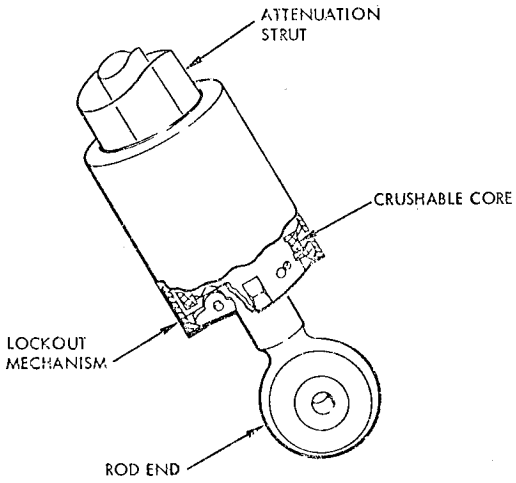
1.1.2.4 C/M Mechanical Controls.

Mechanical controls (figure 1-4) are provided in the crew compartment for manual operation of the crew couch assembly, side access hatch covers, forward access hatch cover, and manual override levers for the





VIEW C
X-X ATTENUATION STRUT LOCKOUT MECHANISM (4 PLACES)



VIEW B
Y-Y ATTENUATION STRUT (2 PLACES)

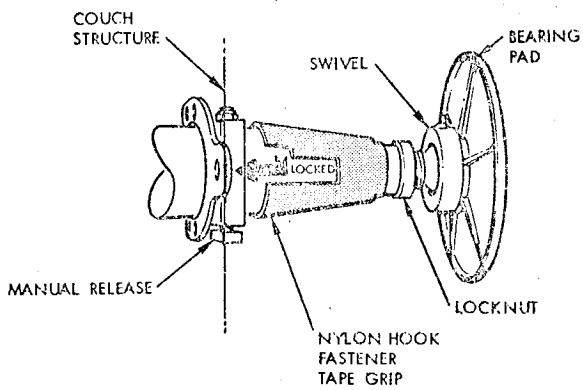


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Figure 1-4. C/M Mechanical Controls (Sheet 1 of 3)

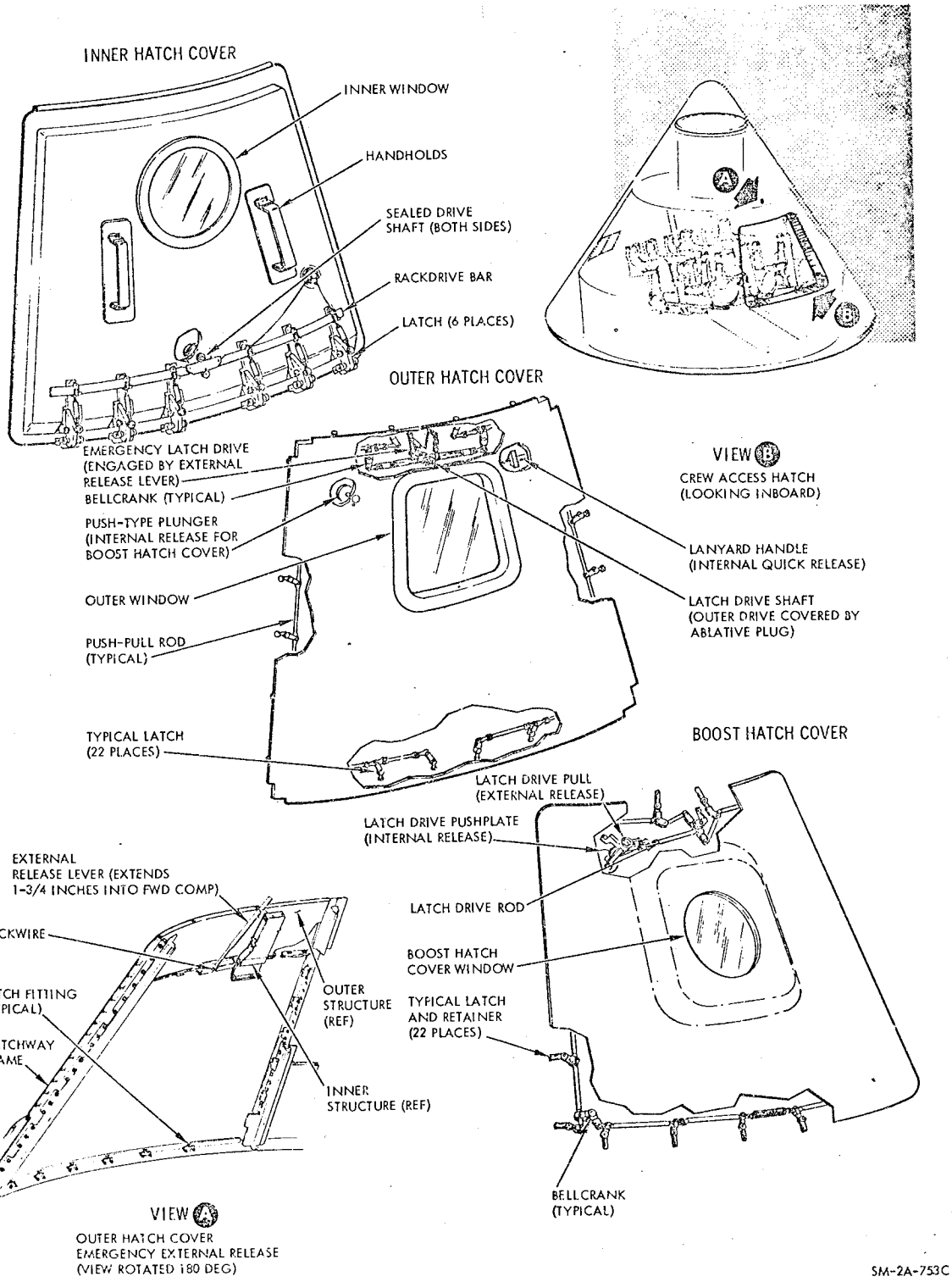


Figure 1-4. C/M Mechanical Controls (Sheet 2 of 3)

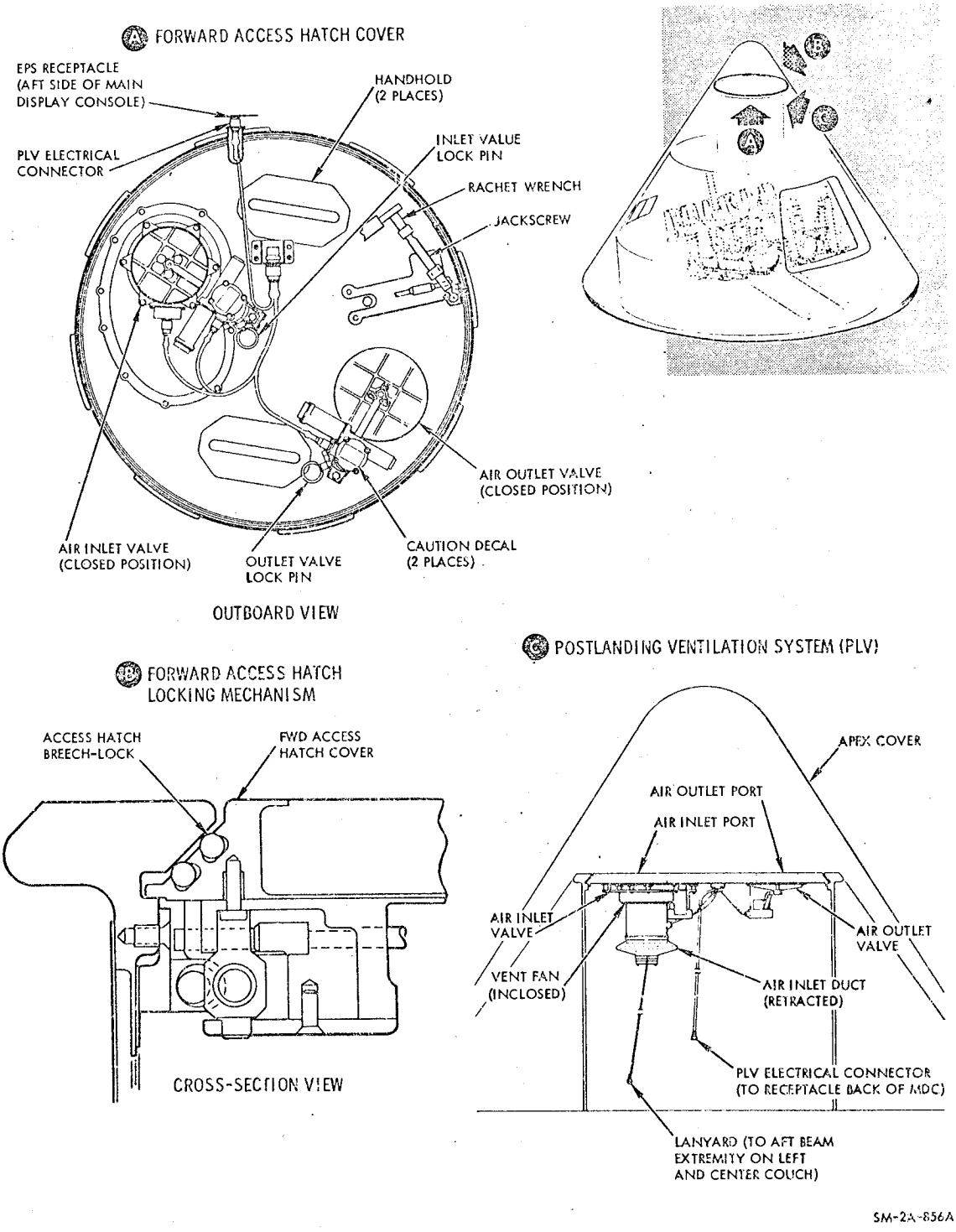


Figure 1-4. C/M Mechanical Controls (Sheet 3 of 3)

ECS cabin pressure regulator. Tools for opening or securing the hatch covers are in the stowage area under the work table in the lower equipment bay; the tools are components of the in-flight tool kit.

1.1.2.4.1 Crew Couch Controls.

Crew couch manual controls for each headrest, armrest, and seat pan assembly are provided for individual crew comfort. The crew couch assembly can also be manually adjusted for crew positioning during simulated docking maneuvers, crew convenience in getting in and out of the couches, and crew access to all equipment bays in the C/M. (For additional information, refer to crew couch assembly in section 6.)

1.1.2.4.2 Couch Attenuation Struts.

Eight attenuation struts are provided for connecting the crew couches to the C/M inner structure. (See figure 1-5.) Each strut is capable of absorbing energy at a predetermined rate through crushable aluminum

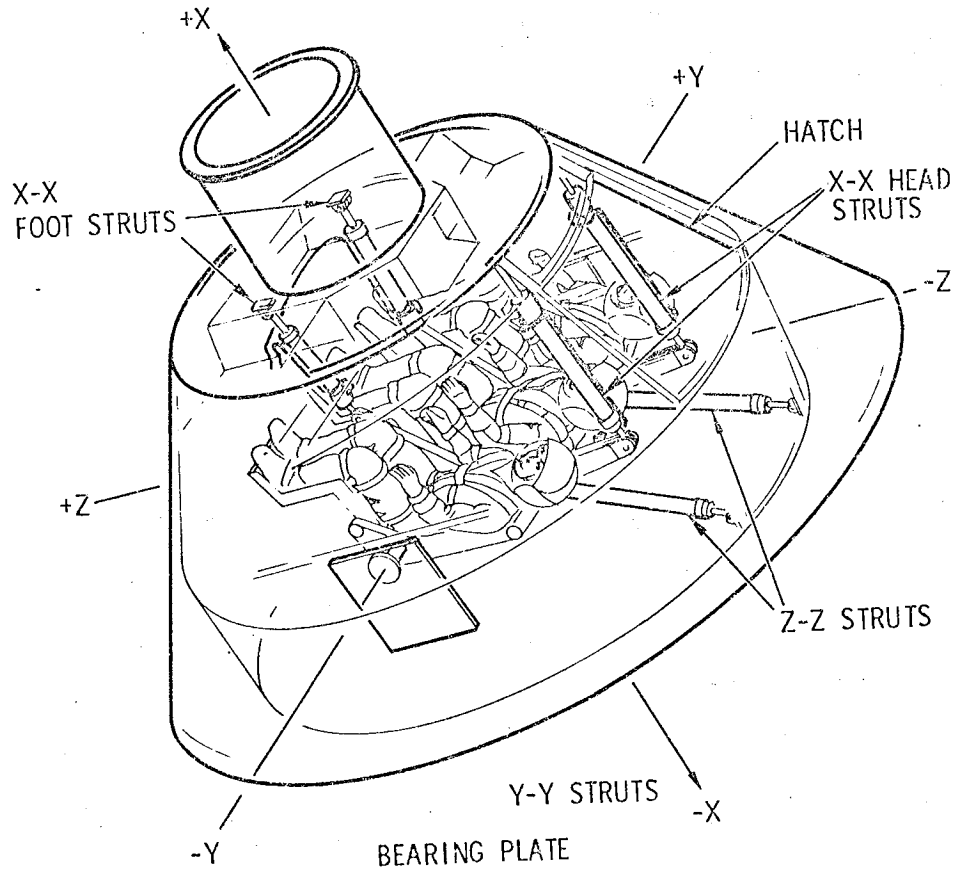


Figure 1-5. Internal Attenuation System

honeycomb cores contained within the strut cylinders. In effect, the strut piston action during C/M impact absorbs energy that the crew is not capable of absorbing.

Two Y-Y axis struts are located at the outer extremities of the couch assembly at the hip beam. The cylinder end of each strut is firmly attached to the unitized couch while the piston end, containing a flat circular foot, reacts against a flat bearing plate (attenuation panel) attached to the structure.

Two Z-Z axis struts are attached to the main couch beams under the unitized backrest and the aft bulkhead of the structure, just below the side access hatch. In addition to the crushable cores within the struts, friction brake snubbers are provided on the end of the pistons for additional breaking action. During a compression stroke or initial tension load, these friction brakes act in conjunction with the inner pistons which simultaneously crush the cylinder inner cores. Additional tension loads are absorbed by a combination of the outer and inner friction mechanisms which continue the crushing action of the cylinder cores.

Four X-X axis struts are attached to the forward C/M structure and the beam extremities of the couch. These struts, except for the addition of lockout mechanisms, are basically the same as the Z-Z axis struts. A lockout mechanism, is provided on each strut to prevent any strut attenuation prior to impact (during normal mission flight loads). Upon impact the honeycomb core will be crushed, allowing the piston rod to stroke.

1.1.2.4.3 Crew Access Hatch Covers.

The C/M crew access hatch is provided with three covers (inner, outer, and boost) and the necessary latching mechanisms for securing the covers to the C/M. (See figure 1-4.) Latches for these covers can be manually operated from either side of the hatch by a removable handcrank or torque wrench with a 7/16-inch drive. The inner cover is equipped with a sealed drive, a rack-drive bar, and six latches which engage fittings on the C/M inner structure (to preload the hatch for sealing). The outer cover is equipped with bellcranks, rollers, and push-pull rods, an overcenter lock, and 22 latches which engage fittings on the C/M outer structure. An ablative screw-in plug is used to protect the outer driver shaft in the outer hatch cover. This plug must be removed before a handcrank can be inserted into the drive shaft from outside the C/M. An emergency latch release is also provided for the outer hatch cover, but can only be operated by personnel outside the C/M during recovery procedures. The boost hatch cover is also equipped with mechanical components (including 22 latches) for installing it flush with the boost protective cover. This hatch cover makes it possible for the crew to get in and out of the S/C during prelaunch operations. A ground support tool (G15-824105 handle) is used to remove (pull) the boost cover from the outside the C/M. A plunger on the inside of the outer hatch engages a latch drive push-plate to release the boost hatch cover from inside the C/M.

1.1.2.4.4 Forward Access Hatch Cover

The C/M forward access hatch is provided with a cover that can be operated from either the inside or outside the crew compartment. (Outside operation is possible only after the launch escape system, boost protective cover, and forward heat shield have been jettisoned. (See figure 1-4.) A breech-lock method is used to engage and rotate the cover in the forward end of the tunnel ring. The internal pressure of the C/M will assist to seal the hatch cover by forcing it against its seat. A jackscrew (with a hex

socket at one end) is mounted on the cover and will bear against a bracket on the tunnel wall. When turned by a handcrank or torque wrench with a 5/32-inch drive, the jackscrew will intend and allow the cover to be rotated and removed. The cover is rotated by use of the inside handholds or the outside by an item of GSE and can only be retrieved from within the crew compartment end of the tunnel.

1.1.2.4.5 Windows and Shades.

Five windows are provided through the inner structure and heat shield of the C/M: two forward viewing, two side observation, and the crew access hatch windows. (See figure 1-3.) During orbital flight, photographs of external objects will be taken through the viewing and observation windows. The inner windows (including the circular inner hatch window) are made of tempered silica glass with 0.25-inch-thick double panes, separated by 0.1 inch of space, and have a softening temperature point of 2000°F. The outer windows (including the square outer hatch window) are made of amorphous fused silicon with a single 0.7-inch-thick pane. Each pane contains an antireflecting coating on the external surface, and has blue-red reflective coating on the inner surface for filtering out most infrared and all ultraviolet rays, a softening temperature point of 2800°F, and a melting point of 3110°F.

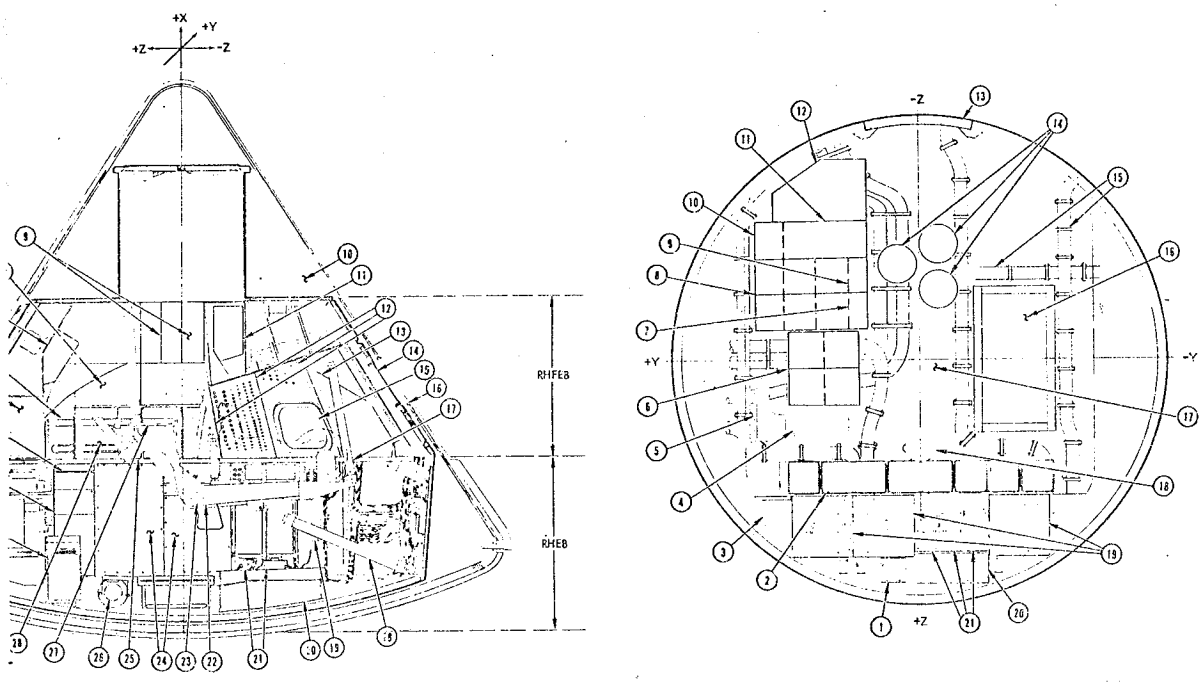
Shades are provided for controlling external light entering the C/M through the triangular forward viewing windows, the square side observation windows, and the circular inner hatch window. These shades, individually designed for each window configuration, are made of mylar film which has been heat-treated to roll up when not held flat. The shades are opaque for zero light transmittal, have a nonreflective inner aluminized surface, two snap fasteners and fabric handles for attaching or removing from a particular window, and a 3/4-inch strip of Velcro hook material around the outer surface for holding the shade against the Velcro pile around the perimeter of the window. If desired, a shade can be peeled back from the Velcro pile material and stowed in place on one side of the window.

1.1.2.4.6 Cabin Pressure Controls.

Two control levers for manually operating the ECS cabin pressure relief valves are located near the C/M left couch and left side window. (See figure 1-4.) These levers are provided as a mechanical override for opening and closing the redundant sides of the automatic cabin pressure regulator. (For additional information, refer to the environmental control system in section 2.)

1.1.2.5 Crew Equipment and Equipment Bays.

Each crewmember has personal and accessory equipment provided for his use in the crew compartment. Major items of personal equipment consist of a pressure garment assembly (PGA) with attaching hose and umbilical, a communications assembly, a constant-wear garment, biomedical sensors, and radiation dosimeters. Major items of accessory equipment shared by the crew consist of an in-flight tool set and a medical kit. (For a detailed list of crew equipment, refer to section 6.) (Specific items contained in the C/M equipment and storage bays are listed in figure 1-6.)



RD EQUIPMENT BAY (RHFEB) AND RIGHT-HAND EQUIPMENT BAY (RHEB)

ment (ref)

(ref)

17 Crew attenuation strut (X-X axis)
18 Crew attenuation strut (Z-Z axis)
19 Phase correcting capacitor fuse box
20 Compartments T, S and Z (ref)
21 Circuit interrupter
22 Right crew couch
23 Crew attenuation strut (Y-Y axis)
24 Side shock attenuation panels
25 Waste storage inlet (on bulkhead)
26 Stowed fecal canister (ref)
27 Sanitation supply stowage
28 Scientific equipment compartment E
29 Battery charger (ref)

AFT EQUIPMENT STOWAGE BAY (AESB)

1 Battery charger
2 CO_2 absorber containers
3 Pyro batteries and circuit breaker panel
4 Fecal canister (stowed)
5 TV lens storage
6 CO_2 absorber containers (4)
7 Pen lights compartment Z
8 CO_2 absorber containers (6)
9 Compartment Y
10 Compartment T
11 Compartment S
12 PGA and sleep restraint stowage bag
13 Crew access hatch (ref)
14 PGA helmet, comm soft hat, light wt headset stowage
15 Bulkhead wireways (typical)
16 Spacesuit (2), life vest (3), sleeping restraint (1) stowage bag
17 Aisleway (under center couch)
18 Fecal canister (usage position)
19 Electrical inverters
20 AC power box
21 Spacecraft storage batteries

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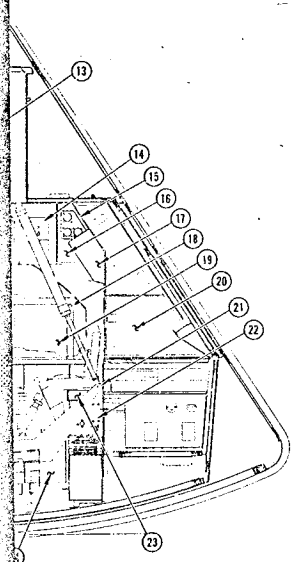
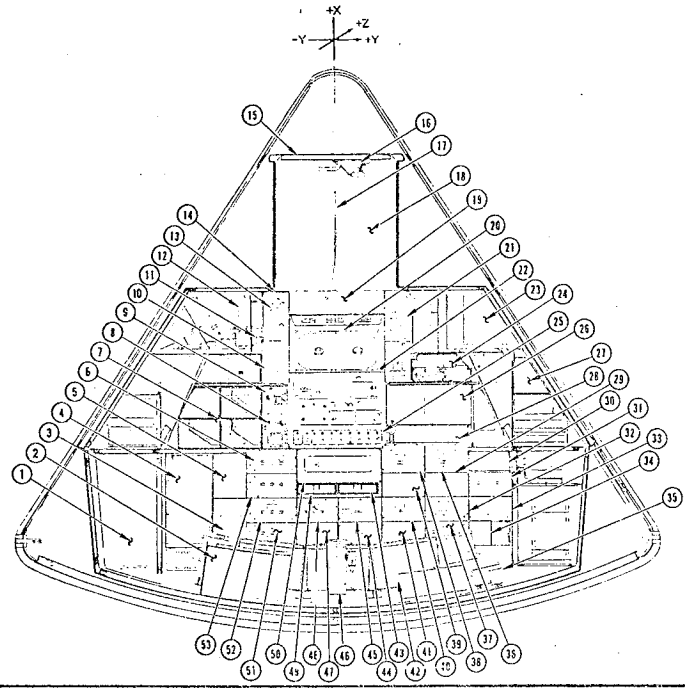
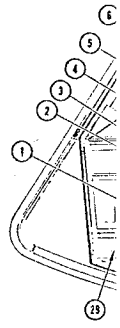
Figure 1-6. C/M Equipment and Stowage Bays







LEFT-HAND EQUIPMENT BAY (LHEB)

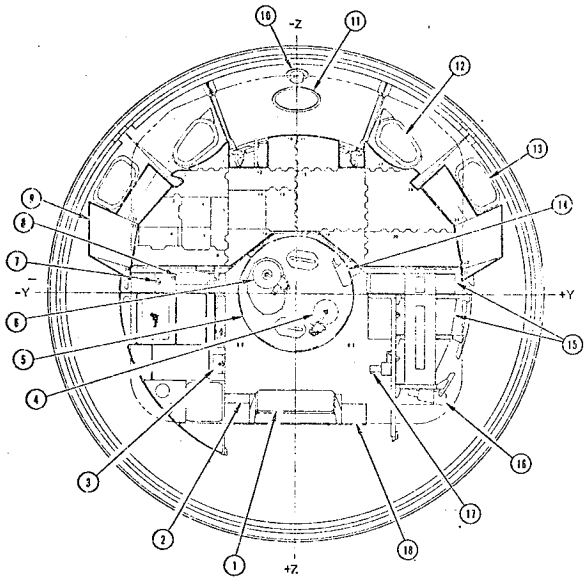
- ock and event timer panel
- N loose parts storage
- xtant and telescope compartment (ref)
- ew attenuation strut (X-X axis)
- thing storage compartment
- rtial measurement unit (ref)
- t crew couch (attenuated)
- ygen control panel
- dical kit (left couch)
- e shack attenuation panels (removable)
- cesuit stowage bag and scientific equipment stowage (ref)
- 5 valves
- 5 oxygen, water, and glycol equipment

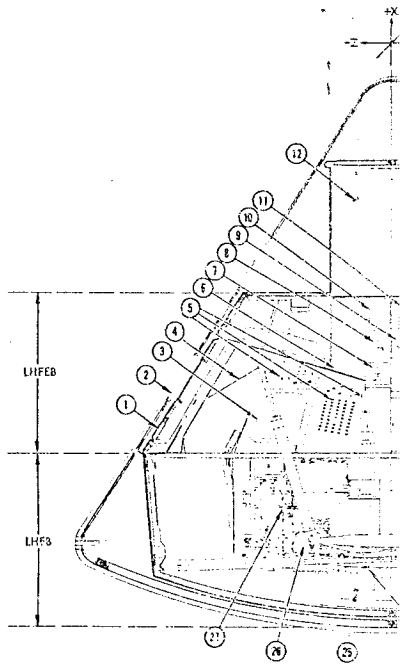
LOWER EQUIPMENT BAY (LEB)

1 ECS components (ref)
2 Spacesuit stowage bag and scientific equipment stowage (ref)
3 Gas chromotograph
4 Flight qualification tape recorder
5 Scientific equipment compartment A
6 Display/attitude gyro-accelerometer (ECA)
7 Food storage (5 containers)
8 Attitude gyro and accelerometer
9 Rate gyro
10 Coupling and display panel
11 Sr pilot suit connector panel and electrical connector (ref)
12 Cabin air recirculation fan (ref)
13 IMU control panel
14 Lighting control
15 Forward access hatch cover (ref)
16 Postlanding ECS air outlet duct
17 Postlanding ECS power cable
18 Forward access hatch (ref)
19 Sextant telescope eyepiece stowage
20 Sextant and telescope panel
21 Computer display and control panel
22 G&N control panel IMU
23 Survival provisions (ref)
24 Clinical monitoring instrument set compartment
25 Power servo assembly (PSA)
26 Data storage equipment
27 Towel storage
28 Signal conditioning equipment
29 VHF multiplexer
30 Data wiring
31 Fremodulation processor
32 VHF recovery beacon and VHF-AM transmitter-receiver
33 Audio center
34 Central timing
35 TV optics storage (ref)
36 Pulse-code modulation (PCM) unit 2 telemetry equipment
37 VHF-FM transmitter and HF transceiver
38 Pulse-code modulation (PCM) unit 1 telemetry equipment
39 Scientific equipment compartment C
40 S-band power amplifier
41 C-band transponder
42 CO_2 absorber container (ref)
43 Food and work table (in-flight tool set)
44 Digital up-data link
45 Unified S-band equipment
46 Fecal canister (positioned)
47 Scientific equipment compartment B
48 Roll channel ECA
49 Data package container (also on outboard couch beams)
50 G&N computer
51 Pitch channel ECA
52 Auxiliary ECA
53 Yaw channel ECA

RIGHT-HAND E

1 CO_2 absorber contain
2 Waste management sys
3 Computer
4 Vacuum cleaner comp
5 IMU compartment (ref.
6 Medical accessories ki
7 Sextant and telescope
8 Food stowage
9 Survival provisions
10 RCS pitch control engi
11 TV camera mount
12 Side console panels (ri
13 Rendezvous window ho
14 Inner hatch cover
15 Side window
16 Outer hatch cover





FORWARD REFERENCE VIEW

1 Optics shroud
2 LEB lighting control panel
3 Food reconstitution device
4 Postlanding ECS air outlet duct
5 Forward access hatch cover
6 Postlanding ECS air inlet duct
7 Water delivery valve
8 Water delivery unit
9 Main display console (MDC panels 1 through 26)
10 Crew access hatch actuator (inner cover)
11 Crew access hatch inner window
12 Forward viewing or rendezvous window (2 places)
13 Side window (2 places)
14 TV camera (launch and entry)
15 Survival provisions
16 TV camera mount (optional)
17 Measurement system instrumentation
18 Apollo guidance computer navigational display keyboard

LEFT-HAND FORWARD EQUIPMENT BAY (LHFE

1 Inner hatch cover
2 Outer hatch cover
3 Side window
4 Rendezvous window housing
5 Side console panels (left)
6 Main display console (ref)
7 Comdr suit connector panel and electrical connector
8 Sr pilot suit connector panel and electrical connector
9 Pilot suit connector panel electrical connector
10 Scientific equipment compartment D
11 Cabin air recirculation fan
12 Forward access hatch or egress tunnel (ref)
13 Postlanding ECS air inlet duct (extended)

1.1.2.6 Food and Water.

Food and water provisions, including water delivery and food preparation equipment, are available in the crew compartment LHEB and LEB, (figure 1-6) for the length of the mission. Food may be prepared by adding water to plastic bags containing the dehydrated food and kneading the mixture. Prepared food can be squeezed directly into the mouth of an astronaut. Hot or cold water is available at the potable water supply panel for food reconstitution. Chilled drinking water is supplied to the crew through a flexible hose from the water delivery unit. The potable water is a by-product of the EPS fuel cells.

1.1.2.7 Waste Management.

Waste management provisions in the crew compartment RHFEB and AESB (figure 1-6) consist of equipment for collecting, sterilizing, and storing human fecal matter and personal hygiene wastes (such as used cleansing pads, towels, etc.). Fecal matter and personal hygiene wastes are collected in polyethylene bags, disinfected, and stored in a vented area. Urine is expelled overboard into space.

1.1.2.8 Survival Equipment.

The survival kits stowed in the crew compartment RHFEB (figure 1-6) are available for the postlanding phase of the mission (land or water). The major items contained in each kit include 6 pounds of water, a desalter kit, a one-man life raft, radio transceiver, portable light, sunglasses, and a machete. Life vests worn by the crew during lift-off and entry are stowed in the space suit stowage bag during the orbit phase of the mission. (See figure 1-6.)

1.1.2.9 Aft Compartment.

The aft compartment (figure 1-3) is the area encompassed by the aft portion of the crew compartment heat shield, aft heat shield, and aft portion of the primary structure. This compartment contains 10 reaction control engines, an impact attenuation structure, instrumentation, and storage tanks for water, fuel, oxidizer, and gaseous helium. (Four crushable ribs, along the S/C +Z axis, are provided as part of the impact attenuation structure to absorb energy during a land impact.)

The aft heat shield, which encloses the large end of the C/M, is a shallow spherically contoured assembly. It is made of the same type of materials as other C/M heat shields. However, the ablative material on this heat shield has a greater thickness for the dissipation of heat during entry. External provisions are made on this heat shield for connecting the C/M to the S/M.

1.1.3 SERVICE MODULE.

The S/M is a cylindrical structure formed by 1-inch-thick aluminum honeycomb panels. Radial beams, from milled aluminum alloy plates, separate the structure interior into six unequal sectors around a circular center section. (See figure 1-7.) Equipment contained within the service module is accessible through maintenance doors located strategically around the exterior surface of the module. Specific items, such as flight control system (SPS and RCS) and most of the S/C on-board consumables (and storage tanks) contained in the S/M compartments, are listed in figure 1-7.

Radial beam trusses on the forward portion of the S/M structure (figure 1-7) provide a means for securing the C/M to the S/M. Alternate beams, one, three, and five, have compression pads for supporting the C/M. Beams two, four, and six, have shear-compression pads, and tension ties. A flat center section in each tension tie incorporates redundant explosive charges for S/M-C/M separation. These beams and separation devices are enclosed within a fairing (26 inches high and 13 feet in diameter) between the C/M and S/M.

1.1.4 SPACECRAFT LEM ADAPTER.

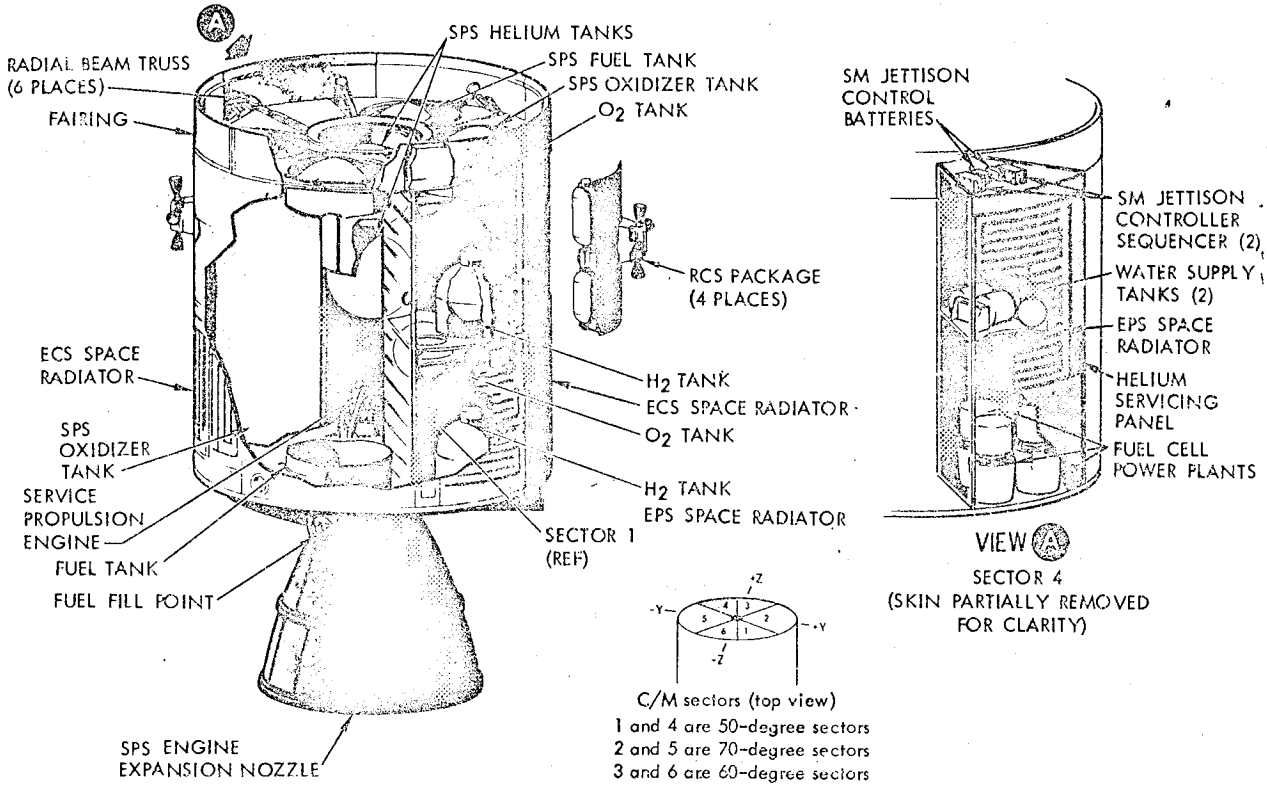
The spacecraft LEM adapter (SLA) is a truncated cone which connects the CSM to the S-IVB instrument unit on the launch vehicle. (See figure 1-1.) This adapter, constructed of eight 2-inch-thick aluminum panels, is 154 inches in diameter at the forward end (C/M interface) and 260 inches at the aft end. Separation of the spacecraft from the SLA is accomplished by means of explosive charges which permit the four SLA forward panels (above station 583.3) to disengage from the CSM and rotate outward 45 degrees from vertical. The four aft panels remain attached to the S-IVB instrument unit. For mission 204A, a cross-shaped stiffener is installed within the SLA in place of a LEM. The S/M SPS nozzle extends into the SLA which also houses an umbilical cable for connecting circuits between the launch vehicle and the spacecraft.

1.1.5 SPACECRAFT SYSTEMS.

Data relating to the operational spacecraft systems and interface information are presented in section 2 of this handbook.

1.2 LAUNCH VEHICLE CONFIGURATION.

A two-stage Saturn IB launch vehicle, consisting of an S-IB booster and an S-IVB second stage, is scheduled to provide the required thrust for inserting S/C 012 into orbit (figure 1-8.) An instrumentation unit, located between the S-IVB and the SLA, controls each of the two boost stages during flight. The total length of the Saturn IB launch vehicle, including the spacecraft, is approximately 224 feet. An emergency detection system sequencer display panel, in the C/M, enables the crew to monitor launch vehicle engine performance during lift-off. (Refer to the sequential systems in section 2.)



SERVICE MODULE ITEMS

Sector 1
- Electrical power system space radiator
- Super-critical oxygen tank (two)
- Super-critical hydrogen tank (two)

Sector 2
- Environmental control system space radiator
- Service propulsion system oxidizer tank
- Reaction control system package (+Y-axis)
- Space radiator isolation valve (two)

Sector 3
- Service propulsion system fuel tank
- Reaction control system package (+Z-axis)
- Service propulsion system helium tanks (two)

Sector 4
- Electrical power system space radiator
- Fuel cell power plant (three)
- Helium servicing panel
- Reaction control system control unit
- Electrical power system power control relay box
- Service module jettison control battery (two)
- Service module jettison controller sequencer (two)
- Water supply tank (two)

Sector 5
- Environmental control system space radiator
- Service propulsion system oxidizer tank
- Reaction control system package (-Y axis)

Sector 6
- Space radiator selection valve, (two)
- Glycol shutoff valves (two)
- Reaction control system package (-Z axis)
- Service propulsion system fuel tank

Center section
- Service propulsion system helium tank (two)
- Service propulsion system engine

SM-2A-643 E

Figure 1-7. Spacecraft 012 Service Module

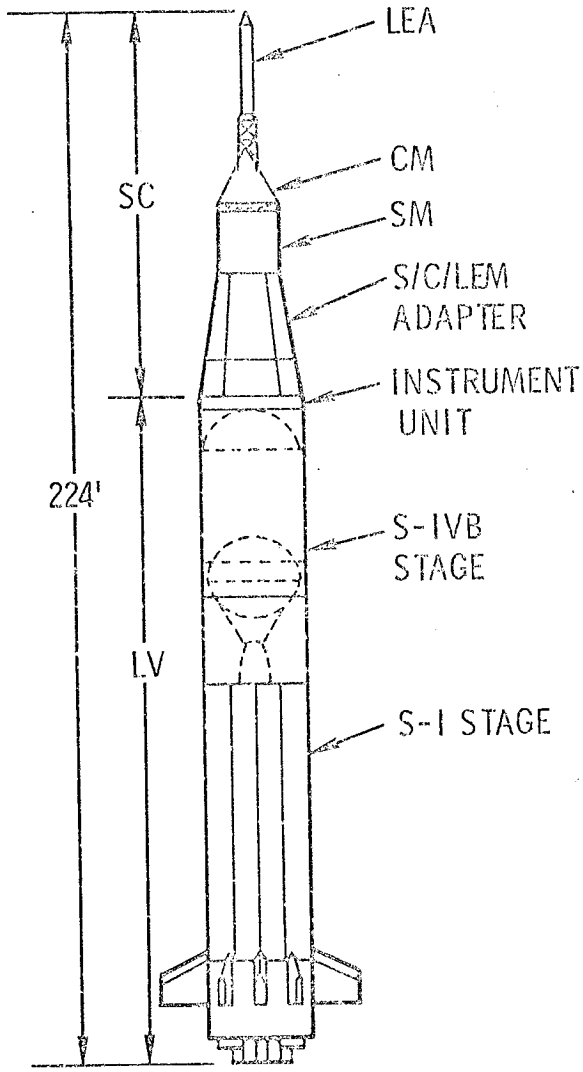


Figure 1-8. Apollo Launch Vehicle (Saturn IB)

1.2.1 S-IB BOOSTER.

The S-IB booster (first stage) for Saturn IB is manufactured by the Chrysler Corporation. This booster is 257 inches in diamater, 82 feet in length, and is powered by eight Rocketdyne H-1 engines. Each engine, burning RP-1 and liquid oxygen, produces 200,000 pounds of thrust for a total stage thrust over 1,600,000 pounds.

1.2.2 S-IVB SECOND STAGE.

The S-IVB second stage for Saturn IB is manufactured by the Douglas Aircraft Company. This stage is 260 inches in diameter, 58 feet in length, and is powered by a single Rocketdyne J-2 engine. The engine, burning liquid hydrogen and oxygen, produces a stage thrust of approximately 200,000 pounds. During flight, the J-2 engine uses three different mixture ratios, resulting in values of thrust ranging from 190,000 to 230,000 pounds.

1.3 MISSION 204A WEIGHT STATUS.

NOTE The NASA-MSC is responsible for providing a detailed weight status for Apollo mission 204A as available in the MSC Reference Trajectory Document.

1.4 POSTLANDING AND RECOVERY.

Information relating to postlanding recovery aids is provided under sequential systems in section 2. Postlanding ventilation for the crew is supplied through two vent valves in the forward access hatch cover. (See figure 1-4.) A handpump and flexible hose, stored under the right crew couch (figure 1-6), is used to obtain water from the sea for conversion to potable water. (Refer to crew equipment in section 6.) An Apollo Recovery Operations Handbook will provide a detailed description of recovery equipment and rescue procedures.

SECTION 2

SYSTEMS DATA

INTRODUCTION.

Systems data include description of operations, component description and design data, operational limitations and restrictions, and telemetry measurements. Subsection 2.1 describes the overall spacecraft navigation, guidance, and control requirements and the resultant systems interface. Subsections 2.2 through 2.10 present data grouped by spacecraft systems, arranged in the following order: guidance and navigation, stabilization and control, service propulsion, reaction control, electrical power, environmental control, telecommunications, sequential, and cautions and warnings. Subsection 2.11 deals with miscellaneous systems data.

SECTION 2

SUBSECTION 2.1

GUIDANCE AND CONTROL

2.1.1 SYSTEMS INTERFACE, GUIDANCE AND CONTROL.

Apollo CSM atmospheric and space flight is achieved by application of controlled translation forces and rotational force moments. Guidance and control initiates and terminates the thrust and rotational forces and force moments as a function of the magnitude of the change required. Guidance and control provides the following basic functions:

- Attitude Control
- Guidance
- Navigation

Attitude control is a function associated with spacecraft orientation with respect to an inertial reference or a known coordinate system. Guidance is a function requiring a combination of attitude control with rate stabilization and steering commands for the purpose of modifying spacecraft trajectory via major velocity changes. Navigation determines spacecraft position and velocity, and predicts future position.

To accomplish mission requirements, the guidance and navigation, stabilization and control, service propulsion, and reaction control systems, plus the astronauts, are integrated into an automatic/manual closed loop control system.

Guidance and control activity is grouped into three profiles of flight: coasting, powered, and atmospheric. The primary control loops involved are illustrated in figures 2.1-1 through 2.1-4. Figure 2.1-1 is an abbreviated integration of all major equipments necessary to accomplish the activities in all three flight profiles. Figures 2.1-2 through 2.1-4 divide the equipment into the proper perspective for each profile.

It must be noted that in figure 2.1-1, the loops are closed that represent coasting flight (CF) functions. For powered flight (PF) or atmospheric flight (AF), open the coasting flight loops and close contacts representing the desired loops.

2.1.2 COASTING FLIGHT

The guidance and control activities involved in coasting flight are accomplished through the basic functional loops shown in figure 2.1-2.

These loops provide attitude reference, attitude control, attitude hold, and automatic and manual maneuver capabilities necessary to accomplish the several tasks involved during coasting flight. They are also the central reference and control loops required for all phases of flight.

A reference attitude frame is established by the G&N inertial measurement unit (IMU), and/or by the SCS body-mounted attitude gyros (BMAGs), and attitude gyro coupling unit (AGCU). Inertial sensors sense S/C motion contrary to the reference frame. The sensed attitude errors and rates are conditioned through servo electronics and logic to initiate countermotions via the reaction jet control (RCS) which nullifies the original motion. The AGC inserts automatic control and maneuver commands into the loop. The rotation, translation, and attitude impulse controls insert manual commands into the loop. The flight director attitude indicator (FDAI) is the S/C attitude visual display.

2.1.3 POWERED FLIGHT.

Powered flight is considered that which will use the S/M service propulsion system (SPS) engine to initiate a major velocity change. Figure 2.1-3 illustrates those basic loops necessary for the tasks involved. As shown, the loops are an extension of those required for coasting flight. Added, are the (SPS) engine on-off thrust logic and the SPS gimbal control loops. In coasting flight, all attitude control is through the RCS. Powered flight, by the SPS engine, requires roll control through the RCS, and pitch and yaw control by gimbaling the SPS engine nozzle. Primary control of thrusting is by the AGC. However, figure 2.1-3 shows how various manual controls can be used instead of or to backup automatic functions.

2.1.4 ATMOSPHERIC FLIGHT

Atmospheric flight is encountered during the entry phase of the mission at which time the S/C experiences aerodynamic forces. Figure 2.1-4 illustrates the basic loops required for control of the S/C during this phase. The central loop is identical to that in figure 2.1-2. The main difference is that service module/command module (S/M-C/M) separation has taken place, and the command module RCS system is used. Another difference is that the aerodynamic forces will stabilize the C/M in pitch and yaw, and the entry g-level (lift vector control) will increase or decrease through roll control. Primary control is automatic, with manual rotation control available, in event of automatic control malfunctions.

For detailed operation of the several loops involved in guidance and control, refer to the descriptions of the guidance and navigation system, subsection 2.2, and the stabilization and control system, subsection 2.3.

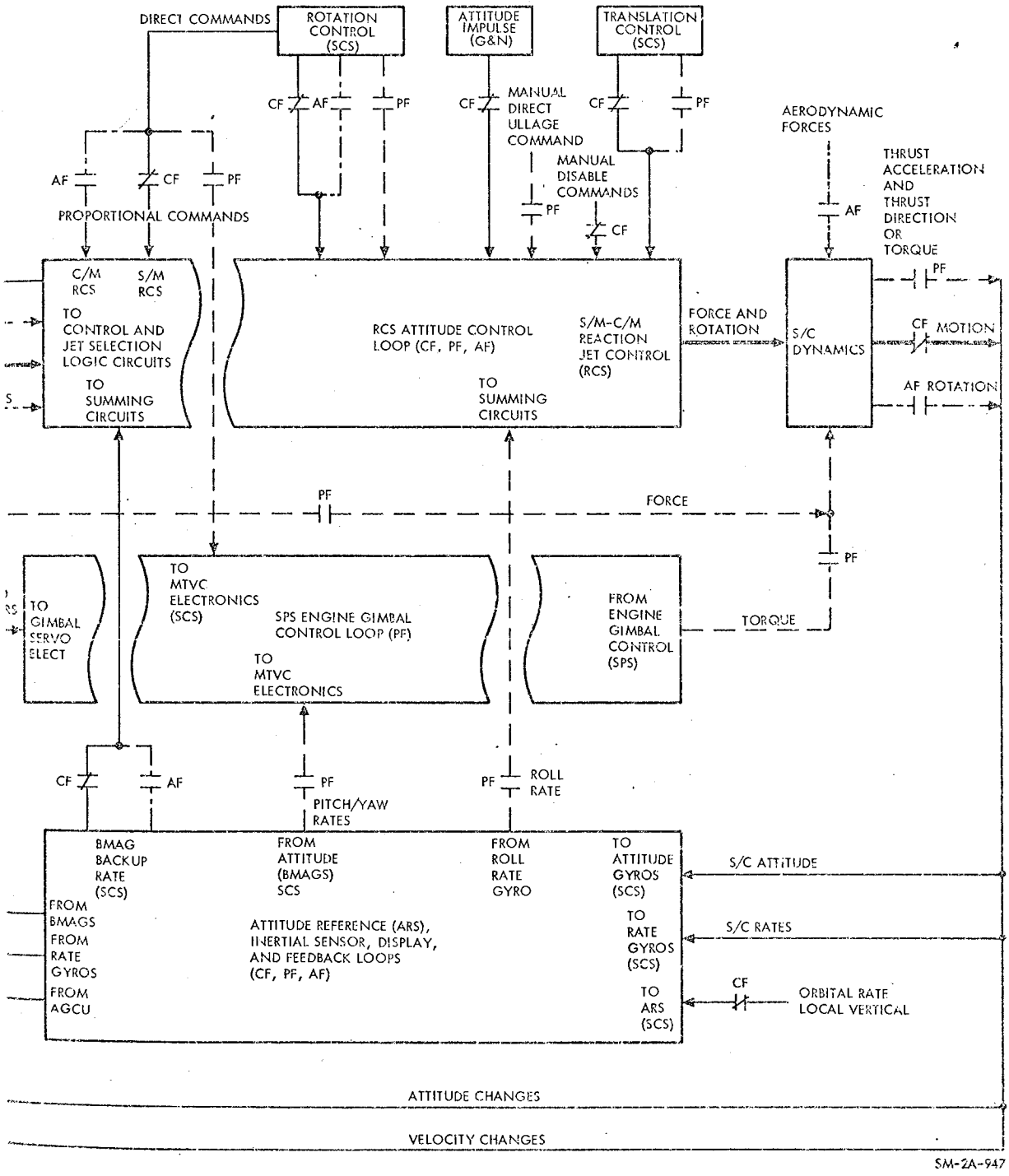
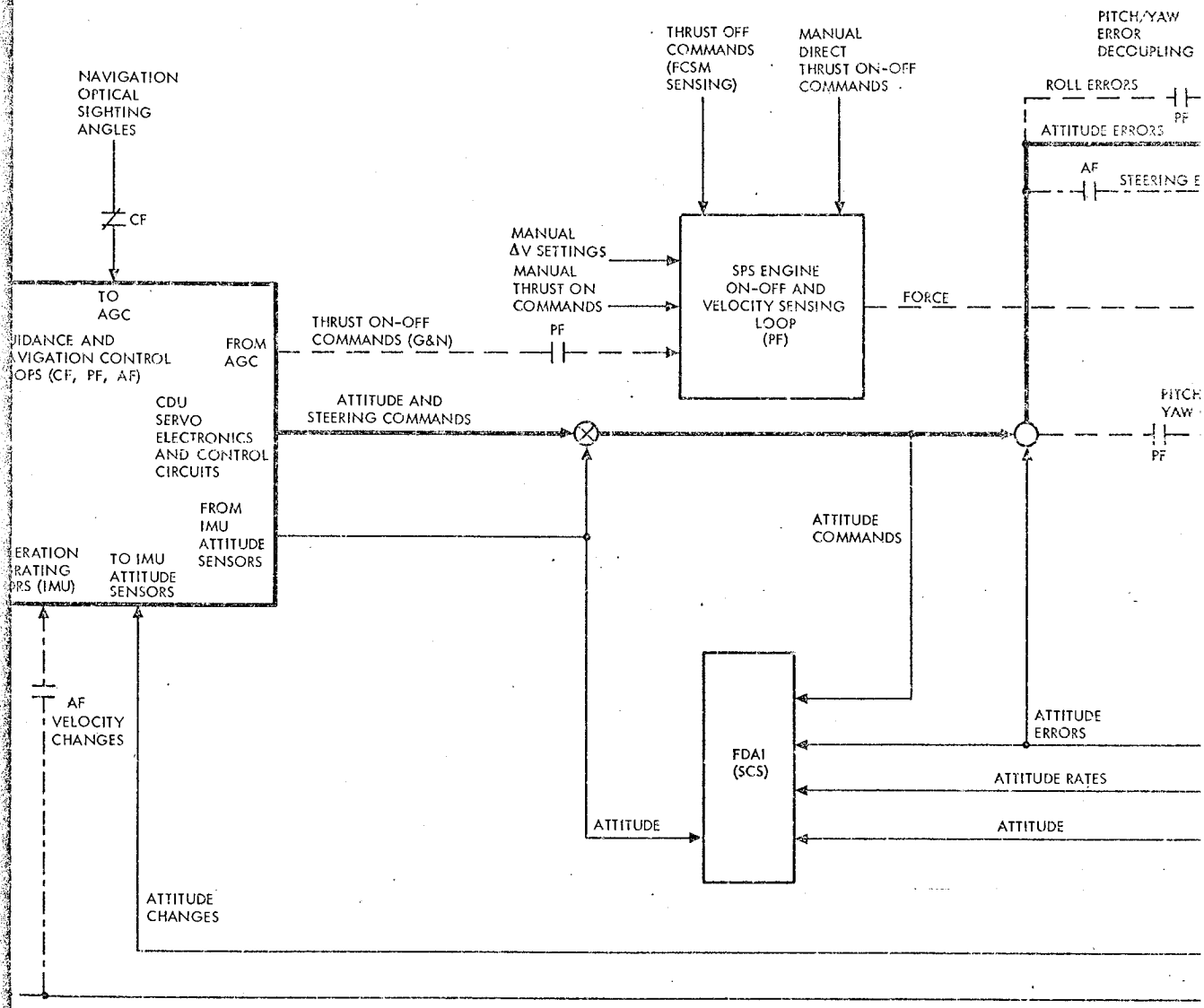
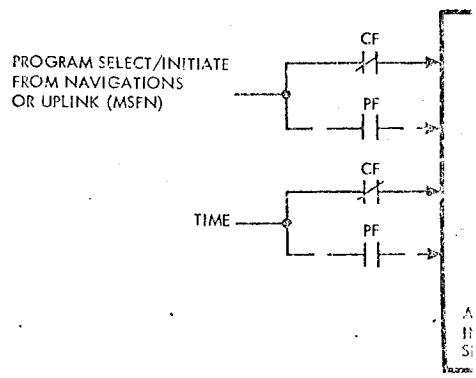


Figure 2.1-1. Integrated Flight Profile Functional Flow Diagram


NAVIGATION OPTICAL SIGHTING ANGLES
CF
TO AGC
IDANCE AND VIGATION CONTROL OPS (CF, PF, AF)
FROM AGC
CDU SERVO ELECTRONICS AND CONTROL CIRCUITS
FROM IMU ATTITUDE SENSORS
ERATION RATING RS (IMU)
TO IMU ATTITUDE SENSORS
AF VELOCITY CHANGES
ATTITUDE CHANGES
THRUST ON-OFF COMMANDS (G&N)
PF
MANUAL ΔV SETTINGS
MANUAL THRUST ON COMMANDS
PF
THRUST OFF COMMANDS (FCSM SENSING)
MANUAL DIRECT THRUST ON-OFF COMMANDS
SPS ENGINE ON-OFF AND VELOCITY SENSING LOOP (PF)
FORCE
PITCH/YAW ERROR DECOUPLING
ROLL ERRORS
PF
ATTITUDE ERRORS
AF
STEERING E
PITCH
YAW
PF
ATTITUDE AND STEERING COMMANDS
ATTITUDE COMMANDS
FDAI (SCS)
ATTITUDE
ATTITUDE ERRORS
ATTITUDE RATES
ATTITUDE


PROGRAM SELECT/INITIATE
FROM NAVIGATIONS
OR UPLINK (MSFN)
CF
PF
TIME
CF
PF
PF
VELOCIT
CHANGE
COASTING FLIGHT (CF)
POWERED FLIGHT (PF)
ATMOSPHERIC FLIGHT (AF)

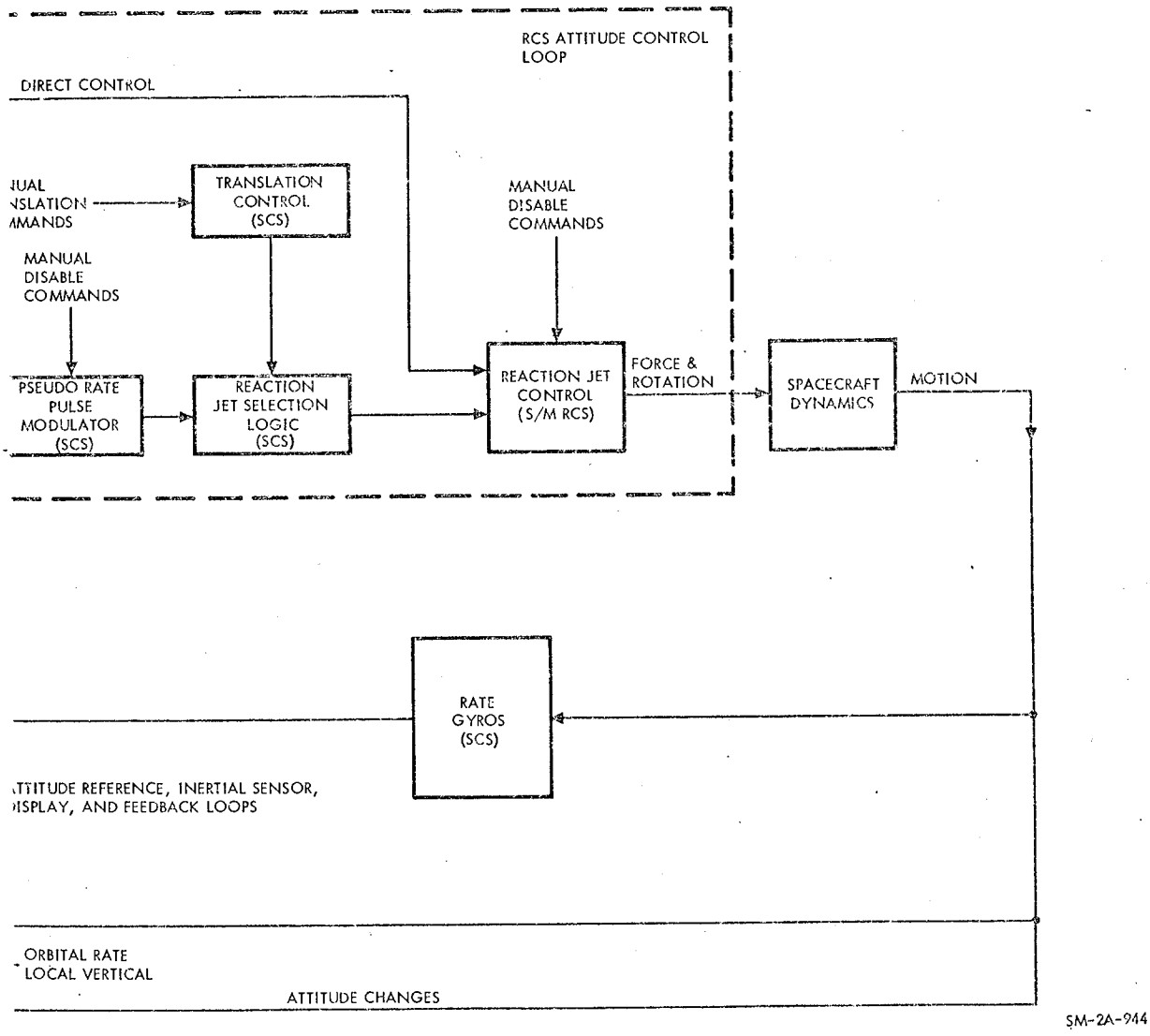
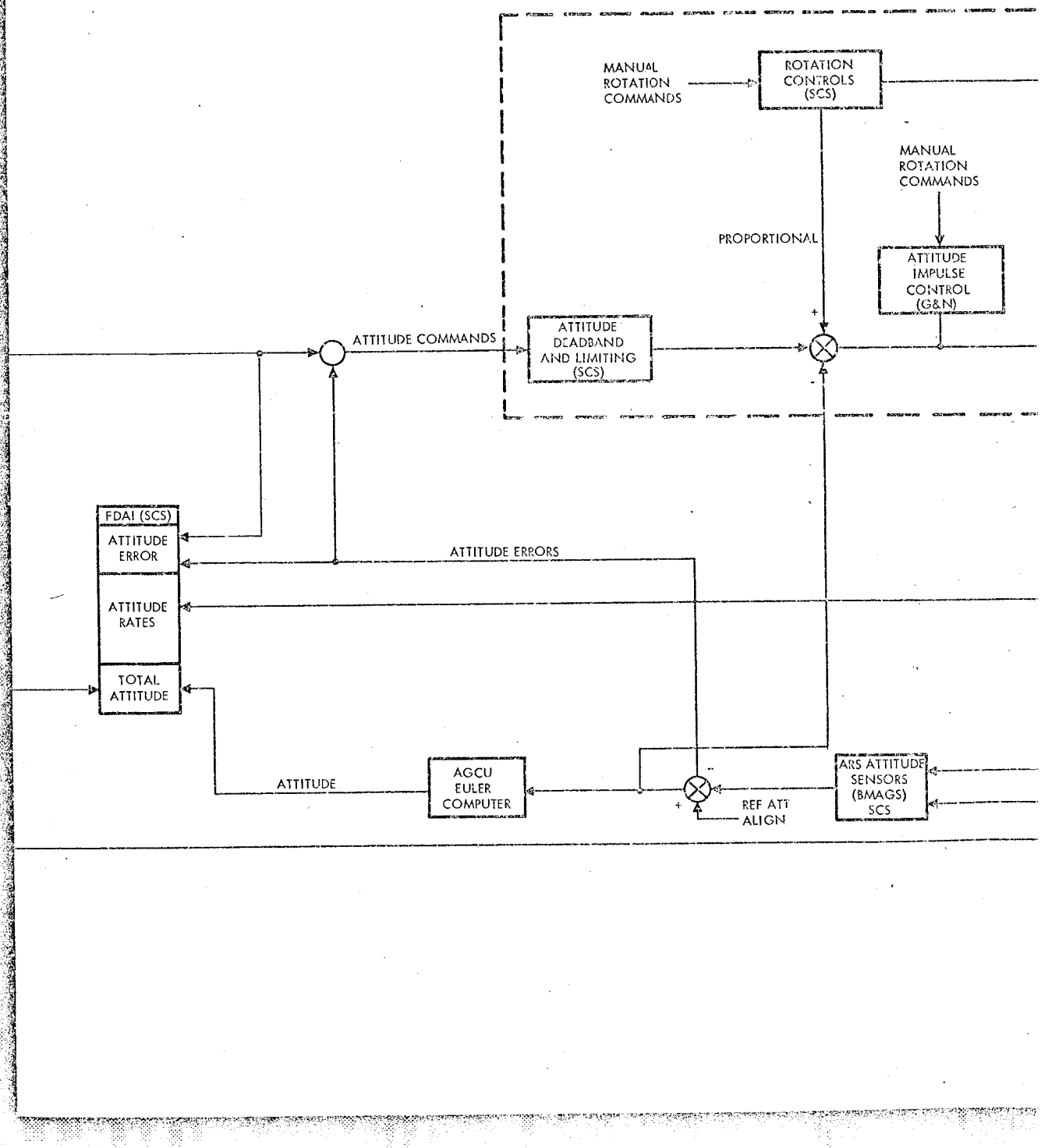
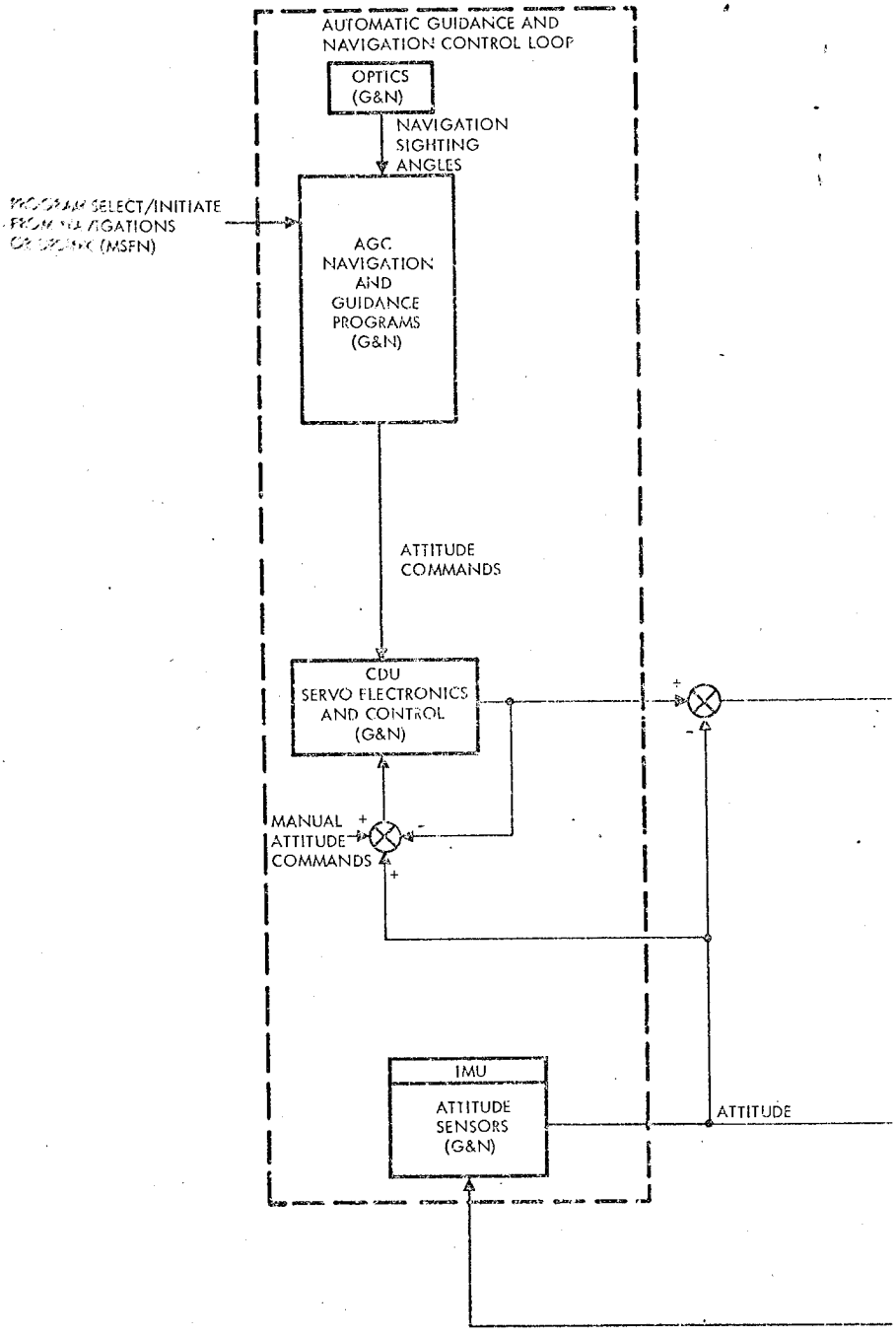


Figure 2.1-2. Coasting Flight Profile Functional Flow Diagram


MANUAL ROTATION COMMANDS
ROTATION CONTROLS (SCS)
MANUAL ROTATION COMMANDS
PROPORTIONAL
ATTITUDE IMPULSE CONTROL (G&N)
ATTITUDE COMMANDS
ATTITUDE DEADBAND AND LIMITING (SCS)
FDAI (SCS)
ATTITUDE ERROR
ATTITUDE ERRORS
ATTITUDE RATES
TOTAL ATTITUDE
ATTITUDE
AGCU EULER COMPUTER
REF ATT ALIGN
ARS ATTITUDE SENSORS (BMAGS) SCS


AUTOMATIC GUIDANCE AND
NAVIGATION CONTROL LOOP
OPTICS
(G&N)
NAVIGATION
SIGHTING
ANGLES
PROGRAM SELECT/INITIATE
FROM NAVIGATIONS
OR UPLINK (MSFN)
AGC
NAVIGATION
AND
GUIDANCE
PROGRAMS
(G&N)
ATTITUDE
COMMANDS
CDU
SERVO ELECTRONICS
AND CONTROL
(G&N)
MANUAL
ATTITUDE
COMMANDS
IMU
ATTITUDE
SENSORS
(G&N)
ATTITUDE

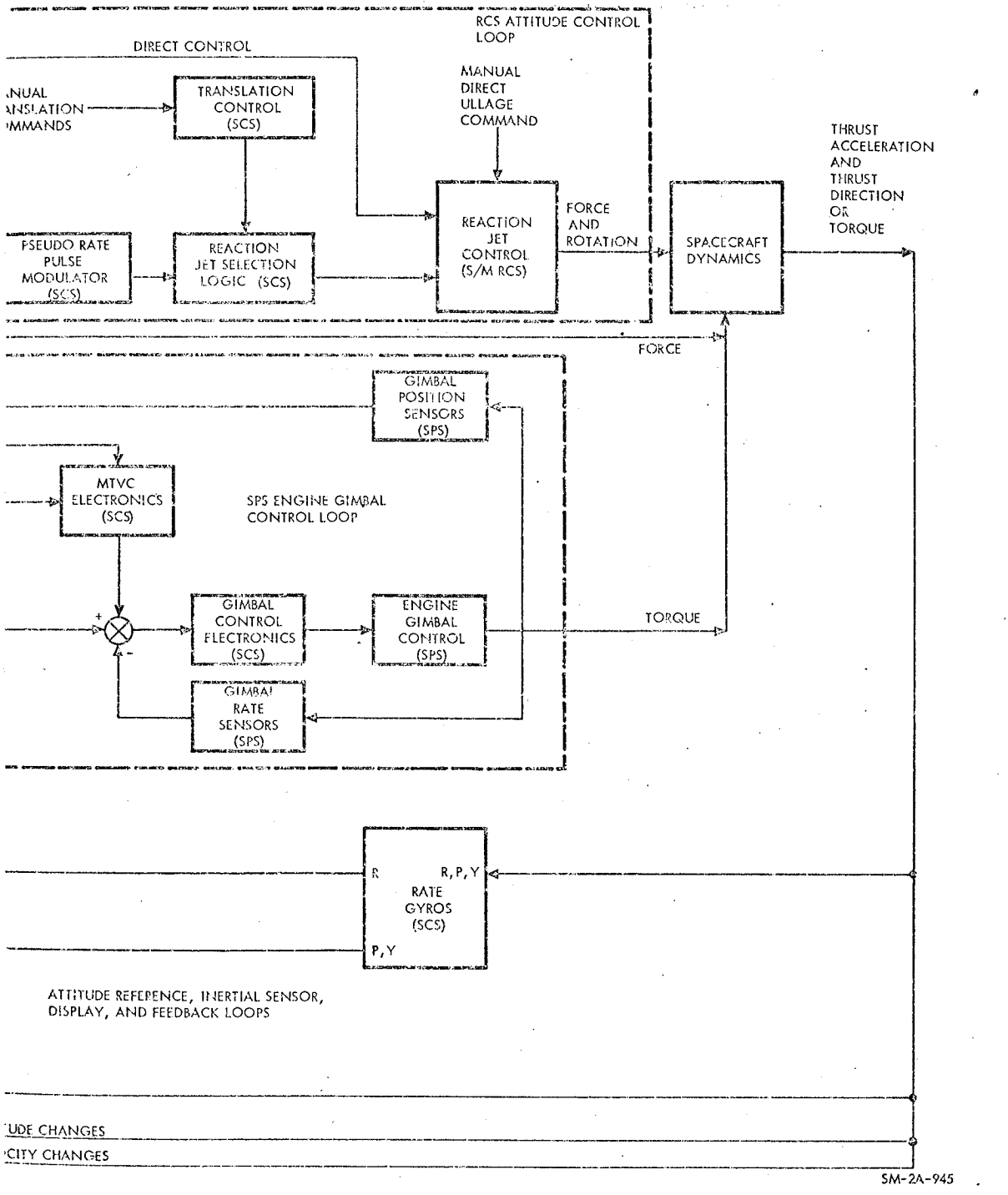
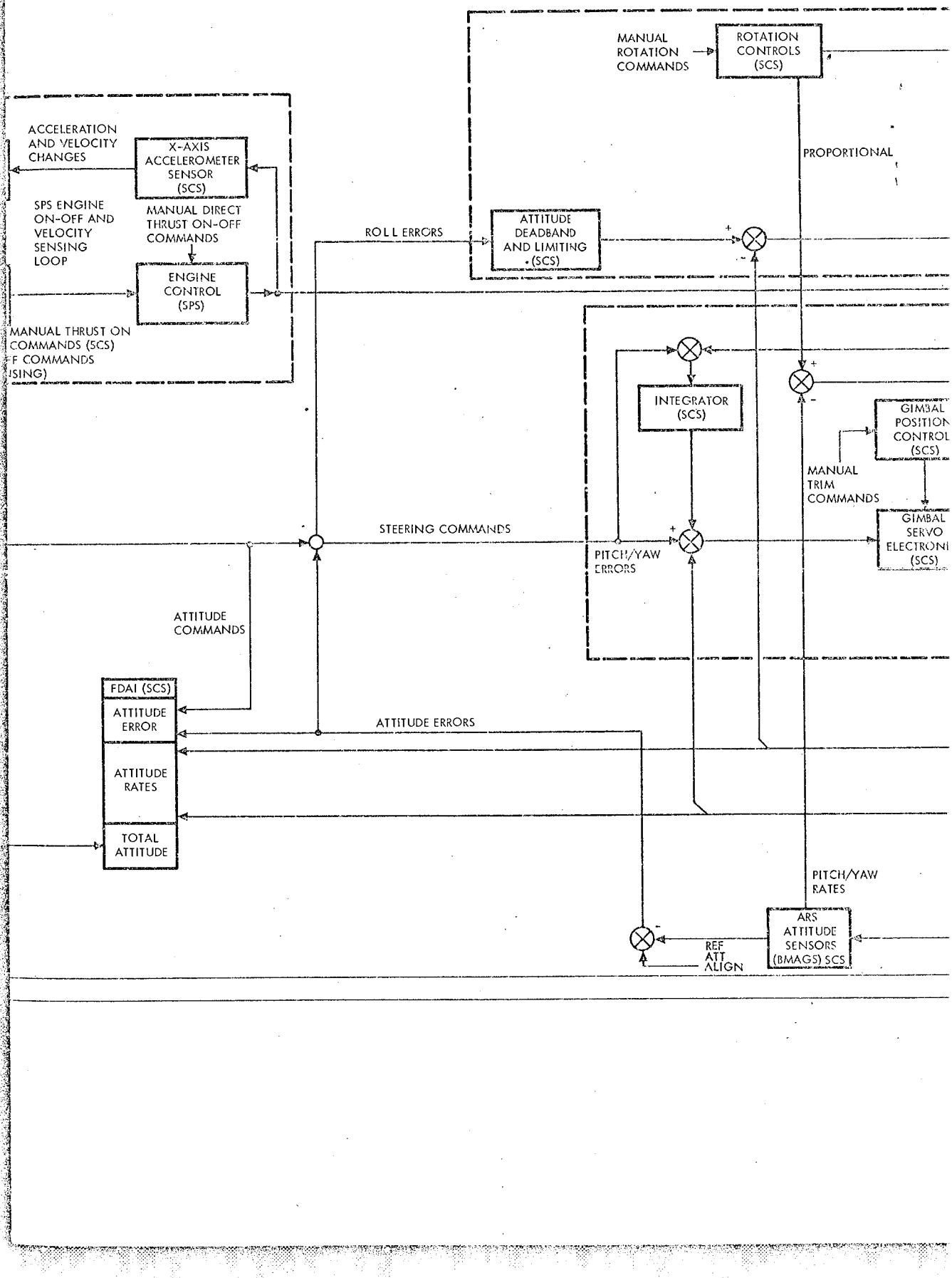
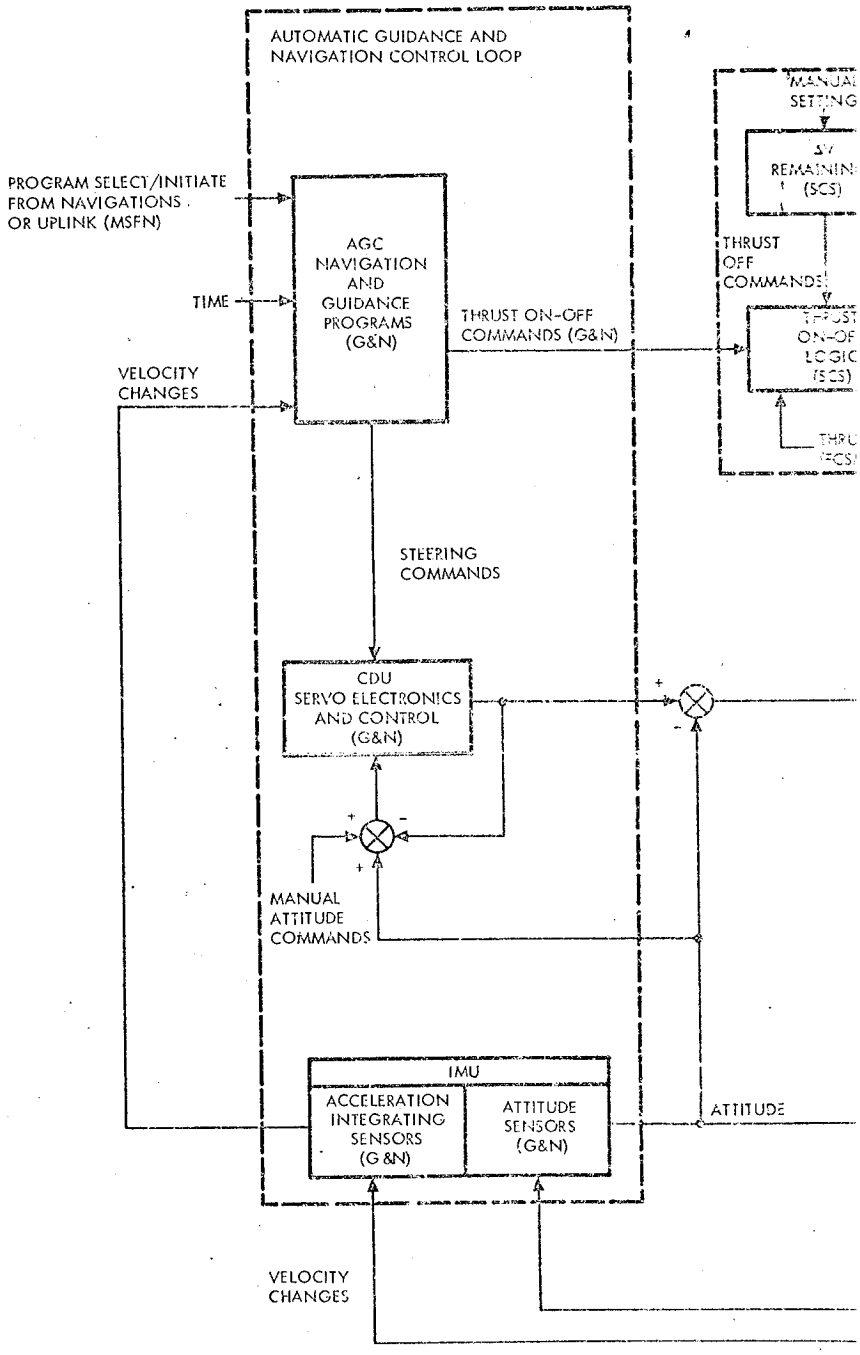


Figure 2.1-3. Powered Flight Profile Functional Flow Diagram


MANUAL ROTATION COMMANDS
ROTATION CONTROLS (SCS)
PROPORTIONAL
ACCELERATION AND VELOCITY CHANGES
X-AXIS ACCELEROMETER SENSOR (SCS)
SPS ENGINE ON-OFF AND VELOCITY SENSING LOOP
MANUAL DIRECT THRUST ON-OFF COMMANDS
ROLL ERRORS
ATTITUDE DEADBAND AND LIMITING (SCS)
ENGINE CONTROL (SPS)
MANUAL THRUST ON COMMANDS (SCS)
F COMMANDS
ISING)
INTEGRATOR (SCS)
GIMBAL POSITION CONTROL (SCS)
MANUAL TRIM COMMANDS
GIMBAL SERVO ELECTRONI (SCS)
STEERING COMMANDS
PITCH/YAW ERRORS
ATTITUDE COMMANDS
FDAI (SCS)
ATTITUDE ERROR
ATTITUDE ERRORS
ATTITUDE RATES
TOTAL ATTITUDE
PITCH/YAW RATES
ARS ATTITUDE SENSORS (BMAGS) SCS
REF ATT ALIGN


AUTOMATIC GUIDANCE AND
NAVIGATION CONTROL LOOP
PROGRAM SELECT/INITIATE
FROM NAVIGATIONS
OR UPLINK (MSFN)
TIME
VELOCITY
CHANGES
AGC
NAVIGATION
AND
GUIDANCE
PROGRAMS
(G&N)
THRUST ON-OFF
COMMANDS (G&N)
STEERING
COMMANDS
CDU
SERVO ELECTRONICS
AND CONTROL
(G&N)
MANUAL
ATTITUDE
COMMANDS
IMU
ACCELERATION
INTEGRATING
SENSORS
(G&N)
ATTITUDE
SENSORS
(G&N)
ATTITUDE
VELOCITY
CHANGES
THRUST
OFF
COMMANDS
(SCS)

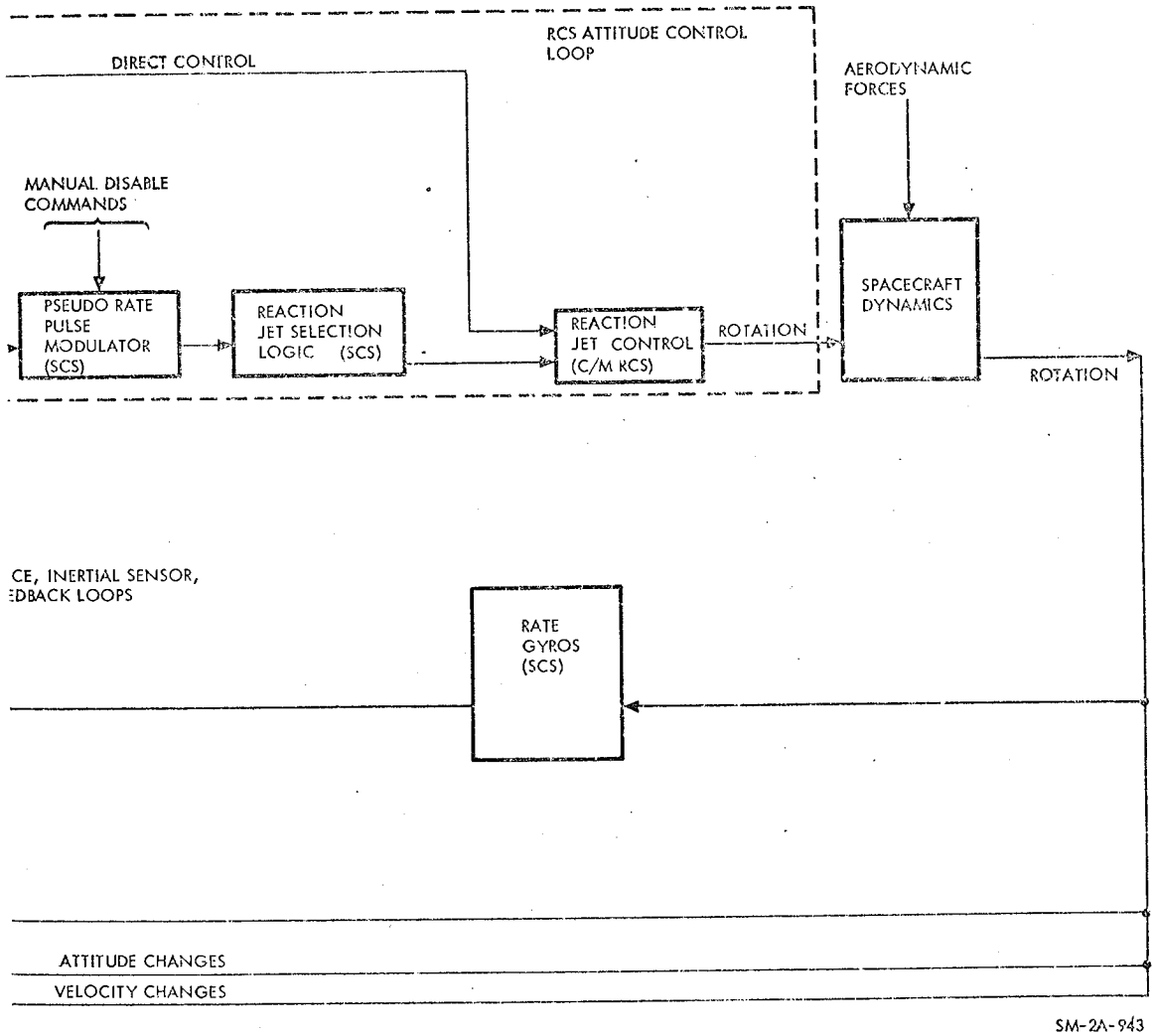
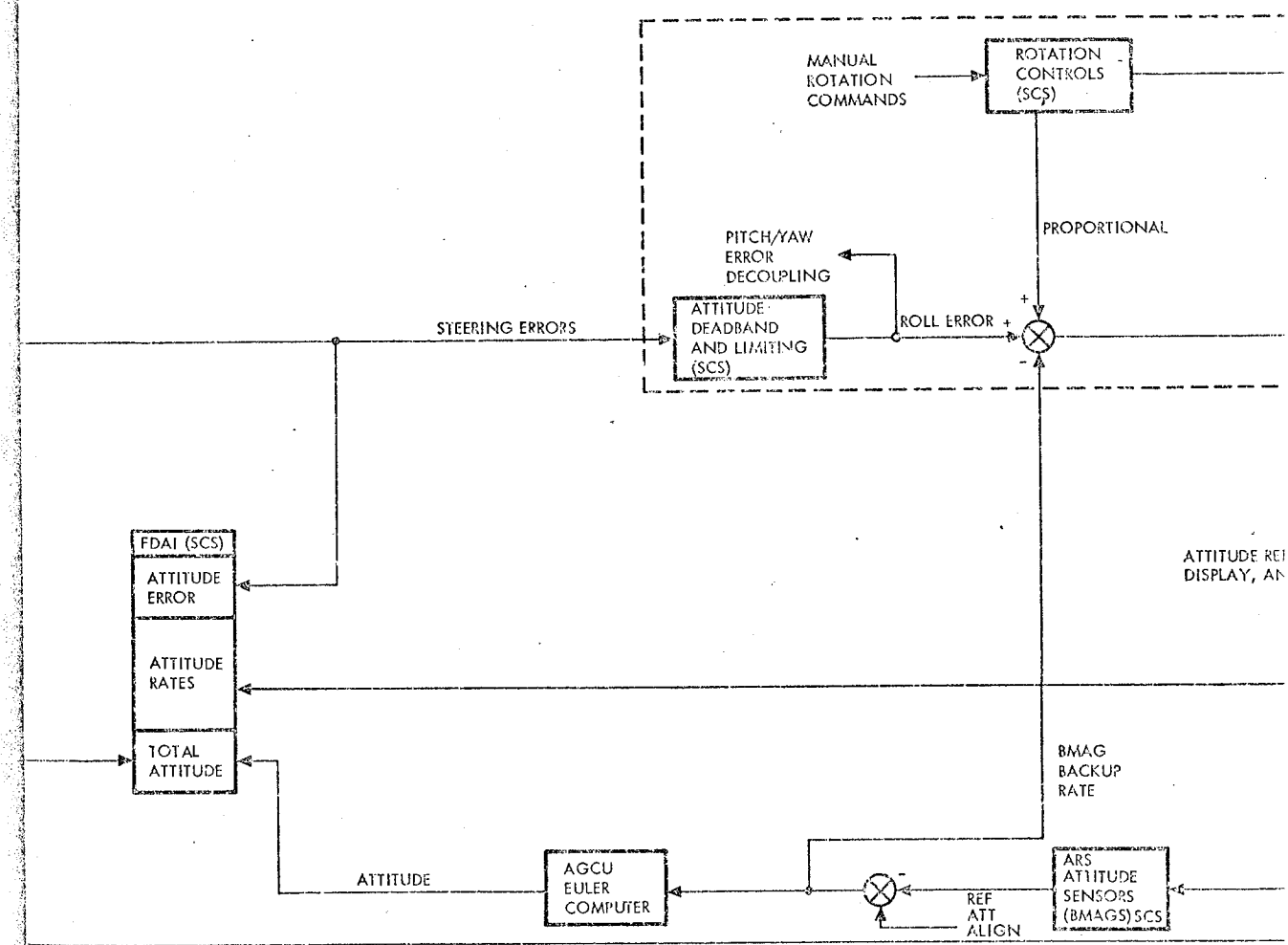
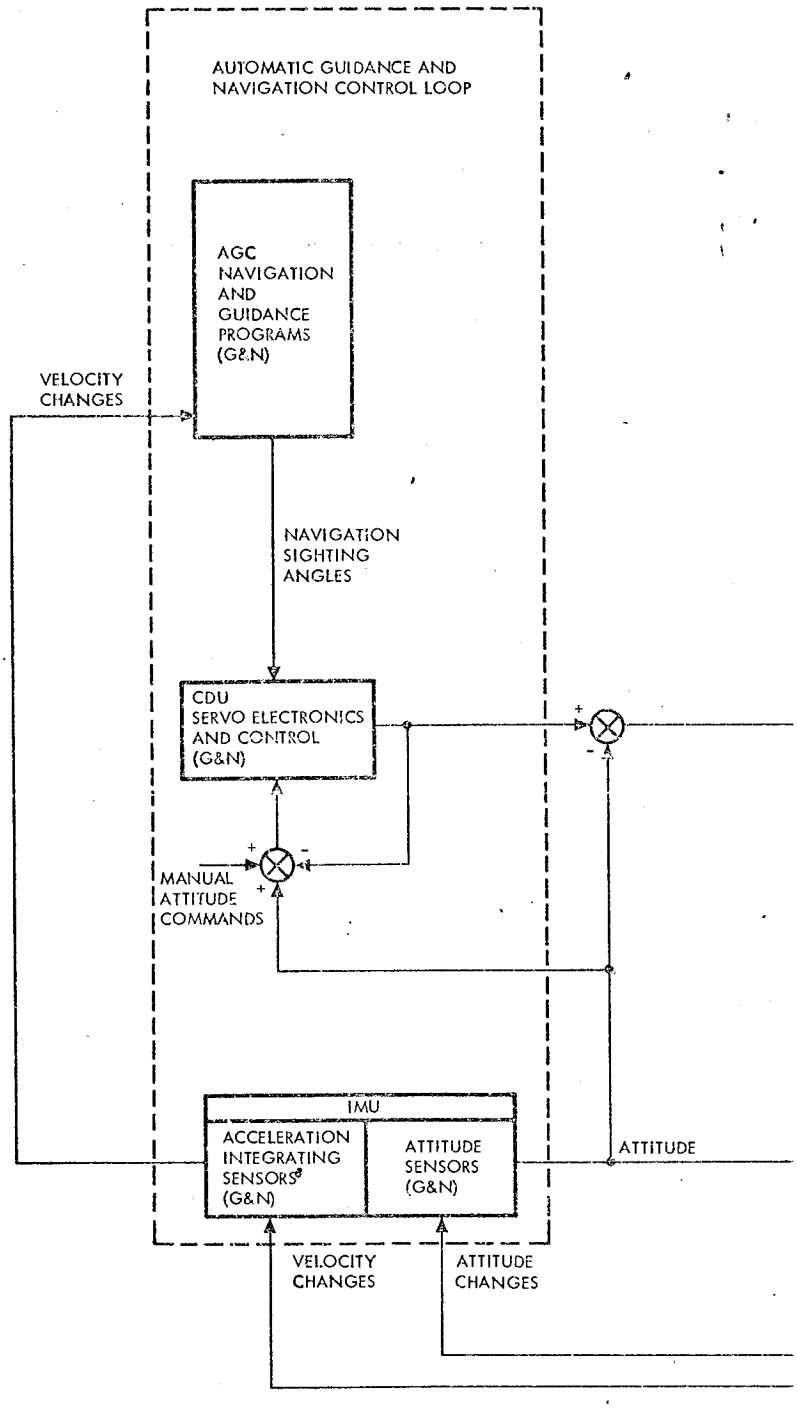


Figure 2.1-4. Atmospheric Flight Profile Functional Flow Diagram


MANUAL
ROTATION
COMMANDS
ROTATION
CONTROLS
(SCS)
PROPORTIONAL
PITCH/YAW
ERROR
DECOUPLING
STEERING ERRORS
ATTITUDE
DEADBAND
AND LIMITING
(SCS)
ROLL ERROR
+
-
FDAI (SCS)
ATTITUDE
ERROR
ATTITUDE
RATES
TOTAL
ATTITUDE
ATTITUDE RE
DISPLAY, AN
BMAG
BACKUP
RATE
ATTITUDE
AGCU
EULER
COMPUTER
ARS
ATTITUDE
SENSORS
(BMAGS) SCS
REF
ATT
ALIGN


AUTOMATIC GUIDANCE AND
NAVIGATION CONTROL LOOP
AGC
NAVIGATION
AND
GUIDANCE
PROGRAMS
(G&N)
VELOCITY
CHANGES
NAVIGATION
SIGHTING
ANGLES
CDU
SERVO ELECTRONICS
AND CONTROL
(G&N)
+
-
+
-
+
MANUAL
ATTITUDE
COMMANDS
IMU
ACCELERATION
INTEGRATING
SENSORS
(G&N)
ATTITUDE
SENSORS
(G&N)
ATTITUDE
VELOCITY
CHANGES
ATTITUDE
CHANGES

SECTION 2

SUBSECTION 2.2

GUIDANCE AND NAVIGATION SYSTEM (G&N)

2.2.1 INTRODUCTION.

The guidance and navigation (G&N) system measures spacecraft attitude and velocity, determines trajectory, controls spacecraft attitude, controls the thrust vector of the service propulsion engine, and provides abort information and display data. Primary determination of the spacecraft velocity and position, and computation of the trajectory parameters is accomplished by the manned space flight network (MSFN).

The G&N system consists of three subsystems as follows:

- Inertial subsystem (ISS)
- Computer subsystem (CSS)
- Optics subsystem (OSS)

The inertial subsystem is composed of an inertial measurement unit (IMU), part of the power and servo assembly (PSA), part of the controls and displays, and three inertial coupling display units (CDUs). The IMU provides an inertial reference with a gimbaled, three-degree-of-freedom, gyro stabilized stable platform.

The computer subsystem is composed of an Apollo guidance computer (AGC), and two display and keyboard panels (DSKYs), which are part of the controls and displays. The AGC is a digital computer which processes and controls information to and from the IMU and optics, and stores programs and reference data.

The optics subsystem is composed of a scanning telescope (SCT), a sextant (SXT), drive motors for positioning the SCT and SXT, parts of the PSA, part of the controls and displays, and two optics CDUs. The SCT and SXT are used to determine the spacecraft position and attitude with relation to stars and/or landmarks.

The three G&N subsystems are configured such that the CSS and OSS may be operated independently. This allows continued use of the CSS and/or OSS in the event of a malfunction in one of these subsystems or the ISS. System power requirements and reference signals are provided by the power and servo assembly (PSA). Major components of the system are located in the command module lower equipment bay (figure 2.2-1). System circuit breakers, caution and warning indicators, and one of the DSKYs are located on the main display console.

2.2.2 FUNCTIONAL DESCRIPTION.

The guidance and navigation system provides capabilities for the following:

- Inertial velocity and position (state vector) computation
- Optical and inertial navigation measurements

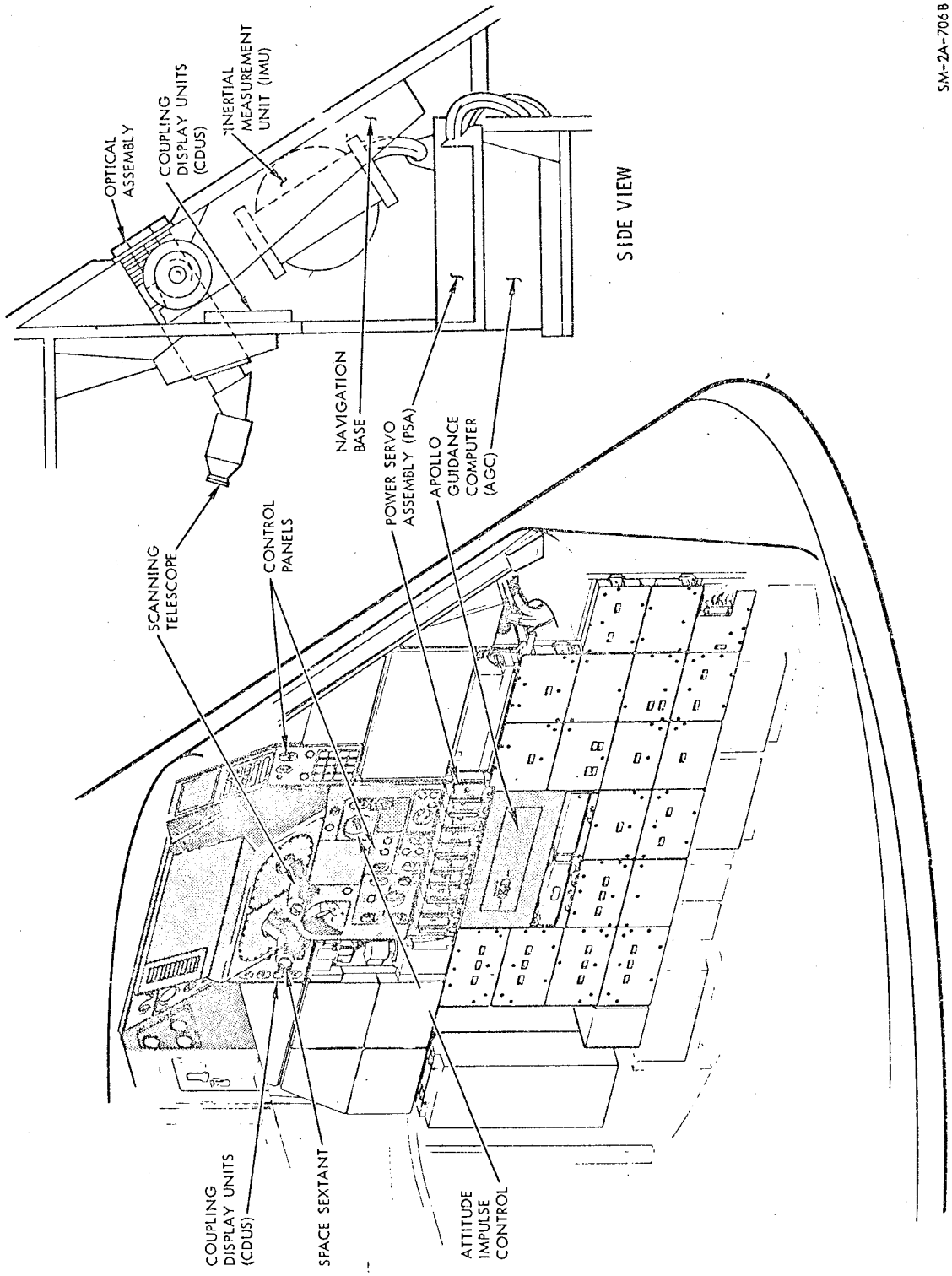


Figure 2.2-1. G&N Equipment Location

- Spacecraft attitude measurement and control
- Generation of guidance commands during CSM-powered flight and C/M atmospheric entry.

The G&N system is initially activated and aligned during the prelaunch phase. During the ascent phase, the system measures velocity and attitude, computes position, compares the actual spacecraft trajectory with a predetermined trajectory, and displays pertinent data. The flight crew uses the displayed information as an aid for decision to abort or continue the mission. However, spacecraft control is maintained by the S-IVB guidance until CSM/S-IVB separation. Upon separation, the G&N system assumes the guidance and navigation functions using the data acquired during ascent.

During periods when onboard velocity and/or attitude change sensing is not required, the IMU is placed in standby operation to conserve electrical power. The AGC is used more extensively than the IMU; however, it will also be placed in standby operation to conserve electrical power. When the guidance and navigation function is to be restored, the IMU and AGC are reactivated, with the AGC using the last computed velocity as the basis for further velocity computations. New positional data must be acquired from optical sightings or MSFN through telemetry or voice communications.

Initial position and attitude information as well as periodic updating of this information is made through use of the optics. This is accomplished by the navigator making two or more landmark and/or star sightings. The sightings are made by acquiring the star-landmark with the SCT and/or SXT. When the viewed object is centered, a mark command is initiated. The AGC reads the optics angles, IMU angles, and time, in conjunction with internal programs to determine the spacecraft position. This position information and the spacecraft velocity are used to compute an estimated trajectory. The actual trajectory is compared with previous trajectory data to generate the trajectory error, if any, for further reference. Optical measurements are also used in aligning the IMU to a specific reference orientation.

The IMU (figure 2.2-2) contains three inertial rate integrating gyros (IRIGs), three angular differentiating accelerometers (ADAs), and three pulsed integrating pendulous accelerometers (PIPAs). The IRIGs, PIPAs, and one ADA are mounted on the stable platform which is gimbaled to provide three degrees of freedom. The two remaining ADAs are mounted on the middle gimbal. The stable platform inertial reference is maintained by the IRIGs and ADAs in conjunction with electronic stabilization loops. Any displacement of the platform is sensed by the IRIGs which produce output signals representative of the magnitude and direction of displacement. The ADAs sense the displacement rate and produce output rate control signals to maintain correct stabilization loop control response. The IRIG and ADA signals are applied to servo amplifiers, which condition the signals to drive gimbal torque motors. The gimbal torque motors then restore the initial platform orientation by driving the gimbals until the IRIG signals are nulled.

The PIPAs are orthogonally mounted and sense changes in spacecraft velocity. An acceleration or deceleration results in output signals which are representative of the magnitude and direction of the velocity change. The output signals are applied to the AGC which uses the information to update spacecraft velocity data. Continual updating of velocity information, with respect to the initial spacecraft position and trajectory, enables the AGC to provide current velocity, position, and trajectory information.

The IMU also provides a space stabilized reference for spacecraft attitude sensing and control. Attitude change sensing is accomplished by monitoring the spacecraft attitude with reference to the stable platform. Resolvers are mounted at the gimbal axes to provide signals representative of the gimbal angles. Inertial CDUs contain resolvers which repeat the platform attitude. Attitude monitoring is afforded by comparing the IMU resolver output signals with the CDU resolver signals. If the angles differ, error signals are generated and applied to the stabilization and control system. If the attitude error is larger than the selected deadband limits, the SCS fires the appropriate RCS engines. The spacecraft is rotated back to the initial reference attitude and the error signals are nulled (within deadband limits).

The AGC provides automatic execution of computer programs, automatic control of ISS and OSS modes, and, in conjunction with the DSKYs, manual control of ISS and OSS modes and computer displays. The AGC contains a two-part memory which consists of a large non-erasable section and a smaller erasable section. Non-erasable memory contains mission and system programs and other predetermined data which are wired in during assembly. Data readout from this section is non-destructive and cannot be changed during operation. The erasable section of memory provides for data storage, retrieval, and operations upon measured data and telemetered information. Data readout from this section is destructive, permitting changes in stored data to be made as desired. Information within the memory may be called up for display on the two DSKYs. The DSKYs enable the flight crew to enter data or instructions into the AGC, request display of data from AGC memory, and offer an interrupt control of AGC operation. The AGC timing section provides timing signals of various frequencies for internal use and to other onboard systems which require accurate or synchronized timing. Data within the AGC is transmitted to MSFN through a "downlink" telemetry function. Telemetered data is transmitted as a function of an AGC program or by request from MSFN. Data within the AGC may be updated through an "uplink" telemetry function controlled by MSFN. The AGC performs guidance functions by executing internal programs using predetermined trajectory parameters, attitude angles from the inertial CDUs, velocity changes from the PIPAs, and commands from the DSKYs (crew) to generate control commands. The navigation function is performed by using stored star-landmark data, optics angles from the optics CDUs, and velocity changes from the PIPAs in the execution of navigation programs.

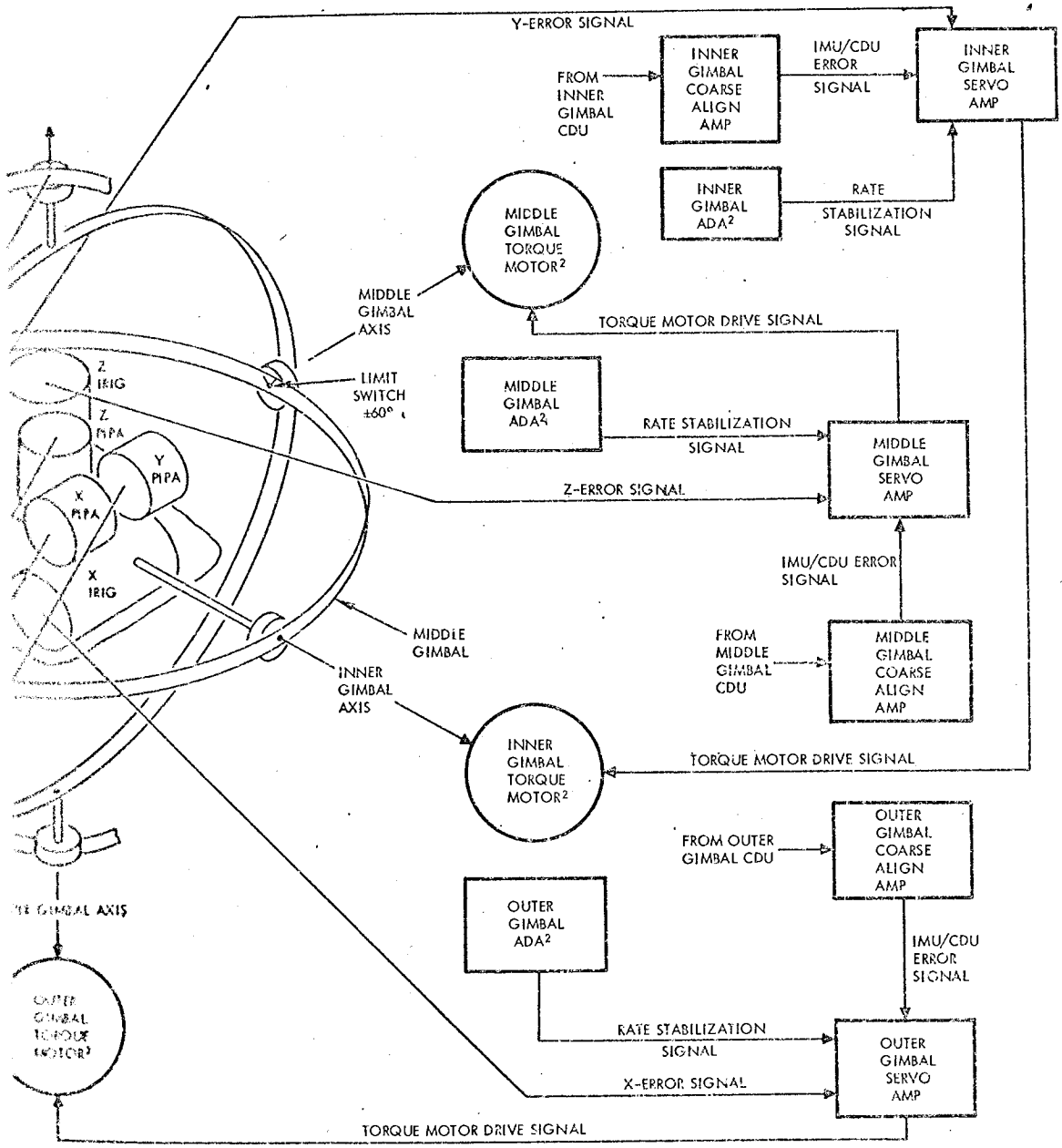


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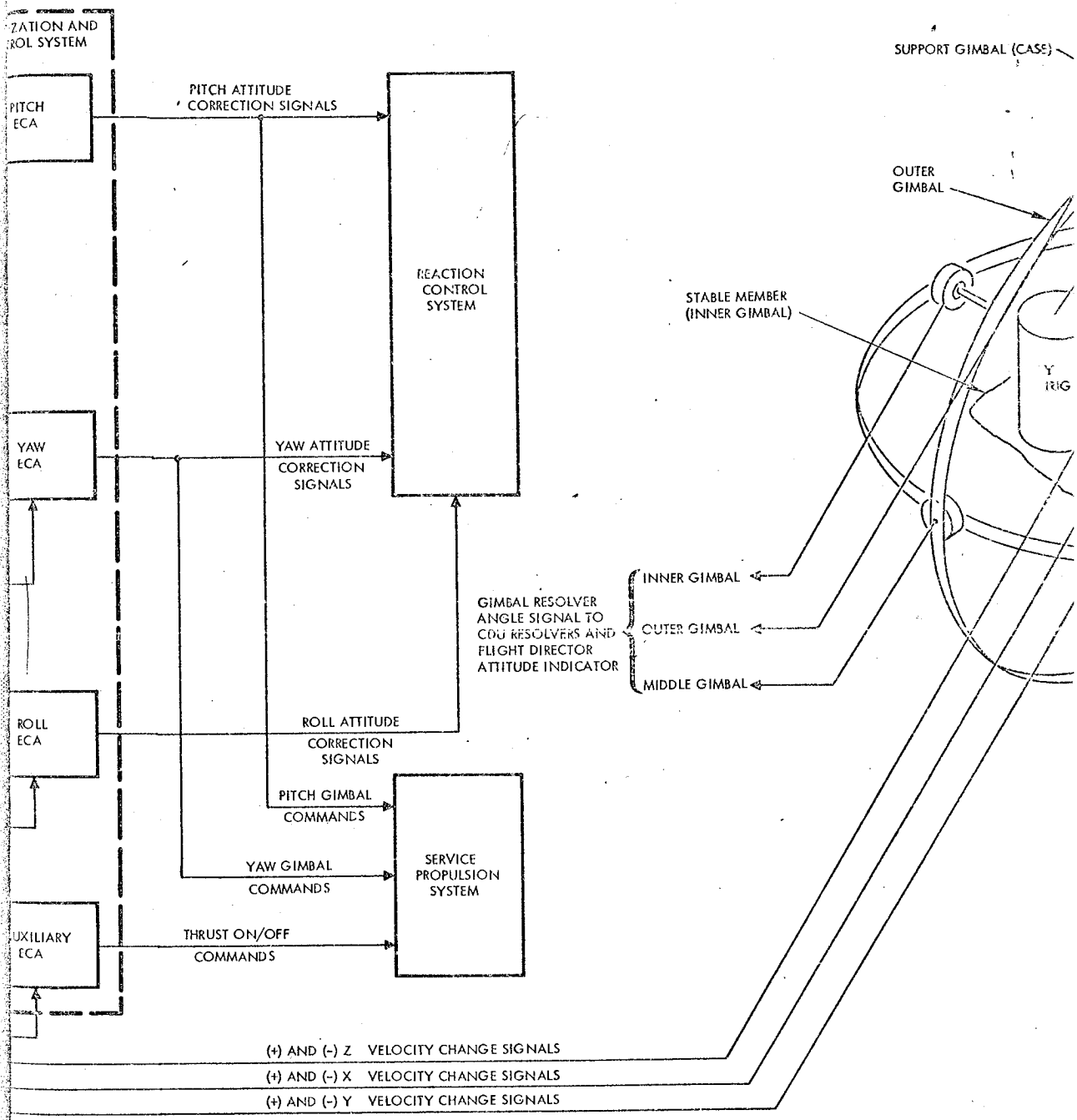
Figure 2.2-2. G&N System Functional Block Diagram


ZATION AND
ROL SYSTEM
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ROLL
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ROLL ATTITUDE
CORRECTION
SIGNALS
PITCH GIMBAL
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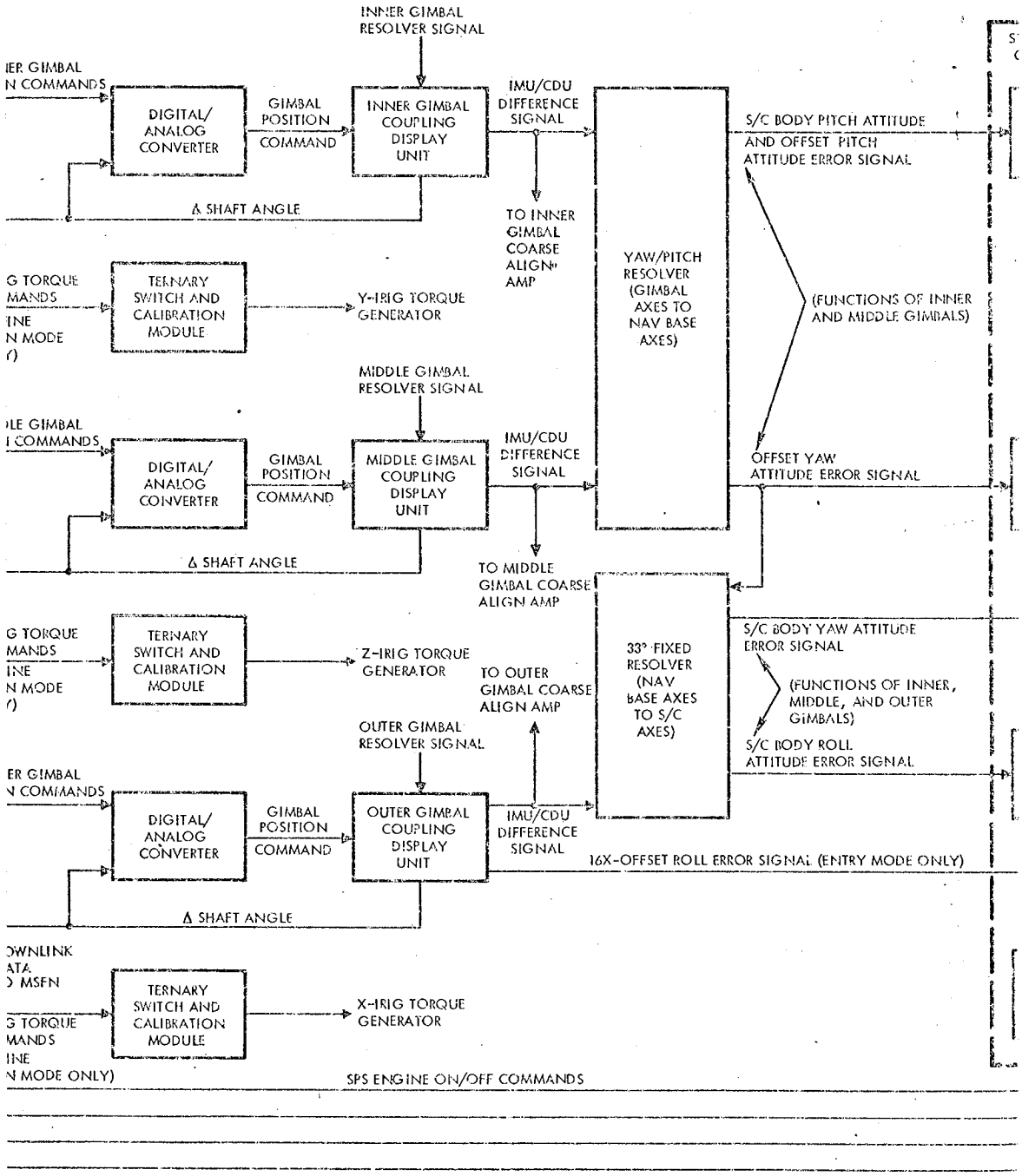
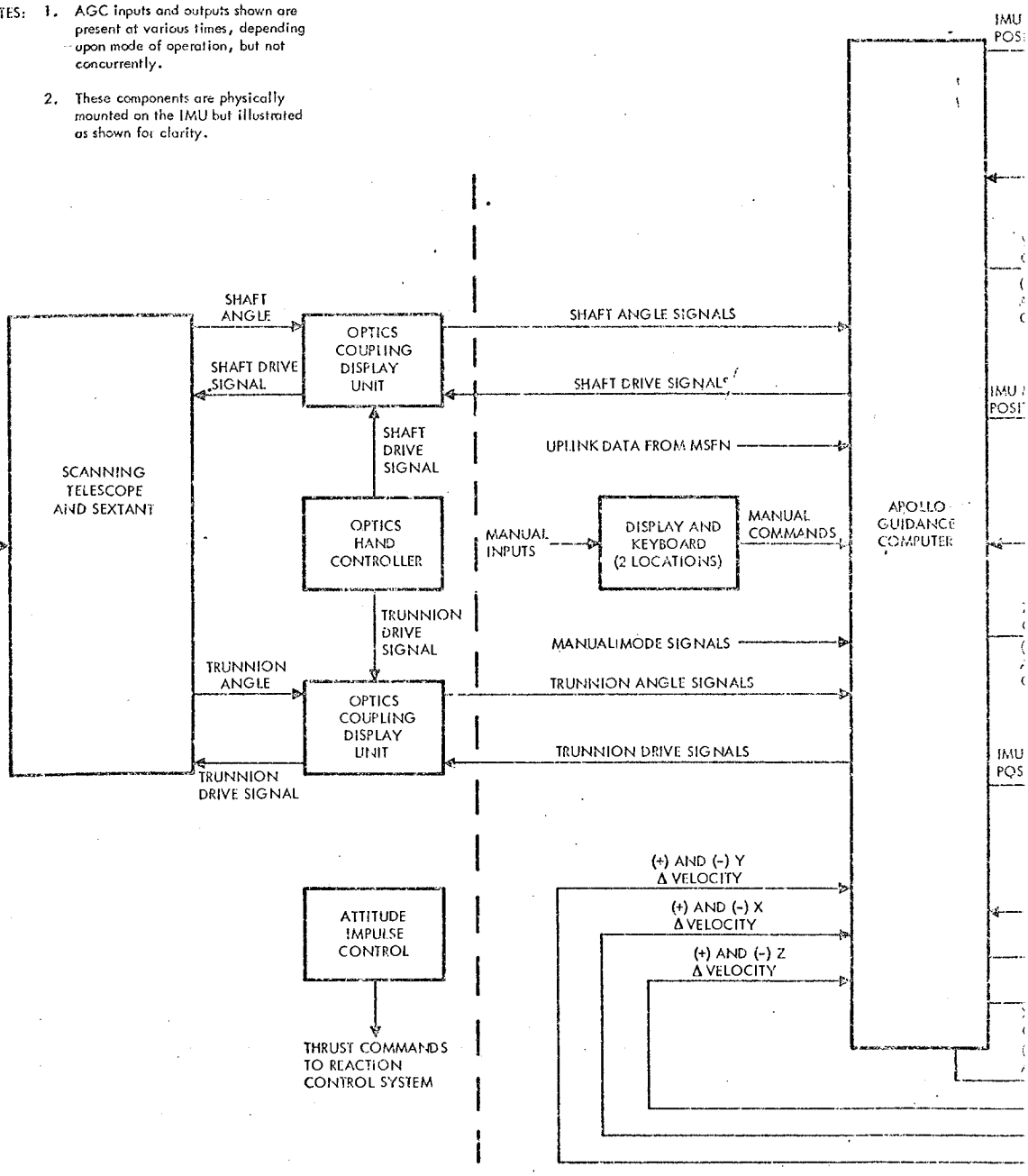
SERVICE
PROPULSION
SYSTEM
UXILIARY
ECA
THRUST ON/OFF
COMMANDS
SUPPORT GIMBAL (CASE)
OUTER
GIMBAL
STABLE MEMBER
(INNER GIMBAL)
Y
IRIG
GIMBAL RESOLVER
ANGLE SIGNAL TO
CDU RESOLVERS AND
FLIGHT DIRECTOR
ATTITUDE INDICATOR
INNER GIMBAL
OUTER GIMBAL
MIDDLE GIMBAL
(+) AND (-) Z VELOCITY CHANGE SIGNALS
(+) AND (-) X VELOCITY CHANGE SIGNALS
(+) AND (-) Y VELOCITY CHANGE SIGNALS


INNER GIMBAL RESOLVER SIGNAL
IER GIMBAL N COMMANDS
DIGITAL/ ANALOG CONVERTER
GIMBAL POSITION COMMAND
INNER GIMBAL COUPLING DISPLAY UNIT
IMU/CDU DIFFERENCE SIGNAL
S/C BODY PITCH ATTITUDE AND OFFSET PITCH ATTITUDE ERROR SIGNAL
Δ SHAFT ANGLE
TO INNER GIMBAL COARSE ALIGN AMP
YAW/PITCH RESOLVER (GIMBAL AXES TO NAV BASE AXES)
G TORQUE MANDS INE N MODE /)
TERNARY SWITCH AND CALIBRATION MODULE
Y-IRIG TORQUE GENERATOR
(FUNCTIONS OF INNER AND MIDDLE GIMBALS)
MIDDLE GIMBAL RESOLVER SIGNAL
LE GIMBAL COMMANDS
DIGITAL/ ANALOG CONVERTER
GIMBAL POSITION COMMAND
MIDDLE GIMBAL COUPLING DISPLAY UNIT
IMU/CDU DIFFERENCE SIGNAL
OFFSET YAW ATTITUDE ERROR SIGNAL
Δ SHAFT ANGLE
TO MIDDLE GIMBAL COARSE ALIGN AMP
G TORQUE MANDS INE N MODE /)
TERNARY SWITCH AND CALIBRATION MODULE
Z-IRIG TORQUE GENERATOR
TO OUTER GIMBAL COARSE ALIGN AMP
33° FIXED RESOLVER (NAV BASE AXES TO S/C AXES)
S/C BODY YAW ATTITUDE ERROR SIGNAL
(FUNCTIONS OF INNER, MIDDLE, AND OUTER GIMBALS)
S/C BODY ROLL ATTITUDE ERROR SIGNAL
OUTER GIMBAL RESOLVER SIGNAL
ER GIMBAL N COMMANDS
DIGITAL/ ANALOG CONVERTER
GIMBAL POSITION COMMAND
OUTER GIMBAL COUPLING DISPLAY UNIT
IMU/CDU DIFFERENCE SIGNAL
16X-OFFSET ROLL ERROR SIGNAL (ENTRY MODE ONLY)
Δ SHAFT ANGLE
OWNLINK ATA D MSFN
G TORQUE MANDS INE N MODE ONLY)
TERNARY SWITCH AND CALIBRATION MODULE
X-IRIG TORQUE GENERATOR
SPS ENGINE ON/OFF COMMANDS

NOTES:
1. AGC inputs and outputs shown are present at various times, depending upon mode of operation, but not concurrently.
2. These components are physically mounted on the IMU but illustrated as shown for clarity.



VISUAL
SIGHTINGS
OF STARS,
LANDMARKS
AND HORIZON

The optics provide accurate star and landmark angular measurements. Sightings are accomplished by the navigator using the SXT and SCT. The optics are positioned by drive motors commanded by the optics hand controller or manually using a universal tool, as desired. The shaft axes are parallel. Trunnion axes may be operated in parallel or offset, as desired. The SCT is a unity power instrument providing an approximate 60-degree field of view. It is used to make landmark sightings and to acquire and center stars or landmarks prior to SXT use. The SXT provides 28-power magnification with a 1.8-degree field of view. The SXT has two lines of sight, enabling it to measure the included angle between two objects. This requires two lines of sight which enable the two viewed objects to be superimposed. For a star-landmark sighting, the landmark line of sight is centered along the SXT shaft axis. The star image is moved toward the landmark by rotating the shaft and trunnion axes until the two viewed objects are superimposed. The shaft and trunnion angles are repeated by the optic CDUs. When the navigator is satisfied with image positions, he issues a mark command to the AGC. The AGC reads the optics CDU angles, IMU CDU angles, and time, and computes the position of the spacecraft. The AGC bases the computation on stored star and landmark data which may also be used by the AGC to request specific stars or landmarks for navigational sightings. Two or more sightings, on two or more different stars, must be taken to perform a complete position determination.

2.2.2.1 Operational Modes.

The G&N system is operated in six basic operational modes. Selection of any one mode is accomplished manually by the flight crew or automatically by the AGC. The basic modes are as follows:

- Monitor (initiated by SCS mode selection)
- Zero encode
- Coarse align
- Fine align
- Attitude control
- Entry

The system configuration necessary to operate in any of the modes is established by relay switching.

The monitor mode is used at launch, ascent, and during orbit until CSM/S-IVB separation, to provide flight path data for crew displays. The coarse align, fine align, and zero encode modes are used to align the IMU after standby periods or to acquire a new stable platform orientation. The attitude control mode provides for spacecraft attitude control and navigation computations to measure position and velocity. The entry mode provides control of the spacecraft lift vector during entry phase.

The ISS and CSS will be operated in on-standby cycles to conserve electrical power. During standby operation, the ISS maintains IMU temperature, and the CSS maintains AGC timing functions. The OSS is shut off when not in use. Since standby operation time varies for each of the subsystems, standby is not considered as basic mode.

2.2.2.1.1 Monitor Mode.

During prelaunch operations, the G&N system is aligned to the desired launch reference attitude and gyro compasses to maintain this attitude. Approximately 3 minutes prior to launch, the gyro compassing is stopped and the system becomes inertially referenced. Upon lift-off the AGC begins monitoring the flight path angles by driving the Inertial Coupling Display Units (ICDUs) through programmed attitude changes. The ICDU angles are compared with the IMU gimbal angles to produce flight path error signals which are displayed by the FDAI error needles. Total spacecraft attitude, with respect to the IMU orientation, is displayed by the FDAI ball. (Prelaunch FDAI readings are 164.76-degree roll, 58.30-degree pitch, and 9.69-degree yaw, with respect to the navigation axis symbol. Display at orbit insertion is 0-degree roll, 310.5-degree pitch, and 0-degree yaw, assuming a 180-degree roll has been performed and launch pad 37 is used.) During boost prior to launch escape tower (LET) jettison, the AGC displays the following:

REGISTER 1 - Inertial flight path angle; inertial velocity with respect to local horizontal in degrees.

REGISTER 2 - Inertial velocity in ft per sec.

REGISTER 3 - Altitude above launch pad in nautical miles (NMs).

Upon receipt of LET jettison signals the displays change to the following:

REGISTER 1 - Predicted Gs for free-fall and entry at 60-degree bank angle.

REGISTER 2 - Altitude of perigee above the mean equatorial radius in NMs.

REGISTER 3 - Time of free-fall to 300,000 ft above mean equatorial radius in minutes and seconds.

This displayed data provides the flight crew with sufficient information to make abort or continue decisions; however, if time is not critical, the decision is made by the flight crew and MSFN jointly.

2.2.2.1.2 Zero Encode Mode.

The zero encode mode enables correction of the CDU data stored in AGC. This mode is used to ensure that the reference angles contained in the CDU registers of the AGC correspond with the actual CDU angles. This is accomplished by driving the CDUs to zero, then clearing the AGC CDU registers. This starts the AGC CDU registers at zero and enables the registers to maintain correct CDU angles by counting pulses from the CDU digital encoders.

2.2.2.1.3 Coarse Align Mode.

The coarse align mode enables stable platform alignment to within approximately 2 degrees of a desired platform orientation. Prerequisite information to accomplish coarse alignment consists of the desired platform orientation and present spacecraft attitude.

The desired platform orientation angles are computed by an alignment program executed by the AGC. The navigator determines the spacecraft attitude immediately prior to coarse alignment by making two or more sightings on stars or landmarks. Upon completion of the sightings, the AGC reads the optic angles and computes the gimbal angles necessary to attain the desired platform orientation. The AGC generates drive signals to position the CDU resolvers to the required gimbal angles. The IMU-CDU resolver error signals, generated by repositioning the CDUs, are applied to the gimbal torque servo amps which drive the gimbal torque motors to position the platform to the desired orientation.

The stable platform orientation will normally be such that the X-axis lies along the spacecraft thrust vector during all powered phases, except ascent, and along the spacecraft stability axis during entry.

2.2.2.1.4 Fine Align Mode

The fine align mode completes stable platform orientation to the required degree of accuracy. The navigator makes two or more star sightings, using on-board data and the optics to acquire the desired stars. Upon receipt of the optic angles the AGC computes the IMU angles necessary to complete the alignment. In the fine align mode, the IMU angles are repeated by the inertial CDUs which are monitored by the AGC to determine the actual IMU orientation. The AGC generates torquing signals to cancel any error between the actual IMU orientation and the desired orientation. These torquing pulses are applied to the IRIG torquing coils. The IRIGs in conjunction with the stabilization loops, reposition the stable platform until the desired orientation is attained. Upon completion of fine alignment, the IMU/CDU resolver signals and the stabilization loop signals are at null.

The system configuration required for fine align mode also applies IMU resolver signals to the SCS as apparent attitude error signals. To prevent these signals from appearing as actual spacecraft attitude errors, the SCS must be operated in an SCS mode which rejects G&N derived signals.

2.2.2.1.5 Attitude Control Mode.

The attitude control mode provides spacecraft attitude change sensing, generates error signals for spacecraft attitude control, velocity change signals for updating AGC velocity information, and signals for timing SPS engine thrust termination commands.

During spacecraft attitude control, the IMU gimbal resolvers sense any displacement of the spacecraft with respect to the stable platform orientation and produce corresponding error signals. The error signals are applied directly to the SCS-FDAI ball for error display and to the inertial CDU resolvers. The IMU-CDU error signals are displayed on the IMU control panel, resolved into spacecraft axes, and applied to the SCS. If the error signals indicate an attitude error larger than the selected deadband, appropriate RCS engines are fired and the desired spacecraft attitude is restored.

For delta V maneuvers, the G&N system provides attitude control, velocity change sensing, and total velocity change control by generating thrust termination commands. Prior to thrusting, the IMU is aligned so that the stable platform X-axis is parallel to the thrust vector. The AGC determines time-to-ignition and total velocity change desired, and performs mode verification routines. At ignition time the AGC flashes the DSKY displays to the crew for initiation of ignition (manual DSKY entry is required). During thrusting, the CDU applies attitude error signals to the SCS. Roll error signals are applied to the RCS engines; however, pitch and yaw error signals are applied to the SPS engine gimbals rather than RCS engines. This ensures alignment of the thrust vector through the spacecraft center-of-gravity and along the correct trajectory. The PIPAs on the stable platform sense the velocity changes and apply proportional output signals to the AGC. The AGC computes and updates spacecraft velocity, and counts down a preset counter with the PIPA signals. When the counter reaches zero, a thrust termination signal is generated and applied through the SCS electronics to the SPS engine.

2.2.2.1.6 Entry.

The entry mode provides for generation of attitude error and steering signals, sensing of deceleration, and computation of velocity changes during the entry phase of the mission. The steering signals provide for control of the spacecraft lift vector through the SCS, to inhibit excessive G-loadings and heat buildup, and to control the flight path to enable landing at a preselected site. Attitude error signals are applied to the FDAI attitude error needles.

Entry configuration is similar to attitude control with the exceptions that the roll response time is reduced, one step of axis resolution is not needed, and the AGC will produce steering signals to the SCS by driving the roll CDU. From initiation of entry mode until 0.05G switching, roll, pitch,

and yaw error signals provide attitude control. Upon 0.05G switching, the pitch and yaw error signals provide display only. Prior to entry, the IMU X-axis is aligned along the spacecraft entry velocity vector. This alignment eliminates the need for navigation base-to-spacecraft body axis resolution. Deceleration is sensed primarily by the IMU X-axis PIPA, although changes in lift vector orientation cause some lateral movement which is sensed by the Y and/or Z PIPAs. The outer gimbal, or roll, 1X resolver is connected to the 16X resolver in the ROLL CDU, giving a 16:1 increase in attitude error signal and reducing the response time of the roll channel. The AGC will produce steering signals by executing a programmed lift vector down entry (to ensure capture), 180-degree roll to lift vector up, then generate further steering signals with respect to G forces, heat buildup, and range needed. These steering signals are routed to the roll CDU where an IMU-CDU resolver error is generated and routed to the SCS for FDAI display and/or RCS engine control. The entry may be performed manually with the pilot flying to the steering signals as displayed on the FDAI, or automatically with the AGC steering signals routed to the roll RCS engines for spacecraft control.

2.2.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.2.3.1 Inertial Subsystem.

The function of the inertial subsystem is to provide a space-stabilized inertial reference from which velocity changes and attitude changes can be sensed. It is composed of the inertial measurement unit (IMU), the navigation base (NB), parts of the power and servo assembly (PSA), parts of the control and display panels, and three coupling display units (CDUs).

2.2.3.1.1 Navigation Base.

The navigation base (NB) is the rigid, supporting structure which mounts the IMU and optical instruments. The NB is manufactured and installed to close tolerances to provide accurate alignment of the equipment mounted on it. It also provides shock mounting for the IMU and optics.

2.2.3.1.2 Inertial Measurement Unit.

The inertial measurement unit (IMU) is the main unit of the inertial subsystem. It is a three-degree-of-freedom stabilized platform assembly, containing three inertial reference integrating gyros (IRIGs), three pulsed integrating pendulous accelerometers (PIPAs), and three angular differentiating accelerometers (ADAs). The stable member itself is machined from a solid block of beryllium with holes bored for mounting the PIPAs, IRIGs, and one of the three ADAs. Three gimbal and six intergimbal assemblies, which house torque motors and resolvers, are also part of the IMU assembly, together with preamplifiers and gimbal-mounted electronics. Figure 2.1-2 shows how the IRIGs and the PIPAs are mounted relative to each other on the stable member (or inner gimbal). The three gimbal axes, about which each of the gimbals rotate, are also shown.

The stable platform attitude is maintained by the IRIGs, ADAs, stabilization loop electronics, and gimbal torque motors. Any displacement of the stable platform or gimbal angles is sensed by the IRIGs and ADAs, which generate error signals. IRIG error signals are resolved and amplified at the IMU and applied to stabilization loop electronics. ADA-produced error signals are summed with the IRIG error signals. The resultant signal is conditioned and applied to the gimbal torque motors, which restore the desired attitude.

The stable platform provides a space-referenced mount for three PIPAs, which sense velocity changes. The PIPAs are mounted orthogonally to sense the velocity changes along all three axes. Any translational force experienced by the spacecraft causes an acceleration or deceleration which is sensed by one or more PIPAs. Each PIPA generates an output signal proportional to the magnitude and direction of velocity change. This signal, in the form of a pulse train, is applied to the AGC. The AGC will use the signal to update the velocity information and also generate signals to torque each PIPA ducosyn back to null.

The temperature of the IRIGs and PIPAs is maintained within required limits during both standby and operating modes of the IMU. The IMU temperature control system contains circuits to supply normal proportional temperature control with the capability of backup or emergency control in case of a proportional control malfunction. The proportional temperature control circuit is the primary means of maintaining the IRIG and PIPA temperature and provides the most accurate control. This type of control is available when either the proportional or auto-override mode is selected with the IMU TEMP MODE selector switch. The purpose of the auto-override mode is to provide automatic switching from that mode to emergency control if there is a malfunction in the proportional control circuit. If a malfunction occurs in the proportional mode, the switching to emergency control must be performed manually. In the proportional mode, the temperature is controlled by the proportional temperature control bridge and is maintained at 135±0.5°F. While in the emergency mode, it is controlled by the mercury thermostat and is held within ±5°F.

The backup temperature control and indicator circuit is intended for use in the event the proportional control fails. The control sensing elements for this system are three PIPA indicating sensors (connected in series) and six IRIG sensing elements (connected in series) in two separate bridges. This system can maintain the temperature to within ±1°F. In this mode of operation, an alarm indication is not available to the astronaut because of modifications to the temperature alarm amplifier circuit.

2.2.3.1.3 Coupling and Display Units.

There are five CDUs mounted below the IMU control panel at the lower equipment bay. Three CDUs function as part of the ISS, while the two remaining CDUs function with the OSS. The optic CDUs (OCDUs) are described in paragraph 2.2.3.2. The three inertial CDUs (ICDUs) are identical and may be interchanged. Display dials on the front panel of each provide a 6-digit readout. Positioning of the ICDUs is accomplished by the AGC. Each ICDU contains a 1/4-speed, 1/2-speed, 1-speed, and 16-speed resolver, the functions of which depend upon the ISS mode of operation. The angular movements of the resolvers are converted into digital signals by a digital encoder, processed by encoder electronics, and routed to AGC registers which maintain current ICDU angles for use as desired. The AGC

commands CDU movements by applying digital drive commands to digital-to-analog converters. The drive signals are converted from digital to analog and applied to CDU motor drive amplifiers which position the CDUs. The 1-speed and 16-speed resolvers function as receivers of signals produced by 1-speed and 16-speed resolvers mounted on the IMU. The 1/2-speed resolvers are used to zero the CDUs and the 1/4-speed resolvers are not used. The resolvers provide input signals to selector circuits which provide motor drive signals or spacecraft attitude error signals, depending upon ISS mode of operation. The IMU outer gimbal 1-speed resolver signals are applied to the roll CDU 16-speed resolver to increase roll control rates during entry.

2.2.3.1.4 Power and Servo Assembly.

The power and servo assembly (PSA), located just below the display and control panel in the lower equipment bay, serves as a central mounting point for most of the G&N electronic units such as power supplies and amplifiers. It also contains the backup electronics used to supply timing pulses to the IMU in case of an AGC timing malfunction. It consists of 10 removable trays mounted adjacent to each other and connected to a junction box. The PSA trays utilize three wiring harnesses to provide electrical connection: one for module-to-module connection, another for module-to-junction box connection, and a third for module connection to a 38-pin female test plug on the front of the PSA tray.

2.2.3.2 Optical Subsystem.

The optical subsystem is used for taking precise optical sightings on celestial bodies and for taking fixes on landmarks. These sightings are used for aligning the IMU and for determining the position of the spacecraft. The system includes the navigational base, two of the five CDUs, parts of the power and servo assembly, controls and displays, and the optics, which include the scanning telescope (SCT) and the sextant (SXT).

2.2.3.2.1 Optics.

The optics consist of the SCT and the SXT mounted in two protruding tubular sections of the optical base assembly. The SCT and SXT shaft axes are aligned parallel to each other and afford a common line-of-sight (LOS) to selected targets. The trunnion axes may be parallel or the SCT axis may be offset depending upon mode of operation.

The sextant is a highly accurate optical instrument capable of measuring the included angle between two targets. Angular sightings of two targets are made through a fixed beam splitter and a movable mirror located in the sextant head. The sextant lens provides 1.8-degree true field of view with 28X magnification. The movable mirror is capable of sighting a target to 57 degrees LOS from the shaft axis. The mechanical accuracy of the trunnion axis is twice that of the LOS requirement due to mirror reflection which doubles any angular displacement in trunnion axis.

The scanning telescope is similar to a theodolite in its ability to accurately measure elevation and azimuth angles of a single target using an established reference. The lenses provide 60-degree true field of view at 1X magnification. The telescope allowable LOS errors are 1 minute of arc rms in elevation with maximum repeatability of 15 arc/seconds and approximately 40 arc/seconds in shaft axis.

2.2.3.2.2 Coupling Display Units.

The function of the OCDUs is to position and repeat angles of the SCT and SXT shaft and trunnion axes. The OCDUs are similar to the ICDUs, but may not be interchanged due to internal mechanical differences allowing higher OCDU rates. Each OCDU has a 6-digit display readout and can be positioned automatically by AGC command. CDU angles are converted to a digital signal by a digital encoder, processed by encoder electronics, and routed to an AGC register. AGC positioning commands are applied to a digital-to-analog converter, converted to a representative analog signal, and applied to a motor drive amplifier in the SXT. Resolvers in the SXT function as transmitters to CDU resolvers which receive the position signals and apply the commanded angles to the CDU motor drive amplifiers to position the CDU motor.

Trunnion CDU 1/4-speed and 16-speed resolvers function as receivers and provide drive signals to the trunnion CDU motor. The SXT trunnion resolvers which drive the CDU resolvers are 1-speed and 64-speed respectively, providing a 1:4 SXT trunnion to CDU trunnion ratio. Visual readouts on the trunnion display dials are thus four times the trunnion angle and two times the star line-of-sight angle from zero position. The 1/2-speed resolver, in conjunction with the cosecant amplifier, provides a variable gain computing resolver which is used in the RESOLVED mode of operation. The 1-speed resolver is not used in the trunnion CDU.

Shaft CDU 1/2-speed and 16-speed resolvers function as receivers and produce drive signals to the shaft CDU motor. SXT resolvers used as transmitters are also 1/2-speed and 16-speed resolvers, affording a 1:1 ratio; thus, the display dials provide direct readouts of the shaft angles. The 1-speed resolver resolves polar coordinates into rectangular coordinates for the RESOLVED mode of operation. The 1/4-speed resolver is not used in the shaft CDU.

2.2.3.2.3 Operational Modes.

Optics positioning is accomplished automatically by the AGC or manually by the crew. Overall mode control is established by crew selection of the ZERO OPTICS, MANUAL, or COMPUTER modes on the OPTICS panel.

ZERO OPTICS mode enables automatic drive of the SXT shaft and trunnion motors to zero. This is accomplished by applying the SXT resolver output signals to the input of the SXT motor drive amplifiers. The drive signals are applied to the CDU and SCT resolvers which follow the SXT shaft and trunnion axes to zero. After 60 seconds, the AGC optics position registers are cleared. This mode may be selected by AGC program or manually.

MANUAL mode enables positioning control of the optics by manual manipulation of the optics hand controller. The hand controller is mechanized such that, right-left movement generates shaft commands, and up-down movement generates trunnion commands. Hand controller drive rates are selected by the position of the CONTROLLER SPEED switch.

Positions HI, MED, and LO control the amplitude of the drive signal to the hand controller. Hand controller drive signals are applied to the SXT shaft and trunnion drive amplifiers through the CONTROLLER MODE switch for selection of DIRECT or RESOLVED mode. In DIRECT mode, the image motion is presented in a polar coordinate reference frame; in RESOLVED mode, the image motion is presented in a rectangular coordinate reference frame.

In DIRECT mode, shaft commands move the image in a circular path around the center of the field of view. Trunnion commands drive the image in a straight line across the center of the field of view. The angular orientation of the trunnion commanded straight line movement is a function of the shaft angle; therefore, direction of image movement with respect to the direction of hand controller movement is also a function of shaft angle. The rate of image movement, for shaft commands, is a function of trunnion angle, wherein increasing trunnion angles result in increasing image movement rates.

In RESOLVED mode, shaft commands move the image left-right in a straight line. Trunnion commands move the image up-down in a straight line. Image movement is in the same direction as hand controller movement and the rate of movement is constant for varying angles.

In COMPUTER mode, the AGC positions the optics to a star or landmark determined by AGC programming. This mode is performed by an AGC routine which is called up automatically by various alignment programs. The target star or landmark may be defined by AGC programming or by the crew. If the target star or landmark is not selected by AGC programming, the crew makes a DSKY entry defining either the latitude, longitude, and altitude for a landmark or the star code for a star. The AGC determines the spacecraft attitude by monitoring the ICDUs, and computes the angles necessary to drive the optics to the desired target. (If the angles necessary to acquire the target are beyond the capabilities of the optics, the AGC flashes the DSKY displays.) When the necessary angles are computed, the AGC displays the desired shaft and trunnion angles on the DSKY and initiates OCDU drive to these angles. When the AGC has completed driving the CDUs, the crew checks the DSKY-displayed angles against the 6-digit CDU displays and the SCT counters. The crew then locates and identifies the target in the SCT, enables manual control, and completes the sighting. The AGC can also perform zero optics functions, if desired, by the AGC program.

The SCT trunnion may be operated in three alternate modes, with respect to the SXT trunnion, as desired. The SLAVE TELESCOPE switch enables crew selection of STAR LOS, LANDMARK LOS 0°, or OFFSET 25°. The STAR LOS position is normally used. In this position, the SCT trunnion is slaved to the SXT trunnion. The LANDMARK LOS 0° position, applies a fixed voltage to the SCT trunnion position loop causing it to null at zero. This holds center of the SCT 60° field of view parallel to the

SXT landmark line of sight. The OFFSET 25° position applies a fixed voltage to the SCT trunnion position loop, causing it to null at 25 degrees off-center. This holds the SCT field of view so that the SXT landmark line of sight remains visible while sweeping the SCT shaft through 360 degrees of rotation, providing an approximate 110-degree total field of view.

2.2.3.3 Computer Subsystem.

The computer subsystem (CSS) consists of the Apollo guidance computer (AGC) and two display and keyboard panels (DSKYs). The AGC and one DSKY are located at the lower equipment bay. The other DSKY is located on the main display console. The AGC mounts one switch on the front panel which applies partial or full power to the computer to enable standby or full operation of the CSS. All other AGC controls and displays are located on the DSKYs. The keyboards on the DSKYs are smiliar; however, the displays on the DSKY in the lower equipment bay are more extensive.

2.2.3.3.1 Apollo Guidance Computer.

The Apollo guidance computer (AGC) is a digital computer using a two-part rope core memory. (See figure 2.2-3.) The AGC processes various data to provide control and computation functions. Input data is received from the crew, ISS, OSS, MSFN, and other spacecraft systems. This data is processed by various programs to provide outputs to the crew, ISS, OSS, MSFN, and other spacecraft systems in the form of commands and displays. The control functions performed by the AGC consist of the following:

- Align the IMU stable platform.
- Position the optics for navigation sightings.
- Command reaction control system engine firings to maintain specific attitude.
- Request initiation and command termination of service propulsion engine firings.
- Provide synchronization pulses to the central timing equipment.
- Command telemetry transmission to MSFN.
- Command ISS moding.
- Command OSS moding.

The reference data used to generate controls may be acquired externally or generated within the AGC. Initiation of the controls may be accomplished by the crew using the DSKYs, by MSFN via telemetry, or by an AGC program.

- Central processor
- Memory
- Timing

Power Supply. The power supply consists of two parts. Input to the power supply is +28 vdc from the spacecraft main d-c bus. The two sections provide +13 vdc and +3 vdc. The +13-vdc output provides power to the DSKYs and, in conjunction with the +3-vdc power, to the logic circuits. The +3-vdc supply provides power to the timing section as well as to the logic circuits. During standby mode of operation, the +3-vdc section only is operated; thus, power consumption is reduced by approximately 100 watts.

Input. The input section consists of four registers which enable intercommunication between the AGC and the other G&N subsystems, the stabilization and control system, the mission sequencer, the S-IVB guidance, and MSFN. The utilization of the registers is such that each bit position in each register is assigned a specific task. For example, bit positions 1, 2, 3, 4, and 5 of input register 0 are assigned to receiving the five bit code generated when a DSKY key is pressed. Data received from the various sources are conditioned by the input registers such that, when it is transferred into the logic circuits, the signal levels and timing are correct. The data received by the four input registers are as follows:

Input 0 Register	Receives 5-bit code from the DSKYs, block uplink signal from the UPTEL switch, control signals from the SCS mode control panel, and mark commands from the MARK pushbutton. Also monitors the signal from the telemetry bit rate detecting circuits.
Input 1 Register	This register is formed by the Scaler A register of the timing section which maintains real time during standby operation, and provides update information to the real time counters when full operation is resumed.
Input 2 Register	Receives 200, 400, 800, and 1600 pps signals from the Scaler A section of the timing section forming an extension of the real time counters for use by other spacecraft systems which require timing of this order. Also receives discrete event signals from the S-IVB instrument unit, CM/SM separation signals from the master events sequence controller, failure signals from the ISS, mode signals from the SCS, and parity fail signals.

Input 3 Register	Receives ISS mode signals from the ISS mode relays and mode signals from the OSS, monitors the position of the TRANSFER switch, and provides a logic OR gate for 33 DSKY relays.

Output. The output section consists of four registers which enable the AGC to communicate with the flight crew, ISS, OSS, and other spacecraft systems. The utilization of the registers is similar to that used for the input section (i.e., each bit position, or group of bit positions is assigned a specific task). The tasks assigned to the various registers and bit positions are as follows:

Output 0 Register	Provides the transmission link from the AGC to the DSKYs by control of 14 banks of relays which provide display of data and routing of control signals to the ISS, OSS, and SCS.
Output 1 Register	Receives internal AGC alarm signals and causes alarm indicators on the DSKYs to illuminate. Receives KEY RLSE request from an AGC program and causes the KEY RLSE indicator to illuminate and flash until the DSKY is released. Receives AGC signal indicating improper DSKY operation and causes the CHECK FAIL indicator to illuminate. Receives SPS engine firing signal from an AGC program, causing the DSKY to flash a request for crew initiation of engine firing. Receives SPS engine off command from an AGC program, removing the engine on signal. Also provides signal to reset the error interrupt trap circuits, identifies the type of word being transmitted by downlink telemetry, and inhibits further loading of telemetry words when the telemetry word rate exceeds 50 words per second.
Output 2 Register	Controls application of 3200 pps control pulses to the ISS and OSS.
Output 3 Register	Serves as a spare register for the central processor when needed.
Output 4 Register	Contains the next word to be transmitted by downlink telemetry.

Central Processor. The central processor contains the logic circuits and registers which perform the programs. Programs are executed by performing instructions in a sequence controlled by the sequence generator. There are two basic types of instructions. The first is the machine instruction which consists of regular, involuntary, and miscellaneous instructions. Regular instructions are contained within the program and are part of the data words being processed. Involuntary instructions are performed as interrupts to the program and are generated externally to the AGC. Miscellaneous instructions are used in the computer test only. The second basic type of instruction is the interpretive instructions and are a programmer convenience which are converted under program control to machine instructions. The execution of the instructions is a function of the sequence generator. The sequence generator combines basic timing pulses with the instruction portion of a data word and performs the program in the necessary sequence. Regular machine instructions are processed by the sequence generator initiation of the instruction. The instruction will perform one or more subinstruction, the last of which will be a subinstruction to proceed to the next instruction. Involuntary instructions are initiated by an interrupt from an external source, after which the instruction is performed in the same manner as a regular instruction. After completion of the involuntary instruction, a "resume" command is executed and the sequence generator returns to the program which was interrupted. The central processor performs the data manipulation by adding, subtracting, shifting, etc., within a group of central registers, adder, and parity block. The functions of the registers are as follows:

A Register	Accumulator. Stores the results of arithmetic processing.
LP Register	Stores the least significant portions of the product of a multiply instruction.
B Register	Used to complement (by reading the reset side of the register), as temporary storage, and as a buffer.
Z Register	Program counter. Contains address of next instruction. Incremented by one as each instruction is performed. (Instructions are usually stored in memory sequentially.)
Q Register	If transfer control occurs the contents of Z are read into and stored in Q until interrupt is completed. Enables interrupted program to restart at the proper instruction. Also used in division. Stores remainder in complemented form.
Input 0, 1, 2, 3	Refer to Input section description.
Output 0, 1, 2, 3	Refer to Output section description.

G Register	Provides access to and from memory. Shifting, under program control, takes place in this register. Parity bit is removed and restored in this register.
S Register	Contains address of word to be called from memory. If word is in fixed memory, this selects word in conjunction with BANK register.
BANK Register	Selects bank in fixed memory. Operates in conjunction with S register.
SQ Register	Stores 4 bit order code of instruction word.
X, Y, U Registers	These registers form the adder. Two numbers to be added are placed in X and Y. The result is stored in U.
Parity Circuit	The parity circuit checks the parity of words coming from memory to be odd. If parity is not correct, this circuit generates a parity alarm. Words being returned to memory are given the proper parity bit by this circuit.

Data flow within the central processor is initiated by an instruction. A data word is brought from memory to the G register. The G register provides temporary storage of the word until it is needed. If the word came from erasable memory, it will usually be written back into the same location during the same memory cycle time it is transferred to the G register. (This is not necessary for words from fixed memory, as readout is not destructive.) The word is then routed to the parity circuits for a parity check and to have the parity bit removed. The sequence generator next controls the transfer of the data word to the other registers for processing. If the result of the processing is to be written back into memory, the word is transferred back into the G register, the parity bit is added, and the word transferred back to memory. If the processing consists of arithmetic functions, it is performed in the adder (X, Y, and U registers). The AGC has the capability to add only; therefore, subtraction, multiplication, and division are performed by complementing and/or shifting, then adding.

Memory. The AGC memory consists of two sections. The largest section is the fixed memory. This is a rope core type having a capability of 24,576 sixteen bit words. Readout is non-destructive and the data contained cannot be changed. All permanent, pre-determined data, such as programs, tables, constants, star and landmark angles, etc., are contained in this section. Addressing the data contained in the fixed

section is accomplished by the S and BANK registers. A smaller erasable section provides temporary storage for transient data. Erasable memory is a coincident-current core array with a capacity of 1024 sixteen bit words. Readout is destructive, so if data is to be retained, it is necessary to write the data back into the location when it is read out. Addressing the data contained in erasable memory is done by the S register.

Timing. The timing section generates the synchronization pulses for AGC operations and timing pulses for other spacecraft systems. The timing section is divided into the following functional groups:

Clock Divider	This group contains the basic clock oscillator which has a 2.048 mc frequency divided to time various AGC logic functions and certain outputs, clock the time pulse generator, and drive Scaler A.
Scalers A and B	Scaler A contains 17 binary dividers producing signals of various frequencies used within the AGC logic, as reference to the PSA, and to drive Scaler B. Scaler B contains 16 binary dividers producing timing signals to the Input 1 register for maintaining real time when the AGC is in standby. Scalers A and B are used in conjunction with the Input 0 register, TIME 1, and TIME 2 counters to provide real time.
Time Pulse Generator	Produces 12 basic timing pulses which define action times. These pulses are used to control internal sequencing of data processing.
Memory Pulse Generator	This group provides timing pulses to fixed and erasable memory to synchronize read and write operations.
Start-Stop Logic	The start-stop logic generates three commands. A monitor stop command inhibits the time pulse generator and stops AGC data word flow. A monitor start command generates the third signal which is a clear command to the sequence generator.

2.2.3.3.2 Display and Keyboard.

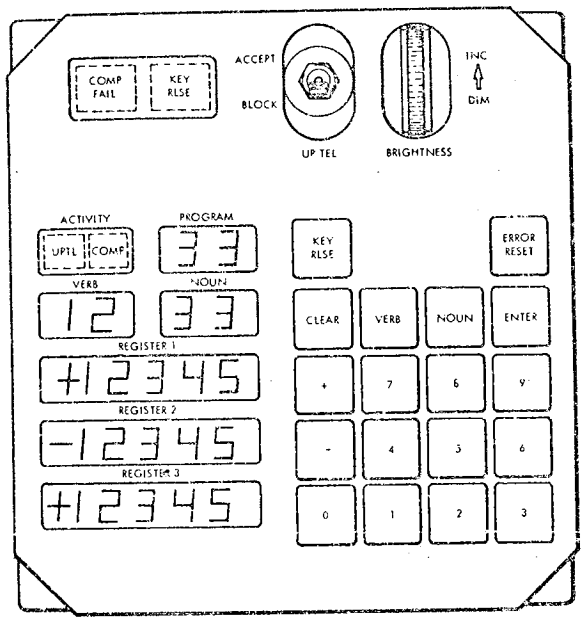
The DSKYs facilitate intercommunication between the flight crew and the AGC. (See figure 2.2-4).) The DSKYs operate in parallel, with the main display console DSKY providing AGC display and control while the crew are in their couches. The two condition lights provided at the main display console DSKY are COMPUTER FAIL, which is a gross AGC failure indicator, and KEY RLSE, which is a request to the crew to release the DSKY circuits to internal AGC program use. The main display console DSKY also has an UPTEL switch which enables the AGC to accept or block telemetered data from MSFN. The DSKY at the lower equipment bay contains the remainder of the condition lights: PROG ALM, RUPT LOCK, PARITY FAIL, TC TRAP, TM FAIL, COUNTER FAIL, SCALER FAIL, CHECK FAIL and KEY RLSE. All the condition lights except KEY RLSE are failure indicators. (KEY RLSE is a request for the crew to release the DSKY circuits to internal AGC program use.) This DSKY also has a TEST ALARM push-button which is wired to the alarm relays to provide a check of the warning lights. The electroluminescent displays are identical on each DSKY and always display identical data. The intensity of these displays is controlled by the BRIGHTNESS thumbwheels.

The exchange of data between the flight crew and the AGC is usually initiated by crew action; however, it can also be initiated by internal computer programs. The exchanged information is processed by the DSKY program. This program allows the following four different modes of operation:

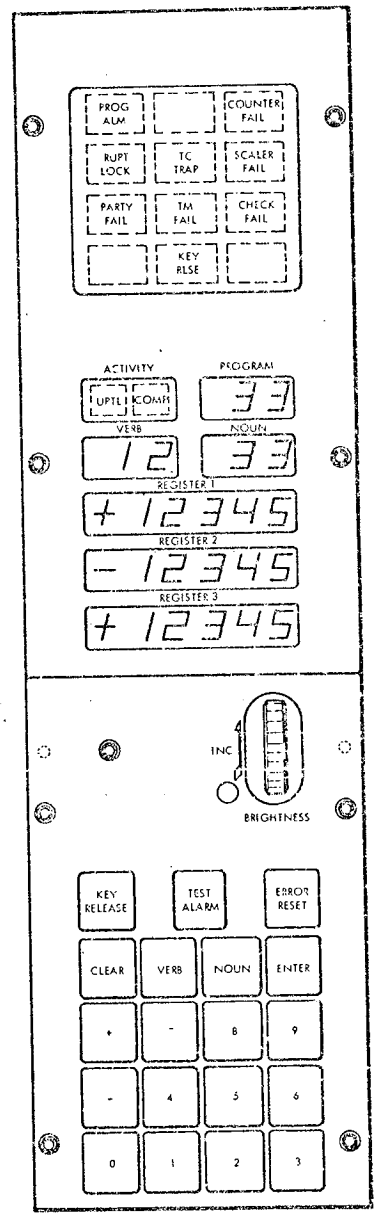
- Display of Internal Data—Both a one-shot display and a periodically updating display (called monitor) are provided.
- Loading External Data—As each numerical character is entered, it is displayed in the appropriate display panel location.
- Program Calling and Control—The DSKY is used to initiate a class of routines which are concerned with neither loading nor display. Certain routines required instructions from the operator to determine whether to stop or continue at a given point.
- Changing Major Mode—The initiation of large scale mission phases can be commanded by the operator.

The data involved in both loading and display can be presented in either octal or decimal form as the operator indicates. If decimal form is chosen, the appropriate scale factors are supplied by the program. Decimal entries are indicated by entering a sign (+, -).

Keyboard Operation. The basic language of communication between the operator and the AGC is a pair of words known as verb and noun. Verb and noun codes are defined in figures 2.2-5 and 2.2-6, respectively. Each



MAIN DISPLAY CONSOLE
DSKY



LOWER EQUIPMENT BAY
DSKY

SM-2A-894

Figure 2.2-4. Display and Keyboard Panels

of these is represented by a two-character octal number. The verb code indicates what action is to be taken (operation); the noun code indicates to what action is applied (operand). Typical verbs are those for displaying and loading. Nouns usually refer to a group of erasable registers within the computer memory. The PROGRAM, VERB, and NOUN displays provide two digit numbers which are coded octal numbers describing the action being performed. The REGISTER 1, 2, and 3 displays provide display of the contents of registers or memory locations. These displays are numbers which are read as decimal numbers if a sign (+, -) is present and octal numbers if no sign is used. The REGISTER displays operate under program control unless the contents of a specific register or memory location is desired. The crew may request display of the contents of a specific register or memory location by commanding the display from the keyboard. The only other displays are the ACTIVITY lights which indicate whether the computer is computing or accepting telemetry from MSFN.

The keyboard provides 18 keys which, when pressed, generate a five bit signal representative of the key pressed. The +, -, and 0-9 keys are used for numerical entries, while the CLEAR, ENTER, VERB, NOUN, KEY RELEASE, and ERROR RESET keys provide instructions. The TEST ALARM key is wired to the alarm relays and provides a check of the warning indicator lights with the exception of SCALER FAIL. The main display console DSKY UPTEL switch enables or inhibits the acceptance of telemetry from MSFN. The function of each of the keys is as follows:

0-9	Enter numerical data, addresses, and action codes.
VERB	Commands AGC to accept the next two numbers as verb code data. Verb display is blanked until numbers are entered.
NOUN	Commands AGC to accept the next two numbers as noun code data. Noun display is blanked until numbers are entered.
ENTER	Instructs AGC to accept keyed-in data as completed and initiate operation specified by data word.
CLEAR	Enters all zeros in data register being loaded. Each successive pressing of this key clears the next higher register.
KEY RLSE	Release the DSKY circuits and displays for use by the AGC program being executed.
ERROR RESET	Momentarily resets AGC failure lights.

(+) and (-)	Denotes sign of data to follow. Denotes that following data is decimal.
TEST ALARM	Sets relays to illuminate LEB DSKY condition lights (except SCALER FAIL) to ensure proper operation. (LEB DSKY only.)
UPTEL	Sets AGC input registers to accept or inhibit telemetered data from MSFN. (MDC DSKY only.)
BRIGHTNESS	Provides control of intensity of electroluminescent displays.

The lower equipment bay DSKY provides nine condition lights of which eight are failure indicators and the remaining light a request for action. The function of each is as follows:

PROG ALM	The AGC program being executed has detected an error.
COUNTER FAIL	Detected failure in input timing pulses. Either interrupt or circuitry failed. Interrupt failure is denoted by RUPT LOCK failure indicator illumination.
RUPT LOCK	Interrupt failed to occur or was not completed within specified time.
TC TRAP	Transfer control instruction has not occurred, or has occurred but was not completed within a specified time.
SCALER FAIL	Failure detected in AGC timing section.
PARITY FAIL	Parity failure detected in data read from memory.
TM FAIL	Telemetry word rate to MSFN either too high or too low. Telemetry word rate from MSFN too high or incorrect transmission of data.
CHECK FAIL	Attempted illegal DSKY operation. Normally operator error.
KEY RLSE	Flashes to indicate AGC program in operation requires DSKY circuitry to continue.

The standard procedure for the execution of keyboard operations consists of a sequence of seven key depressions:

VERB V_2 V_1 NOUN N_2 N_1 ENTER

Pressing the VERB key blanks the two verb lights on the DSKY and clears the verb code register in the AGC. The next two numerical inputs are interpreted as the verb code, in octal form. Each of these characters is displayed by the verb lights as it is inserted. The NOUN key operates similarly with the DSKY noun lights and AGC noun code register. Pressing the ENTER key initiates the program indicated by the verb-noun combination displayed on the DSKY. Thus, it is not necessary to follow a standard procedure in keying verb-noun codes into the DSKY. It can be done in reverse order, if desired, or a previously inserted verb or noun can be used without rekeying it. No action is taken by the AGC in initiating the verb-noun-defined program until the ENTER key is actuated. If an error is noticed in either the verb code or noun code prior to actuation of the ENTER key, it can be corrected simply by pressing the corresponding VERB or NOUN key and inserting the proper code. The ENTER key should not be actuated until it has been verified that the correct verb and noun codes are displayed.

If the selected verb-noun combination requires data to be loaded by the operator, the VERB and NOUN lights start flashing on and off (about once per second) after the ENTER key is pressed. Data is loaded in five-character words and, as it is keyed in, it is displayed character-by-character in one of the five-position data display registers, REGISTER 1, REGISTER 2, or REGISTER 3. Numerical data is assumed to be octal unless the five-character data word is preceded by a plus or minus sign, in which case it is considered to be decimal. Decimal data must be loaded in full five-numeral character words (no zeros may be left out); octal data may be loaded with high order zeros left out. If decimal is used for any component of a multicomponent load verb, it must be used for all components of that verb. In other words, no mixing of octal and decimal data is permitted for different components of the same load verb. The ENTER key must be pressed after each data word. This tells the program that the numerical word being keyed in is complete. The on-off flashing of the VERB-NOUN lights terminates after the last ENTER key actuation of a loading sequence.

The CLEAR key is used to remove errors in loading data as it is displayed in REGISTER 1, REGISTER 2, or REGISTER 3. It does nothing to the PROGRAM, NOUN, or VERB lights. (The NOUN lights are blanked by the NOUN key, the VERB lights by the VERB key.) For single-component load verbs or "machine address to be specified" nouns, the CLEAR key depression performs the clearing function on the particular register being loaded, provided that the CLEAR key is depressed before the ENTER key. Once the ENTER key is depressed, the CLEAR key does nothing. The only way to correct an error after the data is entered for

a single-component load verb is to begin the load verb again. For two- or three-component load verbs, there is a CLEAR backing-up feature. The first depression of the CLEAR key clears whichever register is being loaded. (The CLEAR key may be pressed after any character, but before its entry.) Consecutive CLEAR key actuations clear the data display register above the current one until REGISTER 1 is cleared. Any attempt to back up (clear) beyond REGISTER 1 is simply ignored. The CLEAR backing up function operates only on data pertinent to the load verb which initiated the loading sequence. For example, if the initiating load verb were a "write second component into" type only, no backing up action would be possible.

The numerical keys, the CLEAR key, and the sign keys are rejected if depressed after completion (final entry) of a data display or data load verb. At such time, only the VERB, NOUN, ENTER, ERROR RESET, or KEY RELEASE inputs are accepted. Thus, the data keys are accepted only after the control keys have instructed the program to accept them. Similarly, the + and - keys are accepted only before the first numerical character of REGISTER 1, REGISTER 2, or REGISTER 3 is keyed in and at no other time. The 8 or 9 key is accepted only while loading a data word which is preceded by a + or - sign.

The DSKY can also be used by internal computer programs for subroutines. However, any operator keyboard action (except ERROR RESET) inhibits DSKY use by internal routines. The operator retains control of the DSKY until he wishes to release it. Thus, he is assured that the data he wishes to observe will not be replaced by internally initiated data displays. In general, it is recommended that the operator release the DSKY for internal use when he has temporarily finished with it. This is done by pressing the KEY RELEASE key.

Verb-Noun Formats. The verb-noun codes are defined in figures 2.2-5 and 2.2-6. A noun code may refer to a device, a group of computer registers, or a group of counter registers, or it may simply serve to convey information without referring to any particular computer register. The noun is made up of 1, 2, or 3 components, each component being entered separately as requested by the verb code. As each component is keyed, it is displayed on the display panel with component 1 displayed in REGISTER 1, component 2 in REGISTER 2, and component 3 in REGISTER 3. There are two classes of nouns: normal and mixed. Normal nouns (codes 01 through 54) are those whose component members refer to computer registers which have consecutive addresses and use the same scale factor when converted to decimal. Mixed nouns (codes 55 through 77) are those whose component members refer to nonconsecutive addresses or whose component members require different scale factors when converted to decimal, or both.

A verb code indicates what action is to be taken. It also determines which component member of the noun group is to be acted upon. For

example, there are five different load verbs. Verb 21 is required for loading the first component of the selected noun; verb 22 loads the second component; verb 23 loads the third component; verb 24 loads the first and second component; and verb 25 loads all three components. A similar component format is used in the display and monitor verbs. There are two general classes of verbs: standard and extended. The standard verbs (codes 01 through 37) deal mainly with loading, displaying, and monitoring data. The extended verbs (codes 40 through 77) are principally concerned with calling up internal programs whose function is system testing and operation.

Whenever data is to be loaded by the operator, the VERB and NOUN lights flash, the appropriate data display register is blanked, and the internal computer storage register is cleared in anticipation of data loading. As each numerical character is keyed in, it is displayed in the proper display register. Each data display register can handle only five numerical characters at a time (not including sign). If an attempt is made to key in more than five numerical characters at a time, the sixth and subsequent characters are simply rejected but they do appear in the display register.

The + and - keys are accepted prior to inserting the first numerical character of REGISTER 1, REGISTER 2, or REGISTER 3; if keyed in at any other time, the signs are rejected. If the 8 or 9 key is actuated at any time other than while loading a data word preceded by a + or - sign, it is rejected and the CHECK FAIL light goes on.

The normal use of the flash is with a load verb. However, there are two special cases when the flash is used with verbs other than load verbs.

- Machine Address to be Specified—There is a class of nouns available to allow any machine address to be used; these are called "machine address to be specified" nouns. When the "ENTER", which causes the verb-noun combination to be executed, senses a noun of this type the flash is immediately turned on. The verb code is left unchanged. The operator should load the complete machine address of interest (five-character octal). This is displayed in REGISTER 3 as it is keyed in. If an error is made in loading the address, the CLEAR key may be used to remove it. Pressing the ENTER key causes execution of the verb to continue.

- Change Major Mode—To change major mode, the sequence is VERB 37 ENTER. This causes the noun display register to be blanked and the verb code to be flashed. The two-character octal major mode code should then be loaded. For verification purposes, it is displayed as it is loaded in the noun display register. The entry causes the flash to be turned off, a request for the new major mode to be entered, and a new major mode code to be displayed in the PROGRAM display register.

Verb Code	Description	Remarks
		NOTE Verb codes 01 through 37 denote standard verbs.
01	Display 1st component of	Performs octal display of data on REGISTER 1.
02	Display 2nd component of	Performs octal display of data on REGISTER 1.
03	Display 3rd component of	Performs octal display of data on REGISTER 1.
04	Display 1st and 2nd components of	Performs octal display of data on REGISTER 1 and REGISTER 2.
05	Display 1st, 2nd, and 3rd component of	Performs octal display of data on REGISTER 1, REGISTER 2, AND REGISTER 3.
06	Display all component(s) of	Performs decimal display of data on appropriate registers. The scale factors, types of scale factor routines, and component information are stored within the machine for each noun which it is required to display in decimal.
07	DP decimal display	Performs a double precision decimal display of data on REGISTER 1 and REGISTER 2. It does no scale factoring. It merely performs a 10-character, fractional decimal conversion of two consecutive, erasable registers, using REGISTER 1 and REGISTER 2. The sign is placed in the REGISTER 1 sign position with the REGISTER 2 sign position remaining blank. It cannot be used with mixed nouns. Its intended use is primarily with "machine address to be specified" nouns.
10	Enter request to waitlist (Used only during ground checkout.)	Enters request to "waitlist routine" for any machine address with delay involved. This verb assumes that the desired number of 10-millisecond units of delay has been loaded into the low order bits of the prio/delay register (noun 26). This verb is used with the "machine address to be specified" noun. The complete address of the desired location is then keyed in. (Refer to "Machine address to be specified" in paragraph on Verb/Noun Formats.)
11	Monitor 1st component	Performs octal display of updated data every 1/2 second on REGISTER 1.
12	Monitor 2nd component of	Performs octal display of updated data every 1/2 second on REGISTER 1.
13	Monitor 3rd component of	Performs octal display of updated data every 1/2 second on REGISTER 1.
14	Monitor 1st and 2nd component of	Performs octal display of updated data every 1/2 second on REGISTER 1 and RECISTER 2.
15	Monitor 1st, 2nd, and 3rd component of	Performs octal display of updated data every 1/2 second on REGISTER 1, REGISTER 2, and REGISTER 3.
16	Monitor all components(s) of	Performs decimal display of updated data every 1/2 second on appropriate registers.
17	Monitor DP decimal	Performs double precision display of decimal data on REGISTER 1 and REGISTER 2. No scale factoring is performed. Provides 10-character, fractional decimal conversion of two consecutive erasable registers. The sign is placed in the sign-bit position of REGISTER 1. REGISTER 2 sign bit is blank.
20	Enter request to executive (Used only during ground checkout.)	Enters request to executive routine for any machine address with priority involved. This verb assumes that the desired priority has been loaded into bits 10-14 of the prio/delay register (noun 26). This verb is used with the noun, "machine address to be specified". The complete address of the desired location is then keyed in. (Refer to "Machine address to be specified" in paragraph on Verb/Noun Formats.)
21	Write 1st component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1.

Figure 2.2-5. Verb List (Sheet 1 of 3)

Verb Code	Description	Remarks
22	Write 2nd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 2.
23	Write 3rd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 3.
24	Write 1st and 2nd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1 and REGISTER 2.
25	Write 1st, 2nd, and 3rd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1, REGISTER 2, and REGISTER 3.
26	(Spare)	
27	(Spare)	
30	(Spare)	
31	Bank Display	This verb is included to permit displaying the contents of fixed memory in any bank. Its intended use is for checking program ropes and the BANK position of program ropes.
32	(Spare)	
33	Proceed without data	Informs routine requesting data to be loaded that the operator chooses not to load fresh data, but wishes the routine to contine as best it can with old data. Final decision for what action should be taken is left to requesting routine.
34	Terminate	Informs routine requesting data to be loaded that the operator chooses not to load fresh data and wishes the routine to terminate. Final decision for what action should be taken is left to requesting routine. If monitor is on, it is turned off.
35	(Spare)	
36	Fresh start	Initializes the program control software and the keyboard and display system program.
37	Change major mode to	Change to new major mode. (Refer to "Change major mode" in paragraph on Verb-Noun Formats.)
		NOTE Verb codes 40 through 77 denote extended verbs.
40	Zero	Must be used with noun 20 (ICDU) or noun 55 (OCDU) only. Sets the CDU registers to zero.
41	Coarse align IMU	Must be used with noun 20 (ICDU) or noun 55 (OCDU) only.
42	Fine align IMU	Calls up programs that perform the indicated G&N system procedures.
43	Lock IMU	Calls up programs that perform the indicated G&N system procedures.
44	Set IMU to ATTITUDE CONTROL	Calls up programs that perform the indicated G&N system procedures.
45	Set IMU ENTRY	Calls up programs that perform the indicated G&N system procedures.
46	Return IMU to coarse align	Calls up programs that perform the indicated G&N system procedures.

Figure 2.2-5. Verb List (Sheet 2 of 3)

Verb Code	Description	Remarks
47	(Spare)	
50	Please perform	This verb is used only by internal rountines that wish the operator to perform a certain task. It should never be keyed in by the operator. It is usually used with noun 25, "checklist." The coded number for the checklist item to be performed is displayed in REGISTER 1 by the requesting routine.
51	Please mark	This verb is used only by internal routines that request the operator to "mark". It should never be keyed in by the operator. It is usually used with noun 30, "star numbers". The numbers of the stars to be marked are displayed in REGISTER 1, REGISTER 2, and REGISTER 3 by the requesting routine. The operator should indicate completion of each valid mark by pressing the MARK button. He should never press ENTER with verb 51.
52	Mark reject	Rejects "mark" and returns to verb 51. Must be entered within 20 seconds of pressing MARK button.
53	Free	Calls up programs that perform the indicated G&N system procedures. Used only with noun 20 (ICDU) or noun 55 (OCDU).
54	Pulse torque gyros	Calls up programs that perform the indicated G&N system procedures.
55	Align time	
56	Perform BANK sum	
57	System test (Used only during ground checkout.)	
60	Prepare for standby	
61	Recover from standby	
62	(Spare)	
63	(Spare)	
64	Calculate orbital parameters	
65	Calculate time of arrival at longitude	
66	Calculate latitude and longitude at specified time	
67	Calculate maximum declination and time of arrival	
70	(Spare)	
71	(Spare)	
72	(Spare)	
73	Return to Earth aim point update	
74	Orbit change aim point update	
75	Manual lift-off for flights	
76	R. V. T. update (state vector)	R. V. T. denotes position, velocity, and time.
77	(Spare)	

Figure 2.2-5. Verb List (Sheet 3 of 3)

SYSTEMS DATA

Noun Code	Description	Scale/Units
	NOTE Noun codes 01 through 54 denote normal nouns.	**NOTE** In Scale/Units column: X = significant digit; 0 = zero (always); B = blank.
01	Specify machine address	XXXXX
02	Specify machine address	XXXXX.
03	(Spare)	
04	(Spare)	
05	Angular error	XXX.XX degrees
06	Pitch angle	XXX.XX degrees
	Heads up-down	±00001
07	Change of program or major mode (Used only with verb 50, "Please perform".)	
10	(Spare)	
11	Engine on enable (Used only with verb 50, "Please perform".)	
12	Delta V allowable	XXXXX. ft/sec
	Delta V tailoff	XXXXX. ft/sec
13	Delta V measured (Vector magnitude.)	XXXXX. ft/sec
14	Delta V counter setting.	XXXXX. ft/sec
15	Increment address (Used only during ground checkout.)	Octal only
16	AGC clock time:	
	REGISTER 1	00XXX. hours
	REGISTER 2	000XX. minutes
	REGISTER 3	0XX.XX seconds
17	(Spare)	
20	ICDUs:	
	X-REGISTER 1	XXX.XX degrees
	Y-REGISTER 2	XXX.XX degrees
	Z-REGISTER 3	XXX.XX degrees
21	PIPA counters:	
	X-REGISTER 1	XXXXX. pulses
	Y-REGISTER 2	XXXXX. pulses
	Z-REGISTER 3	XXXXX. pulses
22	New angles I:	
	X-REGISTER 1	XXX.XX degrees
	Y-REGISTER 2	XXX.XX degrees
	Z-REGISTER 3	XXX.XX degrees
23	Delta angles I:	
	X-REGISTER 1	XXX.XX degrees
	Y-REGISTER 2	XXX.XX degrees
	Z-REGISTER 3	XXX.XX degrees
24	Delta time for AGC clock:	
	REGISTER 1	00XXX. hours
	REGISTER 2	000XX. minutes
	REGISTER 3	0XX.XX. seconds
25	Checklist (Used only with verb 50, "Please perform".)	XXXXX.
	Checklist code numbers (Appear in REGISTER 1.)	
	00001 SCS mode to G&N attitude control	
	00002 SCS mode to G&N Delta V	
	00003 SCS mode to G&N entry	
	00004 SCS mode to monitor	
	00007 Manual attitude maneuver	
	00011 Automatic optics positioning	
	00012 Target data entry	
	00013 Switch OSS to computer control	
	00014 Fine align check	
	00015 Perform star acquisition	
	00031 Engine on	
	00035 Prepare AGC for thrusting	
	00036 Thrust terminate	
	00041 C/M-S/M separation	
26	Prio/delay (Used only during ground checkout.)	XXXXX.
27	Self test ON-OFF switch	XXXXX.
30	Star number	XXXXX.

Figure 2.2-6. Noun List (Sheet 1 of 3)

Noun Code	Description	Scale/Units
31	Failure register code	
	NOTE	
	Error codes are defined in paragraph 2.2.2.3.3.	Octal only
	Self-test diagnosis REGISTER 2	Octal only
	Self-test diagnosis REGISTER 3	Octal only
32	Decision time (Used only during ground checkout.)	
33	Ephemeris time (Used only during ground checkout.)	
34	Event time:	
	REGISTER 1	00XXX. hours
	REGISTER 2	000XX. minutes
	REGISTER 3	0XX.XX seconds
35	Delta event time:	
	REGISTER 1	00XXX. hours
	REGISTER 2	000XX. minutes
	REGISTER 3	0XX.XX seconds
36	Delta event time (Display only.)	XXBXX. minutes, seconds
37	(Spare)	
40	Gamma (inertial flight path angle.) REGISTER 1	XXX.XX degrees
	Inertial velocity REGISTER 2	XXXXX. ft/sec
	Altitude above launch pad REGISTER 3	XXXX.X nautical miles
41	Maximum acceleration REGISTER 1	XXXX.X g's
	Perigee altitude REGISTER 2	XXXX.X nautical miles
	Free-fall time REGISTER 3	XXBXX. minutes, seconds
42	Miss distance REGISTER 1	XXXX.X nautical miles
	Perigee altitude REGISTER 2	XXXX.X nautical miles
	Free-fall time REGISTER 3	XXBXX. minutes, seconds

Noun Code	Description	Scale/Units
43	Perigee altitude REGISTER 1	XXXX.X nautical miles
	Apogee altitude REGISTER 2	XXXX.X nautical miles
	Free-fall time REGISTER 3	XXBXX. minutes, seconds
44	Latitude REGISTER 1	XXX.XX degrees
	Longitude REGISTER 2	XXX.XX degrees
	Altitude (Above mean equatorial radius.) REGISTER 3	XXXX.X nautical miles
45	Perigee altitude REGISTER 1	XXXX.X degrees
	Apogee altitude REGISTER 2	XXXX.X degrees
	Delta velocity required REGISTER 3	XXXXX. ft/sec
46	Time to event REGISTER 1	XXBXX. minutes, seconds
	Velocity to be gained REGISTER 2	XXXXX. ft/sec
	Perigee altitude REGISTER 3	XXXX.X nautical miles
47	Flight path angle REGISTER 1	XXX.XX degrees
	Miss distance REGISTER 2	XXXX.X nautical miles
50	Time to event REGISTER 1	XXBXX. minutes, seconds
	Delta time of burn REGISTER 2	XXBXX. minutes, seconds
51	Time to event REGISTER 1	XXBXX. minutes, seconds
	Velocity to be gained REGISTER 2	XXXXX. ft/sec
	Measured velocity change along spacecraft X-axis REGISTER 3	XXXXX. ft/sec

Figure 2.2-6. Noun List (Sheet 2 of 3)

Noun Code	Description	Scale/Units
52	Time to event REGISTER 1	XXBXX. minutes, seconds
	Velocity to be gained REGISTER 2	XXXXX. ft/sec
	Free-fall time REGISTER 3	XXBXX. minutes, seconds
53	Maximum acceleration REGISTER 1	XXXX.X g's
	Free-fall time REGISTER 2	XXBXX. minutes seconds
54	Commanded roll angle REGISTER 1	XXX.XX degrees
	Present acceleration REGISTER 2	XXXX.X g's
	NOTE Noun codes 55 through 77 denote mixed nouns.	
55	OCDUs: X (Shaft angles) REGISTER 1	XXX.XX degrees
	Y (Trunnion angles) REGISTER 2	XX.XXX degrees
56	Uncalled mark data: X (Shaft angles) REGISTER 1	XXX.XX degrees
	Y (Trunnion angles) REGISTER 2	XX.XXX degrees
57	New angles-OCDUs: X (Shaft angles) REGISTER 1	XXX.XX degrees
	Y (Trunnion angles) REGISTER 2	XX.XXX degrees
60	IMU mode status (Used only during ground checkout.)	Octal only
61	Target: (Used only during ground checkout.)	
	Azimuth REGISTER 1	XXX.XX degrees
	[illegible] REGISTER 2	XX.XXX degrees
62	Delta velocity insertion REGISTER 1	XXXXX. ft/sec
	Miss distance REGISTER 2	XXXX.X nautical miles
	Free-fall time REGISTER 3	XXBXX. minutes, seconds

Noun Code	Description	Scale/Units
63	Latitude REGISTER 1	XX.XXX degrees
	Longitude/2 REGISTER 2	XX.XXX degrees
	Altitude REGISTER 3	XXX.XX nautical miles
64	(Spare)	
65	Sampled time (Fetched in interrupt.) REGISTER 1 REGISTER 2 REGISTER 3	00XXX. hours 000XX. minutes 0XX.XX seconds
66	System test results (Used only during ground checkout.)	
67	Delta gyro angles: (Used only during ground checkout.)	
	X-IRIG REGISTER 1	XX.XXX degrees
	Y-IRIG REGISTER 2	XX.XXX degrees
	Z-IRIG REGISTER 3	XX.XXX degrees
70	Pitch trim REGISTER 1	XXX.XX degrees
	Yaw trim REGISTER 2	XXX.XX degrees
	Delta velocity tailoff REGISTER 3	XXXXX. ft/sec
71	(Spare)	
72	Delta position (Used only during ground checkout.)	
73	Delta velocity (Used only during ground checkout.)	
74	(Spare)	
75	Delta position magnitude REGISTER 1	XXXX.X nautical miles
	Delta velocity magnitude REGISTER 2	XXXXX. ft/sec
	Measurement angle deviation REGISTER 3	XXX.XX degrees
76	R-position (Used only during ground checkout.)	
77	V-velocity (Used only during ground checkout.)	

Figure 2.2-6. Noun List (Sheet 3 of 3)

The flash is turned off by any of the following events:

- Final entry of a load sequence
- Entry of verb "proceed without data" (33)
- Entry of verb "terminate" (34).

It is important to conclude every load verb by one of the aforementioned three, especially if the load was initiated by program action within the computer. If an internally initiated load is not concluded validly, the program that initiated it may never be recalled. The "proceed without data" verb is used to indicate that the operator is unable to, or does not wish to, supply the data requested, but wants the initiating program to continue as best it can with old data. The "terminate" verb is used to indicate that the operator chooses not to load the requested data and also wants to terminate the requesting routine.

2.2.3.3.3 Error Codes.

Error code numbers appear in REGISTER 1 with noun 31.

OSS Errors

00101	Optics mode control switched from ZERO OPTICS before end of 30 seconds.
00102	AGC unable to achieve desired optics mode.
00103	Function not valid for SC 012.
00104	No vacant area available for marks.
00105	Internal mark request while mark system is busy.
00106	Function not valid for SC 012.
00107	Mark reject while mark system is not in use.
00110	Mark reject with all requested marks accepted or no marks since initiating last mark reject.
00120	Too many marks.

ISS Errors

00201	Zero encode ended before end of 30 second wait.
00202	AGC unable to achieve desired ISS mode.
00203	No ISS mode indicated to AGC.
00204	ISS mode changed while TRANSFER switch is in COMPUTER position, but AGC did not command mode change.

Procedural Difficulties

00401	Desired gimbal angles will produce gimbal lock. (Middle gimbal angle greater than 60°.)
00402	Star out of field of view.
00403	Same as 00402.
00404	IMU orientation unknown.
00405	SCS mode monitor failure.

00406	Navigation program busy.
00407	Navigation program needed internally.
00410	AGC update not allowed.
	AGC Hardware Malfunctions
01101	Unused interrupt (RUPT 2) occurred
01102	AGC self-test error.
01103	Unused count, compare, and skip (CCS) branch executed.
01104	C-relay failed during C-relay test.
01105	Star search failure.
01106	IMU orientation no good for entry.
	List Overflows
01201	Executive overflow-no vacant areas.*
01202	Executive overflow-no core sets.*
01203	Waitlist overflow-too many tasks.*
01204	Same as 01203.*
01205	Master control overflow-too many jobs waiting.*
01206	DSKY waiting line overflow.*
01207	No vacant area for marks.*
01210	Something already waiting in IMU stall.*
	Interpreter Errors
01301	Arccos-arcsin input angle too large.*
01302	Square root called for with a negative argument.*
	Display Alarms
01401	VG increasing-loss of control.
01402	Delta V too low-engine not on.
	DSKY Program Errors
01501	Check fail alarm during internal use.*

*These alarms are "aborts" and define alarms which initiate a restart of the AGC program which was in progress when the alarm appeared.

2.2.3.3.4 AGC Programs.

The following list of AGC programs defines the programs and routines applicable to SC-012. The AGC programs provide the major modes of G&N system operation. The routines consist of a specific sequence of operations which are performed by more than one program and/or other routine.

Program Number	Title	Contains Routines
00	AGC Idling	
01	Prelaunch Initialization	
02	Gyro Compassing	
03	Optical Azimuth Verification	
04	Inertial Reference	
05	G&N Startup	
06	G&N Power Down	
07	Systems Test (Limited in-flight use.)	
11	Pre-LET Jettison	
12	Post-LET Jettison	R 24, R 34
17	LET Abort	
22	Landmark Tracking	R 27, R 28
23	Star/Landmark Navigation Measurement	
24	Ground Track Determination	
27	AGC Update	
31	Orbit Change (Prethrust)	R 1, R 21, R 35
32	Return to Earth (Prethrust)	R 1, R 21, R 36
33	SPS Minimum Impulse (Prethrust)	R 1, R 21, R 31, R 33
41	Orbit Change	R 2, R 22, R 24, R 31, R 34, R 37

SYSTEMS DATA

Program Number	Title	Contains Routines
42	Return to Earth	R 2, R 22, R 24, R 31, R 34, R 37
43	SPS Minimum Impulse	R 2, R 31, R 34, R 37
51	IMU Orientation Determination	R 27, R 29
52	S-IVB/IMU Align	R 4, R 25, R 27, R 28, R 29, R 30
53	CSM/IMU Align	R 1, R 4, R 21, R 25, R 27, R 28, R 29, R 30
54	IMU Realignment	R 27, R 29, R 30
61	Maneuver To CM/SM Separation Attitude	R 1, R 21
62	CM/SM Separation And Pre-Entry Maneuver	R 3, R 21
63	Initialization	
64	Post 0.05G	
67	Final Phase	
71	First Abort Burn	R 24

Routine Number	Title	Contains Routines
1	Attitude Control Mode Check	R 22
2	Thrust Control Mode Check	R 1, R 21, R 22
3	Entry Control Mode Check	R 22
4	Fine Alignment	R 25, R 27, R 28, R 29, R 30
21	Attitude Maneuver	
22	SCS Discrete Monitor	
24	Delta V Monitor	R 38

SYSTEMS DATA

Routine Number	Title	Contains Routines
25	Coarse Alignment	
27	Sighting Mark	
28	Auto Optics Positioning	
29	Star Data Test	
30	Gyro Torquing	
31	Backup Delta V Counter	
33	Prethrust SPS Minimum Impulse Data Load	
34	Orbit Parameter Display	
35	Prethrust Orbit Change Data Load	
36	Prethrust Return to Earth Data Load	
37	SPS Engine Ignition	R 38
38	SPS Engine Thrust Fail	

2.2.4 PERFORMANCE AND DESIGN DATA.

(TBD)

2.2.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.2.5.1 S/C Attitude.

The S/C should not be maneuvered to an attitude which will align the inner circle of either red area on the FDAI ball under the navigation axis marker. Failure to avoid this condition can result in IMU gimbal lock. Specifically, the following maneuvers should be avoided:

- Yaw maneuver greater than ±75 degrees when roll angle is 0 degree or 180 degrees.
- Pitch maneuver greater than +42 degrees or -108 degrees when roll angle is ±90 degrees.

2.2.5.2 IMU Operation.

- The AGC must be ON before the IMU is placed in operation by engaging the IMU circuit breakers.
- The AGC must be ON or in STANDBY before the IMU is placed in standby mode.
- Allow 15 seconds for the stabilization loops to completely stabilize the platform after applying operating power, i.e., after engaging the IMU circuit breakers.
- The IMU must be in full operation for at least 1 hour before valid operation of the inertial components can be assumed.
- The inertial components will suffer a loss of calibration if the temperature falls below 120°F or exceeds 140°F. Damage will occur if the temperature falls below 40°F or exceeds 160°F.
- Do not operate the IMU such that the middle gimbal angle reaches or exceeds 70 degrees.

2.2.5.3 Optics Operation.

- Do not slew the SXT or SCT into the mechanical stops.
- Do not drive the 2X TRUNNION CDU in excess of 180 degrees as read on the CDU display dials. Insure that this display dial indicates less than 180 degrees before engaging the ZERO OPTICS mode of operation.

2.2.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all G&N system telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 0001 V	Computer digital data 40 bits	+4/+132 vdc		None
CG 1101 V	-28 VDC supply	-30/0 vdc	-28 vdc	None

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 1110 V	2.5 VDC TM bias	TBD	-28 vdc	None
CG 1503 X	IMU +28 vdc operate	Event		None
CG 1513 X	IMU +28 vdc standby	Event		None
CG 1523 X	AGC +28 vdc	Event		None
CG 1533 X	Optics +28 vdc	Event		None
CG 2110 V	IGA torque motor input	TBD		None
*CG 2112 V	IGA 1X res output sine in phase	TBD		None
*CG 2113 V	IGA 1X res output cos in phase	TBD		None
*CG 2117 V	IGA servo error in phase	0/0.5 vrms		None
CG 2140 V	MGA torque motor input	TBD		None
*CG 2142 V	MGA 1X res output sine in phase	TBD		None
CG 2143 V	MGA 1X res output cos in phase	TBD		None
*CG 2147 V	MGA servo error in phase	0/0.5 vrms		None
CG 2170 V	OGA torque motor input	TBD		None
*CG 2172 V	OGA 1X res output sine in phase	TBD		None
*CG 2173 V	OGA 1X res output cos in phase	TBD		None
*CG 2177 V	OGA servo error in phase	0/0.5 vrms		None

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
*CG 2206 V	IGA CDU 1X res error in phase	0/0.2 vrms		None
*CG 2236 V	MGA CDU 1X res error in phase	0/0.2 vrms		None
*CG 2266 V	OGA CDU 1X res error in phase	0/0.2 vrms		None
CG 2300 T	PIPA temp	TBD	+126.0°F/ +134.0°F	None
CG 2301 T	IRIG temp	TBD	+129.5°F/ +137.5°F	None
CG 2302 C	IMU heater current	0/+5 amps	0/+2 amps	None
CG 2303 C	IMU blower current	0/+5 amps	0/+1 amp	None
*CG 3102 V	SXT trun motor drive in phase	TBD		None
*CG 3112 V	SXT shaft motor drive in phase	TBD		None
*CG 3133 V	SCT trun motor drive	TBD		None
*CG 3141 V	Trun CDU 16X res error in phase	TBD		None
*CG 3200 V	Trun CDU motor drive in phase	TBD		None
*CG 3220 V	CDU motor drive RMS	TBD		None
*CG 4300 T	AGC temp monitor	TBD		None
CG 5000 X	PIPA fail	Event		ACCEL FAIL, G&N ACCEL FAIL C&W lights (2).
CG 5001 X	IMU fail	Event		IMU FAIL C&W lights (2).

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 5002 X	CDU fail	Event		CDU FAIL C&W lights (2)
CG 5003 X	Gimbal lock warning	Event		GIMBAL LOCK, GMBL LOCK C&W lights (2).
CG 5005 X	Error detect	Event		PGNS, G&N ERROR C&W lights (2).
CG 5006 X	IMU temp light	Event		IMU TEMP C&W lights (2).
CG 5007 X	Zero encode light	Event		ZERO ENCODER, ZERO ENC. C&W lights (2).
CG 5008 X	IMU delay light	Event		IMU DELAY. C&W light.
CG 5020 X	AGC alarm 1 (Program)	Event		PROG ALM, COMP FAIL (DSKY lights).
CB 5021 X	AGC alarm 2 (AGC activity)	Event		COMP DSKY lights (2).
CG 5022 X	AGC alarm 3 (TM)	Event		TM FAIL, COMP FAIL. (DSKY lights).
CG 5023 X	AGC alarm 4 (prog ck fail)	Event		CHECK FAIL, COMP FAIL. (DSKY lights).
CG 5024 X	AGC alarm 5 (scaler fail)	Event		SCALER FAIL, COMP FAIL. (DSKY lights).
CG 5025 X	AGC alarm 6 (parity fail)	Event		PARITY FAIL, COMP FAIL. (DSKY lights).
CG 5026 X	AGC alarm 7 (counter fail)	Event		COUNTER FAIL, COMP FAIL. (DSKY lights).
CG 5027 X	AGC alarm 8 (key release)	Event		KEY RLSE (DSKY lights) (2).
CG 5028 X	AGC alarm 9 (rupt lock)	Event		RUPT LOCK, COMP FAIL. (DSKY lights).

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 5029 X	AGC alarm 10 (TC trap)	Event		TC TRAP, COMP, FAIL. (DSKY lights).
CG 5030 X	Computer power fail light	Event		AGC PWR FAIL (DSKY lights) (2).
*CG 6000 P	IMU pressure	TBD		None
*CG 6020 T	PSA temp 1 tray 3	TBD		None
*CG 6021 T	PSA temp 2 tray 2	TBD		None
*CG 6022 T	PSA temp 3 tray 4	TBD		None

2.2.7 G&N POWER CONSUMPTION.

The optics are only powered up when a star or landmark sighting is required. The subsystems power levels are as follows:

Description	Control	Power Reqmt's
IMU—operate	CB 59 and58	325.0 watts (dc)
standby	CB 61 and 60	61-7 watts (dc)
AGC—operate	CB 57 and 56	115.0 watts (dc)
standby	AGC Mode Switch	15.0 watts (dc)
Optics—operate	CB 55 and 54	124.4 watts (dc)
		14.4 watts (dc)
Controls and displays	CB 93 and 62 and Switch No. 7	
AGC only		10.0 watts (dc)
AGC and IMU		10-7 watts (dc)
Full G&N operation		18-7 watts (dc)
		7-0 watts (dc)

Minimum power consumption is 76.7 watts (dc) when AGC and IMU are in the standby mode.

2.2.8 INTERFACE SIGNALS.

The following list provides the signal, source, and description of the interface signals.

Signal Name	Source	Description
Stabilization and Control System (SCS) and G&N System Interface		
Engine on-off	AGC (Apollo guidance computer)	Provides pulse train that lasts as long as the engine is required to fire. The time at which the signal terminates takes into account electronic delays within the SCS and tail-off characteristics of the engines.
Discrete signal carrier	AGC	Provides continuous pulse train to the SCS to be switched back to the AGC.
G&N system attitude control (or SCS attitude control)	SCS	Provides power to an attitude control switch on the G&N system.
Minimum impulse enable	G&N system	Disables all three attitude channels simultaneously and supplies voltages to an attitude control switch on the G&N system.
Minimum impulse + and - pitch, yaw, and roll	SCS	Provides six signals to the G&N system for hand controller operation.
Minimum impulse pitch, yaw, and roll	G&N system	Provides the capability to initiate spacecraft attitude changes in the G&N system attitude control mode or the SCS attitude control mode. These changes will be initiated by discrete minimum impulses.
Pitch error body offset and body axis	G&N system	Provides pitch attitude error signal to the SCS.
Yaw error body offset axis	G&N system	Provides yaw attitude error signal to the SCS during G&N system entry mode.
Yaw error body axis	G&N system	Provides yaw attitude error signal to the SCS during normal G&N system operating modes.
Roll error body offset axis	G&N system	Provides roll attitude error signal to the SCS during G&N system entry mode.
Roll error body axis	G&N system	Provides roll attitude error signal to the SCS during normal G&N system operating modes.

SYSTEMS DATA

Signal Name	Source	Description
IMU 28V 800 cps (demodulator reference)	G&N system	Provides an 800 cps, synchronous, in-phase voltage from the G&N system.
IMU sin A_{IG} 1X, IMU cos A_{IG} 1X, IMU sin A_{MG} 1X, IMU cos A_{MG} 1X, IMU sin A_{OG} 1X, and IMU cos A_{OG} 1X	G&N system	Provides total attitude signals to the SCS.
Electrical Power System (EPS) and G&N System Interface		
+28 vdc AGC bus A and bus B	EPS	Provides power to the AGC.
+28 vdc optics bus A and bus B	EPS	Provides power to the optics subsystem.
+28 vdc IMU bus A and bus B	EPS	Provides power to the IMU.
+28 vdc standby bus A and bus B	EPS	Provides IMU temperature control power.
115v 400 cps	EPS	Provides power for all G&N system 6-volt lamps
Communication and Instrumentation System and G&N System Interface		
DLNK sync	AGC	Synchronizes data transferred from the AGC to the communications and instrumentation system.
DLNK end	AGC	Permits two AGC words to be transferred from the AGC to the communications and instrumentation system. Stops the AGC and the transmission of data from the AGC to the communications and instrumentation system.
DLNK start	AGC	Provides pulse signal that occurs at the beginning of every data transmission to the communications and instrumentation system. Sets flip-flop in AGC that enables 5-stage downlink counter.
DLNK data	AGC	Initiates by DLNK start, stopped by DLNK end, and consists of a 40 bit telemetry word (two AGC words and an 8 bit telemetry word order code).
ULNK 1	AGC	Transmitted to the uplink counter in the AGC. Adds one to uplink counter and shifts the counter one increment.

Signal Name	Source	Description
ULNK 0	AGC	Transmitted to the uplink counter in the AGC. Shifts uplink counter one increment.

SECTION 2

SUBSECTION 2.3

STABILIZATION AND CONTROL SYSTEM (SCS)

2.3.1 INTRODUCTION.

The stabilization and control system (SCS) provides a capability for controlling rotation, translation, and thrust vector forces with additional capability of rate stabilization.

The SCS is divided into three basic subsystems: attitude reference, attitude control, and thrust vector control. These subsystems contain the elements which provide for manual attitude control, automatic attitude control, and thrust vector control, plus manual backup provisions for all automatic functions.

The subsystem/control capability allows the free selection of several modes of operation which fall within the boundaries of three entirely different flight control profiles. These include coasting flight (earth orbital environment), powered flight (atmospheric - ascent, and earth orbital environment), and atmospheric flight (entry - unpowered).

Spacecraft displays provide a capability for monitoring S/C attitude, S/C rates, attitude errors, cautions, and warnings. Controls provide switch arrangements for commanding modes, commanding inputs to change operating status and to permit manual override to all automatic functions.

The SCS interfaces with the following S/C systems (See figure 2.3-1).

- Telecommunications System (T/C)

  Provides clock reference frequency for measurement of changes in S/C velocity

  Receives all down-link telemetry from SCS

  Provides up-data position information via AGC or voice

- Electrical Power System (EPS)

  Provides primary power for SCS operation

- Environmental Control System (ECS)

  Transfers heat from SCS electronics

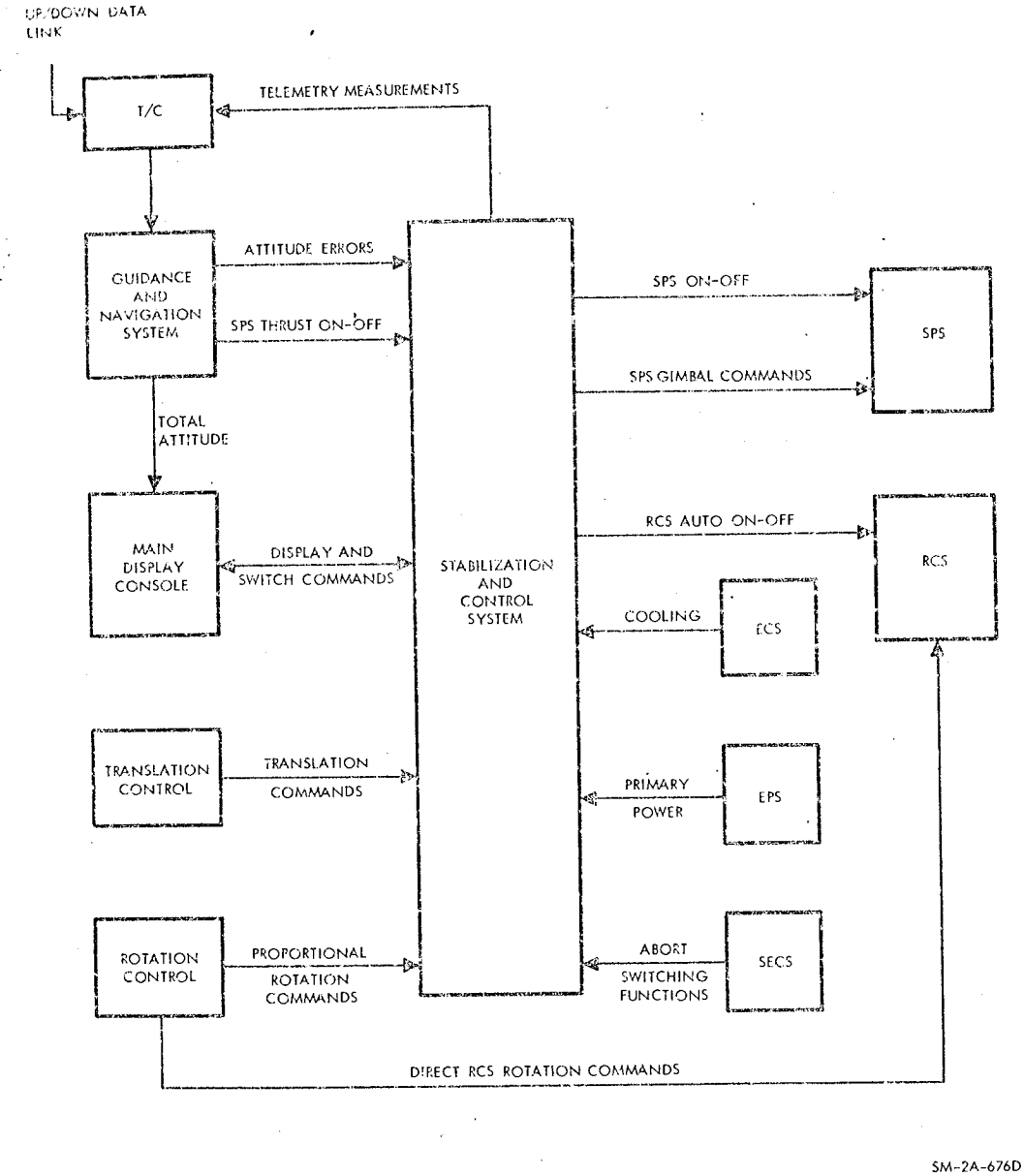


Figure 2.3-1. SCS Functional Interface

- Sequential Events Control System (SECS)

  Provides abort switching function

  By switch control in SCS, initiates abort and enables control functions in SCS

- Guidance and Navigation System (G&N)

  Provides roll, pitch, and yaw total attitude inputs to SCS

  Provides attitude error signals

  Provides thrust on/off command for SPS engine

  Provides steering commands to TVC during G&N ΔV

- Propulsion Systems (SPS, RCS).

  The service propulsion system generates internal forces for large velocity changes

  The reaction control system generates the internal forces required for rotation, and translation.

A detailed description and function of the SCS controls and displays referred to is provided in section 3.

2.3.2 FUNCTIONAL DESCRIPTION.

The functional description of the SCS covers the major areas of control capabilities, Apollo reference axes, and subsystem description.

2.3.2.1 Control Capabilities.

Control capability exists for the manual attitude control, automatic attitude control, and thrust vector control functions. The following paragraphs provide a brief discussion of each control function.

2.3.2.1.1 Manual Attitude Control.

Manually commanded inputs converted to electrical signals, directly or indirectly, cause the propulsion systems to maneuver the spacecraft to a desired attitude and/or change the flight path (trajectory) of the spacecraft. Manual controls include two independent rotation controllers (figure 2.3-8), two translation controllers (figure 2.3-8), and an arrangement of panel-mounted controls and displays.

The rotation controllers command discrete on-off signals for the reaction control system to initiate angular rotations about the S/C X-, Y-, and Z- axes or combinations of these axes. The X-, Y-, and Z-axes are synonomous with the S/C geometric coordinate system of roll (ϕ), pitch (θ), and yaw (ψ), respectively. (See figure 2.3-2.) These commands are primarily used for S/C attitude (orientation) control. The translation controllers, when operated, command signals for the reaction control system to initiate translations (acceleration) along the S/C X-, Y-, and Z-axes or combinations of these axes. These commands for the AS204A mission are primarily initiated to perform ullage maneuvers prior to SPS thrusting. Panel-mounted switches are used for attitude set control functions, application of electrical power, evaluating system status, and selection of operating modes.

The displays provide indications of total attitude, attitude errors, angular rates, and caution and warnings.

2.3.2.1.2 Automatic Attitude Control.

Automatic attitude control is a capability whereby attitude errors and rotational rates are sensed by gyroscopic devices which, in association

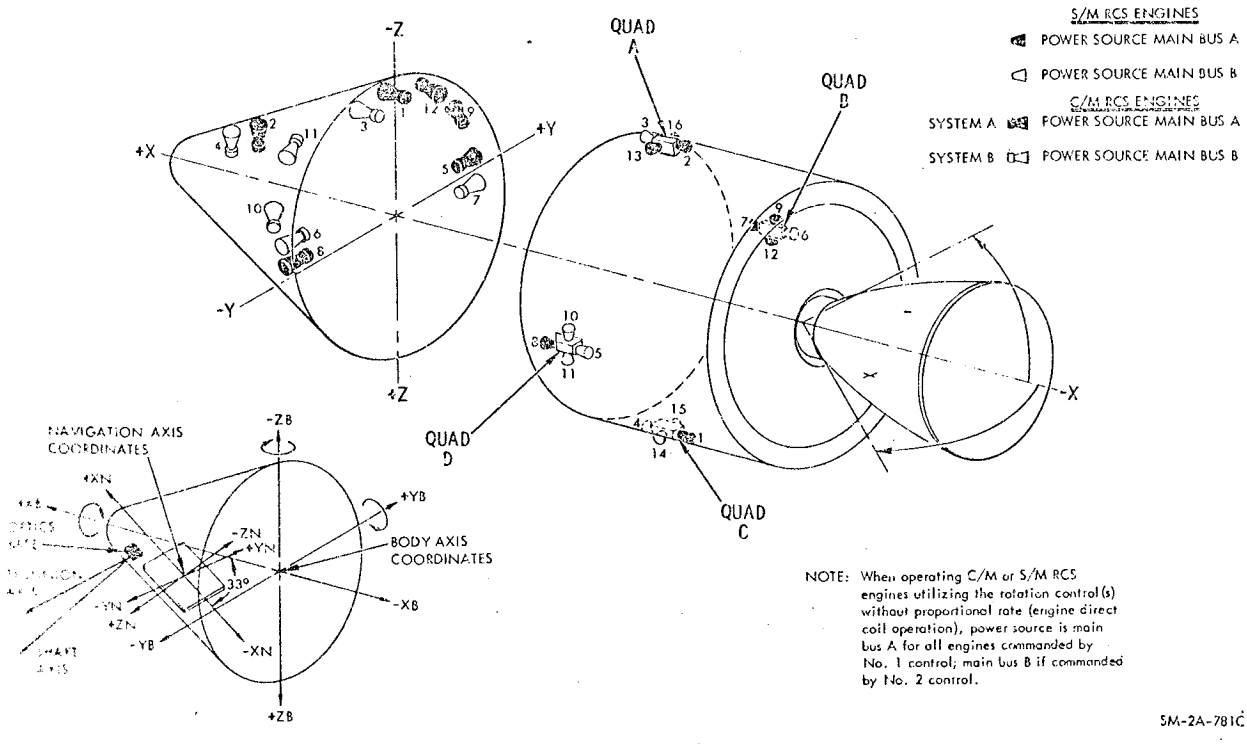


Figure 2.3-2. C/M-S/M-RCS Engine Location/Apollo Reference Axes

with electronic and logic circuits, automatically induce the propulsion systems to maintain a desired inertially fixed attitude. Translation capability is not an automatic control function.

Two methods of automatic attitude control are available. One method requires the use of components of the SCS to establish desired attitude references, and for sensing attitude changes and rates of change. Three orthagonally mounted rate gyros sense angular rates about the S/C X-, Y-, and Z-axes. Body-mounted attitude gyros (BMAGS) and attitude gyro coupling unit (AGCU) establish attitude reference and determines attitude error. The attitude error signals and rate gyro signals are electronically conditioned and subsequently provide a rate-damped automatic attitude hold with respect to an inertially fixed attitude. The attitude is held with drift rates kept within acceptable limits (deadband) for the three axes. A maximum or minimum deadband may be selected by the ATT DEADBAND switch on the SCS control panel (MDC-8). Maximum electrical deadband allows drift limits of ±4.2 degrees from reference attitude. Minimum electrical deadband is ±0.2 degree from reference attitude.

When a manual maneuver is initiated, the automatic attitude control function is interrupted. When the manual maneuver ceases, the automatic attitude control function is reinstated and the new attitude will be the new inertial attitude.

The other method of automatic attitude control incorporates components of the G&N system; whereby, the combined G&N/SCS systems establish attitude references, and sense attitude change and rate of change. In addition, the Apollo guidance computer (AGC) can be commanded through the computer keyboard to automatically establish new attitude references and maintain attitude hold at the new reference. When this is done, attitude change data is taken from on-board charts or received via the manned space flight network (MSFN).

The inertial measurement unit (IMU) in the G&N system provides the inertial reference and senses attitude errors. The rate gyros in the SCS determine the rates of change. The attitude error signals sensed by the IMU and SCS rate gyro signals are electronically conditioned and subsequently provide a rate-damped automatic attitude control with respect to the IMU inertially fixed reference. Again, drift rates about the three S/C axes are held within acceptable limits.

Manual maneuvers can also be performed when using G&N attitude control, providing proper switch configuration is established. The automatic hold function is interrupted until the manual maneuver ceases, at which time the automatic function continues to hold at the new inertial attitude. Inputs to the AGC via the computer keyboard can command the AGC to realign the IMU to a selected inertial reference. The S/C can then be automatically maneuvered to and be maintained at the new attitude.

When automatic attitude control functions are in process, displays are required only for monitoring and comparing attitude with external or known references, and for indications of systems failures.

2.3.2.1.3 Thrust Vector Control.

Thrust vector control (TVC), primarily, accomplishes three main objectives. The first objective is to either manually or automatically initiate thrusting of the SPS engine when large velocity changes are required. The second is to control the thrust vector of the SPS engine such that the vector force is essentially maintained through the S/C center of gravity (c.g.) in the direction of the velocity correction. The third objective requires the automatic, with manual backup, termination of SPS thrusting when a required velocity change has been attained.

When SPS thrusting occurs, thrust vector control uses the same basic commands that are used for the attitude control function, plus additional commands to control the SPS pitch and yaw gimbal actuators. This combination establishes the three-axes attitude control and stability while thrusting. The commands to the pitch and yaw gimbal actuators will hold the SPS thrust vector through the S/C c.g. in the direction of velocity correction, and roll attitude is maintained by the roll attitude control circuits and the RCS roll engines.

There are three methods, or modes, of thrust vector control: G&N delta V, SCS delta V, and manual thrust vector control (MTVC). G&N delta V is the primary mode of control for velocity changes. The G&N system inserts commands into the SPS gimbal servo circuits to control the thrust vector and to automatically initiate SPS thrusting. The G&N/SCS attitude control sensors and electronics perform the remainder of the control functions.

The SCS delta V is normally used as a backup system in the event of G&N failure. When in G&N mode of operation, the SCS BMAG/AGCU loop is aligned to the IMU reference attitude and, therefore, follows the attitude changes sensed by the IMU prior to selecting the ΔV mode. After selecting a ΔV mode, the BMAG/AGCU loop is opened. In the event of G&N failure or IMU failure, a transfer to SCS delta V will allow continuation of the velocity change using attitude error signal inputs originating from the BMAGS. For SCS delta V, there are no major differences in operation of the gimbal servo loop and the rate loops.

Manual thrust vector control is a control function utilizing panel-mounted controls, translation controls, and rotation controls. MTVC is primarily used to limit excessive rate changes that may be created by malfunctions in the SCS or G&N systems. Manipulation of the controls allows velocity changes by the selection of redundant electronics and redundant actuator motors to control gimbal action.

Displays allow monitoring the character of a delta V, monitoring system performance, and detecting system malfunctions.

2.3.2.2 Apollo Reference Axes.

In Apollo, there are two sets of axes, or coordinates, which are used for measuring changes in S/C attitude. (See figure 2.3-2.) One set of coordinates represent the geometric axes of the S/C and are the body axes X_B, Y_B, and Z_B. The other set of coordinates represent the geometric axes of the IMU-optic base or navigations base. They are the navigations axes X_N, Y_N, and Z_N. The inertial sensors are mounted and aligned relative to these two sets of coordinates. The BMAG roll, pitch, and yaw gyros are aligned to the S/C body axes and the IMU is aligned to the navigations axis.

2.3.2.2.1 Body Axes.

As shown in figure 2.3-2, the longitudinal (X_B) axis passes through the geometric center of the S/C. The $+X_B$ is toward the apex of the command module; $-X_B$ is the opposite. Looking in the direction of the apex, the $+Y_B$-axis is to the right; $-Y_B$ is to the left. The $+Z_B$ is in the direction of the footrest of the center couch and $-Z_B$ is toward the headrest of the center couch. The S/C c.g. is included in the plane formed by the X_B- and Z_B-axes.

A + roll rotation is a clockwise rotation about the X-axis, looking from -X to +X; a + pitch rotation is a clockwise rotation about the Y-axis, looking from -Y to +Y; and a + yaw rotation is a clockwise rotation about the Z-axis, looking from -Z to +Z.

2.3.2.2.2 Navigations Axes.

The navigations axes are rotated +33 degrees in pitch about the Y_B-axis. The X_N-axis is parallel to the side of the S/C; the Y_N-axis is parallel to the Y_B-axis; and the Z_N-axis is normal to the side of the S/C and is rotated +33 degrees in pitch about the Y_N-axis. The Z_B-axis lies in the same plane as the X_N-axis. The $\pm X_N$-, $\pm Y_N$-, and $\pm Z_N$-axes point in the same relative directions as the body axes. The IMU +X-, +Y-, and +Z-axes are aligned to the $+X_N$- and $+Z_N$-axes.

2.3.2.2.3 Optics Base Axes.

A line-of-sight telescope and sextant, mounted on the optics base, are used in conjunction with the G&N system to determine S/C inertial attitude and position. The optics base axes are measured in terms of the shaft and trunnion angles of the telescope and sextant. The shaft axes of the two are parallel to the Z_N-axis and trunnion axes are parallel to the Y_N-axis.

2.3.2.3 Subsystems.

The attitude reference, attitude control, and thrust vector control subsystems are described in the following paragraphs. The description covers the purpose and functions of each subsystem, and the integrated association with other systems. Figures 2.3-3 and 2.3-4, provide simplified block, and flow diagrams of the three subsystems and figure 2.3-5 shows the switching logic and functions which affect the three subsystems.

2.3.2.3.1 Attitude Reference Subsystem.

The purpose of the attitude reference subsystem (figures 2.3-4 and 2.3-5) is to relate the S/C attitude in terms of its geometric X, Y, and Z coordinate system to an arbitrarily chosen coordinate system with a fixed reference frame. The relation between the two coordinate systems represents inertial attitude and is presented to the astronauts by visual display.

Visual observation of inertial attitude is necessary to perform manual maneuvers or for monitoring automatic operations. The flight director attitude indicator (FDAI), located on the S/C main display console, displays the information required for the manual and automatic operations. The information displayed includes S/C total attitude, attitude error in three axes, and rotational rates in three axes. The information displayed by the FDAI is obtained from either the G&N system or the SCS.

There are two attitude references associated with the attitude reference subsystem: primary and backup. The primary reference is obtained through the mechanization of subsystems within the G&N system. The backup reference is mechanized within the SCS. Each of the attitude reference loops contain three basic elements: a computer, an inertial reference device, and a visual display.

Attitude Reference/G&N. To obtain an inertial reference using the G&N system, the astronauts, the G&N optics subsystem, the inertial and computer subsystems, and the MSFN are integrated to form a closed loop system.

The G&N system is used to determine inertial attitude and position and initiates alignment of the stable element of the IMU to the desired inertial reference initially established by optical sightings.

After IMU alignment, the IMU in conjunction with the AGC can provide inertial-referenced attitude hold and, if required, inertial-referenced velocity changes. Translational velocities are sensed by accelerometers mounted on the IMU stable element. The AGC processes the accelerometer signals to update velocity and change information for TVC functions.

In addition to the optical alignment of the IMU, the astronauts can use the computer subsystem to establish IMU alignment.

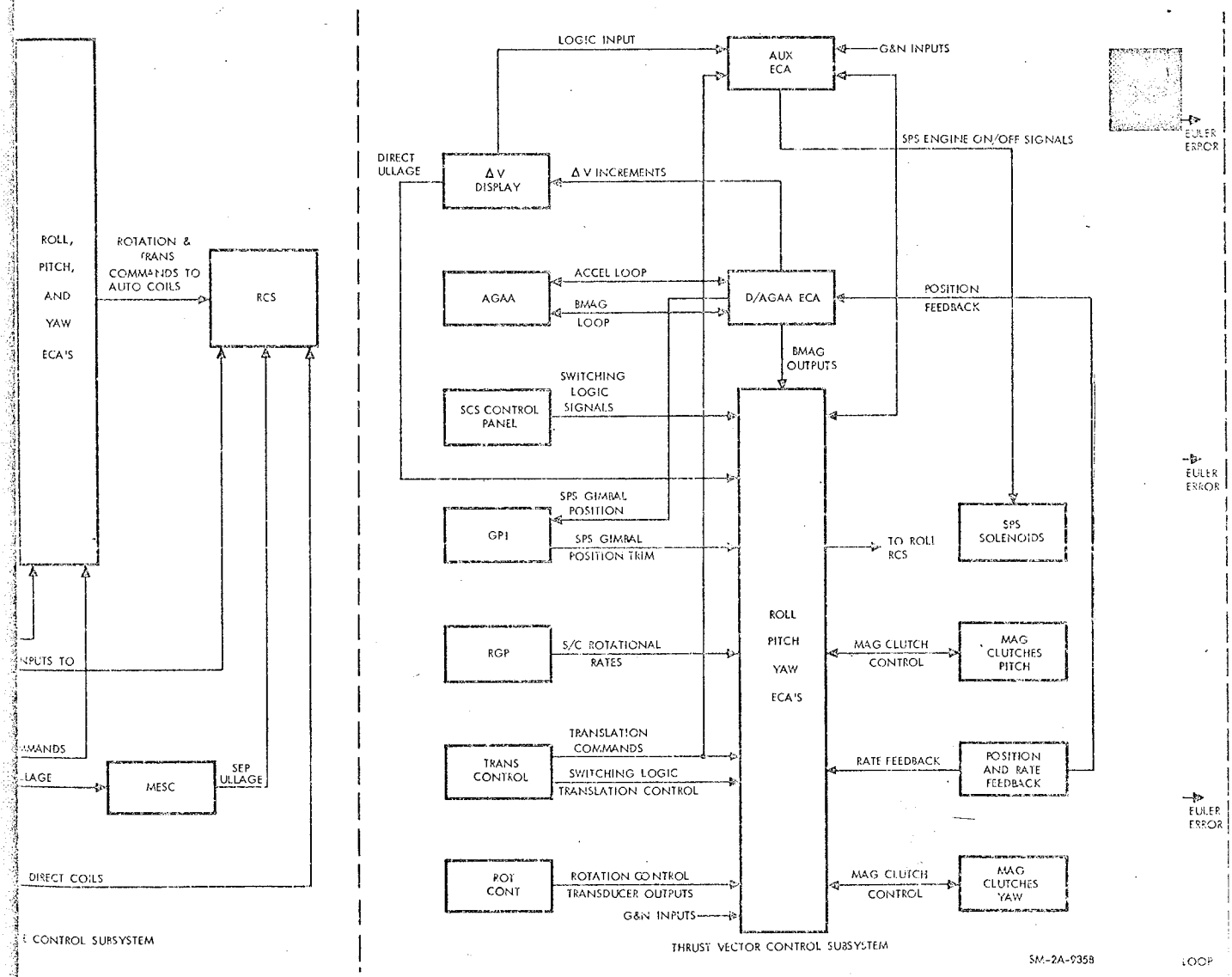
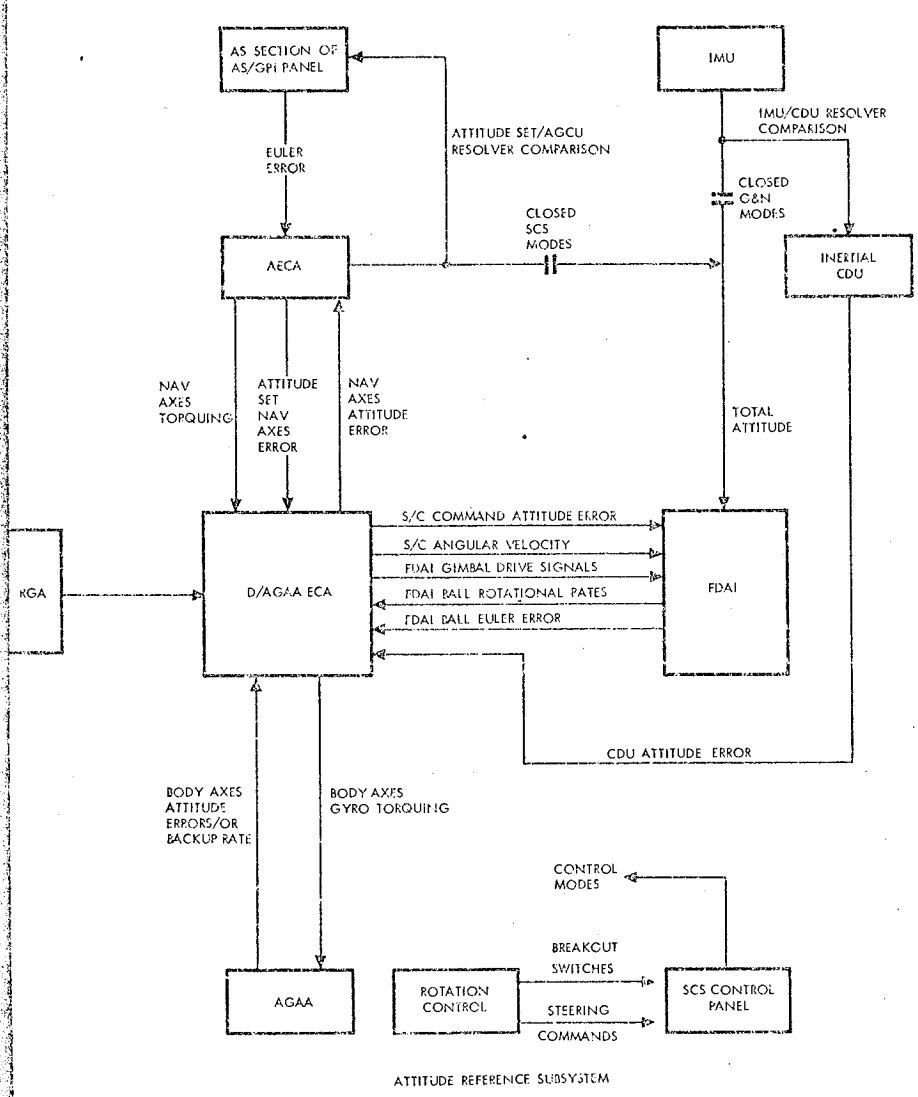
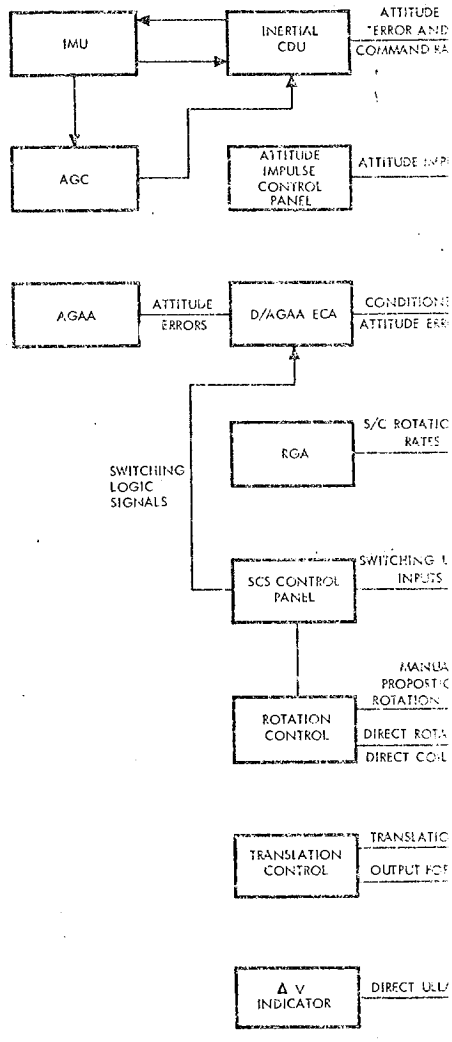
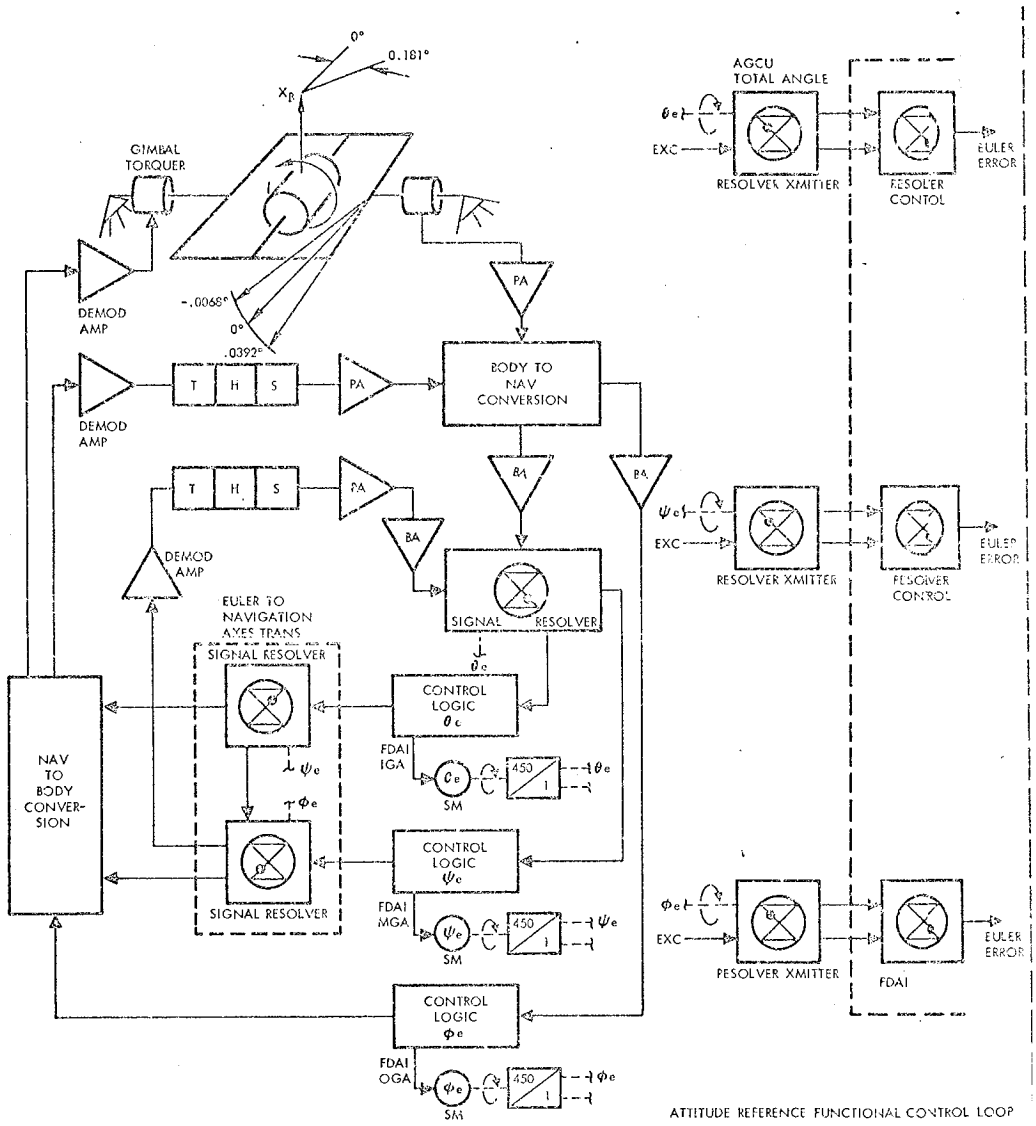


Figure 2.3-3. SCS Functional Block Diagram



ATTITUDE REFERENCE SUBSYSTEM





ATTITUDE REFERENCE FUNCTIONAL CONTROL LOOP

CH2015V
COMBINED ATTITUDE GYRO SMRD
0745 VDC

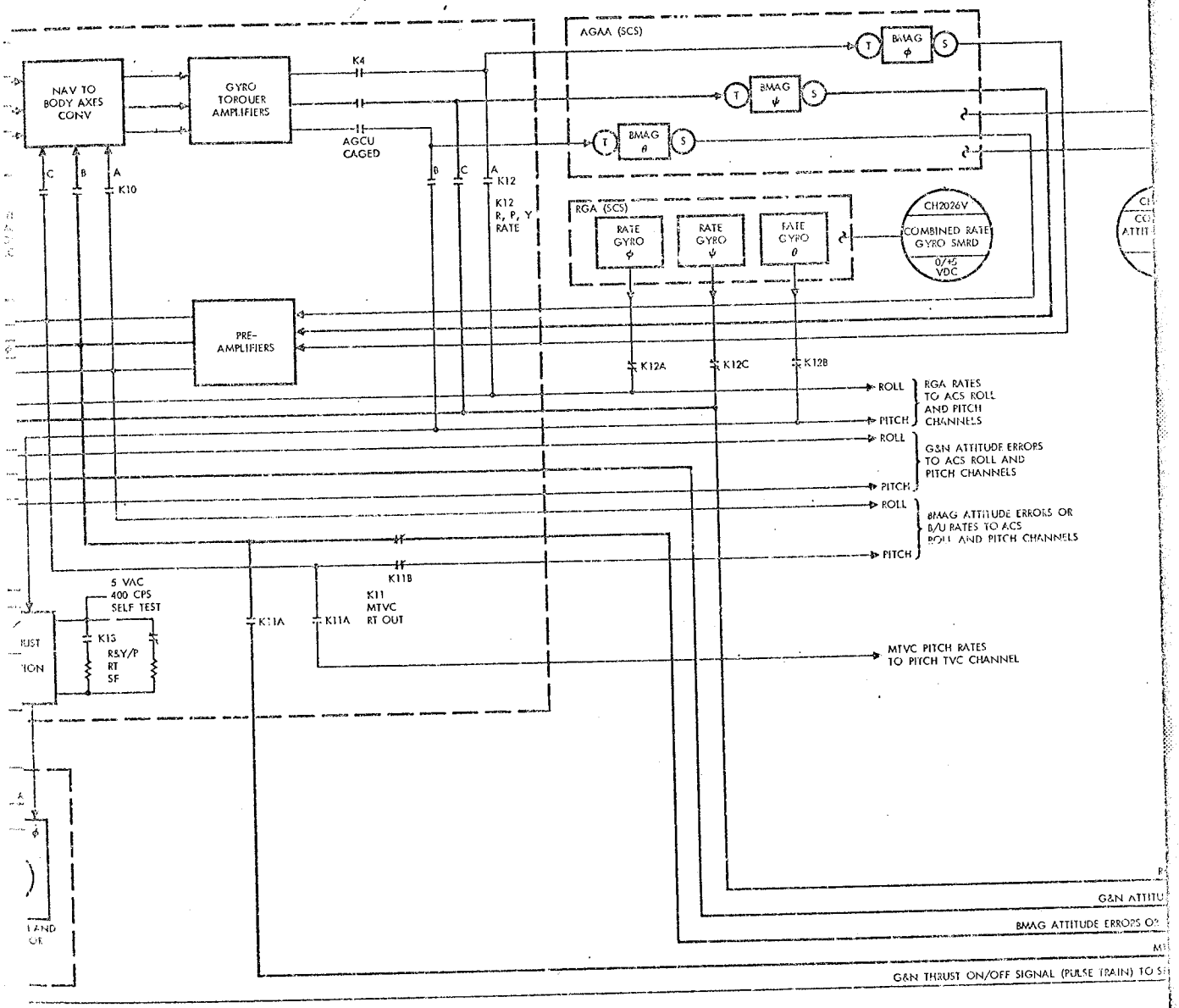
MAJOR MODE	K1 ORBIT RATE	K2 FDAI ALIGN	K3 G&N R, P, Y ATT SINE COS	K4 AGCU CAGED	K5 AGCU ALIGN	K6 AGCU P/V ERROR	K7 R G&N ERR/AGCU VIH G&N P ERROR Y ERR G&N BODY	K8 G&N P, Y ERR S.F.	K9 R, P, Y ERROR AGAA	K10 R, P, Y B/U RATE	K11 MTVC RT OUT	K12 R, P, Y RATE	K13 R & Y/P S.F.
MONITOR			●	●	●		●	●	●	●			
G&N ATTITUDE CONTROL			●	●	●		●		●				
SCS ATTITUDE CONTROL													
SCS LOCAL VERTICAL	●			●									
G&N ΔV			●				●		●				
SCS ΔV	●												
G&N ENTRY			●	●	●		●		●				●
SCS ENTRY													
INTEGRATED MODE FUNCTIONS													
CSS				●	●						●	●	●
MINIMUM IMPULSE CONTROL				●	●								
TRANSLATION CONTROL "CW" SWITCH				●	●								
MTVC										●	●		●
B/U RATE - R, P, & Y										●			
.05G MANUAL (SCS ENTRY)				●	●								
CHANNEL DISABLE (SCS ATT CONT)				●	●								
ATT SET SW ON (SCS MODES)							●			●			
FDAI ALIGN		●											●
SELF TEST													

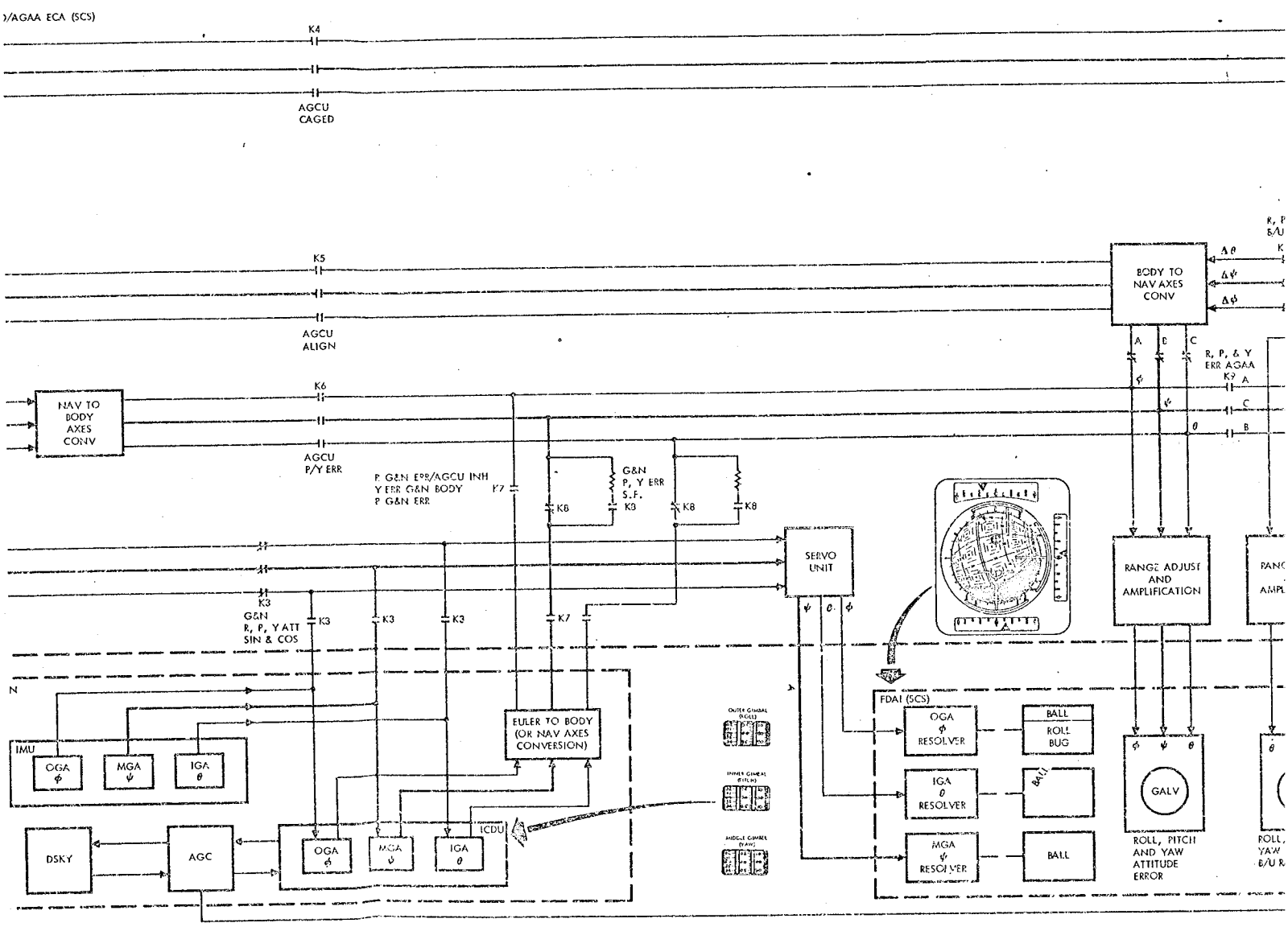
NOTE: For Switching Logic Details, See Figure 2.3-5, Sheet 2

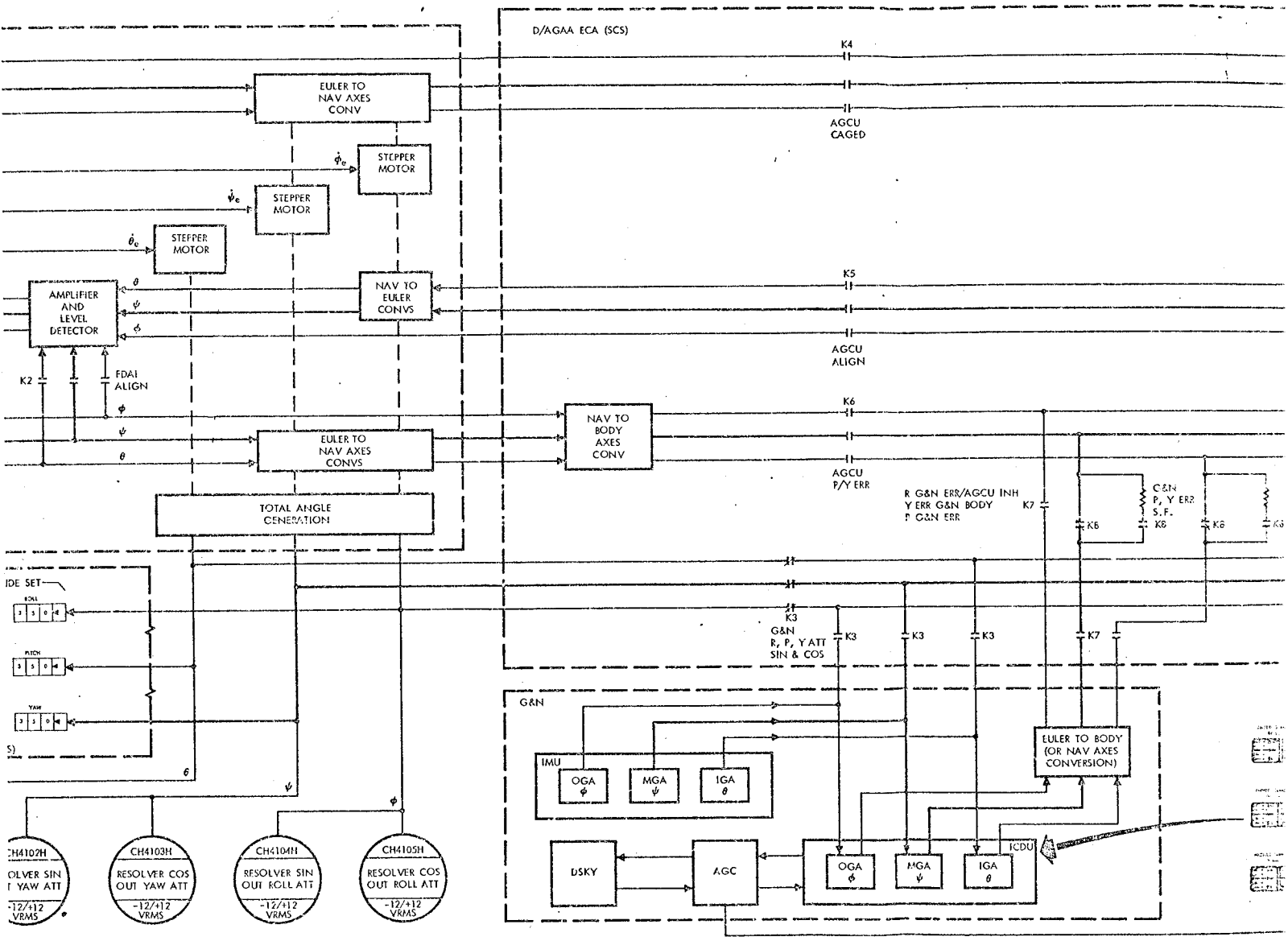
SM-2A-10350

A RATES TO ACS (YAW) → (A)
E ERRORS TO ACE (YAW) → (B)
U RATES TO ACS (YAW) → (C)
} FIGURE 2.3-4, SHEET 2
C RATES TO TVC (YAW) → (D) - FIGURE 2.3-4, SHEET 3
THRUST ON/OFF LOGIC → (E) - FIGURE 2.3-4, SHEET 4

Figure 2.3-4. SCS Functional Flow Diagram (Sheet 1 of 4)


AGAA (SCS)
NAV TO BODY AXES CONV
GYRO TORQUER AMPLIFIERS
K4
AGCU CAGED
C
B
A
K10
B
C
A
K12
K12 R, P, Y RATE
T
BMAG φ
S
T
BMAG ψ
S
T
BMAG θ
S
RGA (SCS)
RATE GYRO φ
RATE GYRO ψ
RATE GYRO θ
CH2026V
COMBINED RATE GYRO SMRD
0/+5 VDC
PRE-AMPLIFIERS
K12A
K12C
K12B
ROLL
PITCH
RGA RATES TO ACS ROLL AND PITCH CHANNELS
ROLL
PITCH
G&N ATTITUDE ERRORS TO ACS ROLL AND PITCH CHANNELS
ROLL
PITCH
BMAG ATTITUDE ERRORS OR B/U RATES TO ACS ROLL AND PITCH CHANNELS
5 VAC 400 CPS SELF TEST
K11B
K11 MTVC RT OUT
K11A
K11A
K13
R&Y/P RT SF
MTVC PITCH RATES TO PITCH TVC CHANNEL
G&N ATTITU
BMAG ATTITUDE ERRORS O
G&N THRUST ON/OFF SIGNAL (PULSE TRAIN) TO S


)/AGAA ECA (SCS)
K4
AGCU CAGED
K5
AGCU ALIGN
K6
AGCU P/Y ERR
NAV TO BODY AXES CONV
BODY TO NAV AXES CONV
R, P, & Y ERR AGAA
P G&N ERR/AGCU INH
Y ERR G&N BODY
P G&N ERR
G&N P, Y ERR S.F.
K7
K8
K9
G&N R, P, Y ATT SIN & COS
K3
SERVO UNIT
RANGE ADJUST AND AMPLIFICATION
FDAI (5CS)
OGA RESOLVER
IGA RESOLVER
MGA RESOLVER
BALL ROLL BUG
BALL
GALV
ROLL, PITCH AND YAW ATTITUDE ERROR
EULER TO BODY (OR NAV AXES CONVERSION)
IMU
OGA
MGA
IGA
DSKY
AGC
CDU
OUTER GIMBAL (ROLL)
INNER GIMBAL (PITCH)
MIDDLE GIMBAL (YAW)


D/AGAA ECA (SCS)
K4
EULER TO NAV AXES CONV
AGCU CAGED
STEPPER MOTOR
STEPPER MOTOR
STEPPER MOTOR
K5
AMPLIFIER AND LEVEL DETECTOR
NAV TO EULER CONVS
AGCU ALIGN
K2
FDAI ALIGN
K6
NAV TO BODY AXES CONV
EULER TO NAV AXES CONVS
AGCU P/Y ERR
R G&N ERR/AGCU INH
Y ERR G&N BODY
P G&N ERR
K7
C&N P, Y ERR S.F.
K8
TOTAL ANGLE GENERATION
K3
G&N R, P, Y ATT SIN & COS
G&N
IMU
OGA
MGA
IGA
EULER TO BODY (OR NAV AXES CONVERSION)
DSKY
AGC
ICDU
CH4102H
CH4103H
RESOLVER COS OUT YAW ATT
-12/+12 VRMS
CH4104H
RESOLVER SIN OUT ROLL ATT
-12/+12 VRMS
CH4105H
RESOLVER COS OUT ROLL ATT
-12/+12 VRMS

AGCU (SCS)
TORQUER GATE ASSY
ORBITAL RATE SOURCE
K1 ORBIT RATE
CH4100H RESOLVE SIN OUT PITCH ATT

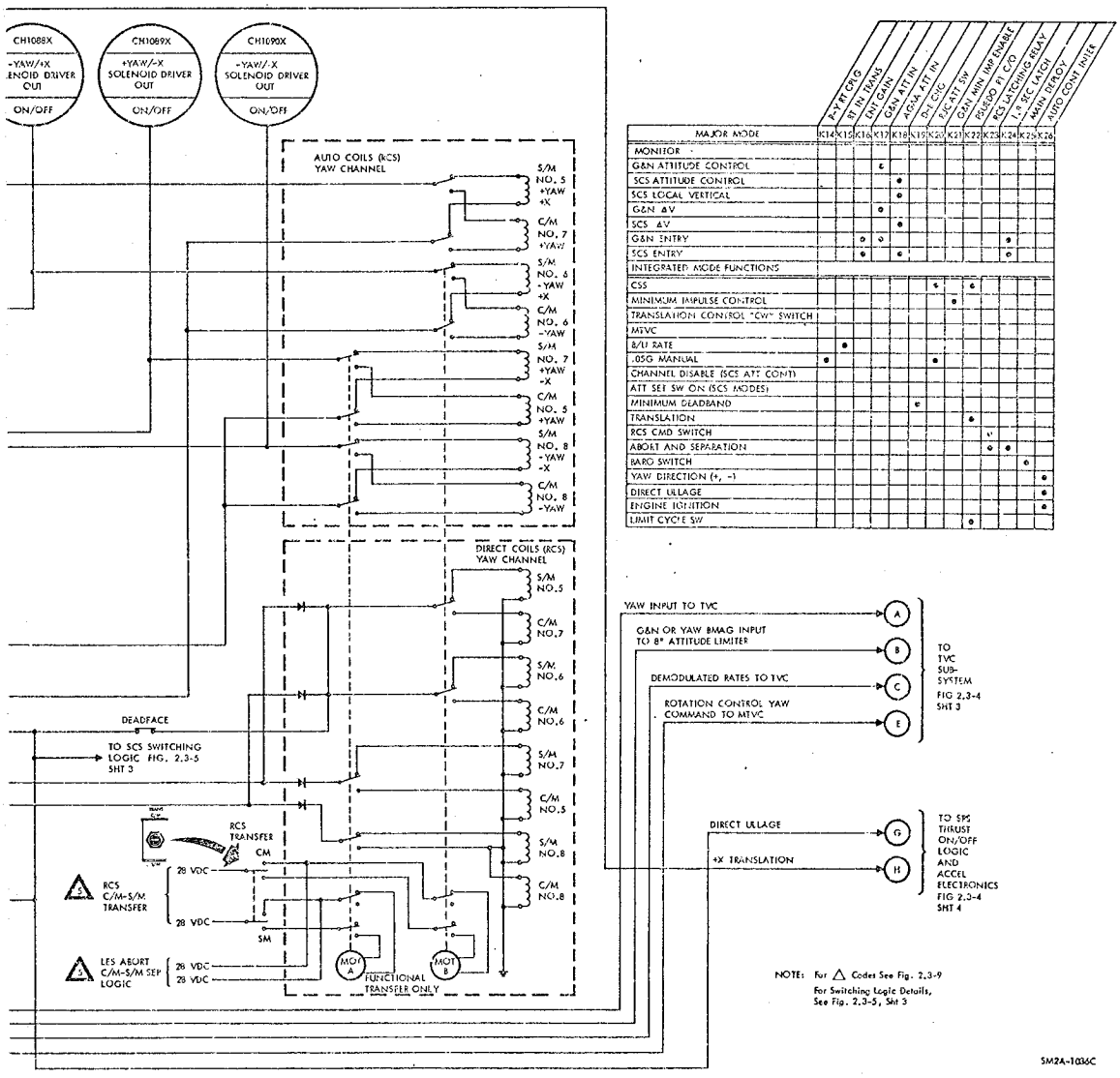
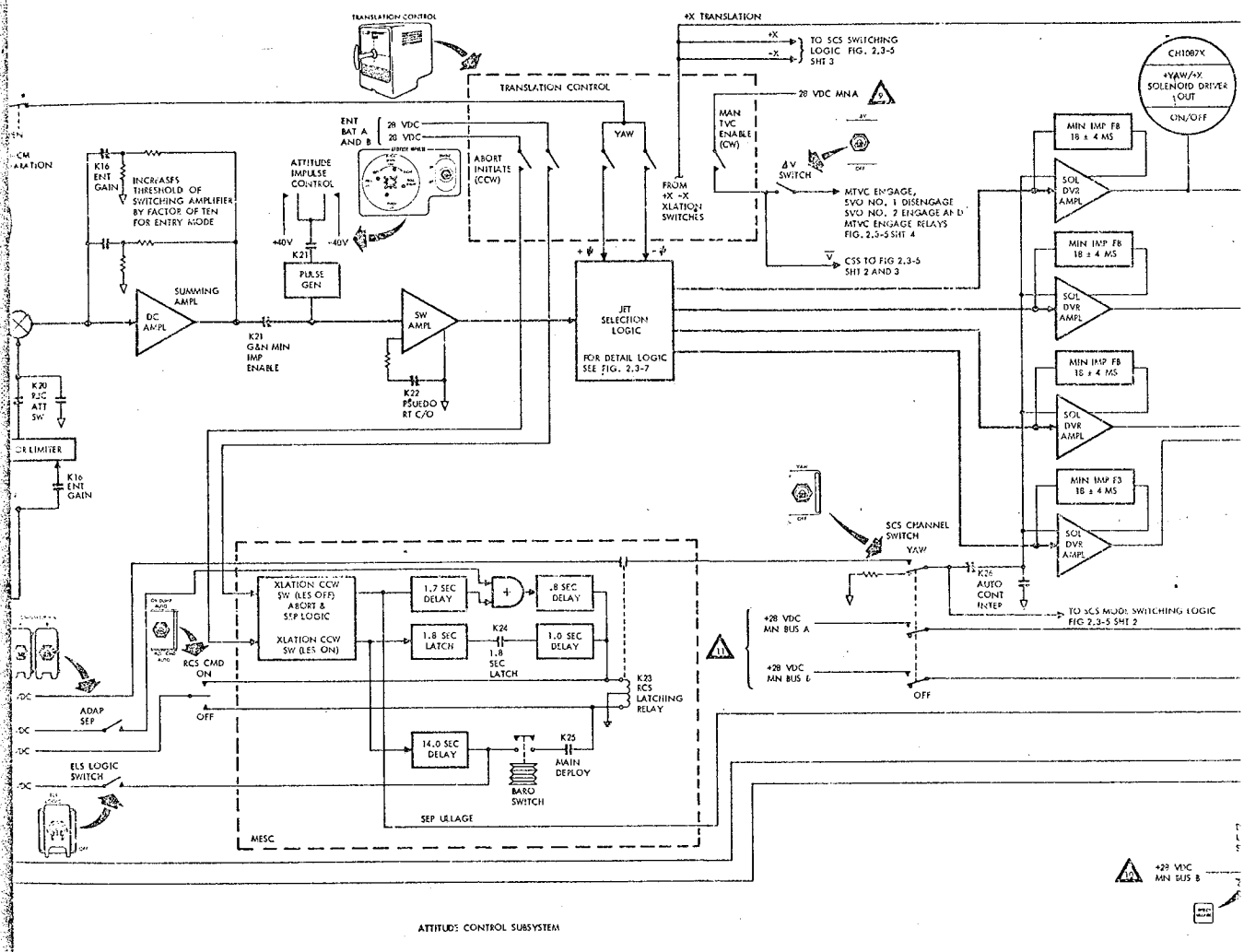
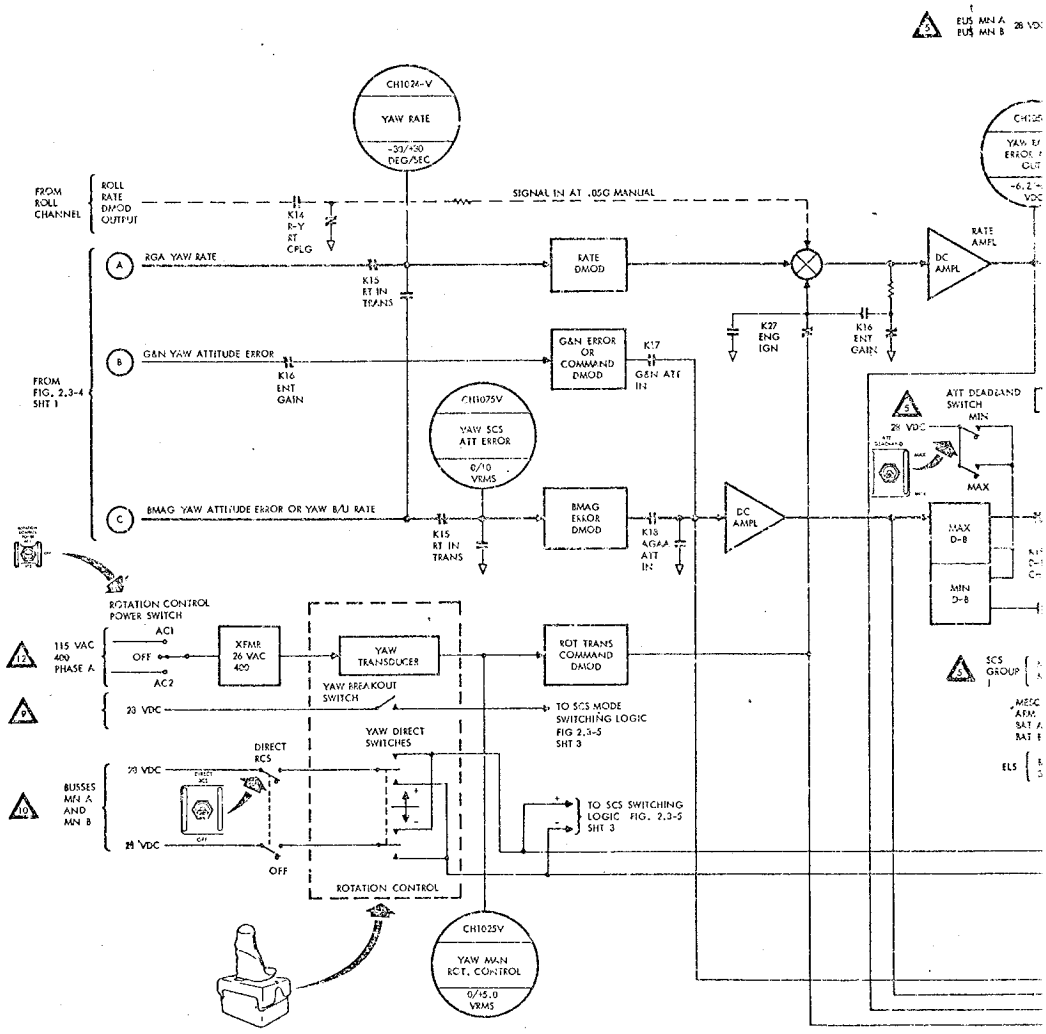


Figure 2.3-4. SCS Functional Flow Diagram (Sheet 2 of 4)



ATTITUDE CONTROL SUBSYSTEM


CH1024-V
YAW RATE
-30/+30 DEG/SEC
FROM ROLL CHANNEL
ROLL RATE DMOD OUTPUT
SIGNAL IN AT .05G MANUAL
K14 R-Y RT CPLG
A RGA YAW RATE
K15 RT IN TRANS
RATE DMOD
RATE AMPL
DC AMPL
K27 ENG IGN
K16 ENT GAIN
B G&N YAW ATTITUDE ERROR
K16 ENT GAIN
G&N ERROR OR COMMAND DMOD
K17 G&N ATT IN
FROM FIG. 2.3-4 SHT 1
CH1075V
YAW SCS ATT ERROR
0/10 VRMS
ATT DEADBAND SWITCH
MIN
MAX
C BMAG YAW ATTITUDE ERROR OR YAW B/U RATE
K15 RT IN TRANS
BMAG ERROR DMOD
K18 AGAA ATT IN
DC AMPL
MAX D-B
MIN D-B
ROTATION CONTROL POWER SWITCH
ACI
OFF
AC2
115 VAC 400 PHASE A
XFMR 26 VAC 400
YAW TRANSDUCER
ROT TRANS COMMAND DMOD
YAW BREAKOUT SWITCH
28 VDC
TO SCS MODE SWITCHING LOGIC FIG 2.3-5 SHT 3
YAW DIRECT SWITCHES
DIRECT RCS
BUSSES MN A AND MN B
TO SCS SWITCHING LOGIC FIG. 2.3-5 SHT 3
OFF
ROTATION CONTROL
CH1025V
YAW MAN RCT. CONTROL
0/15.0 VRMS

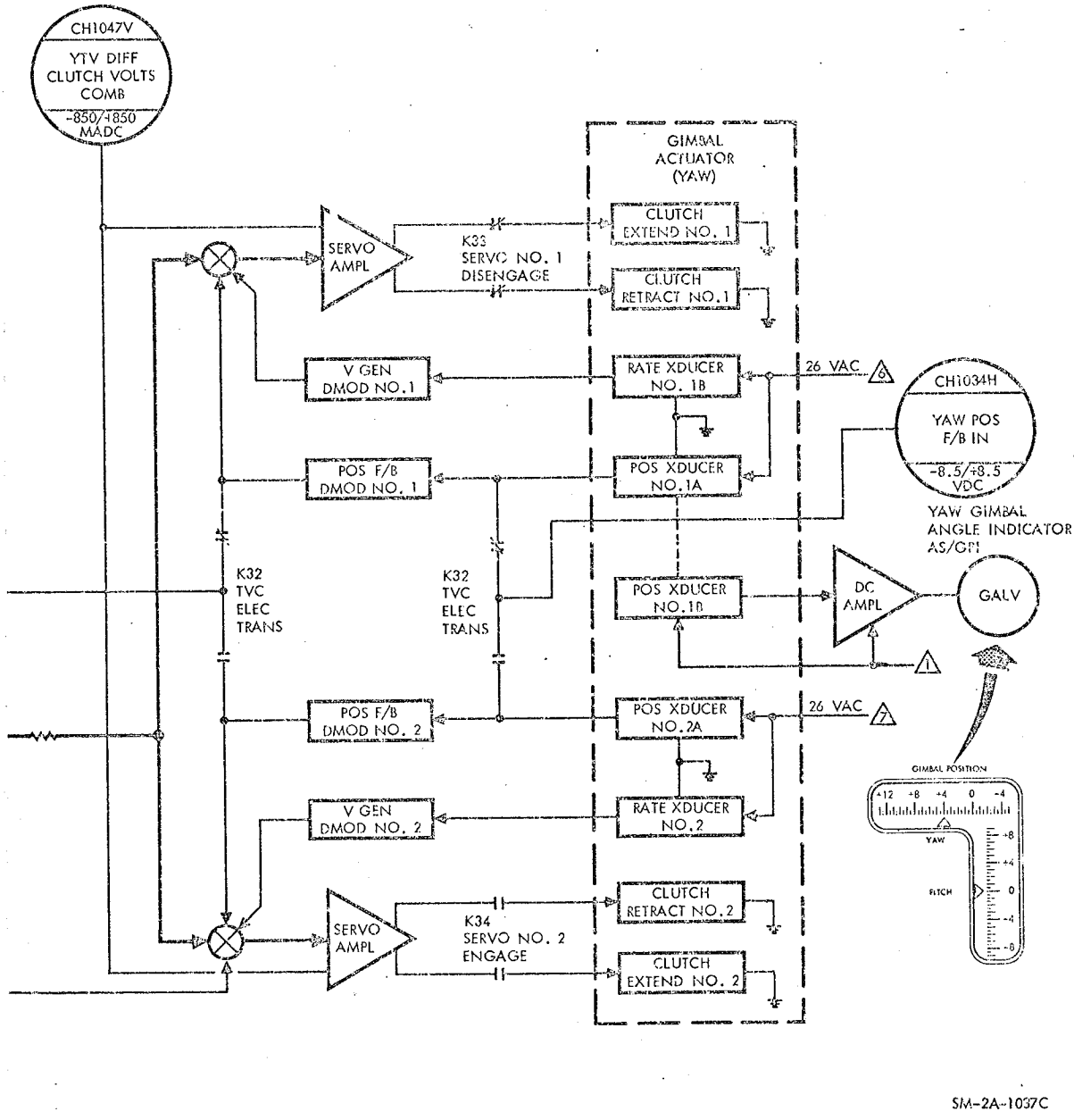
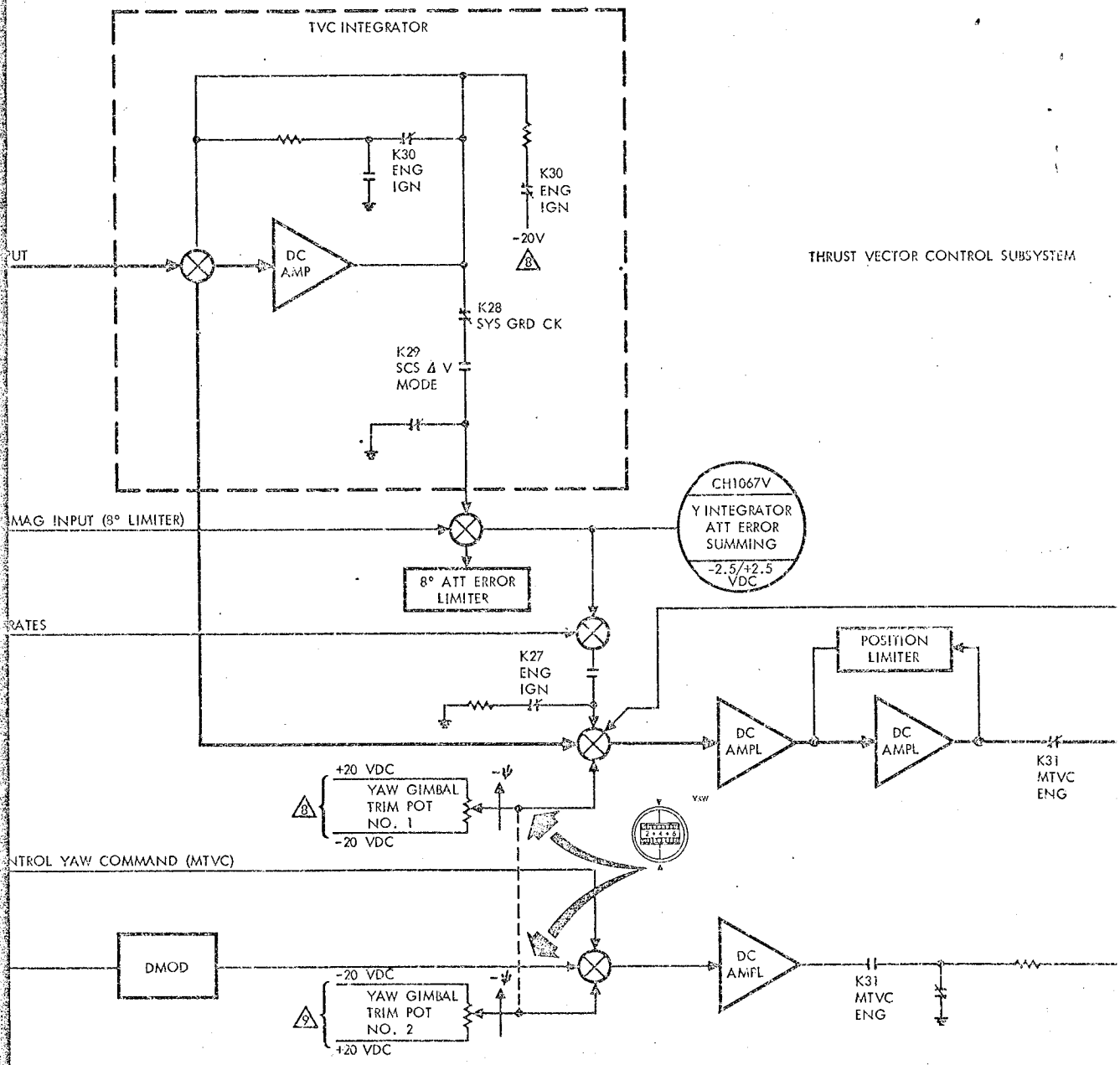


Figure 2.3-4. SCS Functional Flow Diagram (Sheet 3 of 4)


TVC INTEGRATOR
K30 ENG IGN
K30 ENG IGN
-20V
8
DC AMP
K28 SYS GRD CK
K29 SCS Δ V MODE
UT
MAG INPUT (8° LIMITER)
8° ATT ERROR LIMITER
CH1067V
Y INTEGRATOR ATT ERROR SUMMING
-2.5/+2.5 VDC
RATES
K27 ENG IGN
POSITION LIMITER
DC AMPL
DC AMPL
K31 MTVC ENG
+20 VDC
8
YAW GIMBAL TRIM POT NO. 1
-20 VDC
YAW
NTROL YAW COMMAND (MTVC)
DMOD
-20 VDC
9
YAW GIMBAL TRIM POT NO. 2
+20 VDC
DC AMPL
K31 MTVC ENG

MAJOR MODE	K27 ENG IGN	K28 SYS GRD CK	K29 SCS ΔV MODE	K30 ENGINE IGN	K31 MTVC ENGAGE	K32 TVC ELEC TRANS	K33 SERVO NO. 1 DISENGAGE	K34 SERVO NO. 2 ENGAGE
SCS ΔV			●					
INTEGRATED MODE FUNCTIONS								
ENGINE IGNITION	●			●				
SYSTEM GRD CHECK		●						
MTVC ENGAGE					●		●	●
TVC MONITOR						●	●	●
TVC NO. 1 OFF						●	○	●

NOTE:

1. For Switching Logic Details, See Figure 2.3-5, Shts 3 & 4
2. For △ Codes, See Figure 2.3-9

FROM FIG 2.3-4 SHT 2

(A) BMAG YA

(B) G&N OR Y

(C) DEMODUL

(E) ROTATION

FROM FIG 2.3-4 SHT 1

(D) MTVC RAT

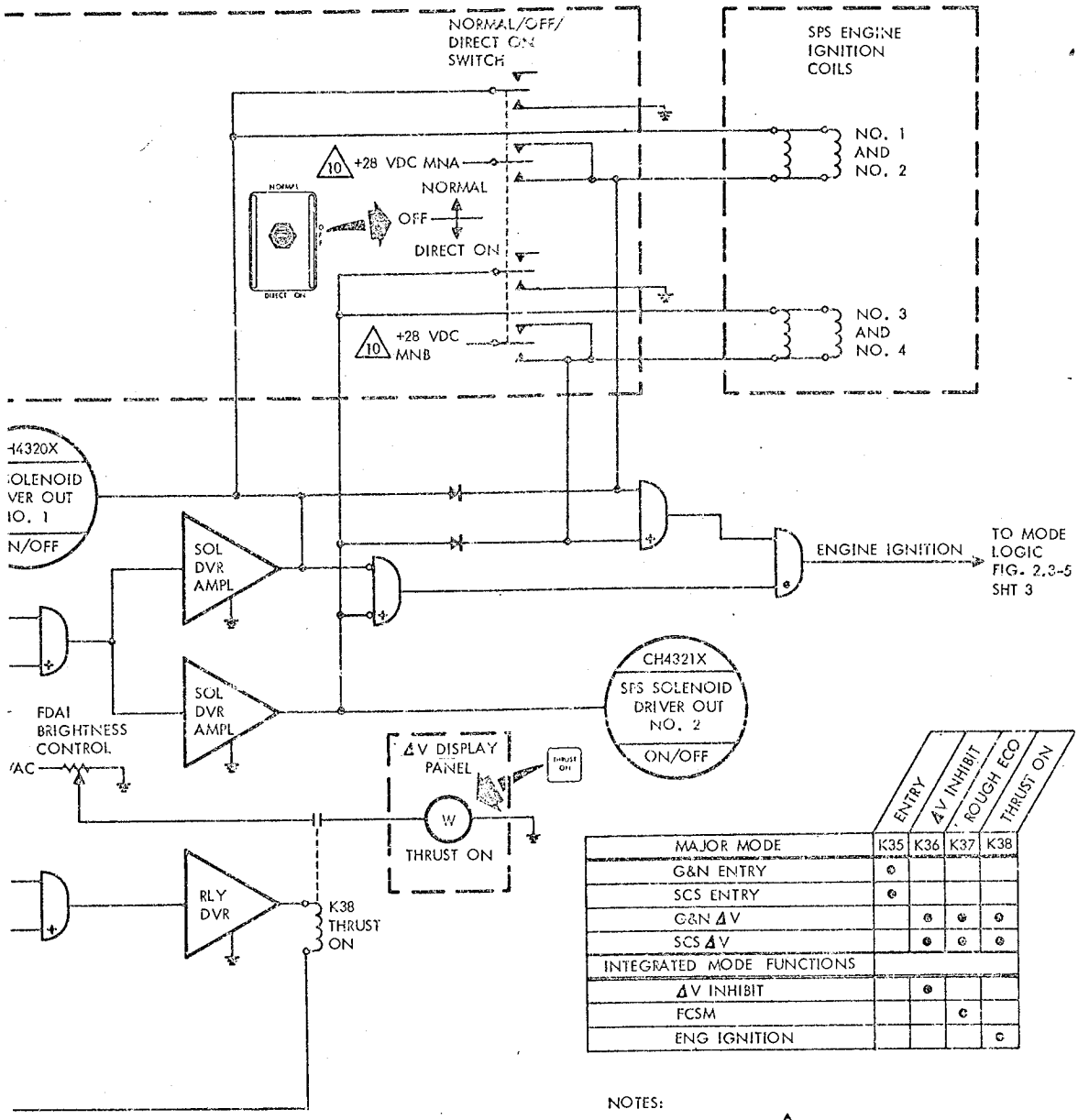
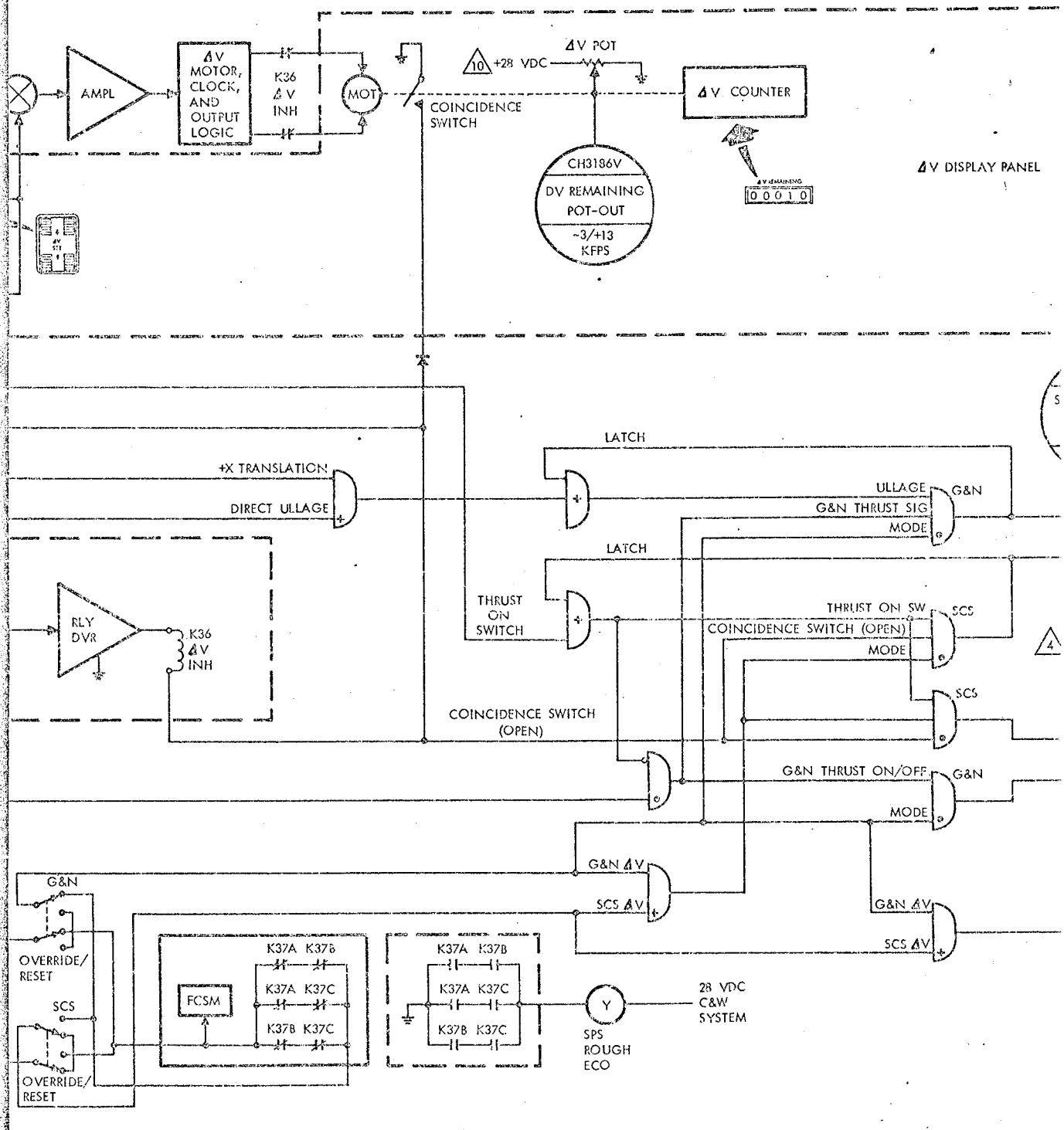
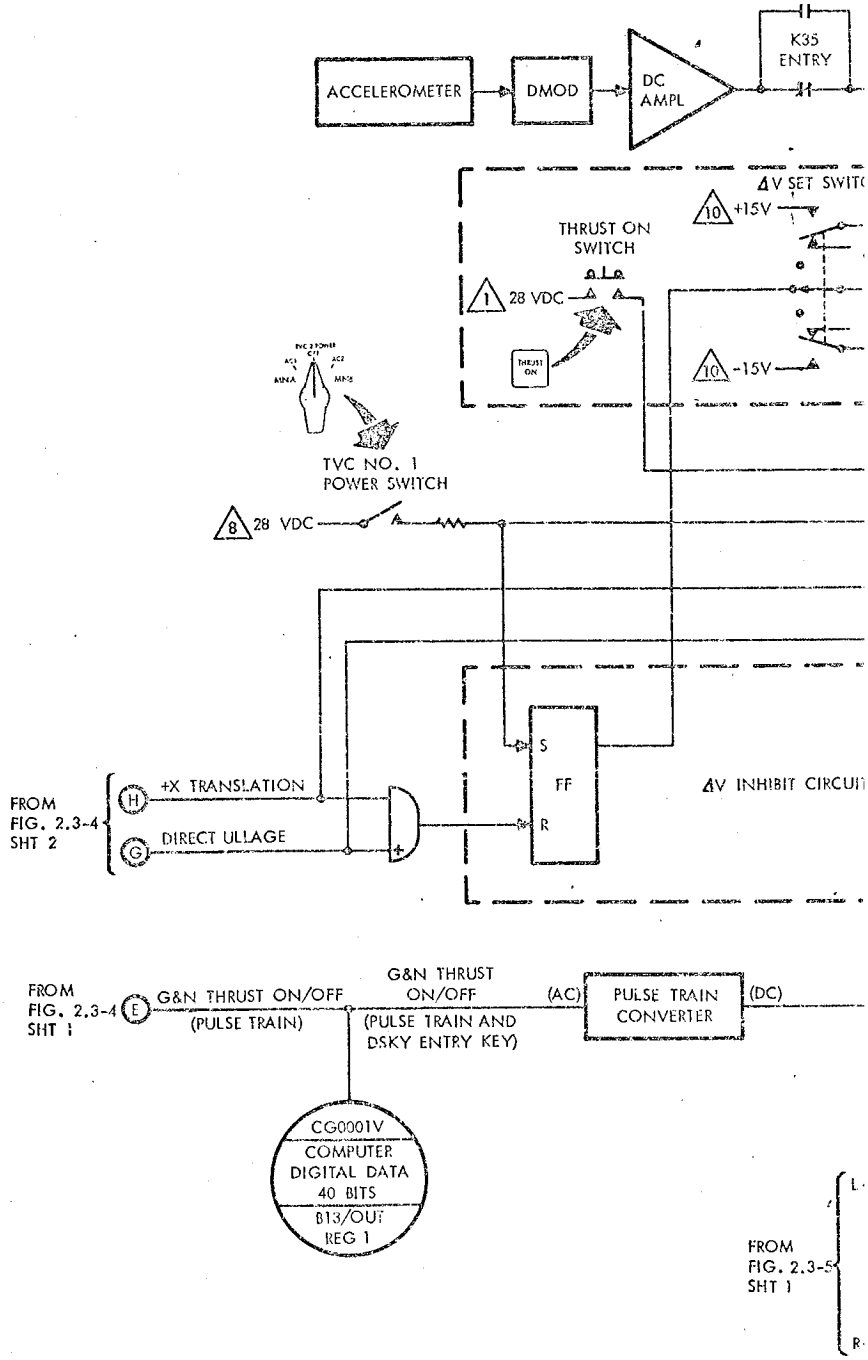


Figure 2.3-4. SCS Functional Flow Diagram (Sheet 4 of 4)


ΔV MOTOR, CLOCK, AND OUTPUT LOGIC
AMPL
K36 ΔV INH
MOT
COINCIDENCE SWITCH
10 +28 VDC
ΔV POT
ΔV COUNTER
CH3186V
DV REMAINING POT-OUT
~3/+13 KFPS
ΔV DISPLAY PANEL
+X TRANSLATION
DIRECT ULLAGE
LATCH
ULLAGE
G&N THRUST SIG
MODE
G&N
THRUST ON SWITCH
THRUST ON SW
COINCIDENCE SWITCH (OPEN)
SCS
RLY DVR
K36 ΔV INH
G&N THRUST ON/OFF
G&N ΔV
SCS ΔV
OVERRIDE/ RESET
SCS
FCSM
K37A K37B
K37A K37C
K37B K37C
Y
28 VDC C&W SYSTEM
SPS ROUGH ECO


ACCELEROMETER
DMOD
DC AMPL
K35 ENTRY
ΔV SET SWITC
10 +15V
THRUST ON SWITCH
1 28 VDC
THRUST ON
10 -15V
TVC NO. 1 POWER SWITCH
8 28 VDC
S
FF
R
ΔV INHIBIT CIRCUI
FROM FIG. 2.3-4 SHT 2
H +X TRANSLATION
G DIRECT ULLAGE
FROM FIG. 2.3-4 SHT 1
E G&N THRUST ON/OFF (PULSE TRAIN)
G&N THRUST ON/OFF (PULSE TRAIN AND DSKY ENTRY KEY)
(AC)
PULSE TRAIN CONVERTER
(DC)
CG0001V
COMPUTER DIGITAL DATA 40 BITS
B13/OUT REG 1
FROM FIG. 2.3-5 SHT 1
L
R

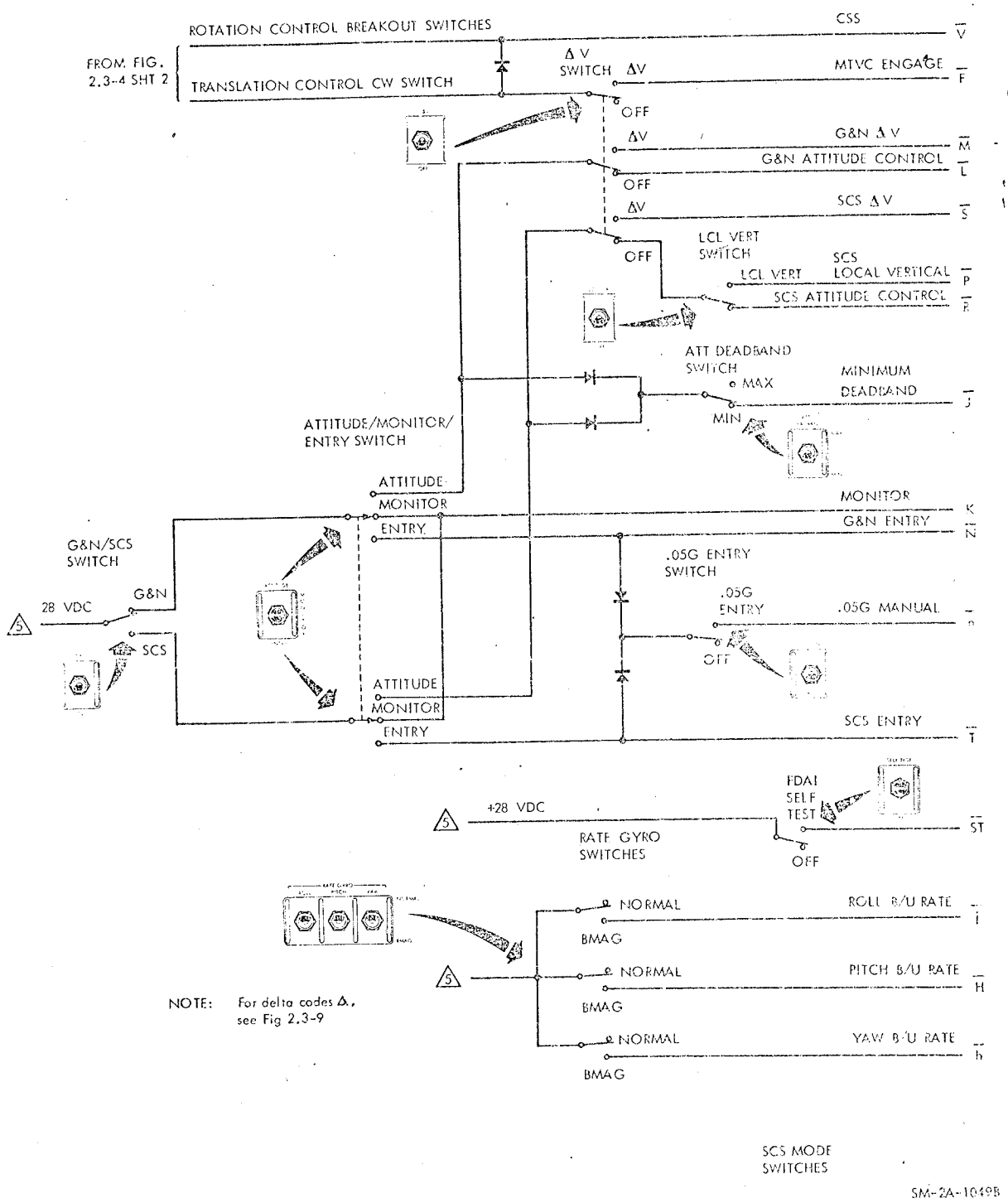


Figure 2.3-5. SCS Switching Logic (Sheet 1 of 4)

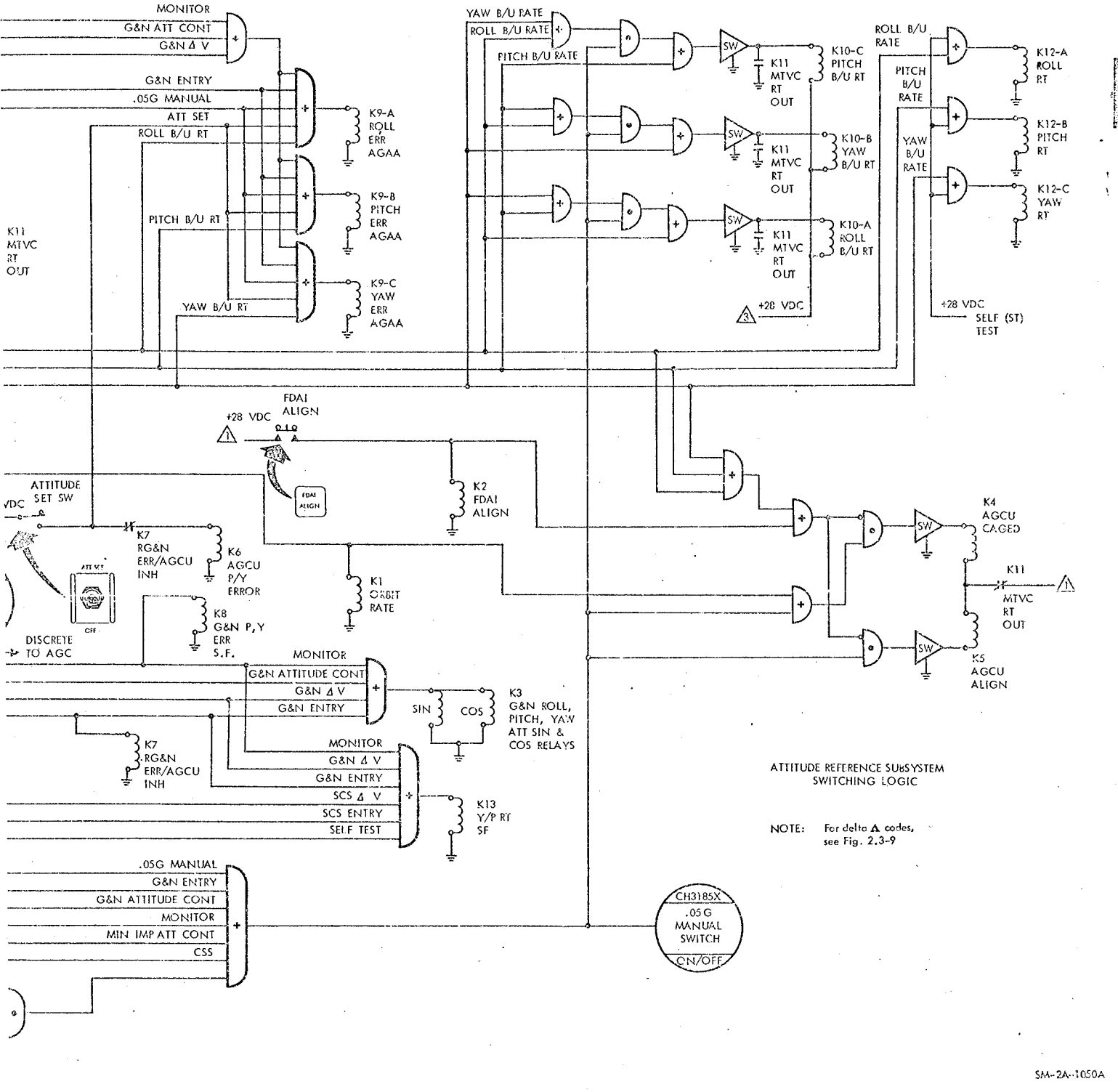
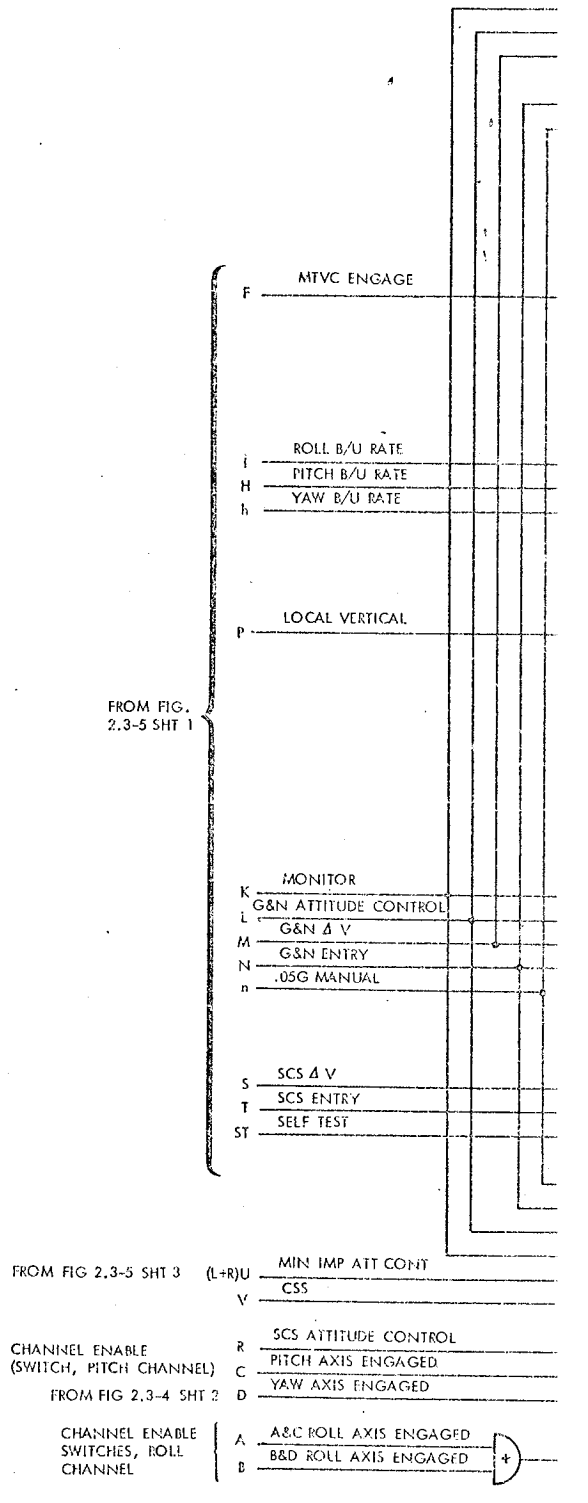


Figure 2.3-5. SCS Switching Logic (Sheet 2 of 4)


FROM FIG. 2.3-5 SHT 1
F
MTVC ENGAGE
i
ROLL B/U RATE
H
PITCH B/U RATE
h
YAW B/U RATE
P
LOCAL VERTICAL
K
MONITOR
L
G&N ATTITUDE CONTROL
M
G&N Δ V
N
G&N ENTRY
n
.05G MANUAL
S
SCS Δ V
T
SCS ENTRY
ST
SELF TEST
FROM FIG 2.3-5 SHT 3
(L+R)U
MIN IMP ATT CONT
V
CSS
CHANNEL ENABLE (SWITCH, PITCH CHANNEL)
R
SCS ATTITUDE CONTROL
C
PITCH AXIS ENGAGED
FROM FIG 2.3-4 SHT 2
D
YAW AXIS ENGAGED
CHANNEL ENABLE SWITCHES, ROLL CHANNEL
A
A&C ROLL AXIS ENGAGED
B
B&D ROLL AXIS ENGAGED
+

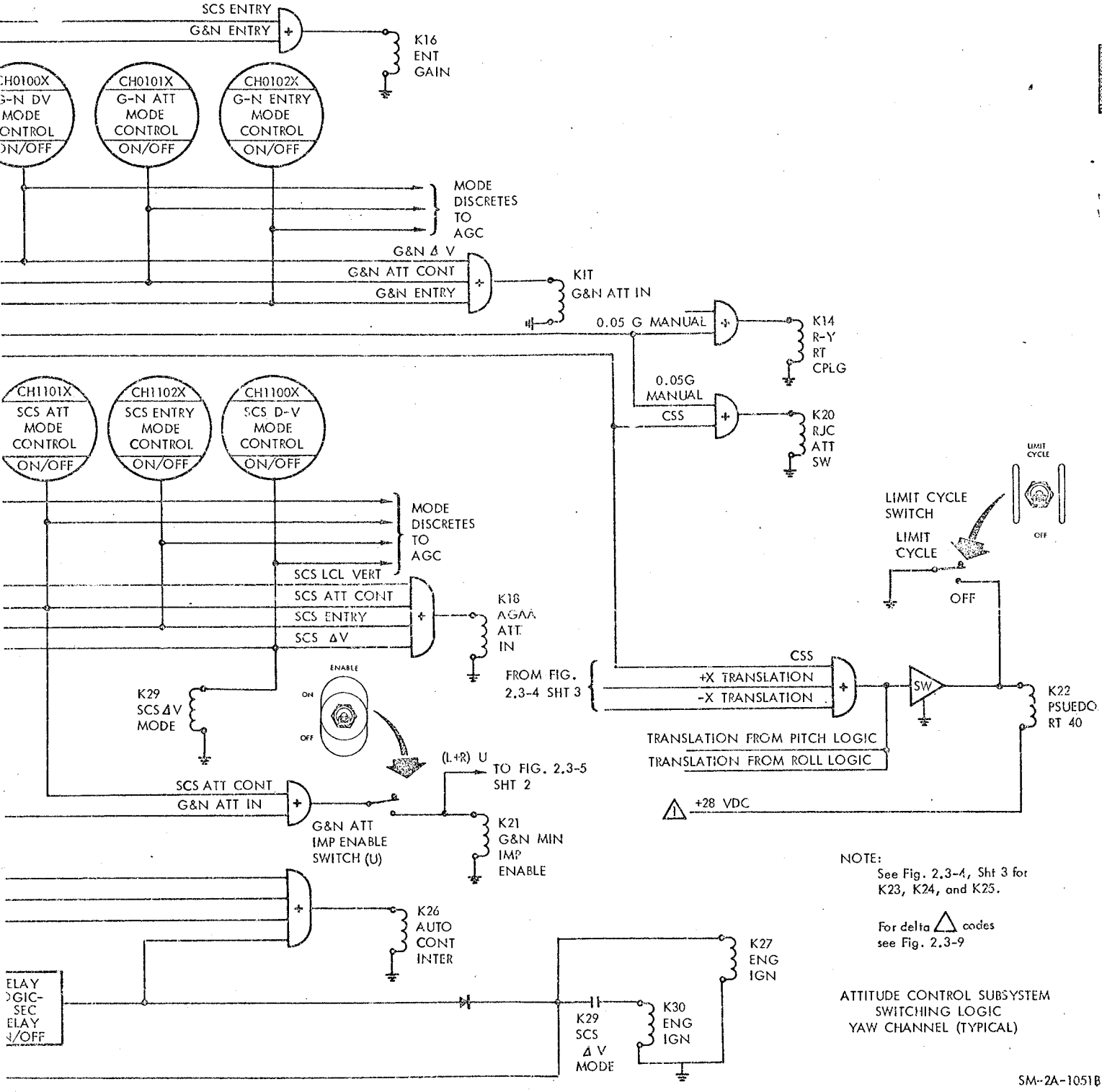
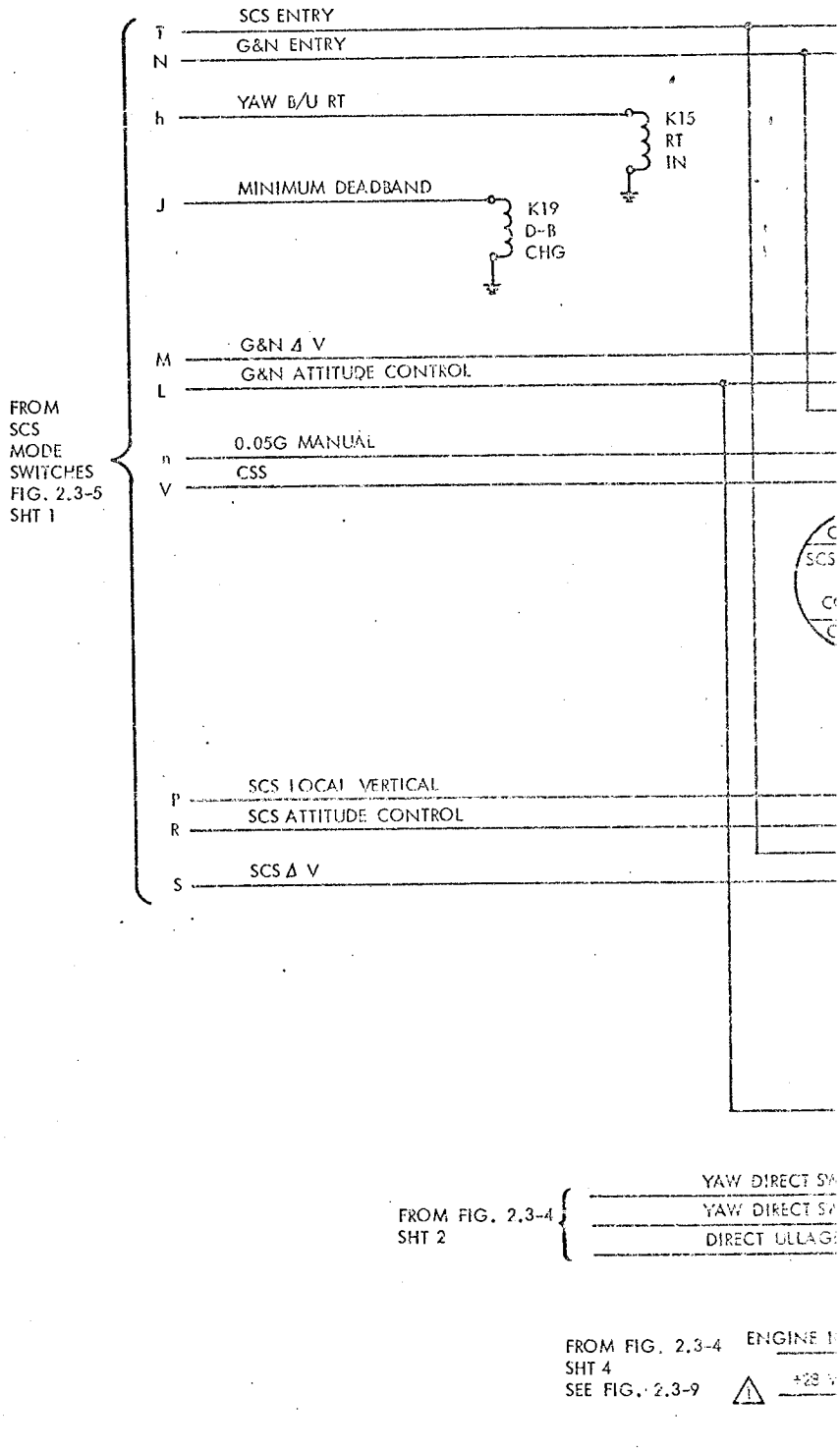
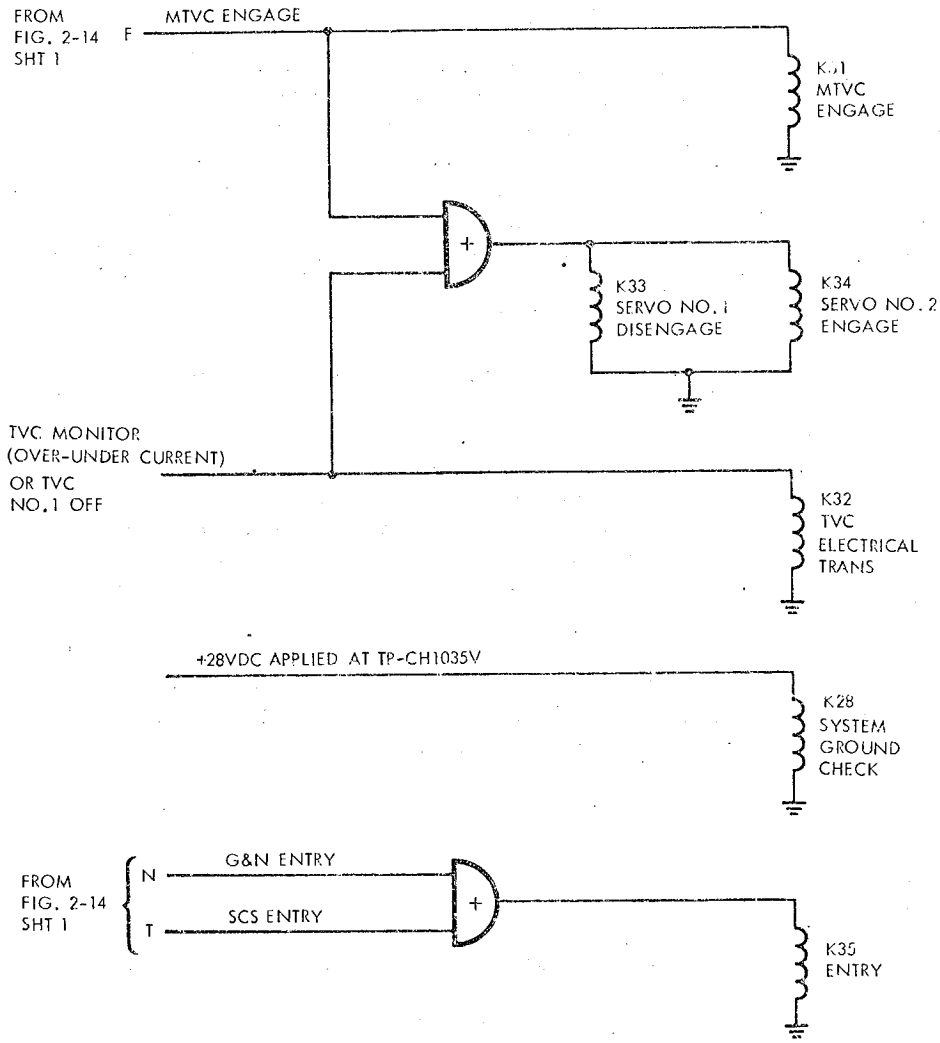


Figure 2.3-5. SCS Switching Logic (Sheet 3 of 4)


FROM SCS MODE SWITCHES FIG. 2.3-5 SHT 1
T
SCS ENTRY
N
G&N ENTRY
h
YAW B/U RT
K15 RT IN
J
MINIMUM DEADBAND
K19 D-B CHG
M
G&N Δ V
L
G&N ATTITUDE CONTROL
n
0.05G MANUAL
V
CSS
P
SCS LOCAL VERTICAL
R
SCS ATTITUDE CONTROL
S
SCS Δ V
FROM FIG. 2.3-4 SHT 2
YAW DIRECT SW
YAW DIRECT SW
DIRECT ULLAGE
FROM FIG. 2.3-4 SHT 4 SEE FIG. 2.3-9
ENGINE
+28 V



NOTE: See Fig. 2-13 Sht 5 for relays K36, K37, & K38.

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Figure 2.3-5. SCS Switching Logic (Sheet 4 of 4)

Inertial reference data may also be received by the astronauts via the MSFN voice link for AGC updating and/or for IMU alignment. With the computer subsystem in the G&N loop, automatic maneuvers and/or G&N-controlled velocity changes are possible.

The FDAI receives total attitude and attitude error information from the G&N system. The FDAI indicates S/C total attitude (S/C reference attitude) and attitude error. Total attitude represents the gimbal angles of the IMU; and attitude error is the difference between the IMU gimbal angles and the desired attitude. The desired attitude is obtained by maneuvering the S/C either manually or automatically in the directions that null out the indicated errors. This establishes S/C attitude to the desired inertial reference. The FDAI also displays rotational rates obtained from the SCS rate gyros. The SCS rate gyros supply rate information for all G&N and SCS control and display functions.

In G&N modes, the FDAI ball is continuously controlled by signals from the IMU gimbal angle resolvers. In SCS modes, the ball is controlled by the AGCU total angle resolvers. AGCU signals are applied to the ball only during manually initiated attitude changes (assuming none of the BMAGs are rate caged) and in the SCS entry mode after 0.05 G switching. At all other times, the ball remains stationary. The ball is always driven with reference to the IMU axes with the AGCU providing the conversion for the BMAGS from body axes to IMU axes.

Attitude Reference/SCS. If the IMU cannot be used for attitude reference, a backup or strapdown attitude reference comprised of assemblies contained within the SCS will provide inertial attitude reference. The strapdown reference is mechanized within the following:

- Attitude Gyro Accelerometer Assembly (AGAA)

Contains the body-mounted attitude gyros (BMAGS), X-axis accelerometer, and self-contained electronics. Provides attitude error signals for the attitude control subsystem, AGCU, and FDAI. The BMAGS are also a source for backup rate signals, if required.

- Rate Gyro Assembly (RGA)

Provides angular rate signals to the attitude control (ACS) subsystems and to the FDAI.

- Attitude Set/Gimbal Position Indicator (AS/GPI)

The AS section provides a capability to set in desired reference attitudes and align the ARS to those attitudes. The GPI section allows the astronauts to manually position the SPS engine gimbals to a trim position prior to a delta V maneuver.

- Display/Attitude Gyro Accelerometer Assembly Electronic Control Assembly (D/AGAAECA)

  AGAA section: Contains electronics required to operate the BMAGS and to interface with the AGCU

  DECA section: Provides the interface electronics between all sensors and corresponding displays

- Auxiliary Electronic Control Assembly (AECA)

  AGCU section: Performs the mathematical computations and contains the transformation matrices required to display attitude and attitude errors of the S/C. The AGCU is the primary control device for the SCS ARS.

  The remainder of the AECA contains circuitry for the SPS engine thrust ON/OFF control function.

- Flight Director Attitude Indicator (FDAI)

  The FDAI (figure 2.3-12) provides the visual displays for S/C attitude; included is total attitude readout (FDAI ball) gimbaled in three axes: roll, pitch, and yaw.

  Pitch and yaw total attitude is read from either the body axes index (ν) or the navigation axes index (⊙). The indices are fixed to the instrument faceplate. Roll is indicated by a roll bug (indicator needle driven by the roll gimbal through a gear mechanism). Roll attitude is read by comparing the roll bug position with reference to a scaled bezel ring about the instrument periphery.

  Attitude errors are indicated by three fly-to needles.

  Angular rates are indicated by three fly-to needles.

  A + roll rate or + roll error will cause those needles to deflect left. A - roll rate or - roll error will cause the needles to deflect right.

  A + pitch rate or + pitch error will cause those needles to deflect down. A - pitch rate or - pitch error will cause the needles to deflect up.

  The yaw rate and error needles deflect in the same directions as the roll needles.

  To correct the error, the S/C is automatically or manually rotated in the direction of needle deflection.

The SCS attitude reference subsystem is mechanized such that it is used primarily for monitoring S/C attitude. Consequently, automatic maneuvering is not possible when SCS modes of operation are selected. However, by using the FDAI as a monitor and by proper selection of controls, precision manual maneuvers can be performed.

The subsystem, acting as a strapdown reference, will supply all of the attitude data normally available from the IMU. These data are subsequently applied to the FDAI for presentation of S/C attitude. The IMU is a three-gimbal platform and therefore will achieve a gimbal lock condition. The middle and outer gimbals become parallel and the output is not predictable. The AGCU has a similar function which creates an effective gimbal lock. This occurs in both systems for a 90-degree yaw displacement with respect to the navigation base. The FDAI and yaw attitude set control provides markings that will serve as a warning prior to achieving a gimbal-lock condition.

Basically, the body-mounted attitude gyros (BMACS), attitude gyro coupling unit (AGCU), and the FDAI are the primary inertial sensing, computing, and display elements of the strapdown system. Attitude errors in roll, pitch, and yaw body axes are sensed by the body-mounted attitude gyros. The error signals are conditioned and subsequently directed to the FDAI for display of total attitude and attitude error. The major part of the conditioning takes place in the AGCU which provides signal inputs to the FDAI comparable to that of the IMU.

The AGCU section of the auxiliary electronic control assembly is the primary control or computing device for the SCS attitude reference subsystem. It performs most of the inertial reference computations and performs the mathematical conversions and transformations required to display total attitude and attitude error. The attitude gyro torquing loop, that the AGCU electromechanical elements are a part of, perform the following:

- Generate a pulse train that is equivalent to the total change in S/C attitude
- Provide two-directional control of resolver shaft angles
- Provide torquing current for the attitude gyros
- Provide forward and reverse conversion of gyro and attitude set error signals to appropriate axes representation for FDAI display, and for gyro torquing.

The SCS rate gyros sense vehicle angular velocity, and supply angular rate signals to the system for rate stabilization and to the FDAI rate indicators. The proper selection of switches will place the BMAGS in a backup-rate condition, and provide rate signals to the FDAI rate indicators. Whenever manual thrust vector control is selected, the BMAGS will automatically be placed in the backup-rate condition.

Attitude Reference Control. After a maneuver or a series of maneuvers, the S/C attitude (body axes) is, each time, different with respect to the inertial reference frame. Therefore, the requirement exists for a method of resolving the rotations about the different body axes, and

establish a relationship between the body axes and the axes of the fixed reference frame. This relationship is established through an Euler angle transformation process obtained from either the IMU (stable element) or the strapdown attitude reference subsystem. The Euler angle, then, is the resolved difference between the S/C body axes coordinates and the coordinate's of the fixed inertial reference. The Euler angle attitude of the S/C, as displayed on the FDAI, is with respect to the coordinates of the fixed reference frame.

The conversion from body axes to Euler angle readout on the FDAI, basically, consists of a forward transformation and a reverse transformation. (See figure 2.3-3.) The forward transformation is essentially body-to-navigation axes conversion, then navigation axes-to-Euler angle transformation by resolvers in the AGCU. The resolvers and gimbal servos in the FDAI position the total attitude displays, resulting from the Euler errors. The reverse transformation is essentially Euler angle-to-navigation axes transformation by resolvers in the AGCU, then navigation-to-body axes conversion for signal application to the attitude gyro torquing amplifiers. After amplification, the signals are demodulated and applied to the gyro torquing coils which torque the gyros to null the original error.

After initial alignment to the IMU reference, the BMAG/AGCU loop is opened by relay action and further positioning of the FDAI ball is prevented. However, if the rotation control, for example, is displaced, the loop will be closed and the FDAI ball will follow S/C motion until the control is neutralized. The BMAG/AGCU loop will open and the ball will again be stationary. If in G&N mode, the FDAI ball is always coupled to represent and follow IMU gimbal angles.

Attitude Errors. The FDAI attitude error indicators represent the difference between actual S/C attitude and the inertial reference. The error is referenced to the S/C body axes in all modes of operation, except for G&N entry mode.

Signals that position the attitude error indicator of the FDAI come from three possible sources. (See figures 2.3-3 and 2.3-4.) In SCS modes, either the BMAGS or the AGCU provide body axes error signals to the error indicator meter movements. AGCU signals are applied when ATT SET is selected on the attitude set section of the AS/GPI. This applies the body axes equivalent of the difference between the attitude set resolver shaft and the AGCU resolver shaft.

When ATT SET is not selected, the outputs of the three BMAGS are applied to the attitude error meter movements of the FDAI. Whether from the BMAGS or the AGCU, the error signals are directed to the meter

movements through scaling, range adjust, demodulator, and amplifier circuits. The following chart provides mode versus full-scale error indications as read on the FDAI.

Mode	Roll	Pitch	Yaw
Monitor	±25°	±15°	±15°
SCS and G&N Entry	±25°	±5°	±5°
All other modes	±5°	±5°	±5°

When G&N modes are selected, the error signals are directed to the FDAI via the inertial coupling display units (CDUs) and the attitude reference conversion circuitry. The roll and yaw channel signals are referenced to either the navigation base axes or the S/C body axes. Conversion in the pitch channel is not required. The capability to reference the roll and yaw channel signals to either the navigation base of S/C body axes is required to facilitate roll and yaw channel cross-coupling control. This is required when G&N entry maneuvers are performed; in which case, reference is to the navigation base axes.

Rates. The following chart provides mode versus full-scale rate indications as read on the FDAI.

Modes	Roll	Pitch	Yaw
Monitor SCS Entry G&N Entry	±25°/sec	±5°/sec	±5°/sec
SCS LCL Vert or SCS ATT Cont or G&N ATT Cont	±1°/sec	±1°/sec	±1°/sec
SCS and G&N V	±5°/sec	±5°/sec	±5°/sec

SCS Attitude Reference Alignment. Alignment of the attitude reference subsystem is performed by comparing the outputs of the total attitude set resolvers in the AGCU with the attitude set resolvers of the AS/GPI. The attitude set resolver shaft can be positioned by using the attitude set dials (thumbwheels) on the front of the AS/GPI. The dials indicate Euler angle of the attitude set resolver shaft, and the output of the resolver is the Euler angle difference between the attitude set resolvers and the total attitude resolvers in the AGCU.

When the FDAI ALIGN switch on the AS/GPI panel is pressed, the AGCU resolvers will align to the attitude set resolvers. Euler-to-navigation axes transformation, and navigation axes-to-body axes conversion takes place for the FDAI attitude error display functions. In SCS control modes, the attitudes indicated on the attitude set dials will be indicated on the FDAI with respect to the navigation axes symbol and the roll index.

2.3.2.3.2 Attitude Control Subsystem.

The attitude control subsystem (ACS) (figures 2.3-4 and 2.3-5), essentially, provides the means for controlling spacecraft motion. Control is either manual or automatic when using controlled inputs from the G&N system. Spacecraft motion, other than drift, is initiated through the use of the S/M RCS jets prior to C/M-S/M separation. After separation (entry), the C/M RCS jets are used. An attitude control logic chart is presented in figure 2.3-6.

There are four types of controls that the ACS contends with which to satisfy mission requirements. (See figures 2.3-4 and 2.3-7.) These are rotation, translation, attitude hold, and rate damping only. Rotational motion is required to establish navigational sightings with the G&N optics subsystem telescope and sextant for S/C alignment prior to a velocity change for TVC functions, for antenna orientation, for T/C transmission and reception, and for lift vector control (roll control plus pitch and yaw rate stabilization) during entry.

Translation control for the AS204A mission is required for the ullage function prior to SPS engine ignition.

Holding attitude (attitude hold) to a fixed reference (established by the ARS) is necessary for navigational sightings, preparing for a velocity change and ullage maneuvers. After establishing attitude hold, the S/C motion involved is the amount of drift that the S/C is allowed to rotate about its axes. The drift is limited to a selectable minimum or maximum deadband about all three axes.

Rate damping only provides rate stabilization during entry or in the event of an abort prior to launch escape system (LES) jettison. The motions involved here are the finite firings of the RCS jets when rotational rates exceed certain limits. The RCS jet firings will decrease the rates to within predetermined limits. The rates are limited to 0.2 degree/sec for all modes, except SCS and G&N entry modes when the rates are increased to 2 degrees/second.

The ACS includes the roll, pitch, and yaw electronic control assemblies (ECAs), the delta V indicator, attitude impulse section of the G&N optics control panel and, in addition, utilizes all of the physical elements and functions of the attitude reference subsystem.

ROLL QUAD & C/M SYSTEM		S/M RCS ENGINES														C/M RCS ENGINES											
		QUAD A				QUAD B				QUAD C				QUAD D				SYSTEM A						SYSTEM B					
ENGINE NO.		2	3	13	16	7	6	9	12	1	4	14	15	8	5	10	11	1	2	5	8	9	12	3	4	6	7	10	11
ROTATION	PITCH UP		●							●								●						●					
	PITCH DOWN	●									●								●						●				
	YAW RIGHT					●									●					●						●			
	YAW LEFT						●							●							●					●			
	ROLL RIGHT			●				●					●				●					●							●
	ROLL LEFT				●				●			●				●							●					●	
TRANSLATION	+X	●					●			●					●														
	-X		●			●					●			●															
	+Y			●								●																	
	-Y				●								●		●														
	+Z							●								●													
	-Z								●								●												
																		TRANSLATION MANEUVERS NOT APPLICABLE TO C/M RCS											
SCS CIRCUIT BREAKERS *		MN A / MN B		M A N		MN A / MN B		M A N		MN A / MN B		M B N		MN A / MN B		M B N		M A N		M A N		M A N		M B N		M B N		M B N	
		PITCH		A&C ROLL		YAW		B&D ROLL		PITCH		A&C ROLL		YAW		B&D ROLL		PITCH		YAW		B&D ROLL		PITCH		YAW		B&D ROLL	
SCS CHANNEL PITCH AND YAW SWITCHES		PITCH		A&C ROLL		YAW		B&D ROLL		PITCH		A&C ROLL		YAW		B&D ROLL		PITCH		YAW		B&D ROLL		PITCH		YAW		B&D ROLL	

* CIRCUIT BREAKER TABULATION IS APPLICABLE TO RCS ENGINES AUTOMATIC COIL OPERATION ONLY. FOR MANUAL DIRECT COIL OPERATION, POWER IS APPLIED FROM SCS DIRECT CONT CIRCUIT BREAKERS MN A OR MN B BY ACTUATION OF THE PILOTS OR CO-PILOTS HAND CONTROLLER, RESPECTIVELY.

NOTES:
1. Combinations of translation and rotation maneuvers requiring the simultaneous firing of identical S/M RCS engines is prohibited by jet selection logic circuit design.
2. Minimum impulse operation is accomplished in the roll axis by two engines only. Remaining engines are disabled by setting the A&C ROLL CHANNEL switch to OFF and pulling one B&D ROLL circuit breaker; or setting the B&D ROLL CHANNEL switch to OFF and pulling one A&C ROLL circuit breaker.
3. Fuel conservation and/or consumption balance between quads may be accomplished by using applicable SCS CHANNEL switches and circuit breakers to select single-engine operation in each direction.

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Figure 2.3-6. SCS Attitude Control Logic Chart

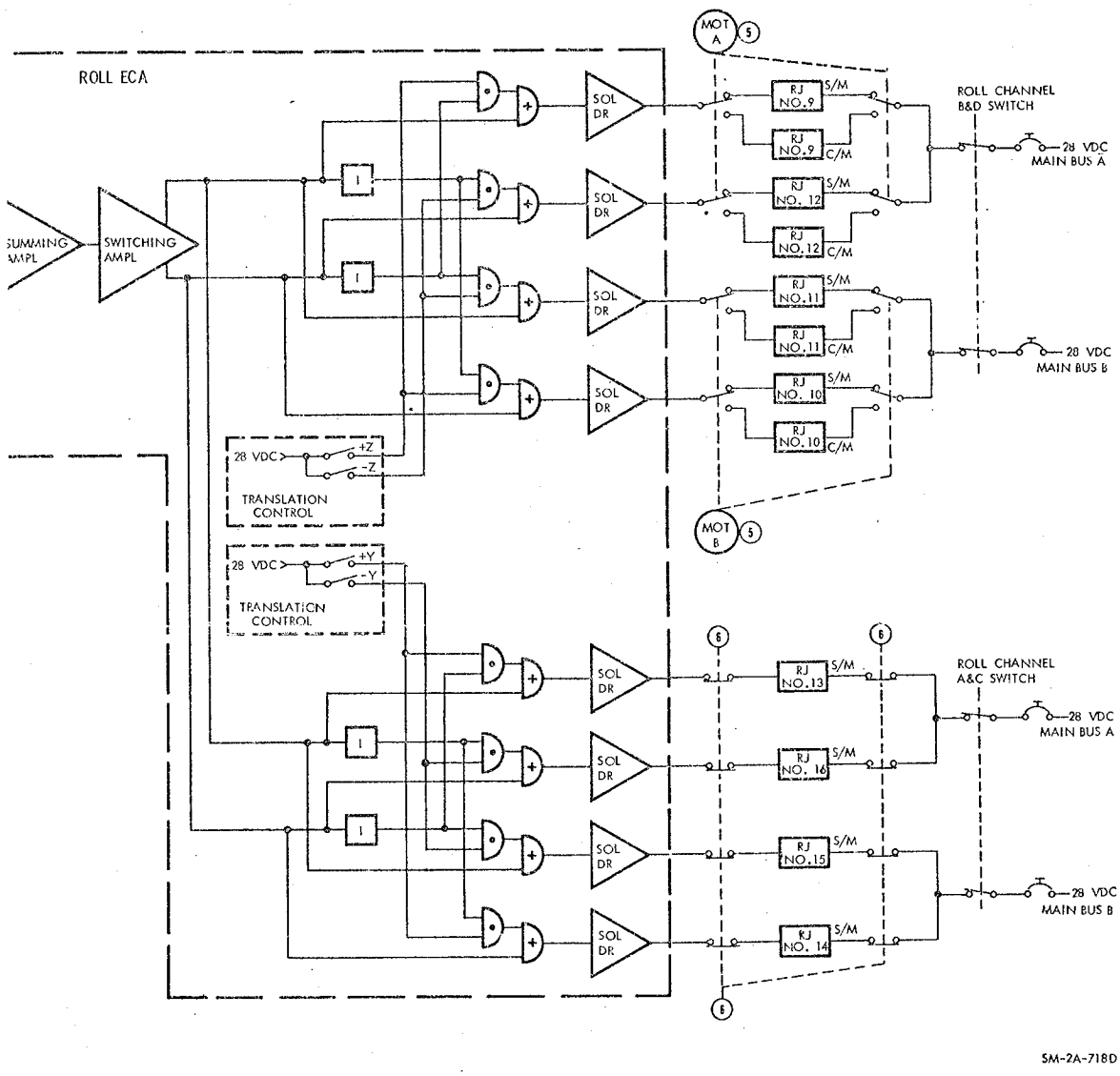
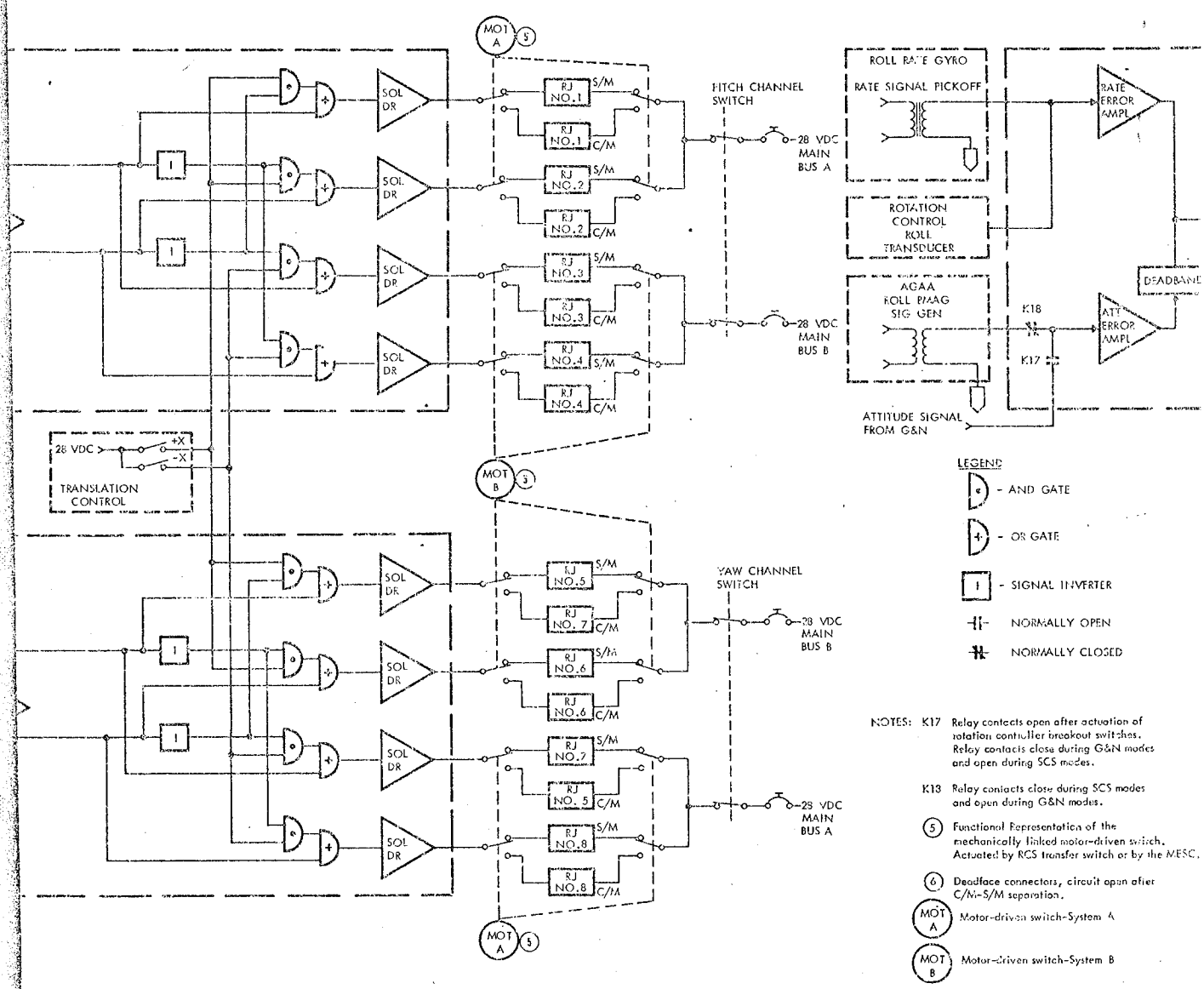


Figure 2.3-7. Jet Selection Logic Functional Flow Diagram



LEGEND

- AND GATE
- OR GATE
- SIGNAL INVERTER
- NORMALLY OPEN
- NORMALLY CLOSED

NOTES: K17 Relay contacts open after actuation of rotation controller breakout switches. Relay contacts close during G&N modes and open during SCS modes.

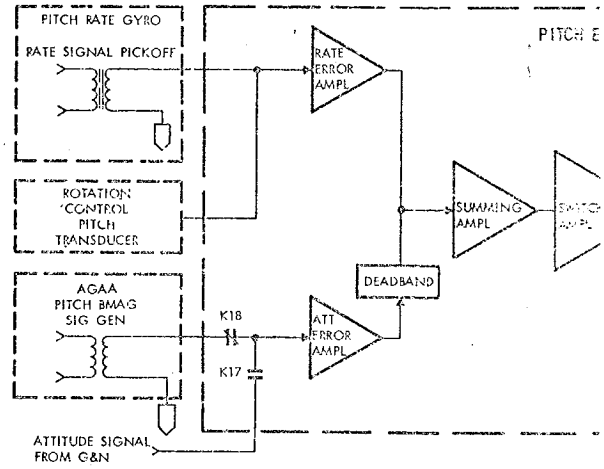
K18 Relay contacts close during SCS modes and open during G&N modes.

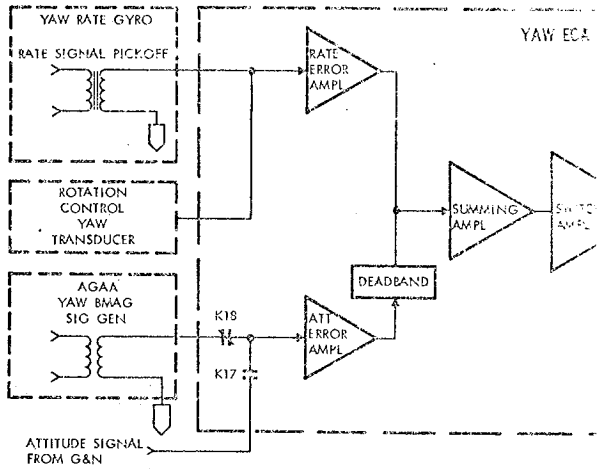
(5) Functional Representation of the mechanically linked motor-driven switch. Actuated by RCS transfer switch or by the MESC.

(6) Deadface connectors, circuit open after C/M–S/M separation.

MOT A — Motor-driven switch-System A

MOT B — Motor-driven switch-System B


PITCH RATE GYRO
RATE SIGNAL PICKOFF
ROTATION CONTROL PITCH TRANSDUCER
AGAA PITCH BMAG SIG GEN
ATTITUDE SIGNAL FROM G&N
K18
K17
RATE ERROR AMPL
ATT ERROR AMPL
DEADBAND
SUMMING AMPL
PITCH E


YAW RATE GYRO
RATE SIGNAL PICKOFF
ROTATION CONTROL YAW TRANSDUCER
AGAA YAW BMAG SIG GEN
ATTITUDE SIGNAL FROM G&N
K18
K17
RATE ERROR AMPL
ATT ERROR AMPL
DEADBAND
SUMMING AMPL
YAW EC

The attitude control subsystem electronics is contained within the roll, pitch, and yaw ECAs. The ECAs accept the manual and automatic inputs, conditions them, and directs on-off electrical command signals through jet selection logic to appropriate automatic (normal) coils of the RCS jets. The output of the jet selection logic will be either a time-modulated signal or a steady-state +20-vdc signal.

There are basically two types of inputs to the attitude control subsystem: manual and inertial sensor (AGAA, RGA, IMU). Manual inputs are provided by the rotation and translation controls, switches on the SCS control panel, attitude impulse switch on the attitude impulse section of the G&N optics control panel, and the direct ullage switch on the delta V display panel. These controls can be used for manual ullage maneuvers or as a backup during automatic delta V functions. The attitude impulse switch commands inputs to the ACS and subsequently to the RCS jets for small angular accelerations.

The inertial sensor inputs are provided by the AGAA, RGA, and the IMU via the G&N system. The AGAA (BMAG) and rate gyros (RGA) inputs are used for attitude hold, rate stabilization, and manual rotation control. The IMU inputs provide G&N attitude hold and command rate signals for manual or automatic rotational maneuvers.

Rotation Maneuvers. Rotation maneuvers can be performed by using four different types of manual controls or automatically by using the G&N computer subsystem. Manual rotation maneuvers are accomplished by using the rotation control, commonly called control stick steering (CSS), direct or emergency control which is a function of the rotation control, attitude impulse control, and positioning of the inertial CDUs. Automatic maneuvers result from astronaut inputs to the AGC via the DSKY. The AGC, according to computer program, automatically positions the CDUs and will command S/C motion to the programmed attitude.

Normal CSS is a proportional manual function and is available at any time in all operational modes. The maximum CSS proportional rates that can be commanded are as follows:

- 19 degrees per second (roll axis) entry mode
- 5 degrees per second (pitch and yaw axes) entry mode
- 0.79 degree per second (all axes) all other modes.

Even though CSS commands greater rates, the SCS electronics will limit the rates to those values given. Proportional control is obtained by using the rate gyro output to cancel the output of a transducer within the rotation control. CSS proportional commands are always directed to the automatic solenoid coils of the RCS engines.

When the rotation control (stick) is displaced, a transducer within the stick will command a rotation proportional to the amount of stick displacement. The rotational rates are limited to predetermined values, depending on the operational mode.

When in SCS attitude control mode and as the stick is displaced approximately 2.5 degrees from neutral, breakout switches within the stick close causing the BMAG and the AGCU to become closed loop. It also inhibits BMAG error signals to the SCS electronics. As the S/C rotates, the AGCU applies torquing current to the BMAG torquer coils. The gyros, then, are torqued at a rate proportional to the magnitude of BMAG error, keeping attitude error at approximately zero. Thus, the AGCU will follow S/C motion and establish a new attitude reference when the stick is returned to neutral.

When in G&N attitude control mode, a G&N SYNC switch must be energized to enable the attitude hold function when the control stick is returned to neutral. The G&N sync function provides IMU/CDU closed loop operation which keeps attitude errors at approximately zero during the maneuver. Consequently, the S/C will hold the new attitude when the stick is returned to neutral. If G&N sync is not enabled, the S/C will return to the attitude established before stick displacement.

NOTE For the AS204A mission the G&N SYNC switch will remain OFF for the entire mission.

The computer program will control the actual maneuver rate, but the SCS will limit the maximum. The maximum non-entry maneuver rate is 10°/second and entry maneuver rate is 17°/second in all axes.

Direct rotation control is a nonproportional function whereby initiated commands are applied directly to the RCS direct coils. To accomplish direct rotation, the DIRECT RCS/OFF switch (MDC-8) is set to DIRECT RCS; the SCS-CHANNEL switches (MDC-8) are set to OFF; if high rates are to be maintained, and the control stick is rotated about the desired axis or axes to hardstops. Just prior to engaging the hardstops, a switch closes and applies a direct command to the RCS direct coils. Rate feedback is not used to cancel stick movement. The breakout switches, however, close the BMAG/AGCU loop, and attitude error output to the SCS electronics is inhibited. With proper control and switch configuration, direct control is available at any time.

The attitude impulse control (G&N optics control panel) provides the capability for commanding low-rotational rates about all three axes. Attitude impulse control is available only in SCS or G&N attitude control modes and is used primarily for precise attitude maneuvers during navigational or star sighting periods. After the control is enabled and displaced, a switch closure in the control and an RC network combination generate one

pulse, which is applied to the RCS jet selection logic. One pulse is generated for each attitude impulse switch closure (control displacement). It is not a proportional control and attitude hold is not available when the control is returned to neutral. When the control is enabled, relay action removes all rate, attitude error, and rotation control inputs to the SCS electronics.

Automatic positioning of the CDUs is accomplished by using the DSKY. This method of control is primarily used during G&N entry.

Translation Maneuvers. There are three methods of initiating translation maneuvers: normal translations, using the translation control; direct ullage, using the direct ullage button on the delta V control panel; and separation ullage, using the translation control.

Translation commands are not proportional; operation is through switch closure only and is available during all modes of operation prior to C/M-S/M separation. During normal translation, switch closures within the translation control provide commands to the jet selection logic which fire the appropriate jets for the desired direction of translation. The commands are directed to the automatic RCS engine coils. A primary function of normal translation is the ullage maneuver, which is necessary in preparation for a velocity change. Ullage maneuvers require translation along the +X-axis.

Direct ullage is accomplished by using the DIRECT ULLAGE pushbutton on the delta V control panel. When pressed, switch closures command the appropriate direct RCS coils to initiate translation along the +X-axis. Direct ullage is available at any time prior to C/M-S/M separation. Upon C/M-S/M separation, the direct ullage function to the C/M pitch and yaw direct coils is inhibited by deadfacing. It is primarily a backup operation in the event of normal translation failure. Ullage will continue as long as the DIRECT ULLAGE pushbutton is pressed.

The separation ullage function requires a CCW rotation of the translation control into a detent position. Ullage commands are directed to the direct RCS coils. The separation ullage maneuver is performed when SPS aborts are necessary or when S-IVB separation is required. If the LES has been jettisoned, the signal from the translation control in CCW detent will command the sequential events control system (SECS) to sequence the separation ullage and consequent separation from the S-IVB. If the LES is attached to the S/C, the same command will initiate a LES abort.

In G&N and SCS modes, a clockwise rotation of the translation control into a detent generates a CSS logic signal that inhibits attitude gyro signals from the SCS electronics, and provides BMAG/AGCU closed loop operation. It also initiates manual thrust vector control (MTVC).

The CW rotation enables capability for manual roll control by the rotation controller during G&N entry. This is normally an automatic function of the G&N system and entry program.

Attitude Hold. Attitude hold is a capability of the ACS to hold S/C attitude within selected deadband limits of a fixed reference attitude. The deadband (amount S/C is allowed to drift either side of reference attitude) is selected by setting the ATT DEADBAND switch on MDC8 to either MAX or MIN. In the G&N or SCS entry modes, however, the deadband will be maximum regardless of deadband switch position.

The ACS accomplishes attitude hold by inputting summed attitude error and rate gyro signals to the jet selection logic, which will turn on appropriate jets to keep the S/C within the selected deadband. The attitude error signal is conditioned by a deadband circuit and rate limiter before it is summed at the input of a summing amplifier with the rate gyro signal. When the summed input to the amplifier is greater than its threshold, the amplifier will cause a switching amplifier to pulse the jet selection logic. The lower the angular rates, the closer the S/C is allowed to drift to the deadband limits. As angular rates increase, the summed error/rate signal increases in magnitude proportionate to time. Therefore, the sooner the threshold of the summing amplifier is reached, the sooner the jets will fire, damping the oscillation.

A limit cycle switch on MDC8 can be used to provide time modulated pulses to the jet selection logic. Limit cycle is primarily used for fuel conservation purposes. The limit cycle switch enables a psuedo rate feedback circuit at the output of the switching amplifier previously discussed. The psuedo rate, and consequently the time-modulated pulses, is a function of signal magnitude at the switching amplifier input. For large signal inputs, the output pulses will cause the RCS jets to pulse at a higher frequency and for longer periods. As the error decreases, the pulse widths and frequency decrease proportionately until the error is nulled.

The psuedo rate loop is normally used at all times (limit cycle on) when an inertial attitude is being maintained.

Attitude hold is available at all times in three axes, except during monitor mode and SCS entry mode after the 0.05 G switching. During G&N entry after 0.05 G switching, roll attitude hold is still enabled. Yaw and pitch attitude hold is inhibited.

Rate Damping Only. In addition to attitude control and maneuvering capabilities, the ACS provides a rate damping only capability. Although rate damping is a normal function during attitude control modes, rate damping can be used to limit S/C rotational rates (rate stabilization) when attitude hold is not being used. Normally, when S/C rotational rates exceed 0.2 degree per second in any axis, the rate gyros or the BMAG in

backup rate sense the angular accelerations. The signals, conditioned via the roll, pitch, and yaw ECAs and through jet selection logic, are applied to applicable RCS engines to keep the S/C rates within the 0.2-degree-per-second rate deadband. If in SCS or G&N entry mode, the rate deadband is increased to 2 degrees per second. Rate stabilization, in addition to the attitude control functions, is available when any of the following conditions exist:

- Selection of monitor mode after S-IVB separation
- Selection of monitor mode for LES aborts
- Clockwise rotation of translation control after S-IVB separation
- SCS entry mode after 0.05 G switching
- G&N entry mode after 0.05 G switching (pitch and yaw axes only).

2.3.2.3.3 Thrust Vector Control Subsystem.

The purpose of the thrust vector control (TVC) subsystem (figures 2.3-4 and 2.3-5) is to align or position the gimbaled SPS engine to a trim position prior to SPS thrusting and maintain this trim during the acceleration period. The S/C experiences a changing center of gravity (c.g.) caused by the consumption of fuel and oxidizer during acceleration. The TVC subsystem maintains the SPS engine thrust vector through the c.g. and holds S/C attitude so that the thrust vector will remain in the desired direction. This compensates for undesirable forces that affect S/C stability because of the shifting c.g. Thrust vector control, in addition to the TVC subsystem, utilizes the functions of the G&N system, the propulsion systems, and the SCS attitude reference and attitude control subsystems.

The TVC subsystem essentially controls the SPS engine gimbals, and consequently the thrust vector, by energizing the gimbal actuators; one for pitch and one for yaw.

The normal method for controlling thrust is through the G&N delta V mode. This provides the most accurate control. The accelerometers on the IMU stable element and the AGC provide steering commands to the SPS engine gimbals and continuous trajectory corrections to compensate for undesired accelerations. The AGC also compensates for the near-body orbital and gravity affects on the S/C. So, the actual versus required velocity change will result in a curved trajectory.

Normally, both G&N delta V and SCS delta V modes operate by driving No. 1 and No. 2 servo electronics. If a failure occurs in No. 1, an automatic switchover to drive No. 2 servo electronics and No. 2 gimbal motor will occur. Or, No. 2 will drive if No. 1 is switched off or if manual thrust vector control is initiated.

A manual method of thrust vector control is provided to control the position of the SPS engine gimbal. When operating manually, inputs from the rotation control, translation control, and the BMAGs are directed to redundant servo electronics No. 2 and the No. 2 gimbal actuator motor. The nominal authority from either rotation controller is ±6 degrees of SPS gimbal engine deflection.

The gimbal position display section of the AS/GPI panel, the delta V display, SCS control panel, rotation control, translation control, and the SPS switches on MDC-3 are the principle controls and displays associated with TVC. They provide the capability for control and monitoring of system performance.

Thrust Vector Control. When G&N delta V mode is selected, automatic thrust on-off, attitude, and steering commands initiate in the G&N system. However, before the ullage maneuver and thrust-on, the gimbal position trim control thumbwheels on the AS/GPI are used to position the engine gimbals. The engine position is verified on the AS/GPI visual display. The gimbals are aligned such that, at the moment of thrust-on, the thrust vector will be through the S/C c. g. This is necessary before any delta V to prevent undesirable rotational movements about the c. g. when thrusting begins.

In addition to initial positioning of the gimbals, the amount of acceleration required for the velocity change less tailoff is set into the delta V remaining counter on the delta V display. This allows the crew a method of monitoring delta V remaining and, when in SCS ΔV mode, provides automatic thrust-off capability. A coincidence switch in the delta V display will, by inhibiting the thrust on logic, automatically terminate thrust when the ΔV remaining counter indicates zero. The accelerometer in the AGAA senses +X acceleration, and supplies acceleration signals to timing and output logic which subsequently drives the delta V remaining potentiometer to zero. The accelerometer thrushold is 1×10^{-4} g, but the ΔV counter will only step once for each 0.25 +t/sec velocity change.

NOTE It is possible, but not recommended, to have SPS engine ignition without ullaging when in SCS ΔV mode.

Prior to SPS ignition, the G&N system inputs attitude error information to the ACS to hold the S/C at a constant attitude in all three axes. Attitude errors from the G&N system and rate information from the SCS rate gyros are also applied to the SPS gimbal servo loops. Upon engine ignition, the combined attitude error and rate gyro inputs, conditioned by the servo electronics, reposition the gimbals as necessary to rotate the S/C to compensate for c. g. shift. The gimbal position is also modified by steering commands from the AGC so that the thrust vector will point in the right direction for the curved trajectory.

The BMAG/AGCU loop remains open and follows IMU changes so that the SCS will have the same inertial reference in the event a switchover to SCS delta V mode is necessary.

Normally, G&N delta V mode utilizes the primary gimbal servo and actuator motor No. 1. If the gimbal motor switches on MDC-3 are activated, a TVC monitor signal generator (over-undercurrent sensor) in the actuator will sense a failure of motor No. 1. If motor No. 1 fails, the sensor will automatically cause a switchover to motor No. 2 in the actuator. Since the No. 2 servo electronics are driven simultaneously with No. 1, an interruption during the velocity change will not occur. Motor No. 2 also contains a TVC monitor signal generator, but is not used. In the event of motor No. 2 failure, causing an excessive current drain on the d-c bus, a 70-ampere circuit breaker in the line will disconnect the motor from the d-c supply bus. Motor No. 2 has no switchover or warning light capability.

In SCS delta V mode, the gimbal servo loops function the same as in G&N delta V mode. Attitude error information, however, is derived from the BMAGS. The rate loop is identical, unless in backup rate condition. SCS delta V will not function if the BMAGS are required for backup rate because of the loss of attitude error information.

SCS delta V keeps the thrust vector through the c. g. by first comparing the trim position commands set by the gimbal position thumbwheels and the position transducer feedback signals. The difference, combined with attitude error information from the BMAGs, conditions the servo electronics to energize the actuator clutches.

Except for mode selection and thrust-on requirements, the same prerequisites for thrust-on, and the control and display functions are the same as for G&N delta V. The SCS system does not provide automatic thrust-on. A thrust-on switch on the delta V display provides the thrust-on command for SCS delta V mode. Thrust-off, however, is automatic by closing of the coincidence switch. A NORMAL-OFF-DIRECT-ON switch on the delta V display is also provided for manual thrust-on and serves as a manual backup for all automatic thrust-off commands.

If the translation controller cannot be used for the ullage maneuver prior to thrust-on, a DIRECT ULLAGE switch on the delta V display provides a manual backup to initiate ullage.

A manual delta V can be performed, providing a delta V mode has been selected and the translation control is rotated CW into detent. This removes all normal inputs into the TVC servo loops, allows commanded inputs from the rotation control, and rate data from the BMAGs in backup-rate condition, into the redundant No. 2 servo electronics and motor No. 2 of the gimbal actuators. This provides rate-stabilized manual control of the thrust vector. Thrust-on is initiated by the momentary thrust-on switch located on the delta V display.

The rotation control must be held to a given displacement to control the gimbals about the initial trim position established by the settings of the AS/GPI. The GPI provides the only indication of the position of the gimbal angles with respect to the S/C body axes.

2.3.3 FLIGHT CONTROL PROFILES.

There are three basic flight control profiles associated with mission AS204A. These include powered flight, coasting flight, and entry. Within these profiles, various modes of operation are established either within the atmosphere or in earth orbital environment. Because of the division of powered flight, i.e., ascent and earth orbital environment, the description is divided as follows:

- Ascent (including aborts)
- Coasting flight (earth orbital)
- Powered flight (earth orbital)
- Entry (nonpowered atmospheric flight).

As the various operational modes are discussed, reference will be made to figures 2.3-4, 2.3-5, and 2.3-6. A typical control channel yaw is shown in figure 2.3-4, sheet 2; therefore, differences not typical to the yaw channel will be clarified.

It should be noted that relays in figures 2.3-4, 2.3-5, and 2.3-7 are not relays of the actual system by number. However, the relay nomenclature is system oriented and may be cross-referenced by using the following chart.

Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
K1	ORBIT RATE	24A14K3
K2	FDAI ALIGN	24A14K1
		24A14K2
K3	G&N ROLL, PITCH, YAW ATT SIN AND COS	22A16A3K4
		22A16A3K6
		22A17A3K4
		22A17A3K6
		22A18A3K4
		22A18A3K6
K4	AGCU CAGED	22A8K1
		22A8K2
		22A8K4
		22A8K5
K5	AGCU ALIGN	22A8K6
		22A8K7

Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
K6	AGCU P/Y ERROR	21A3K2
K7	R G&N ERR/AGCU INH	22A3K3
	G&N P ERR	20A3K3
	Y ERR G&N BODY	21A3K3
K8	G&N P, Y, ERR S.F.	22A20A3K1
		22A21A3K1
K9	ROLL, PITCH, YAW ERR AGAA	22A20A3K4
		22A21A3K4
	MONITOR + G&N ΔV + G&N ATT CONTR + G&N ENTRY +.05G MANUAL + AS + YAW B/U RATE	22A23A3K2
K10	ROLL, PITCH, YAW, B/U RATE	22A9K1
		22A9K2
		22A13K1
		22A13K2
		22A11K1
		22A11K2
K11	MTVC RT OUT	22A9K3
		22A11K3
		22A12K3
K12	ROLL, PITCH, YAW RATE	22A23A3
		22A20A3
		22A21A3K
K13	Y/P RT SF	22A22A3
K14	R-Y RT CPLG	23A11K2
K15	RT IN TRANS	23A19K1
		23A19K1
		19A26K1
K16	ENT GAIN	23A15K1
		23A15K2
		23A17K2
K17	G&N ATT IN	23A19K2
K18	AGAA ATT IN	23A19K3
K19	D-B CHG	23A15K3
K20	RJC ATT SW	23A11K1
K21	G&N MIN IMP ENABLE	23A13K
K22	PSUEDO RT CO	23A13K
K23	RCS LATCHING RELAY ARMED (JET DVRS ENABLED) SAFE (JET DVRS DISABLED)	MESC Z19
K24	1.8 SEC LATCH	MESC Z8

Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
		MESC Z12
K25	MAIN DEPLOY	23A11K3
K26	AUTO CONT INTER	23A21K2
K27	ENG IGN	23A21K3
K28	SYS GRD CK	23A21K1
K29	SCS ΔV MODE	23A27K1
K30	ENG IGN	23A18K2
K31	MTVC ENGAGE	23A25K1
K32	TVC ELEC TRANS	23A14K1
K33	SERVO NO. 1 DISENGAGE	23A18K1
K34	SERVO NO. 2 ENGAGE	22A8K8
K35	ENTRY	22A21A3K6
K36	ΔV INH	22A20A3K6
K38	THRUST ON LAMP	

2.3.3.1 Ascent.

During the ascent phase, capability exists for monitoring boost vehicle stability. The SCS is in a monitor mode with all subsystems active, but supplies no active commands for control purposes for the first 61 seconds of flight. After 61 seconds, if aborts are required, the SCS will be used to supply signals for S/C stabilization and control.

2.3.3.1.1 Monitor Mode.

The monitor mode provides the capability of monitoring deviations from programmed launch vehicle attitude prior to S-IB separation and CSM attitude after S-IVB separation. The S-IVB utilizes a different guidance technique and monitoring C/M instruments relative to S-IVB operation provides no useful purpose. Monitor mode also provides rate stabilization, when required, any time during the mission.

Normal Ascent. At time of launch, RCS latching relays in the SECS system will be open to inhibit commands to the RCS jets. Relays K4 and K5 will be closed, providing BMAG/AGCU closed loop. The FDAI will be following IMU gimbal angle changes. The motor-driven switch 5 (figure 2.3-7) is set to the S/M position when the REACTON CONTROL SYS—TRANS C/M-S/M switch on MDC - 16 is set to S/M.

Total attitude and attitude error signals from the IMU and inertial CDU (figure 2.3-4, sheet 1) are applied to the FDAI through relays K3, K7, and K8, respectively. Attitude error signals represent deviations from the trajectory for the first stage booster only. The SCS rate gyros apply attitude rates to the SCS electronics directly and to the FDAI via relay K12.

The X-axis accelerometer will be active, but its output will be used only if an abort delta V is required. The TVC subsystem is activated to hold the SPS engine thrust vector through the c.g. in the event of an SPS abort, and to keep the nozzle centered and stationary within the adapter. The SPS engine gimbals are aligned to null offset (pitch +0.4 degrees and yaw +3.6 degrees) prior to launch. Quiecsent current on the gimbal motor clutches maintains these angles during ascent.

LES Abort. If an LES abort is initiated (61 seconds or more after lift-off) requiring SCS operation, the SCS is enabled one second after LES ignition. The SCS is enabled by the arming of the RCS latching relays in the SECS, and the S/M-C/M transfer switch will be driven to the C/M position. The RCS latching relay will open by the operation of a barometric switch at approximately 24,000 feet during descent and will disable active commands to the C/M RCS. Besides rate stabilization, specific command inputs to the SCS above 24,000 feet will depend on altitude and other factors.

SPS Abort. An SPS abort would be initiated after the LES jettison. The translation control is rotated CCW into detent and the switch closure will cause the MESC to command a +X translation (separation ullage) via the direct coils of the S/M RCS. The direct coils are activated through the RCS transfer switch.

Before separation from the S-IVB, a delta V mode must be selected. For an SPS abort, alignment of the SPS engine gimbals is not required since they were preset prior to launch and no propellant has been consumed. At separation, an abort can be made into earth orbit or to a downrange landing site.

2.3.3.2 Coasting Flight (Earth Orbital).

The coasting flight profile ranges from a free-drift configuration (no control) to monitor mode (passive) to attitude hold (active control). The following paragraphs describe the various modes relative to the earth orbital environment.

2.3.3.2.1 G&N Attitude Control.

G&N attitude control will provide inertially stabilized attitude by utilizing the attitude reference and attitude control subsystems. Attitude data is obtained from the inertially referenced IMU. Relays K4 and K5 provide BMAG/AGCU closed loop so that if SCS attitude control is selected, the AGCU will have the same reference as the IMU for control and display purposes.

Attitude errors from the inertial CDU through relays K7 and K8 are applied to the FDAI and SCS electronics for attitude error display, and to provide attitude corrections. The errors from the CDU are the difference between the IMU gimbal angles and the commanded output of the AGC. Total attitude from the IMU is applied to the FDAI via relay K3. The

attitude rates from the SCS rate gyro and relay K12 will drive the FDAI rate indicator at a scale range of ±1 degree/second.

The maximum deadband limit is normally set for G&N attitude control. If navigation sightings are required, the minimum deadband may be selected. The G&N system and SCS attitude control subsystem will maintain attitude within the selected deadband limits.

Maneuvering. Automatic maneuvers may be executed by inserting commands into the AGC via the DSKY. The S/C will automatically maneuver to the computer-commanded attitude. The SCS will follow the attitude error signal inputs from the CDU in response to AGC inputs for maneuvering to the commanded attitude. Manual maneuvers can be commanded with or without attitude hold.

In G&N mode, relay K18 (figure 2.3-7) is open. Relay K17 is closed. Relay K18 inhibits BMAG inputs and allows G&N attitude error signals into the jet selection logic for the attitude hold function. When the rotation control is displaced, the breakout switches open K17, inhibiting G&N signals and allowing proportional command (rotation control plus rate gyro) signals into the jet selection logic. When the control is returned to neutral, relay K17 closes and the G&N attitude hold function is restored, provided G&N sync is active.

Translation in all axes can be commanded by the translation control. As shown in figure 2.3-5, switch closures within the control apply command signals directly to the jet selection logic and, subsequently, to the auto RCS coils. Attitude hold is a normal function when translations are initiated, using the translation control.

The direct ullage switch on the delta V display is a backup for +X translations. When this switch is activated, the signal is applied directly to the RCS direct coils. Attitude hold is not a function of direct ullage.

Attitude impulse control (panel 105, LEB) is a manual control capability for G&N and SCS attitude control modes only. Each displacement of the attitude impulse control (figure 2.13-4, sheet 3) provides an output attitude impulse command to two RCS engines for a duration of 18±4 ms. The pulses command body angular rates of approximately 3 arc min/sec.

2.3.3.2.2 G&N Local Vertical.

The G&N local vertical mode is an extension of G&N attitude control. The purpose of this mode of operation is to accurately maintain the S/C X-axis at a fixed angle with respect to the local vertical (relative to the earth surface) while maintaining the S/C Y-axis normal to the orbital plane. The G&N local vertical mode is an AGC-commanded function. A computer program (not available for AS204A mission) is called by the astronaut by DSKY entry. After IMU alignment, with the S/C X-axis in the direction of the desired orbital path, the computer program provides an orbit rate

source to command torquing of the IMU at a rate that will maintain the local vertical attitude. This mode may be used to make navigational sightings of earth landmarks by keeping the G&N optics within the area of the earth surface.

2.3.3.2.3 SCS Attitude Control.

SCS attitude control mode will hold the S/C at an inertial-referenced attitude and will limit S/C drift to the selected deadband limits, normally, ±5 degrees in earth orbit. If SCS attitude control is selected after a G&N attitude control function, the attitude reference subsystem is aligned to the IMU (BMAG/AGCU closed loop). If not, an FDAI/AGCU align function is required.

When SCS attitude control is selected, G&N inputs are removed from the FDAI and SCS electronics. The following relay contacts (figure 2.3-4, sheet 2) are activated to supply SCS-generated commands for display and control purposes.

- Relay K4 open—FDAI ball stationary
- Relay K12—Applies body rates to FDAI
- Relay K3 closed to AGCU—Applies attitude errors to FDAI
- Relay K11B—Applies attitude errors to SCS electronics

FDAI/AGCU Align. If the AGCU has not been aligned to the IMU or if a new attitude reference is desired while in SCS attitude control mode, the astronaut will determine S/C attitude from star sightings or from the MSFN. Inertial angles are dialed into the AS/GPI with the ATTITUDE SET dials and the FDAI ALIGN pushbutton is pressed. Relay K2 closes and the AGCU and FDAI ball will drive to the selected attitude.

Manual Maneuvers. After AGCU reference has been established, the S/C can be maneuvered to the desired attitude reference by flying out the errors, using CSS. The ATT SET/OFF switch is activated, relay K23 is activated, the RCS latching relays are closed to the S/M RCS, relays K6 and K9 close, and K20 will open. Attitude error, equal to the difference between ATTITUDE SET dial position and AGCU resolver shaft position, is then applied to the FDAI from the AGCU through K6. Attitude error from the BMAG is removed from the FDAI when K9 activates. When the rotation control is moved out of detent, CSS commands are applied through the ACS to the jet selection logic and auto coils of the RCS engines. At the same time, relays K4 and K5 close providing BMAG/AGCU closed loop. The BMAGs follow S/C rotation and repositions the FDAI ball. When the rotation control is returned to neutral, the BMAG/AGCU loop is opened, relays K4 and K5 open, and the new attitude will hold within the selected deadband.

When the ATT SET/OFF switch is OFF, relays K6 and K9 de-energize and attitude error signals from the BMAGs are now applied to the FDAI and ACS. If further attitude changes are desired, they can be accomplished by using CSS. The BMAG/AGCU loop will be closed, and opened when the rotation control is returned to neutral. The attitude error needles will indicate the difference between the AGCU and the S/C attitude. The error needles are fly-to needles and will be at full scale if the error is greater than 5 degrees. To fly out the error, the astronaut must fly-to the needles or use the FDAI ball markings until the needles come off full scale, and then fly-to the needle to null the remaining error.

Free Drift. Free drift is normally used during extended periods of time when power and RCS propellant conservation is desired. Free drift can be established in either attitude control mode by placing the SCS CHANNEL switches to OFF, inhibiting all command signals to the RCS auto coils. With an SCS attitude mode selected and an SCS CHANNEL switch to OFF (PITCH or YAW or A&C ROLL and B&D ROLL), relay action closes the BMAG/AGCU loop and updates the ARS while drifting. However, if one BMAG is placed in backup rate and a channel switch is off, relay action rate cages the remaining BMAGs and opens the BMAG/AGCU loop, thus, preventing the ARS from being updated.

2.3.3.2.4 SCS Local Vertical.

SCS local vertical mode is an extension of SCS attitude control. Its purpose is to maintain S/C attitude with respect to the local vertical. When the LCL VERT/OFF switch on MDC-8 is set to LCL VERT, relay K1 energizes and an orbit rate source with a preset level is applied to the BMAG/AGCU servo loop. At present, the preset level established for the orbit rate source is most accurate for a 100-n mi circular orbit and will maintain the attitude reference system at the local vertical with torque rates of 246 degrees/hour, or 4.1 degrees/minute. It will maintain an approximate attitude when the AGCU is aligned to represent S/C attitude when the S/C XZ plane is parallel to the orbital plane at the time LCL VERT is selected. All three RCS channels must be enabled for the local vertical mode. Modifications of the local vertical attitude can be made using CSS. The translation control is also active and available during this mode of operation

2.3.3.3 Powered Flight (Earth Orbital).

Powered flight includes those modes that provide the capability for velocity changes using the SPS engine. Included in the following discussion are the G&N delta V, SCS delta V, and the manual delta V modes.

2.3.3.3.1 G&N Delta V.

G&N delta V mode is the normal method for velocity changes. Prior to engine ignition, however, G&N attitude control mode must be established.

System relays apply the following (G&N/SCS switch on MDC-8 set to G&N and ATTITUDE/MONITOR/ENTRY switch set to ATTITUDE (figure 2.3-5, sheet 1)):

- Relay K7 and K8—Attitude error from CDUs to FDAI
- Relay K9—Attitude error from CDUs to SCS electronics
- Relay K3—Total attitude from IMU to FDAI ball
- Body rates to FDAI and SCS electronics
- RCS latching relay in MESC closed to RCS system

The FCSM-SCS-RESET/OVERRIDE and G&N-RESET/OVERRIDE switches on MDC-2 may be set to SCS and G&N positions. These switches provide an automatic monitoring of SPS engine combustion performance. If rough combustion occurs, the SPS ROUGH ECO warning light on MDC-10 will light and engine thrust will terminate. A restart can be made by resetting the FCSM switches and then setting them back to SCS and G&N. Or, the monitor can be bypassed by setting the FCSM switches to RESET/OVERRIDE.

Attitude information from the IMU is displayed on the FDAI ball. Attitude errors from the CDUs are also applied to the FDAI (±5-degree scale) and are used by the SCS to control attitude in response to AGC commands. Rotational rates are displayed by the FDAI rate indicators with a scale range of ±5 degrees/second. The computer-controlled velocity change will be monitored on the delta V display. The required velocity less tailoff will be set into the delta V display by the ΔV SET switch, using velocity information obtained from the G&N system or MSFN. Minimum deadband is set on MDC-8, the gimbal motor switches, and the inject pre-valve switches on MDC-3 are activated. The SPS gimbal trim angles are determined, set into the AS/GPI by the gimbal position thumbwheels, and gimbal position verified on the GPI. The NORMAL/OFF/DIRECT switch on the delta V display is set to normal.

Approximately 15 seconds prior to ignition, after the digital event timer (MDC-5 and 8) has been set for countdown, the astronaut will command a +X ullage using the translation control. At T = 0, the AGC will command a signal through the thrust on-off logic and enable the solenoid drivers of the TVC subsystem. The solenoid drivers will then activate the SPS engine ignition coils and SPS thrusting will occur. The lamp portion of the THRUST ON switch on the delta V display will light, verifying the automatic computer command.

System delay (AUTO CONT INTER) logic will terminate the RCS ullage approximately one second after SPS ignition. The computer will command pitch and yaw attitude of the SPS gimbals via the TVC to control the thrust vector. Roll commands will be applied to the roll RCS during the maneuver.

When the delta V remaining counter indicates zero, thrusting will terminate and the THRUST ON light will go out. The NORMAL/OFF/DIRECT ON switch will be set to OFF and the SPS motor switches, inject pre-valves, and the TVC electronics will be de-activated. Approximately one second after thrust terminates, pitch and yaw control is transferred back to the SCS for the attitude control function.

If a malfunction occurs during the maneuver, a switchover to SCS delta V will allow continuation of the velocity change. If there is no response from the translation control at ullage initiation, the DIRECT ULLAGE pushbutton on the delta V display may be used for the ullage maneuver prior to ignition of the SPS engine. Also, if automatic thrust-on does not occur at T = 0, the THRUST ON pushbutton on the delta V display will provide engine ignition.

2.3.3.3.2 SCS Delta V.

SCS delta V mode is a primary backup for the G&N delta V. Preliminary to engine ignition, SCS attitude control is established by setting the G&N/SCS switch on MDC-8 to SCS. After SPS engine ignition, the SCS uses S/M RCS roll jets to maintain roll attitude and applies commands to the SPS engine gimbals to control the thrust vector. Relays in figure 2.3-4 apply the following (RCS latching relay in the SECS is closed to the S/M RCS throughout the maneuver):

- Relays K9 and K10—Attitude errors from BMAGs to FDAI
- Relay K11B—Attitude errors from BMAGs to SCS electronics
- Relays K4 and K5 open—FDAI ball stationary
- Body rates to FDAI and SCS electronics (RGA).

The control and display activation process that was performed for the G&N delta V will be performed for SCS delta V. The major differences are as follows:

- Control of attitude and the thrust vector is through the SCS.
- At T = 0, ignition is initiated manually by pressing the THRUST ON pushbutton on the delta V display.
- Thrust is terminated automatically when the ΔV remaining counter (delta V pot.) indicates zero.

As in the G&N delta V mode, if the required command responses to not occur, the same backup controls can be used to perform the delta V.

In SCS delta V mode, if engine ignition does not occur when the THRUST ON switch is pressed, the NORMAL/OFF/DIRECT ON switch can be set to DIRECT ON. This applies a command signal directly to the SPS engine ignition coils and will initiate thrusting. The NORMAL/OFF/DIRECT ON switch must be set to OFF to terminate engine thrust.

2.3.3.3.3 Manual Delta V (MTVC).

A manual delta V will be performed only as a backup to a G&N or SCS delta V. Manual thrust vector control is initiated by a CW rotation of the translation control into detent. At this time, relays K4 and K5 will close, providing rate caging of all three BMAGs; and relays K10 and K11B will open removing rate gyro outputs from the FDAI and SCS electronics. The rate-caged BMAGs through relay and K12 will switch BMAG backup-rate signals into the SCS electronics.

In the G&N and SCS delta V modes, TVC servo electronics No. 1 and SPS gimbal drive motor No. 1 was used. When MTVC is initiated, relays K32, K33, and K34 activate. This closes the servo loop for commanding SPS gimbal drive motor No. 2.

Gimbal trim commands are applied through relay K31. When the rotation control is moved out of detent, pitch and yaw commands are applied to motor No. 2 through relay K31 and gimbal position feedback is through relay K32.

The summation of backup rate and proportional CSS commands into the TVC provides a rate-damped manual control of the engine gimbals. The astronaut must keep the rotation control at a given displacement to keep the thrust vector through the c.g. and to fly the correct trajectory.

If CW switches of the translation control are engaged while in G&N delta V, G&N attitude control, or G&N entry mode, attitude errors are not removed from the FDAI. This allows the astronaut to monitor and, if necessary, fly a G&N programmed maneuver using CSS.

2.3.3.4 Entry.

The entry profile consists of the various methods of controlling the S/C for the entry phase of the mission. The entry mode is normally selected after S/M-C/M separation. At separation, the motor-driven RCS transfer switches are closed to the C/M RCS.

2.3.3.4.1 G&N Entry.

G&N manual mode is the primary method of control for entry into the atmosphere for the AS204A mission. Automatic entry may be used in lieu of G&N manual mode.

G&N Manual. This is normally a backup for the G&N entry automatic mode. The translation control is rotated CW into detent. This removes inertial CDU attitude errors from the SCS electronics. Normally, the astronauts will call up the entry program via the DSKY shortly after S/M-C/M separation.

The entry angle, required pullout angle, and other required entry data is presented on the computer displays. The astronaut can manually perform a controlled g-level entry by using CSS to fly out the commanded attitude errors displayed on the FDAI. The BMAG/AGCU has been closed loop for backup reference in case switchover is necessary.

After .05 g, aerodynamic forces build up sufficiently to stabilize the S/C in the pitch and yaw axes. At this time, CSS will be effective in the roll channel only. The SCS will rate-damp the pitch and yaw channels, and the astronauts will have steering capability by using roll CSS to control the lift vector.

Automatic Entry. The FDAI rate display scale range changes to ±25 degrees/second in roll, and ±5 degrees/second in pitch and yaw. Deadband is maximum. The rate deadband is ±2 degrees/sec.

Prior to .05 G switching, attitude error from the inertial CDUs is applied to the FDAI error indicator through relays K7 and K8, and to the SCS electronics through relay K9. The RGA applies rate gyro body rates to the FDAI and SCS electronics. Relay K3 applies total attitude to the FDAI ball.

At .05 g, the .05 G ENTRY/OFF switch on MDC-8 is set to .05 G ENTRY. The SCS pitch and yaw channels perform rate stabilization only. The roll channel is still subject to computer-controlled roll commands. The AGC will fly the S/C according to a pre-established entry program.

2.3.3.4.2 SCS Entry.

The SCS entry mode is a primary backup to G&N entry mode. When selected, total attitude information to the FDAI is supplied throughout the entry. Prior to .05 g, the BMAGs apply attitude errors to the FDAI and SCS electronics through relays K3 and K9. After .05 g, relays K3 and K9 remove attitude errors from the FDAI and SCS electronics. Relays K4 and K5 close, providing BMAG/AGCU closed loop. For the remainder of entry, attitude errors are not displayed. There is no attitude hold capability. The rate gyros, however, provide rate signals for rate stabilization. The SCS electronics increase rates to a 2-degree/second rate deadband. The FDAI displays total attitude. The astronauts will initiate the necessary commands using CSS to fly a controlled g-level entry. After aerodynamics stability in pitch and yaw, steering capability will be in the roll channel only.

If, after .05 g, it is necessary to place a BMAG in backup rate, only the BMAG selected by the rate gyro select switch will have its inputs in the SCS for rate stabilization. When backup rate is selected, relays K9, K10, K12, and K15 activate, providing backup rate to the FDAI and SCS electronics. Loss of FDAI ball reference will occur. Relay K12 removes rate gyro output from the FDAI and SCS electronics. The astronauts will control the lift vector with the CSS roll channel. If they wish to decrease the g level, they will roll the S/C to keep the lift vector up. If they wish to increase the g level, they will roll the S/C so that the lift vector is down.

2.3.4 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The SCS consists of the following major components:

- Rate gyro assembly (RGA)
- Attitude gyro accelerometer assembly (AGAA)
- Pitch electronic control assembly (pitch ECA)
- Roll electronic control assembly (roll ECA)
- Yaw electronic control assembly (yaw ECA)
- Auxiliary electronic control assembly (aux ECA)
- Display and attitude gyro accelerometer assembly electronic control assembly (DISPLAY-AGAA ECA)
- Rotation control
- Translation control
- Flight director attitude indicator (FDAI)
- Attitude set/gimbal position indicator (AS/GPI)
- Velocity change indicator (ΔV display).

2.3.4.1 Rate Gyro Assembly.

The rate gyro assembly contains three identical rate gyros, mounted orthogonally along the spacecraft body axes, and associated gyro electronics. No provision is made for heaters or temperature control of the gyros. Each gyro is a single-axis unit, with the input axis determined by the gyro mounting fixture. Self-test capabilities are provided by torquing coils which enable the gyro to be displaced at a known rate and by spin motor rotation detection circuits which allow monitoring of the gyro spin motor speed. All self-test circuits are completely isolated from operational circuits to prevent a failure in the former from affecting gyro

operation. The gyro outputs are used by the SCS as primary damping or stabilization signals and, in addition, as negative feedback to null rotational control commands and provide a proportional maneuver rate capability. The rate gyros also provide an indication on the FDAI of the rate-of-attitude change in pitch, roll, and yaw axes. An attitude change about any of the axes results in an output signal which is representative of the rate of displacement.

Each miniature rate gyro assembly consists of a spin motor, damping system, gimbal assembly, quadrilever spring, and self-check circuitry. The gyro spin motor is a 400-cps 3-phase synchronous hysteresis motor powered by 26 volts ac. The maximum time allowed for the gyro to come up to operating speed is 17 seconds. Damping is accomplished by positive displacement of the damping fluid through temperature-controlled orifices. The quadrilever spring provides the torsional restraint required by the gyro, together with radial support for the gimbal assembly. Some important rate gyro characteristics are as follows:

Full-scale range	30°/sec
Input range (to limit stop)	30°/sec
Maximum rate without damage	600°/sec

2.3.4.2 Attitude Gyro Accelerometer Assembly.

The attitude gyro accelerometer assembly contains three body-mounted attitude gyros (BMAGs) and an accelerometer. Electronic control circuits for the gyros and accelerometer are contained in the display and attitude gyro accelerometer assembly electronic control assembly.

2.3.4.2.1 Body-Mounted Attitude Gyros.

The three BMAGs are identical units, mounted orthogonally along the spacecraft body axes, to sense attitude displacement along the pitch, roll, and yaw axes. Each gyro is a single-axis unit, with the input axis determined by the physical mounting in the S/C. A spin motor detection circuit is included in each gyro to allow monitoring of gyro spin motor speed. This will be telemetered data only.

The BMAGs provide information denoting the angular displacement of the spacecraft from a preset attitude. They are initially set to a specific space-stabilized orientation; thereafter, any displacement from this initial setting results in output signals which are representative of the amount of angular displacement. The output signals are used to produce attitude error signals for an attitude-hold mode or for display on the flight director attitude indicator. The outputs may also be applied to the attitude gyro coupler unit (AGCU) for attitude change storage and for conversion to inertial measurement unit (IMU) axes. IMU axes differ from the spacecraft body axes. The AGCU and BMAGs are used as a substitute or backup inertial reference unit for the IMU during the periods when the IMU is

turned off or has malfunctioned. The BMAGs can also be used to produce attitude rate-of-change information, as backup for the rate gyros.

The BMAGs are single-degree-of-freedom, miniature integrating gyros contained in electrically heated individual packages. The heater will maintain individual BMAG temperature at 170±2°F. Degraded gyro operation will result if this temperature is not maintained. The gyro spin motors are 3-phase 24,000-rpm synchronous devices, powered by 13.6 volts 400 cps from a supply in the attitude gyro accelerometer package electronic control assembly. With C/M temperature at 80°F and the mounting plate temperature at 55°F, the maximum time allowed for the BMAG to reach operating limits is 40 minutes. A few gyro characteristics are listed as follows.

Acceleration sensitive drift	4 deg/hr
Maximum self-torquing rate	25 deg/sec
Maximum attitude range	±20 deg
AGCU coupled torquing limits	20° sec roll, 5° sec pitch and yaw

2.3.4.2.2 Accelerometer.

The accelerometer is mounted along the spacecraft X-axis to sense velocity changes along this axis. It is a pendulous-type accelerometer with electronic null and balance. The temperature is maintained at 170±2°F under normal operating conditions. A signal output is generated by a velocity change along the X-axis. This velocity change causes the pendulous mass to move, resulting in a change of coupling between the primary and secondary windings of a signal generator. This results in an output signal which is demodulated and amplified to provide acceleration information in the form of digital signals to a counter in the delta V display (paragraph 2.3.4.10). The pendulous mass is returned to null by the balancing action of the electronic caging signal when the velocity change ceases.

2.3.4.3 Pitch, Roll, and Yaw Electronic Control Assemblies.

The pitch, yaw, and roll electronic control assemblies (ECAs) are nearly identical, with slight differences due to different requirements for each axis. The ECAs provide the circuitry for input control signal processing and SCS mode control and configuration. Input control signals consist of attitude error signals from the SCS BMAGs and from the G&N system, minimum impulse commands, rate gyro angular signals, translation and rotation control commands, service propulsion engine gimbal position commands, and SPS engine gimbal rate and position feedback signals. Mode control inputs are received from switches on panel 8 of the main display console (MDC). These input signals are applied to logic-controlled relays which enable circuit configurations corresponding to the desired mode. ECA output signals consist of reaction jet firing commands and SPS gimbal position commands. The reaction jet commands are generated in the jet selection logic portions of the ECAs. Preignition SPS engine gimbal position commands are generated manually at the AS/GPI by thumbwheels which provide input signals to the gimbal control circuits. Post-ignition

gimbal control is provided by automatic thrust vector control (TVC) circuitry in the pitch and yaw ECAs.

2.3.4.4 Auxiliary Electronic Control Assembly.

The auxiliary electronic control assembly contains the attitude gyro coupling unit and service propulsion system thrust on-off command circuitry. The AGCU portion of the auxiliary ECA receives BMAG signals from the DISPLAY-AGAA ECA and processes the data for display on the FDAI. It also transforms attitude set dial signals to body axes. The SPS engine on-off control circuitry in the AUX ECA receives engine on-off commands from the G&N system or the SCS. These commands are conditioned and applied to the SPS engine solenoid valves.

2.3.4.5 Display and Attitude Gyro Accelerometer Assembly Electronic Control Assembly.

The display and attitude gyro accelerometer assembly electronic control assembly provides the electronic circuitry required to control and power the displays, BMAGs, and accelerometer. The DISPLAY ECA portion consists of the circuitry necessary to receive and condition the following:

- Attitude error signals from the G&N system or the BMAGs to the FDAI attitude error indicators
- Attitude rate-of-change signals from the rate gyros or BMAGs to the FDAI attitude rate indicators
- Feedback signals from the SPS engine gimbals to the gimbal position indicators
- Accelerometer signals from the AGAA to the delta V display integrator.

The AGAA ECA portion consists of circuitry necessary to accomplish the following:

- Accept and condition BMAG inputs for the AGCU
- Accept and condition AGCU torquing commands to the BMAGs
- Control BMAG and accelerometer temperature controls
- Control and condition the accelerometer rebalance loop and inputs to the integrator
- Supply reference voltages to the BMAGs and accelerometer
- Condition the BMAG and accelerometer outputs to telemetry.

2.3.4.6 Rotation Controls.

Two identical rotation controls are provided to enable manual command of the spacecraft attitude (figure 2.3-8). Each control is a control stick containing breakout switches and transducers (figure 2.3-9) which apply control signals to the reaction jet selection logic circuitry in the pitch, yaw, and roll ECAs. When the stick is moved, the breakout switches close the loop between the BMAGs and AGCU, and control signals from the pitch, yaw, and roll transducers are applied to the appropriate control ECAs. Proportional response to the control stick movement is provided by rate gyro feedback to the ECA electronics (figure 2.3-10). The reaction jet solenoids can also be controlled via the direct application of control voltages from switches in the controller. The latter method, requiring use of the DIRECT MODE switch on MDC-8, does not provide proportional response. With the direct mode enabled and the stick commanding a rotation about one axis, the rate damping circuits in the other axes are active.

Provision is made to mount the controls at four different locations in the C/M: the right armrest of the left crew couch, both armrests of the right crew couch, and at the navigation station in the lower equipment bay. Normally, one control is attached to the left crew couch mount and the other is used at any of the other three locations. Simultaneous operation of both controls is possible but not advised; however, each control has a locking device to prevent inadvertent operation.

2.3.4.7 Translation Controls.

Two identical translation controls are provided to enable manual command of spacecraft translational maneuvers. (See figure 2.3-8.) Each control is a T-handle type control stick containing switches, which apply control signals to the reaction jet selection logic circuitry in the pitch, yaw, and roll ECSs (figure 2.3-11). The reaction jets are activated in groups of two or four, depending upon the direction of desired translation. Left-right and up-down translations are accomplished by firing two reaction control jets with the same direction of thrust. Forward and reverse translations are accomplished by firing the four forward thrusting or four rearward thrusting reaction control jets. The translation maneuver commanded is in direct response to the direction in which the T-handle is moved.

The primary control has switches which initiate a spacecraft abort if the T-handle is rotated counterclockwise. Both controls have switches which enable manual thrust vector control and disable automatic attitude control if the T-handle is rotated clockwise. Each control has a locking device to prevent inadvertent operation of the translation control.

Both controls are mounted in the C/M on the left armrest of the crew couch. The primary control is identified with yellow stripes and is the only one provided with abort switching capability.

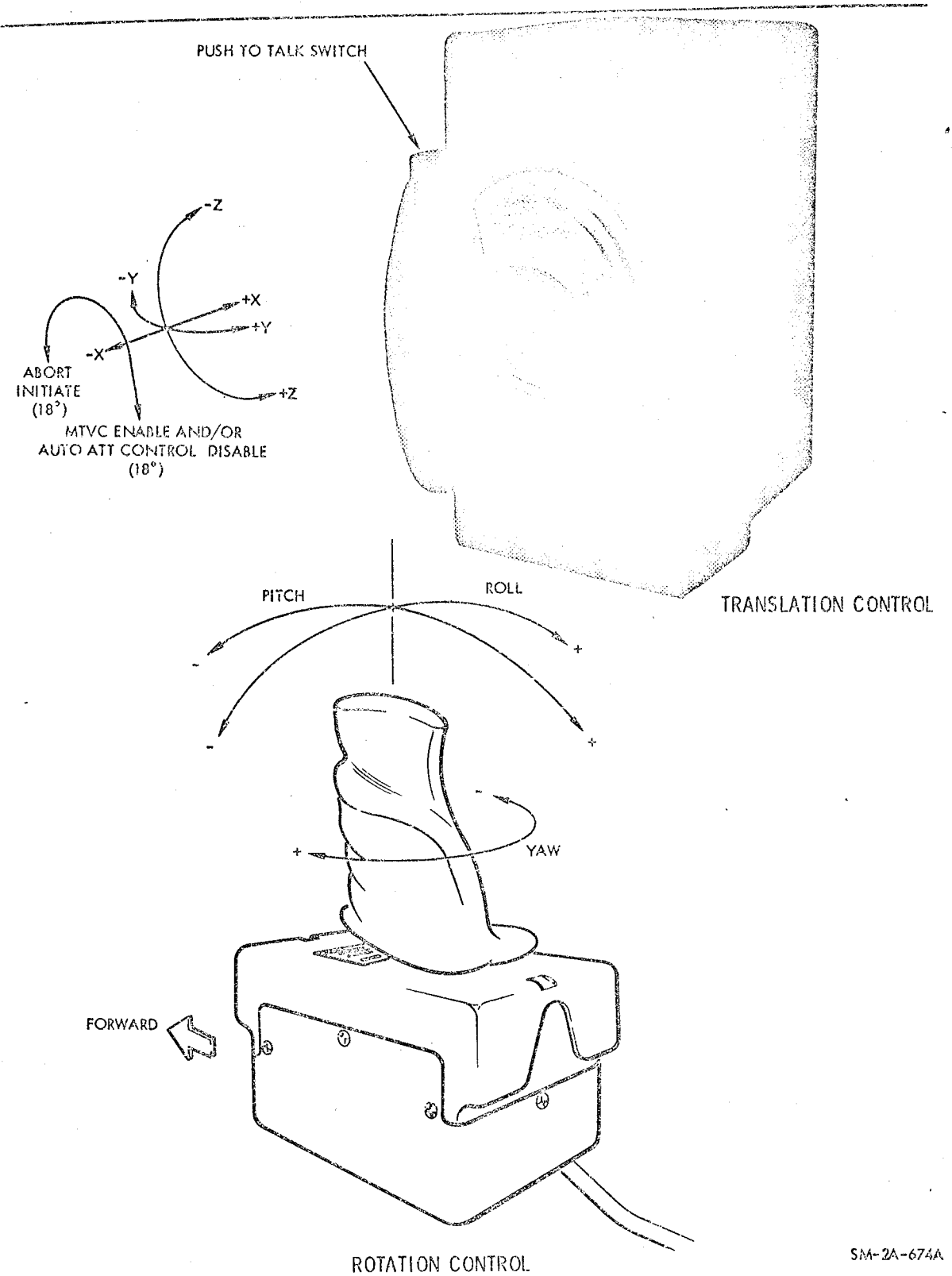
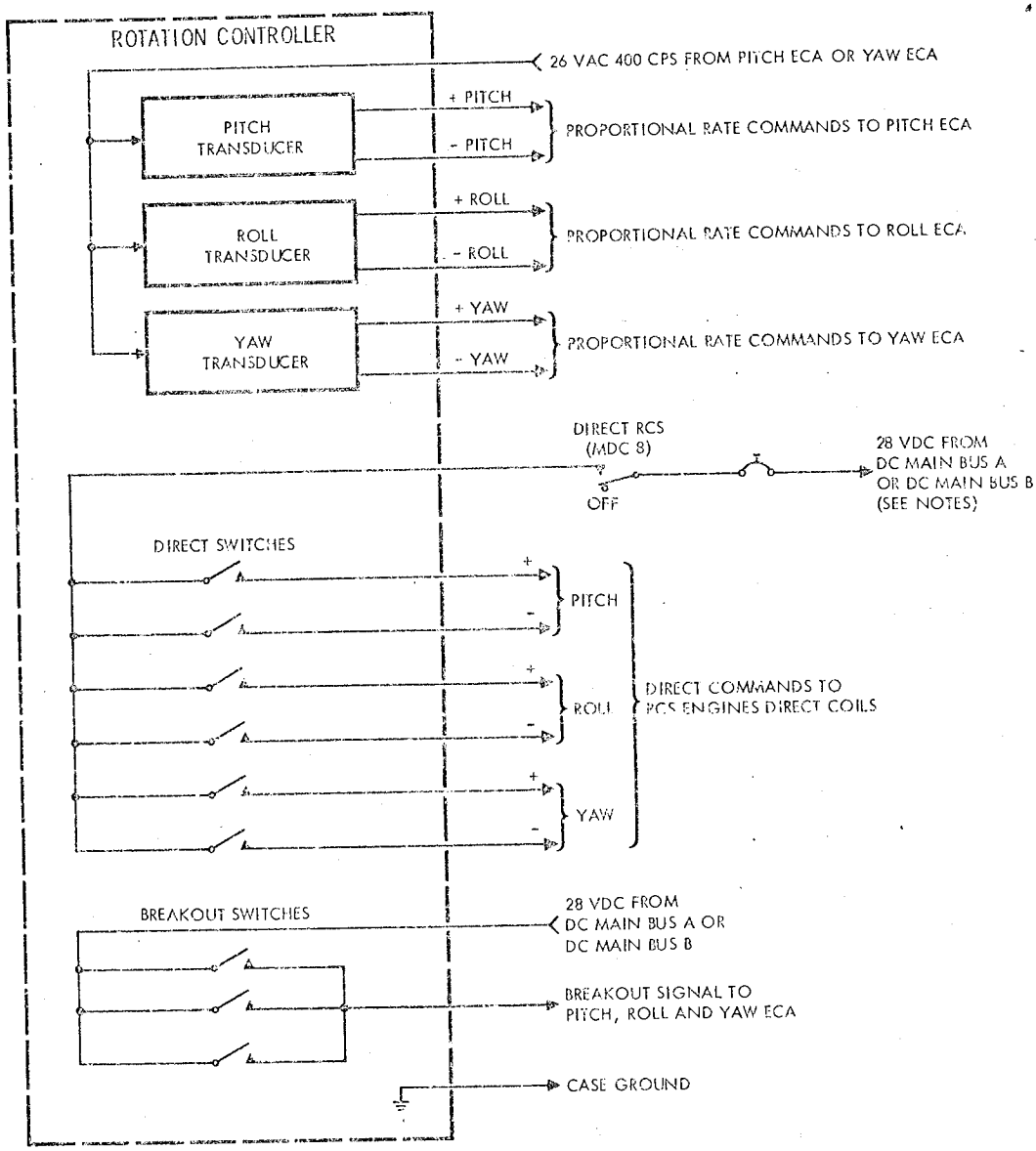


Figure 2.3-8. Rotation and Translation Controls



NOTES: 1. DC main bus A supplies power to direct switches in rotation control No. 1.
2. DC main bus B supplies power to direct switches in rotation control No. 2.

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Figure 2.3-9. Rotation Control Schematic

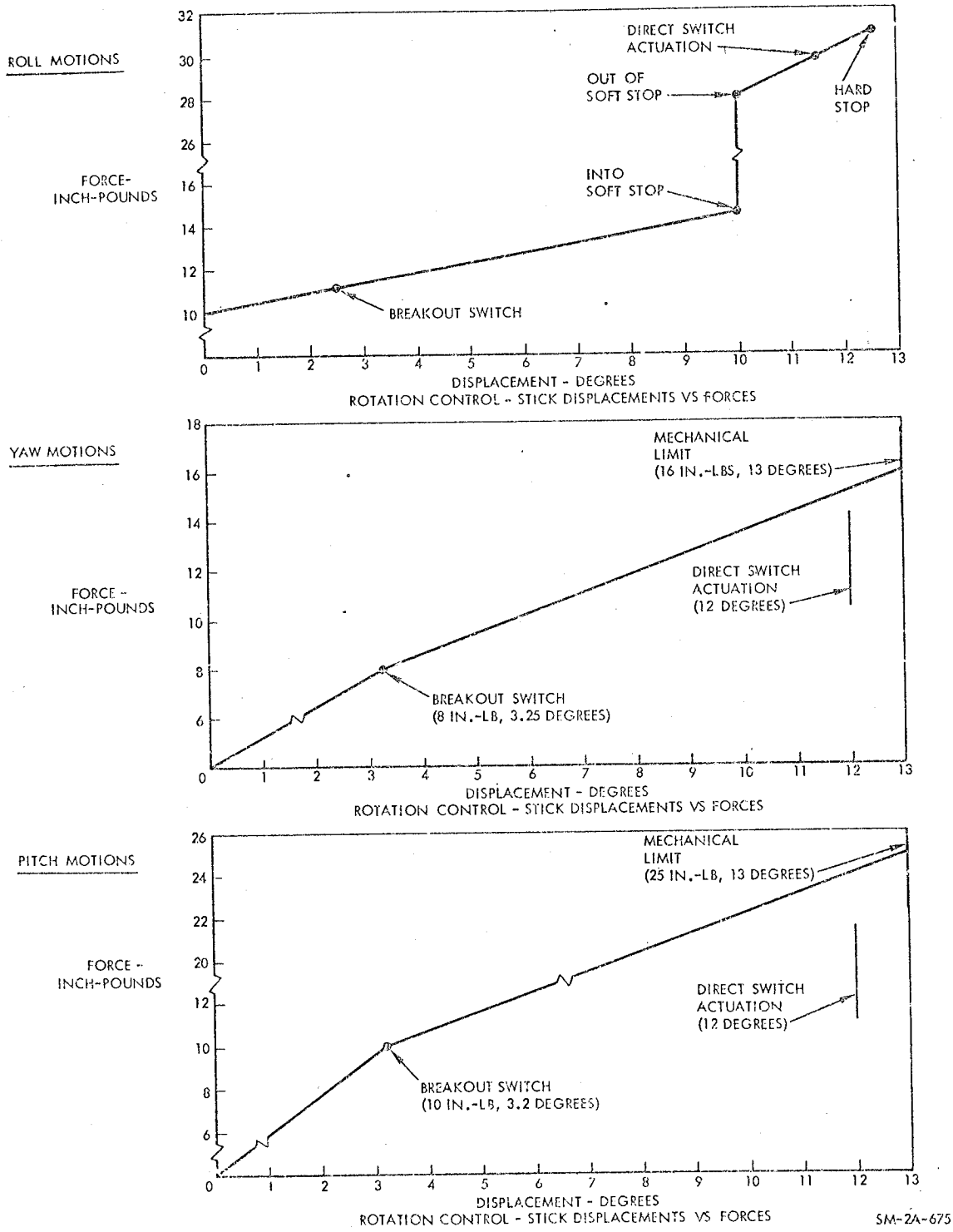


Figure 2.3-10. Rotation Control Charts

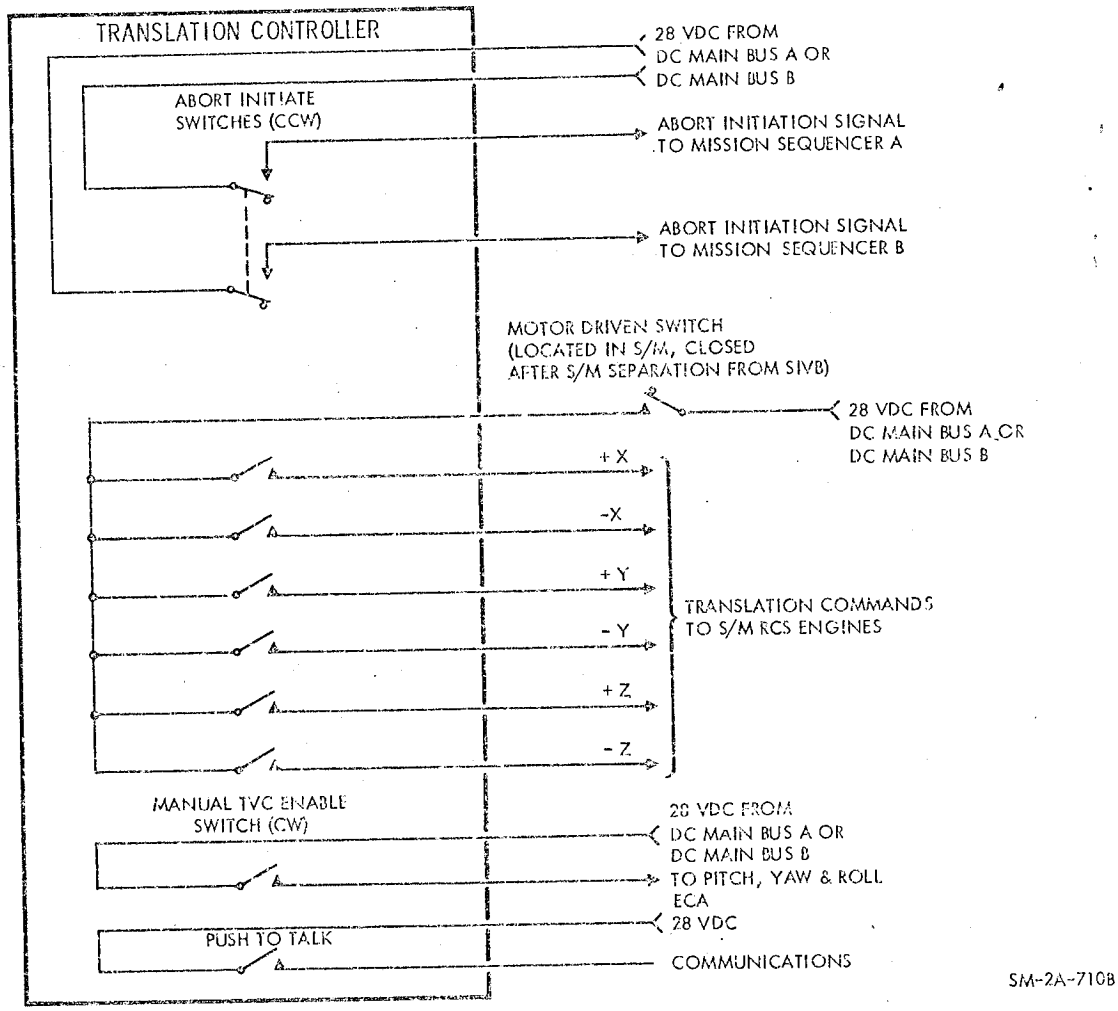
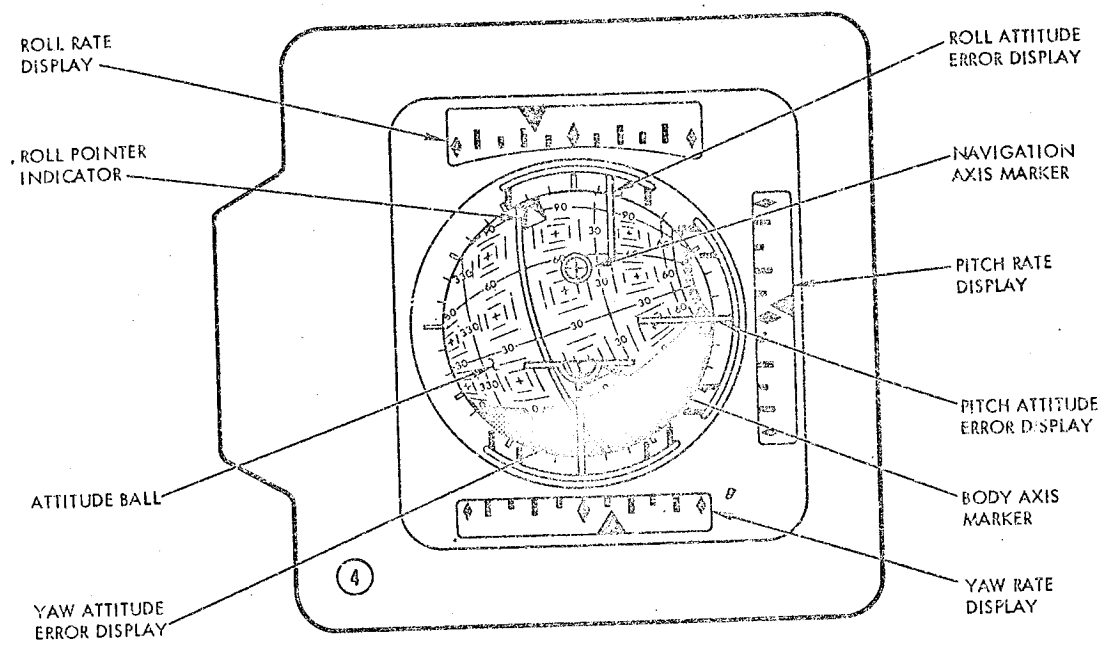


Figure 2.3-11. Translation Control Schematic

2.3.4.8 Flight Director Attitude Indicator.

The flight director attitude indicator, located on MDC-4, provides attitude, attitude error, and attitude rate-of-change display information. (See figure 2.3-12.) The FDAI indicates attitude rate of change and attitude error on indicators and spacecraft attitude on a 3 degree-of-freedom, inertially referenced ball and roll indicator. The roll rate display is located across the top of the FDAI. The pitch rate display is located along the right side of the FDAI. The yaw rate display is located across the bottom of the FDAI. The attitude error displays are pointers which move across the face of the ball. The rate and error displays are fly-to displays. The roll attitude pointer is located at the top and points down towards the center of the ball. The pitch attitude pointer is located at the right and points left toward the center of the ball. The yaw pointer is located at the



DISPLAY	AXIS		
	Pitch (θ)	Yaw (ψ)	Roll (ϕ)
Attitude Ball	+55°	+21°	
Roll "Bug"			+21°
Attitude Error Indicators	0°	0°	-2.5°
Angular Rate Indicators	-.1°/Sec	-.2°/Sec	+.3°/Sec

NOTE: On this illustration, the attitude ball display is read with reference to the navigation axis marker.

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Figure 2.3-12. Flight Director Attitude Indicator

bottom and points up toward the center of the ball. The FDAI is located in the center of the display. The ball face is marked in degrees of pitch and yaw and is referenced to the IMU axes. Two reference markers are located on the face of the display to indicate attitude in reference to either spacecraft body axes or IMU (navigation) axes The body axes marker is on the lower face of the display. The IMU or navigation axes marker is located on the upper face of the display. Roll attitude is the IMU reference and is indicated by the roll indicator (bug) which travels around the circumference of the ball. Roll attitude zero reference is located at the top of the ball.

FDAI display operation will vary, depending upon mode. The rate display is operative at all times. Each rate indicator has a calibrated display scale, with the range of the scale dependent upon the mode selected. Maximum full-scale deflection will be as indicated in the following tabulation.

Mode	Full-Scale Deflection		
	Pitch	Roll	Yaw
Delta V modes	±5°/sec	±5°/sec	±5°/sec
Entry modes and monitor mode	±5°/sec	±25°/sec	±5°/sec
All other modes	±1°/sec	±1°/sec	±1°/sec

The attitude error display function depends upon mode. During attitude hold modes, the attitude error pointers display attitude changes within the selected deadband. The maximum deadband will allow approximately ±5 degrees of spacecraft movement in any axis, which is equivalent to full-scale deflection for the attitude error pointers. This results in easily discernible pointer movement. The minimum deadband allows approximately ±0.5 degrees of spacecraft movement in any axis, which results in very little pointer movement. In SCS control modes, the attitude error signals are derived from the BMAGs or AGCU. The AGCU alone provides the driving signals only when used in conjunction with the ATT SET switch for a dialed attitude change. In G&N modes, the attitude error signals are derived from the G&N coupling display units (CDUs). Full-scale deflection varies depending upon the mode selected, as indicated by the following tabulation.

Mode	Full-Scale Deflection		
	Pitch	Roll	Yaw
Entry modes	±5°	±25°	±5°
Monitor mode	±15°	±25°	±15°
All other modes	±5°	±5°	±5°

The gimbaled attitude ball is colored half gray and half black, with the line of separation at the 0-degree to 180-degree pitch angle. This two-color scheme permits rapid recognition of the specific pitch hemisphere being displayed. There are two concentric circles located at 90-degree yaw/0-degree pitch and 270-degree yaw/0-degree pitch. The inner circles are solid red 30-degree circles which represent the base of a cone with the apex at the center of the ball. This area denotes possible IMU gimbal lock. The outer circles enclose a red 40-degree circle which also represents the base of a cone with the apex at the center of the ball. This area denotes attitudes which result in AGCU inaccuracy. The ball is read against one of two reference marks, depending upon the mode of operation. The IMU axes reference mark is the upper marker (⊕) which indicates spacecraft attitude in pitch and yaw axes with reference to the IMU gimbals or stability axes. The body axes marker is the lower marker (⌒) which indicates spacecraft attitude with reference to the body axes. The included angle between the markers is 32 degrees. The roll indicator is referenced to the zero mark on the periphery of the ball display face in all operational modes. In SCS modes, the ball is driven only during manual maneuvers, during FDAI alignment, and after 0.05 g is sensed during entry. During these functions, the ball is driven by signals received from the AGCU. In G&N modes, the ball displays IMU gimbal angles. Figure 2.3-13 provides a tabular listing of the various FDAI display configurations.

SCS

FLIGHT CONTROL MODES	SCS Entry	SCS ΔV	SCS Local Vertical	SCS Attitude Control
Total Attitude (Ball)	Before 0.05 Gs, ball driven only during manual maneuver or FDAI alignment; after 0.05 Gs driven continuously.	Ball driven only during manual maneuver or FDAI alignment.	Ball driven only during manual maneuver or FDAI alignment.	Ball driven only during manual maneuver or FDAI alignment.
Attitude Errors	BMAGs P & Y±5° max deflection; R±25° max deflection.	BMAGs P, Y, & R±5° max deflection.	BMAGs P, Y, & R±5° max deflection.	BMAGs P, Y, & R±5° max deflection.
Attitude Rate Errors	Rate gyros (BMAGs when backup rate switch actuated). P & ° 5°/sec deflection. R 25°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R±5°/sec deflection.	Rate gyros (BMAGs when backup switch actuated). P, Y, & R±1°/sec deflection.	Rate gyros (BMAGs when backup rate switch activated). P, Y, & R±1°/sec deflection.
Roll Bug	AGCU roll angle	AGCU roll angle	AGCU roll angle	AGCU roll angle

G&N

FLIGHT CONTROL MODES	G&N Entry	G&N ΔV	G&N Attitude Control	Monitor
Total Attitude (Ball)	Ball repeats IMU position.	Ball repeats IMU position.	Ball repeats IMU position.	Ball repeats IMU position
Attitude Errors	CDU P, Y, ±5° max deflection. R±25° max deflection.	CDU P, Y, & R±5° max deflection.	CDU P, Y, & R ±5° max deflection.	CDU P, Y±15°, & R±25° max deflection.
Attitude Rate Errors	Rate gyros (BMAGs when backup rate switch actuated). P & Y±5°/sec deflection. R±25°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R 5°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R 1°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R 5°/sec deflection.
Roll Bug	IMU roll angle	IMU roll angle	IMU roll angle	IMU roll angle

Figure 2.3-13. FDAI Display Configuration

2.3.4.9 Attitude Set/Gimbal Position Indicator.

The attitude set/gimbal position indicator (AS-GPI) provides two separate functions. The attitude set portion enables FDAI-AGCU alignment and provides a reference for acquiring new attitudes. The gimbal position display portion provides positioning control of the SPS engine gimbal angles and displays gimbal position. The attitude set portion provides a comparison of the angle between the attitude displayed on the ATTITUDE SET indicators and the position of the AGCU resolver shaft. It also provides control of the inputs to the FDAI attitude error pointers and aligns the FDAI to the attitude indicated on the ATTITUDE SET indicators. The attitude set function is controlled by manual operation of the thumbwheels. The desired position is dialed by a thumbwheel, with the display providing visual indication of the position selected by the thumbwheel. The attitude display may be used to align the FDAI-AGCU or to indicate a new attitude for the spacecraft. To accomplish FDAI-AGCU alignment, the desired position is set on the attitude set display. The FDAI ALIGN pushbutton is then pressed. This provides a signal which drives the AGCU stepper motor and control logic to position the AGCU resolver shaft. The stepper motor drives the shaft to the commanded position, resulting in an output from an angle generator to the FDAI ball, driving the ball to the commanded position. To manually maneuver the spacecraft to a predetermined attitude, the display is set to the desired attitude and the ATT SET switch is placed to ATT SET. The output signal is applied to the attitude error display pointers on the FDAI, providing a manual maneuver indication to the space crew. The display configuration is a fly-to type, with the crew manually maneuvering the spacecraft toward the pointers. (The pointers will peg if the new attitude is in excess of 5 degrees from the original attitude.)

The SPS engine gimbal position display allows positioning of the gimbals and provides indication of gimbal position. Two thumbwheels enable the pitch and yaw engine gimbals to be positioned prior to SPS engine firing. The gimbals position the engine to an attitude which ensures that the SPS engine thrust vector is through the spacecraft center of gravity. Movement of the thumbwheels results in the generation of control signals which engage the SPS gimbal ring torque motor magnetic clutches. Clutch engagement connects the gimbal torque motor and gear train to move the gimbal ring. Position transducers send a signal to the gimbal position displays to indicate the angle of the gimbal. The yaw gimbal position scale is graduated in increments of one-half degree from -5 degrees to +13 degrees. Center is located at the +4-degree position due to an inherent offset in the yaw center of gravity. The pitch gimbal position scale is graduated in increments of one-half degree from -9 degrees to +9 degrees, with the center position at 0 degrees.

2.3.4.10 Velocity Change Indicator.

The delta V display provides control and display of spacecraft velocity changes. The display portion of the panel consists of the ΔV REMAINING indicator, which is a five-digit display. The digital display is set by the variable speed ΔV SET switch. Three panel switches control the SPS and RCS engine firing commands. The DIRECT ULLAGE switch is a pushbutton, momentary-contact switch which, when depressed energizes the direct coils of the +X reaction jet solenoids. It serves as a backup for the translation control, which is used under normal conditions for +X translations for SPS fuel settling (ullage). The THRUST ON switch is an illuminated pushbutton, momentary-contact switch which is used to fire the SPS engine in the SCS delta V mode. The switch is enabled when the SPS THRUST switch is in the NORMAL position. The pitch and yaw RCS control and firing circuits are inhibited during SPS engine firing. After ignition, the SPS engine continues to fire until the ΔV REMAINING display counts down to zero. The THRUST ON switch is also used to back up the Apollo guidance computer firing commands in the G&N delta V mode in the event of an AGC failure. The SPS THRUST switch provides overall control of SPS engine firing. The NORMAL position enables normal engine firing sequences. The OFF position provides a positive off command as backup in case of a malfunction. The DIRECT ON position provides a positive firing command to the SPS engine.

The ΔV SET switch sets up the ΔV REMAINING display and logic circuits prior to delta V maneuvers. Pressing the upper section of the ΔV switch sets up logic circuitry which causes a slew motor to drive the ΔV REMAINING display in the positive direction (increasing velocity). Pressing the lower section of the switch drives the display in the negative direction (decreasing velocity). The switch has two sets of contacts in both the upper and lower positions. Pressing the switch lightly engages the first set of contacts, which results in a signal that will drive the display at a rate of two feet per second. Pressing the switch harder (past an easily felt hard/soft point) engages the second set of contacts, which results in the display being driven at a rate of 64 feet per second. As the display is driven to the desired velocity, the integrator and logic circuit is set to a logical value equal to the desired change. The translation command signal energizes a relay which applies the output of the AGAA accelerometer to the integrator and logic circuit, which compares the desired velocity increment with the actual velocity change received from the accelerometer. When the actual velocity change equals the value set, the ΔV REMAINING counter sends a signal to a coincidence detector logic circuit which, in turn, transmits a stop firing command to the thrust control logic. Although this causes the SPS engine to stop firing, some thrusting continues as a result of the tail-off inherent to the engine. The ΔV REMAINING display continues to count past zero (i.e., 99999, 99998, 99997, etc.) until no further acceleration is felt. Tail-off effects will be calculated prior to flight and compensated for by the crew when the display is being set up for delta V maneuvers.

2.3.4.11 Electrical Power Distribution.

See figures 2.3-14 and 2.3-15.

2.3.5 PERFORMANCE AND DESIGN DATA.

Figure 2.3-16 contains the latest available power consumption data for the Block I SCS. The translation controls were not included in the SCS component breakdown because they do not dissipate a significant amount of power within themselves.

The X-axis accelerometer is a servo-rebalanced pendulous accelerometer. Some of the accelerometer design characteristics are as follows.

Operating range	0.001 g to 2 g
Threshold	1×10^{-4} g (max)
Null torque	1×10^{-4} g (max)
Signal generator sensitivity	50 millivolts/millirad
Signal generator null	1 mr (max)

The body-mounted attitude gyros are single-degree-of-freedom gyros. Some of the gyro design characteristics are as follows.

Acceleration sensitive drift	4 deg/hr/g
Random drift	0.05 deg/hr
Maximum torquing rate	25 deg/sec
Maximum input attitude	±20 deg
Gyro threshold	0.02 deg/hr
Gyro transfer function	1.15 millivolts/millirad
Signal generator null	3.5 millivolts
Excitation frequency	400±0.01% cps

The rate gyros are single-axis miniature gyros. Some of the gyro design characteristics are as follows.

Full-scale range	30°/sec
Input range (to limit stop)	30°/sec
Maximum rate without damage	600°/sec
Excitation frequency	400±0.01% cps
Threshold	0.02°/sec

2.3.6 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.3.6.1 S/C Attitude Change.

It is recommended that vehicle attitude change be held to maximum rates of less than 20 degrees per second roll and 5 degrees per second in pitch and yaw to prevent possible loss of attitude reference. Because of the AGCU digital logic, the stepping motor can be stepped at a maximum

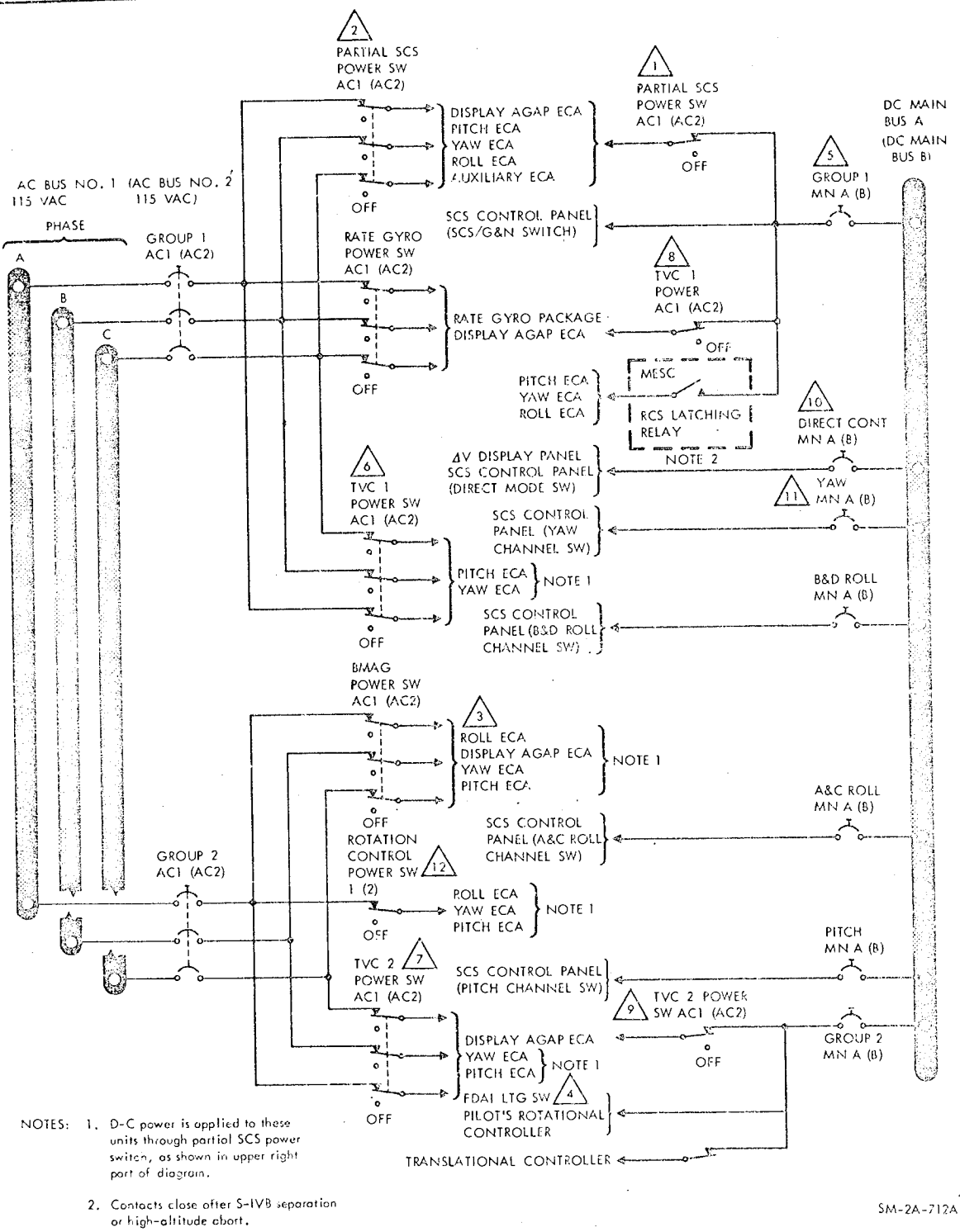

Figure 2.3-14. SCS Power Distribution

SYSTEM CAPABILITIES	REQUIRED SCS POWER SWITCHES					
	PARTIAL SCS POWER	RATE GYRO POWER	BMAG POWER	ROTATION CONTROL POWER	TVC 1 POWER	TVC 2 POWER
BACKUP RATE	●		●			
CHANNEL ENABLE						
DIRECT ROTATION CONTROL						
PROPORTIONAL ROTATION CONTROL	●	●	● (1)	●		
ATTITUDE IMPULSE	●					
G&N SYNC						
TRANSLATION	●					
ΔV SET					●	
SPS ENGINE IGNITION	● (2)					
MANUAL SPS GIMBAL TRIM	●				●	● (3)
DIRECT ULLAGE						
THRUST VECTOR CONTROL	●	●	● (4)		●	● (3)
MANUAL THRUST VECTOR CONTROL			●	●		●
ATTITUDE HOLD	●	● (7)	● (5)			
RATE DAMPING	●	●	● (1)			
FDAI ALIGN	●					
RATE INDICATORS VALID	●	●	● (1)			
BALL & ROLL BUG DRIVEN	●					
ATTITUDE ERROR INDICATORS VALID	● (8)		● (6)			

NOTES:
1. If backup rate has been selected in any axis. If backup rate has been selected in all 3 axes, RATE GYRO POWER need not be on.
2. PARTIAL SCS POWER must be on if ΔV switch is at NORMAL. However, SPS engine can be turned on when all power switches are off, by placing ΔV switch to DIRECT ON.
3. TVC 2 POWER switch must be on if manual TVC is engaged.
4. SCS ΔV mode only. However, in G&N ΔV mode, BMAG POWER must be on if backup rate has been selected in any axis. If backup rate has been selected in all three axes, RATE GYRO POWER switch is set to OFF.
5. SCS modes only; also G&N modes if backup rate has been selected in any axis.
6. SCS modes only, if backup rate has not been selected.
7. RATE GYRO POWER switch may be set to OFF for extended periods of attitude hold.
8. FDAI ALIGN and G&N modes only.

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Figure 2.3-15. SCS Power vs System Capability

SYSTEM STEADY-STATE POWER CONSUMPTION-WATTS (SQ-1)

MODE / SWITCH	MONITOR 115 VAC 400 CPS				G&N ATTITUDE 115 VAC 400 CPS				SCS ATTITUDE 115 VAC 400 CPS				G&N ENTRY 115 VAC 400 CPS			
	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC
PARTIAL SCS PWR (1) POWER FACTOR	25.2 0.94	24.1 0.89	17.6 0.91	16.7	26.0 0.95	24.2 0.89	18.3 0.88	9.0	27.6 0.94	24.3 0.89	18.5 0.88	11.8	25.1 0.94	24.5 0.89	18.0 0.88	19.8
FDAI POWER FACTOR	3.4 1.0				3.4 1.0				*3.4 1.0				3.4 1.0			
RGA POWER POWER FACTOR	5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		*5.2 *0.98	*3.4 *0.85	*11.8 *0.99		5.2 0.98	3.4 0.85	11.8 0.99	
ROT. CONT POWER POWER FACTOR	5.6 0.92				5.6 0.92				*5.6 *0.92				5.6 0.92			
TVC SW NO. 1 POWER FACTOR	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3
TVC SW NO. 2 POWER FACTOR	11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63	
BMAG POWER POWER FACTOR	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	*6.1 *0.99	*3.4 *0.78	*7.0 *0.80	*62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3
CONT PANEL INPUT (1)				11.82				5.13				4.22				28.13

SYSTEM STEADY-STATE POWER CONSUMPTION-WATTS (SQ-1) (CONTINUED)

MODE / SWITCH	SCS ENTRY 115 VAC 400 CPS				G&N ΔV 115 VAC 400 CPS				SCS ΔV 115 VAC 400 CPS				LOCAL VERTICAL 115 VAC 400 CPS			
	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC	ϕA	ϕB	ϕC	DC
PARTIAL SCS PWR (1) POWER FACTOR	27.5 0.94	24.5 0.89	18.3 0.88	22.9	25.7 0.94	24.0 0.88	18.6 0.91	59.4	28.3 0.93	23.3 0.88	19.0 0.91	61.3	26.1 0.94	22.6 0.88	17.6 0.90	12.4
FDAI POWER FACTOR	3.4 1.0				3.4 1.0				3.4 1.0				3.4 1.0			
RGA POWER POWER FACTOR	5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99	
ROT. CONT POWER POWER FACTOR	5.6 0.92				5.6 0.92				5.6 0.92				5.6 0.92			
TVC SW NO. 1 POWER FACTOR	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	*16.4 *0.96	*8.7 *0.86	*8.7 *0.86	*16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3
TVC SW NO. 2 POWER FACTOR	11.5 0.75	4.3 0.57	4.2 0.63		*11.5 *0.75	*4.3 *0.57	*4.2 *0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63	
BMAG POWER POWER FACTOR	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3
CONT PANEL INPUT (1)				23.07				13.33				6.95				5.65

NOTES:
1. Power measurements made in each mode.
*2. Power consumption assumed same in each mode. Asterisk indicates mode in which measurement was made.
3. Measurements made with SPS engine off. (Two solenoids and 2 relays.)
4. Line losses and inverter efficiencies not considered.
5. All values indicated are in watts.
6. Figure does not include energizing RCS engines for maneuvers.

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Figure 2.3-16. SCS Steady-State Power Consumption Data

rate of 100 steps per second in roll and 25 steps per second in pitch and yaw. This is equivalent to gyro torquing rates of 20 degrees per second in roll and 5 degrees per second in pitch and yaw. Therefore, if vehicle rates exceed the gyro torquing rates, the stepping motor will lag behind the vehicle rates. Under this condition, the BMAG-AGCU loop may not be able to maintain the SCS attitude reference.

2.3.7 TELEMETRY MEASUREMENTS.

The following is a complete listing of all SCS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickup or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low-bit rate operation.

Figure 2.3-4, sheet 2, identifies telemetry measurements for the SCS yaw channel. Identical measurements in the following list, relative to the roll and pitch channels, are taken from the same circuit junctions as for the yaw channel.

Measurement Number	Description	Sensor Range	Crew Display
* CH 0024 V	Pitch rate		FDAI
* CH 0025 V	Pitch rate manual rotation control	Zero/+5 VRMS	FDAI
* CH 0034 V	Pitch pos feedback in	-6/+6 vdc	None
* CH 0047 V	PTV diff clutch volts comb	TBD	None
CH 0050 V	Pitch rate error amp out	-6.2 to +6.2 vdc	FDAI
CH 0067 V	Pitch integrator/att error summing	TBD	None
* CH 0074 V	MTVC pitch rate	TBD	None
CH 0075 V	Pitch SCS att error	Zero/+10 VRMS	FDAI
* CH 0087 X	+ Pitch/+X solenoid driver out	Off/on event	None
* CH 0088 X	- Pitch/+X solenoid driver out	Off/on event	None
* CH 0089 X	+ Pitch/-X solenoid driver out	Off/on event	None
* CH 0090 X	- Pitch/-X solenoid driver out	Off/on event	None
CH 0100 X	G-N DV mode control	Event	None
CH 0101 X	G-N DV att mode control	Off/on event	None
CH 0102 X	G-N entry mode control	Off/on event	None
CH 0103 X	Monitor mode control	Off/on event	None
* CH 1024 V	Yaw rate	-30 to +30°/sec	FDAI
* CH 1025 V	Yaw manual rotation control	Zero/+5 VRMS	FDAI
* CH 1034 H	Yaw pos feedback in	-8.5/+8.5 vdc	None
* CH 1047 V	YTV diff clutch volts comb	-85 to +85 MADC	None
CH 1050 V	Yaw rate error amp out	-6.2 to +6.2 vdc	FDAI
CH 1067 V	Y integrator/att error summing	-2.5 to +2.5 vdc	None
* CH 1074 V	MTVC yaw rate	TBD	None

Measurement Number	Description	Sensor Range	Crew Display
CH 1075 V	V yaw SCS att error	Zero/+10 VRMS	FDAI
* CH 1087 X	+ Yaw/+X solenoid driver out	Off/on event	None
* CH 1088 X	- Yaw/+X solenoid driver out	Off/on event	None
* CH 1089 X	+ Yaw/-X solenoid driver out	Off/on event	None
* CH 1090 X	- Yaw/-X solenoid driver out	Off/on event	None
CH 1100 X	SCS DV mode control	Event	None
CH 1101 X	SCS att mode control	Event	None
CH 1102 X	SCS entry mode control	Event	None
CH 1103 X	SCS local vertical mode control	Event	None
CH 1104 X	MTVC mode control	Event	None
* CH 2015 V	Combined AG SMRD	0 to 5 vdc	None
* CH 2024 V	Roll rate	TBD	FDAI
* CH 2025 V	Roll man rotation control out	Zero/+5 VRMS	FDAI
* CH 2026 V	Combined RG SMRD	-0 to +5 vdc	None
* CH 2030 T	Combined attitude gyro temp	0 to +5 vdc	AGAP TEMP LIGHT
CH 2050 V	Roll rate error amp out	-6.2 to +6.2 vdc	FDAI
* CH 2070 V	Roll attitude error amp out	-25/+25 vdc	None
CH 2075 V	Roll SCS att error	Zero/10 VRMS	FDAI
* CH 2087 X	+ Roll/+Z solenoid driver out	Event	None
* Ch 2088 X	- Roll/-Z solenoid driver out	Event	None
* Ch 2089 X	+ Roll/-Z solenoid driver out	Event	None
* CH 2090 X	- Roll/-Z solenoid driver out	Event	None
* CH 2091 X	+ Roll/+Y solenoid driver out	Event	None
* CH 2092 X	- Roll/+Y solenoid driver out	Event	None
* CH 2093 X	+ Roll/-Y solenoid driver out	Event	None
* CH 2094 X	- Roll/-Y solenoid driver out	Event	None
CH 3185 X	.05 g Manual switch	Event	None
* CH 3186 V	DV remaining pot out	-3 to +13 KFPS	ΔV Counter
CH 4100 H	Resolver sin out pitch att	-12 to +12 VRMS	None
CH 4101 H	Resolver cos out pitch att	-12 to +12 VRMS	None
CH 4102 H	Resolver sin out yaw att	-12 to +12 VRMS	None
CH 4103 H	Resolver cos out yaw att	-12 to +12 VRMS	None
CH 4104 H	Resolver sin out roll att	-12 to +12 VRMS	None
CH 4105 H	Resolver cos out roll att	-12 to +12 VRMS	None
* CH 4320 X	SPS solenoid driver out 1	Event	None
* CH 4321 X	SPS solenoid driver out 2	Event	None
CG 0001 V	Computer digital data 40 bits	Event	Delta V Display

SECTION 2

SUBSECTION 2.4

SERVICE PROPULSION SYSTEM (SPS)

2.4.1 FUNCTIONAL DESCRIPTION.

The service propulsion subsystem provides the major impulse for all major velocity changes (AV's) throughout a mission, plus the S/M abort after the launch escape tower is jettisoned. To perform this function, the susbystem incorporates a helium pressurization system, a propellant feed system, a propellant gauging and utilization system, and a rocket engine. The oxidizer is nitrogen tetroxide, and the fuel is a blended hydrazine (approximately 50% unsymmetrical dimethyl hydrazine and 50% anhydrous hydrazine). The pressurizing gas is helium. The subsystem incorporates displays and sensing devices to permit ground-based stations and the crew to monitor its operation.

A functional flow diagram is contained in figure 2.4-1.

The helium pressure is directed to the helium pressurizing valves which isolate the helium during nonthrusting periods, or allows the helium to pressurize the fuel and oxidizer tanks during thrusting periods. The helium pressure is reduced at the pressure regulators to a desired working pressure. The regulated helium pressure is directed through check valves that permit helium flow in the downstream direction when the pressurizing valves are open, and prevent a reverse flow of propellants during non-thrusting periods. The heat exchangers transfer heat from the propellants to the helium gas to reduce any pressure excursions that may result from a temperature differential between the helium gas and propellants in the tanks. The relief valves maintain the structural integrity of the propellant tank systems if an excessive pressure rise occurs.

The total propellant supply is contained within four similar tanks: an oxidizer storage tank, oxidizer sump tank, fuel storage tank, and fuel sump tanks. The storage and sump tanks for each propellant system are connected in series by a single transfer line. The regulated helium enters into the fuel and oxidizer storage tank, pressurizing the storage tank propellants, and forces the propellant to an outlet in the storage tank which is directed through a transfer line into the respective sump tank standpipe, pressurizing the propellants in the sump tank. The propellant in the sump tank is directed to the exit end into a propellant retention reservoir, retaining sufficient propellants at the tank outlets to permit engine restart capability in a zero g condition. The propellants exit from the respective sump tanks into a single line to the heat exchanger.

A propellant utilization valve is installed in the oxidizer line, and is powered only during SPS thrusting periods. The propellant utilization valve aids in maintaining the center of mass in a relatively confined area in the Y - Z plane, in addition to simultaneous propellant depletion. The oxidizer supply and fuel supply are connected from the sump tank to the engine interface flange.

The propellants flow from the propellant sump tank feed through their respective plumbing to the main propellant orifices and filters to the bipropellant valve. The bipropellant valve assembly contains the main propellant valves that are pneumatically controlled and allows the propellant valves to distribute the propellants to the engine injector during thrusting periods, or isolates the propellants from the injector during nonthrusting periods.

The engine injector distributes the propellants through orifices in the face of the injector where the fuel and oxidizer impinge upon each other, atomize, and ignite due to hypergolic ignition.

The ablative combustion chamber absorbs the heat generated within the chamber. The nozzle extension is attached to the ablative chamber and radiates to space.

The engine assembly is mounted to the structure of the service module and is gimbaled to permit thrust vector alignment through the center of mass, prior to thrust initiation and thrust vector control during a thrusting period. A flight combustion stability monitor system is employed to monitor the engine for instability during thrusting periods.

Propellant quantity is measured by two separate sensing systems: primary and auxiliary. The sensing systems are powered only during thrust-on periods due to the capacitance and point sensor measuring techniques. The linearity would not provide accurate indications during the zero g SPS nonthrusting periods.

The control of the subsystem is automatic with provisions for manual override.

2.4.2 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.4.2.1 Pressurization Subsystem.

The pressurization subsystem consists of two helium tanks, two helium pressurizing valves, two dual pressure regulator assemblies, two dual check valve assemblies, two pressure relief valves, and two heat exchangers. The critical components are redundant to increase reliability.

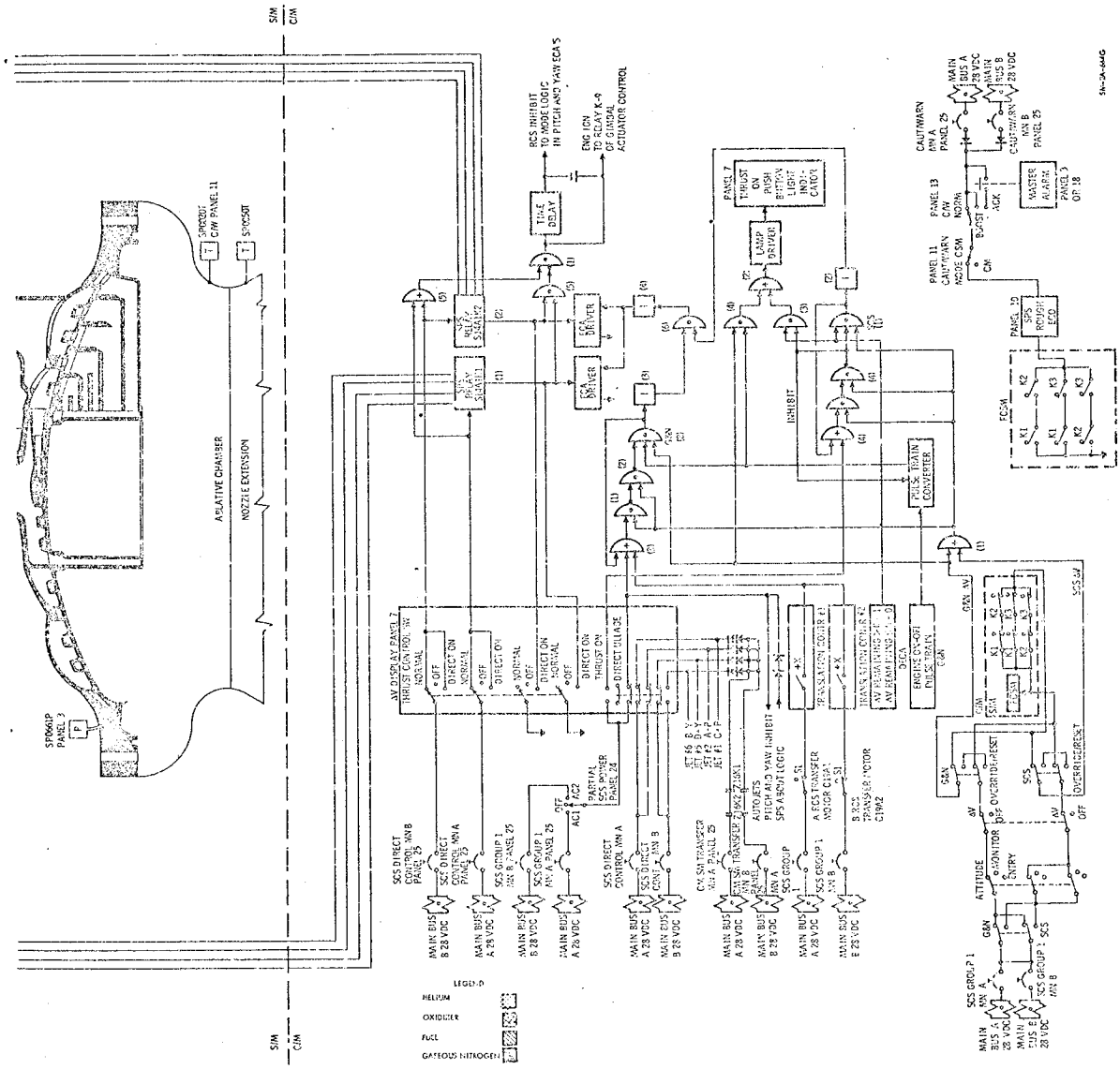
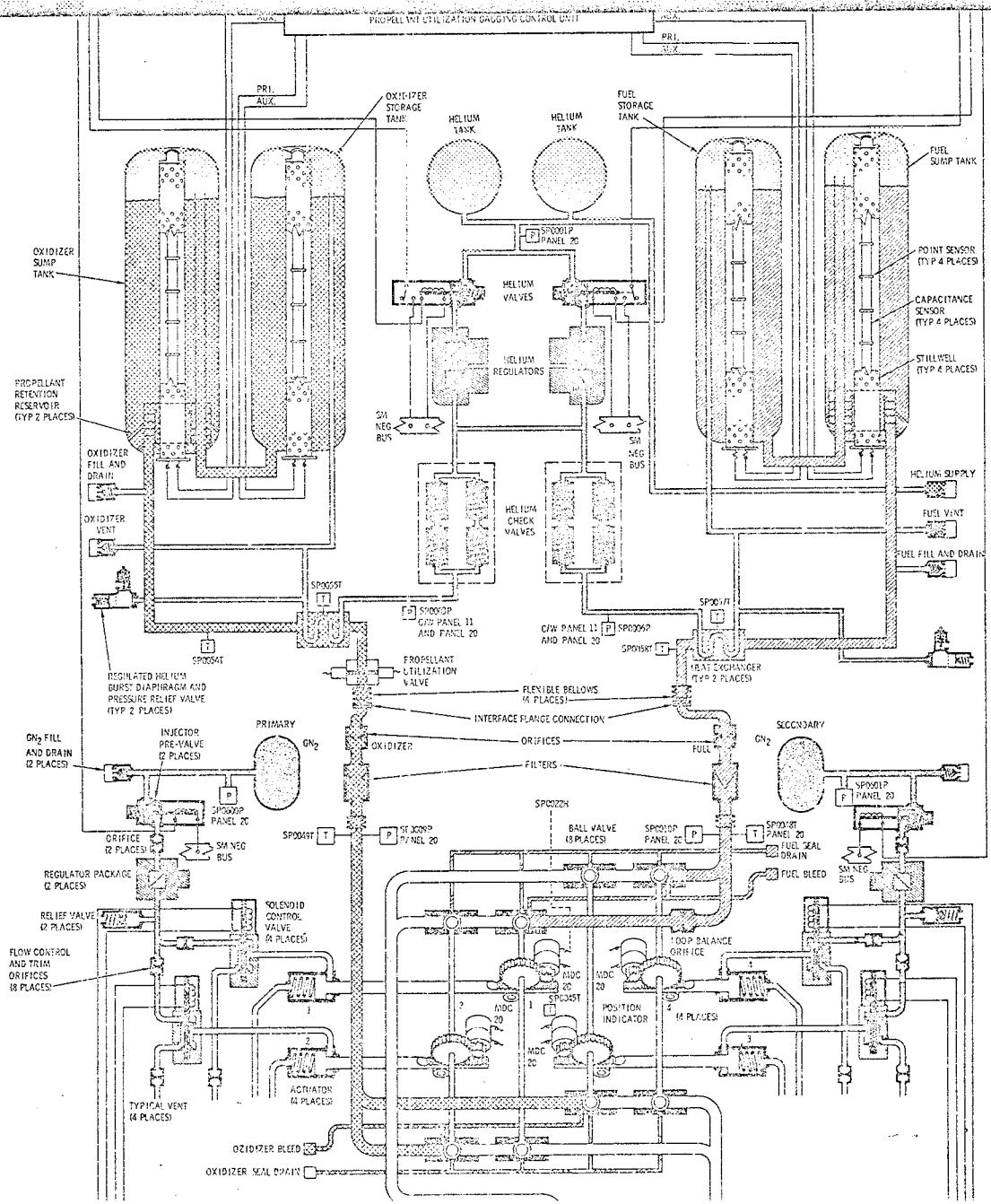
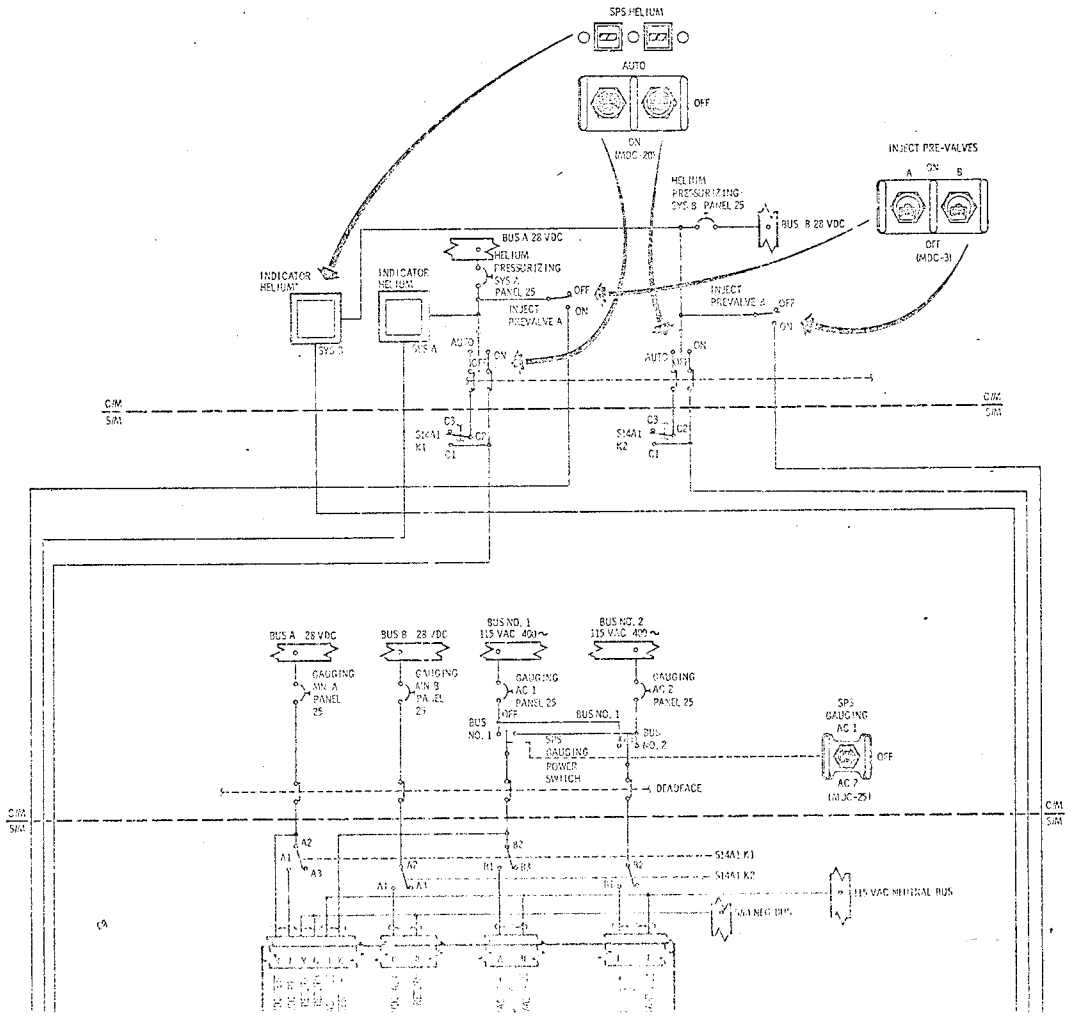


Figure 2.4-1. SPS Functional Flow Diagram


PROPELLANT UTILIZATION GAGING CONTROL UNIT
PRI.
AUX.
OXIDIZER STORAGE TANK
HELIUM TANK
HELIUM TANK
FUEL STORAGE TANK
FUEL SUMP TANK
SP0001P PANEL 20
POINT SENSOR (TYP 4 PLACES)
OXIDIZER SUMP TANK
HELIUM VALVES
CAPACITANCE SENSOR (TYP 4 PLACES)
HELIUM REGULATORS
STILLWELL (TYP 4 PLACES)
PROPELLANT RETENTION RESERVOIR (TYP 2 PLACES)
SM NEG BUS
SM NEG BUS
OXIDIZER FILL AND DRAIN
HELIUM SUPPLY
OXIDIZER VENT
HELIUM CHECK VALVES
FUEL VENT
FUEL FILL AND DRAIN
SP0005T
SP0003P C/W PANEL 11 AND PANEL 20
SP0006P C/W PANEL 11 AND PANEL 20
SP0007T
SP0004T
SP0015T
HEAT EXCHANGER (TYP 2 PLACES)
REGULATED HELIUM BURST DIAPHRAGM AND PRESSURE RELIEF VALVE (TYP 2 PLACES)
PROPELLANT UTILIZATION VALVE
FLEXIBLE BELLOWS (4 PLACES)
INTERFACE FLANGE CONNECTION
PRIMARY
SECONDARY
GN_2 FILL AND DRAIN (2 PLACES)
INJECTOR PRE-VALVE (2 PLACES)
GN_2
OXIDIZER
ORIFICES
FUEL
GN_2
FILTERS
SP0001P PANEL 20
SP0022H
SP0009P PANEL 20
ORIFICE (2 PLACES)
SM NEG BUS
SP0049T
SE 3009P PANEL 20
BALL VALVE (3 PLACES)
SP0010P PANEL 20
SP0034T PANEL 20
FUEL SEAL DRAIN
SM NEG BUS
REGULATOR PACKAGE (2 PLACES)
FUEL BLEED
RELIEF VALVE (2 PLACES)
SOLENOID CONTROL VALVE (4 PLACES)
LOOP BALANCE ORIFICE
FLOW CONTROL AND TRIM ORIFICES (8 PLACES)
MDC 20
SP0045T
MDC 20
MDC 20
POSITION INDICATOR
(4 PLACES)
MDC 20
ACTUATOR (4 PLACES)
TYPICAL VENT (4 PLACES)
OZIDIZER BLEED
OXIDIZER SEAL DRAIN


SPS HELIUM
AUTO
OFF
ON
(MDC-20)
INJECT PRE-VALVES
A
ON
B
OFF
(MDC-31)
HELIUM PRESSURIZING SYS B PANEL 25
BUS B 28 VDC
BUS A 28 VDC
HELIUM PRESSURIZING SYS A PANEL 25
INDICATOR HELIUM
SYS B
INDICATOR HELIUM
SYS A
OFF
ON
INJECT PREVALVE A
INJECT PREVALVE B
AUTO
C/M SIM
S14A1 K1
S14A1 K2
C3
C2
C1
BUS A 28 VDC
BUS B 28 VDC
BUS NO. 1 115 VAC 400~
BUS NO. 2 115 VAC 400~
GAUGING MN A PANEL 25
GAUGING MN B PANEL 25
GAUGING AC 1 PANEL 25
GAUGING AC 2 PANEL 25
BUS NO. 1
BUS NO. 2
SPS GAUGING POWER SWITCH
SPS GAUGING AC 1
AC 2
(MDC-25)
DEADFACE
S14A1 K1
S14A1 K2
115 VAC NEUTRAL BUS

2.4.2.1.1 Helium Tanks.

The two helium supply spherical pressure vessels are located in the center section of the service module.

2.4.2.1.2 Helium Pressurizing Valves.

These two continuous duty solenoid-operated valves are normally closed to the helium supply pressure. The valves are energized open and spring-loaded closed. When the helium switches on panel 20 are in the AUTO position, the valves are energized and de-energized by the thrust ON-OFF signal. The valves may be manually controlled by the crew, utilizing the ON and OFF position of the helium switches. Each valve is controlled individually by a separate switch on panel 20.

Each valve contains a position switch which controls a position indicator above each switch on panel 20. When a valve is closed, the position switch is open and the indicator is gray (same color as the panel). When a valve is open, the position switch is closed and the indicator has diagonal lines, indicating the valve is open.

In the event of a failure in the automatic mode of operation, the crew manually enables the pressurizing valve or valves on panel 20. In the event of a problem with one of the regulating units, the crew manually isolates the required pressurizing valve.

2.4.2.1.3 Pressure Regulator Assemblies.

Pressure regulation is accomplished by two pressure regulating units in parallel, downstream of each helium pressurizing valve. Each regulator unit contains a primary and secondary regulator in series, and a pressure surge damper installed on the inlet to each regulating unit.

The primary regulator is normally the controlling regulator, while the secondary is normally open during a dynamic flow condition. The secondary regulator will not become a controlling regulator until the primary, due to a problem, allows a higher pressure than normal, and allows the secondary regulator to function and become the controlling regulator. All regulator pressures are in reference to a bellows assembly that is vented to ambient.

One of the regulating units incorporated in one of the parallel paths is considered the working regulator. The regulating unit in the remaining parallel path is normally locked up when the system is dynamic. The regulator that is normally locked up would not function until the normal regulator allowed the regulated helium pressure to decrease, due to a problem, and allow the normally locked-up regulator to become the functioning regulator.

2.4.2.1.4 Check Valve Assemblies.

Each assembly contains four independent check valves connected in a series-parallel configuration which provides added redundancy. The check valves will not open until there is a 4-psi pressure differential between the check valve assembly inlet and outlet lines.

2.4.2.1.5 Helium Pressure Relief Valves.

The pressure relief valves consist of a relief valve, a burst diaphragm, and a filter.

In this event, excessive helium and/or propellant vapor ruptures the burst diaphragm and the filter (filter is to be a nonfragmentation type) filters any fragmentation. The relief valve opens and vents the applicable system to space, and will close and reseal after the excessive pressure has returned to the operating level. The burst diaphragm provides a more positive seal of helium than a relief valve. The filter prevents any fragments from the diaphragm from entering the relief valve seat.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage from the diaphragm. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure.

2.4.2.1.6 Heat Exchangers.

Each unit is a line-mounted, counterflow heat exchanger consisting of a portion of the helium pressurization line, coiled helically within an enlarged section of the propellant supply line. This arrangement causes the helium gas, flowing through the coiled line, to approach the temperature of the propellant.

2.4.2.2 Propellant Subsystem.

This subsystem consists of two fuel tanks (storage and sump), two oxidizer tanks (storage and sump), propellant feed lines, and bipropellant valve assembly.

2.4.2.2.1 Propellant Tanks.

The total propellant supply is contained within four hemispherical-domed cylindrical tanks within the service module. The storage tanks are pressurized from the helium supply, and an outlet transfers the propellant and/or helium gas from the storage tanks through their respective transfer lines to the sump tanks. A standpipe, in the sump tanks, allows the propellant and/or helium gas from the storage tanks to pressurize the sump tanks. Thus, the propellants in the sump tanks are directed in the retention reservoirs, to the outlet, and then to the engine.

The retention reservoirs are installed in the exit end of the sump tanks only. The umbrella propellant retention screens retain a quantity of propellant in the exit end of the sump tanks, in addition to retaining propellant within the retention reservoir can and in the plumbing from the sump tank outlet to the bipropellant valve of the SPS engine during zero g conditions. An ullage maneuver must be performed prior to a thrust-on signal to the SPS engine by the S/M RCS. The ullage maneuver is performed to ensure that no gases are retained below or aft of the retention screens, in addition to settling the propellants and ensuring that the retention screens are not damaged.

2.4.2.2.2 Tank Propellant Feed Lines.

The propellant feed lines have flexible bellows assemblies installed to permit alignment of the tank feed plumbing to the engine interface plumbing.

2.4.2.3 Bipropellant Valve Assembly.

The bipropellant valve assembly consists of two gaseous nitrogen (GN_2) pressure vessels, two injector prevalves, two GN_2 regulators, two GN_2 relief valves, four solenoid control valves, four actuators, and eight propellant ball valves.

2.4.2.3.1 Gaseous Nitrogen (GN_2) Pressure Vessels.

Two GN_2 tanks are mounted on the bipropellant valve assembly that supply pressure to the injector prevalves. One GN_2 tank is in the primary pneumatic control system A and the remaining GN_2 tank is in the secondary pneumatic control system B.

2.4.2.3.2 Injector Prevalves.

The injector prevalves are two-position solenoid-operated valves, one for each pneumatic control system and identified as A and B. The valve is energized open and spring-loaded closed. The injector prevalve is opened upon command from the crew, panel 3, prior to an engine thrusting period. The injector prevalves energized open allows GN_2 supply tank pressure to flow to an orifice and on into the regulator.

2.4.2.3.3 GN_2 Pressure Regulators.

A single-stage regulator is installed in each pneumatic control system between the injector prevalves and the solenoid control valves. The regulator reduces the supply GN_2 pressure to a desired working pressure.

2.4.2.3.4 GN_2 Relief Valves.

A pressure relief valve is installed in each pneumatic control system, downstream of the GN_2 pressure regulators, to limit the pressure applied to the solenoid control valves in the event a GN_2 pressure regulator malfunctioned open. The orifice, between the injector prevalve and regulator, is installed to restrict the flow and allow the relief valve to relieve the pressure in event the regulator fails to open, preventing any damage to the solenoid control valves and/or actuators.

2.4.2.3.5 GN_2 Solenoid Control Valves.

Four solenoid-operated, three-way, two-position control valves are utilized for actuator control. Two solenoid control valves are located downstream of the GN_2 regulators in each pneumatic control system. The two solenoid control valves in the primary system are identified in 1 and 2, and the two in the secondary system are identified as 3 and 4. The two solenoid control valves in the primary system control the actuator and ball valves 1 and 2. The two solenoid control valves in the secondary system control the actuator and ball valves 3 and 4. The SPS thrust ON-OFF command controls the energizing or de-energizing of all four solenoid control valves.

2.4.2.3.6 GN_2 Ball Valve Actuators.

Four piston-type, pneumatically operated actuators are utilized to control the eight propellant ball valves. Each actuator piston is mechanically connected to a pair of propellant ball valves; one fuel and one oxidizer. When the solenoid control valves are opened, pneumatic pressure is applied to the opening side of the actuators. The spring pressure, on the closing side, is overcome and the actuator piston moves. Utilizing a rack and pinion gear, linear motion of the actuator connecting arm is converted into rotary motion, which opens the propellant ball valves. When the engine firing signal is removed from the solenoid control valves, the solenoid control valves close removing pneumatic pressure source from the opening side of the actuators. The actuator closing side spring pressure now forces the actuator piston to move in the opposite direction, causing the propellant ball valves to close. The piston movement forces the remaining GN_2, on the opening side of the actuator, back through the solenoid control valves where they are vented overboard.

2.4.2.3.7 Bipropellant Valves.

The eight propellant ball valves are used to distribute fuel and oxidizer to the engine injector assembly. Four linked pairs, each pair consisting of one fuel and one oxidizer ball valve controlled by a single actuator, are arranged in a series-parallel configuration. The parallel arrangement provides redundancy to ensure engine ignition, and the series arrangement to ensure thrust termination. When the actuators

are opened, each propellant ball valve is rotated, thereby aligning the ball to a position that allows propellants to flow to the engine injector assembly. The mechanical arrangement is such that the oxidizer ball valves maintain an 8-degree lead over the fuel ball valves upon opening, which results in smoother engine starting transients. Each pair of propellant valves incorporates a potentiometer drive gear and housing. Each housing contains two potentiometers that are mechanically driven: one provides an electrical signal converted into a visual indication of valve position of panel 20, and the remaining provides a signal to telemetry.

2.4.2.3.8 Engine Propellant Lines.

Integral propellant lines are utilized, on the engine, to route each propellant from the interface points in the gimbal plane area to the propellant engine gimbaling, orifices for adjustment of oxidizer/fuel ratio, and screens for keeping particle contaminants from entering the engine.

2.4.2.4 Engine Injector.

The injector is bolted to the ablative thrust chamber attach pad. Propellant distribution to the injector orifices, on the combustion face of the injector, is accomplished through concentric annuli machined in the face of the injector assembly and covered by concentric closeout rings. Propellant distribution to the annuli is accomplished through alternate radial manifolds welded to the backside of the injector body. The injector is regeneratively cooled and baffled to provide combustion stability. The fuel and oxidizer orifices impinge upon each other, atomize, and ignite due to hypergolic reaction.

2.4.2.5 Ablative Combustion Chamber.

The ablative combustion chamber material extends from the injector attach pad to the nozzle extension attach pad. The ablative material consists of a liner, a layer of insulation, integral metal attach flanges for mounting the injector and nozzle extension, and structural outer reinforcement. The only restriction on a restart is dependent upon the SPS WALL TEMP HI caution and warning light, on panel 11, monitoring the outside wall temperature at the throat.

2.4.2.6 Nozzle Extension.

The bell-contoured, nozzle extension is bolted to the ablative thrust chamber exit area. The nozzle extension is radiant-cooled and contains an external stiffener to provide additional strength.

2.4.2.7 Flight Combustion Stability Monitor (FCSM).

The FCSM ia an accelerometer package, mounted to the SPS engine injector, to monitor the engine for vibration buildup characteristic of combustion instability.

The three accelerometers provide signals into an FCSM box assembly which amplifies it and, when the vibration g-level exceeds 180 g's peak to peak for 70±20 milliseconds, a level detector triggers a power switch gating power to the summing logic. The stability monitor will monitor only in a frequency range where instability would occur (approximately 600 to 5000 cycles per second).

The summing logic, if there are two or more rough combustion signals received from the normally closed contacts, will open removing power from the G&N and SCS driver logic; and will close the normally open contacts providing a ground to the SPS ROUGH ECO caution and warning light, on panel 10, informing the crew the SPS engine was shut down due to combustion instability.

The FCSM trigger circuits will provide power to the voting logic relays continuously once unstable combustion is sensed; and power remains applied to the voting logic relays even though the engine is shut down, unstable combustion is no longer sensed, and the SPS ROUGH ECO remains illuminated.

When the engine is shut down to unstable combustion and to remove power from the voting logic relays, the crew would place any one of the following switches to the position indicated to reset the FCSM voting logic:

a. AUTO-OVERRIDE switches to OVERRIDE.
b. ΔV switch to OFF.
c. ATTITUDE-MONITOR-ENTRY switch to either MONITOR or ENTRY.
d. FCSM SCS and G&N switches to RESET/OVERRIDE.

When the FCSM is reset, the SPS ROUGH ECO light on panel 10 will not be illuminated.

The RESET/OVERRIDE switches, on panel 2, provide a bypass capability of the FCSM system. With the FCSM RESET/OVERRIDE switches, on panel 2, in the RESET/OVERRIDE position, power is not provided to the FCSM box and summing logic assemblies rendering the FCSM inoperative as well as the SPS ROUGH ECO caution and warning light on panel 10. If unstable combustion occurs, the engine continues to thrust.

The FCSM box assembly and summing logic assembly receives power from the SCS through the following switches:

a. Mode select switch to G&N or SCS mode, panel 8.
b. ATTITUDE-MONITOR-ENTRY switch to ATTITUDE, panel 8.
c. ΔV switch to ΔV position, panel 8.
d. FCSM G&N, RESET/OVERRIDE switch to G&N position, panel 2.
e. FCSM SCS, RESET/OVERRIDE switch to SCS position, panel 2

2.4.2.8 SPS Electrical Heaters.

Twenty-six electrical strip heaters are employed on the propellant line brackets, fuel and oxidizer heat exchangers, propellant utilization valve, bipropellant valve assembly, and the injector tubes. These electrical strip heaters are employed to control the temperature of the entire aft bulkhead and engine areas, thus the propellants.

The strip heaters are controlled as a normal manual function of the crew, on panel 19 (figure 2.4-2), utilizing the SPS HEATER switch. The crew will place the switch to position A or B when the propellant temperature indicator, on panel 20, reads - 40°F (lower red line indication) which is equivalent to a propellant temperature of +40°F. The propellant temperature readout is derived from the engine fuel-feed line measurement (figure 2.4-1). The crew will place the SPS HEATER switch to OFF when the propellant temperature indicator, on panel 20, reads +80°F (upper red line indication) which is equivalent to a propellant temperature of +120°F.

Propellant Temperature Comparison

Propellant Temperature Indicator Reading °F															
-100	-80	-60	-40	-20	0	+20	+40	+60	+80	+100	+120	+140	+160	+180	+200
Equivalent Temperature °F															
+0	+13.33	+26.67	+40	+53.34	+66.67	+80	+93.34	+106.67	+120	+133.34	+146.67	+160	+173.34	+186.67	+200

When the SPS HEATER switch is placed to position A, all 26 heating elements (A) will receive 28 vdc. When the SPS HEATER switch is placed to position B, all 26 heating elements (B) will receive 28 vdc. The OFF position of the SPS HEATER switch removes all electrical power from the SPS heating elements.

2.4.2.9 Thrust Mount Assemblies.

The thrust mount assembly consists of a gimbal ring, engine-to-vehicle mounting pads, and gimbal ring-to-combustion chamber assembly supports. The thrust structure is capable of providing ±8.5 degrees inclination about the Z-axis and ±7.5 degrees about the Y-axis.

2.4.2.9.1 Gimbal Actuator.

Thrust vector control of the service propulsion engine is achieved by dual- , servo- , electro-mechanical actuators. The gimbal actuators are capable of providing control around the Z-Z axis (yaw) of 7 (+1/2, -0) degrees in either direction from a +4-degree null offset, and around the Y-Y axis (pitch) of 6(+1/2, -0) degrees in either direction from a zero-degree null offset. The reason for the 4-degree offset to the +Y axis is due to the offset center of mass in the spacecraft.

Each actuator assembly (figure 2.4-3) consists of four electromagnetic particle clutches, two d-c motors, a bull gear, jackscrew and ram, ball nut, four linear position transducers, and two velocity generators. The actuator assembly is a sealed unit and enclose those portions protruding from the main housing.

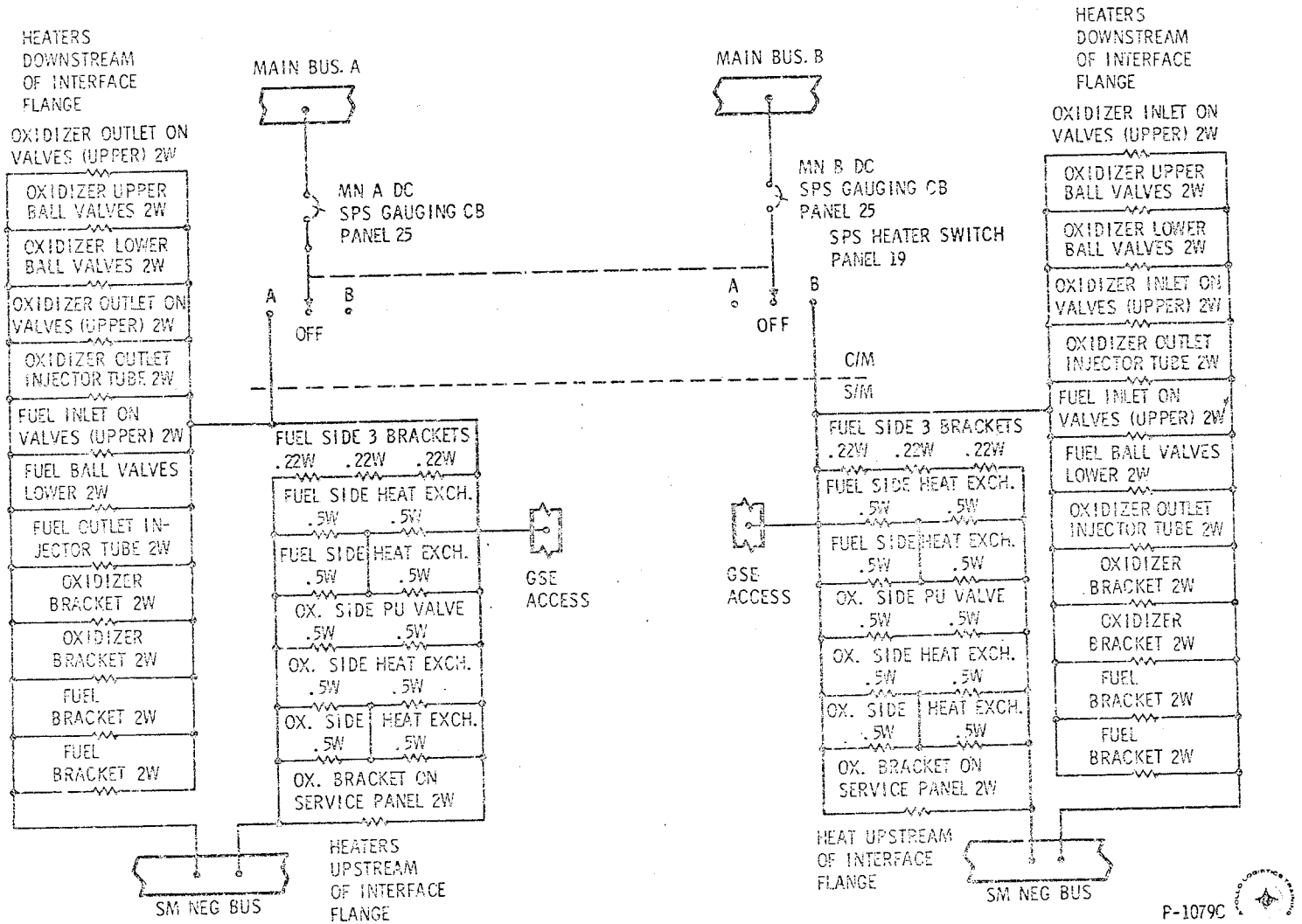


Figure 2.4-2. SPS Electrical Heaters

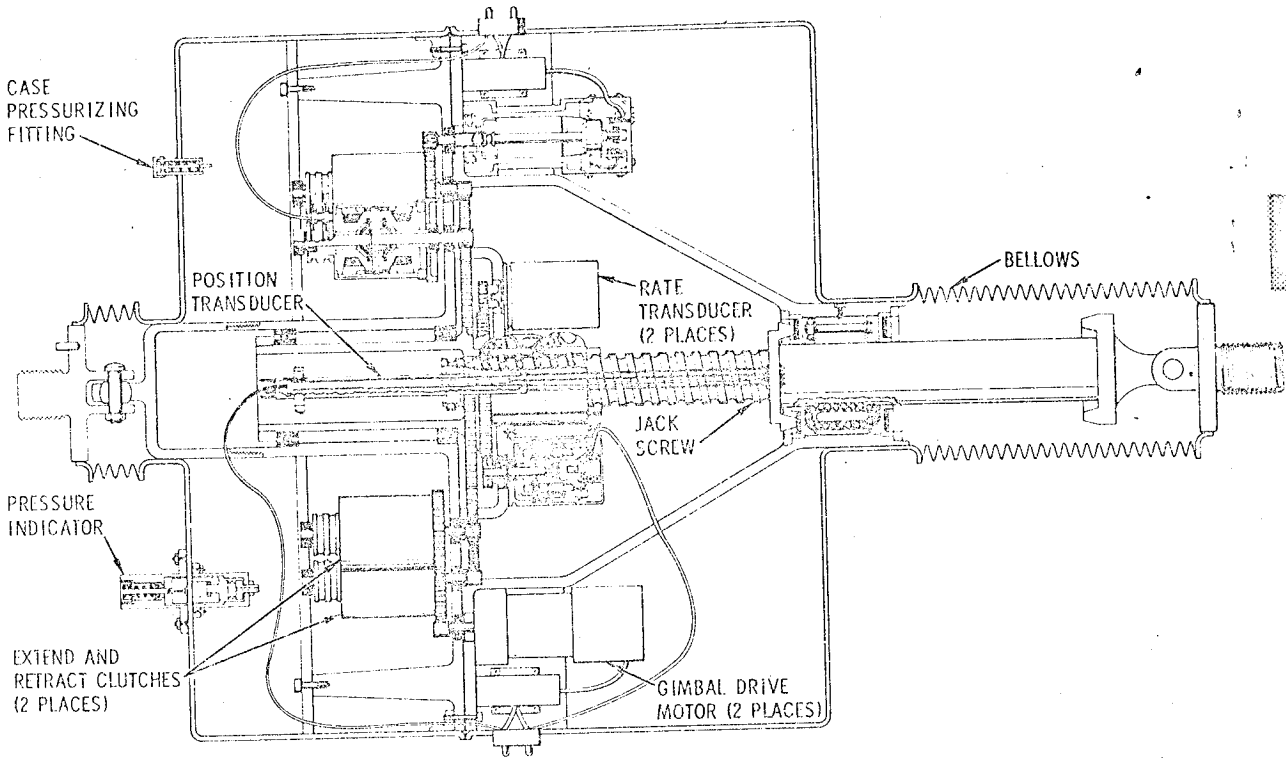


Figure 2.4-3. SPS Electro-Mechanical Gimbal Actuator

One motor and a pair of clutches (extend and retract) are identified as system No. 1, and the remaining motor and pair of clutches (extend and retract) are identified as system No. 2 within the specific actuator.

An over and undercurrent relay is employed for each primary gimbal motor (figure 2.4-4), and is controlled individually by a switch on panel 3. When the primary GIMBAL MOTORS switches are placed to the START position, power is applied to the motor-driven switch within the over and undercurrent relay of the primaries. The motor switch then supplies power from the main bus A to the gimbal motor. When the switch is released, it spring-loads to the ON position which activates the over and undercurrent sensing circuitry of the primary relay which monitors the current to the gimbal motor.

The over and under current relay of the primaries are utilized to monitor the current to the gimbal motor due to the variable current flow to the gimbal motor that is dependent upon the gimbal angle change required.

Using No. 1 yaw system as an example, and identifying the upper motor and clutches in figure 2.4-3 as system No. 1, the operation of the current monitoring system is as follows:

a. If the relay senses an over or undercurrent to gimbal motor No. 1, the monitor circuitry within the relay will drive the motor-driven switch, removing power from gimbal motor No. 1.

b. Simultaneously, a fail sense signal is sent from the relay, the SCS, which opens relay K13 removing inputs from the No. 1 clutches and closes relay K14 applying inputs to the No. 2 clutches within the same actuator; and the top contact of K12 opens and the bottom contact of K12 closes for TVC monitor.

c. Simultaneously a signal is sent to illuminate a caution and warning light on panel 11, to indicate the primary gimbal motor has failed.

The primary switches on panel 3 are then placed in the OFF position. Normally the OFF position is used to shut down the gimbal motors upon the completion of a thrusting period.

The No. 2 systems employ a 70-amp circuit breaker that is located in the service module near the SPS power distribution box.

Using No. 2 yaw system as an example (figure 2.4-4), the operation of the current monitoring system is as follows:

a. When the secondary GIMBAL MOTORS switches are placed to the START position, power is applied to the motor-driven switch within the over and undercurrent relay of the secondaries. The motor switch then supplies power from the main bus B through the 70-amp circuit breaker, and through the motor-driven switch to the secondary gimbal motor.

b. When the secondary switch is released, it spring-loads to the ON position which performs no functions on the secondaries.

c. The 70-amp circuit breaker will monitor the current to the secondary gimbal motor; and if a current of 70 amps is sensed, the circuit breaker in the service module will remove power from the secondary gimbal motor.

d. There is no fail sense signal sent to the stabilization and control system, and no illumination of the caution and warning light on panel 11 from the secondary system.

e. If the No. 2 system has failed due to an overcurrent, the circuit breaker removes power from gimbal motor No. 2 only, and that specific actuator is inoperative if the No. 1 system has previously failed.

The secondary switches on panel 3 are then placed to OFF position. Normally, the OFF position is used to shut down the gimbal motors upon the completion of a thrusting period.

The clutches are of a magnetic particle type. The gimbal motor drive gear meshes with the gear on the clutch housing. The gears on each clutch housing mesh and as a result, the clutch housings counterrotate. The current input is applied to the electro-magnet mounted to the rotating clutch housing from the stabilization control system or in the guidance and navigation system through the stabilization control system. A quiescent

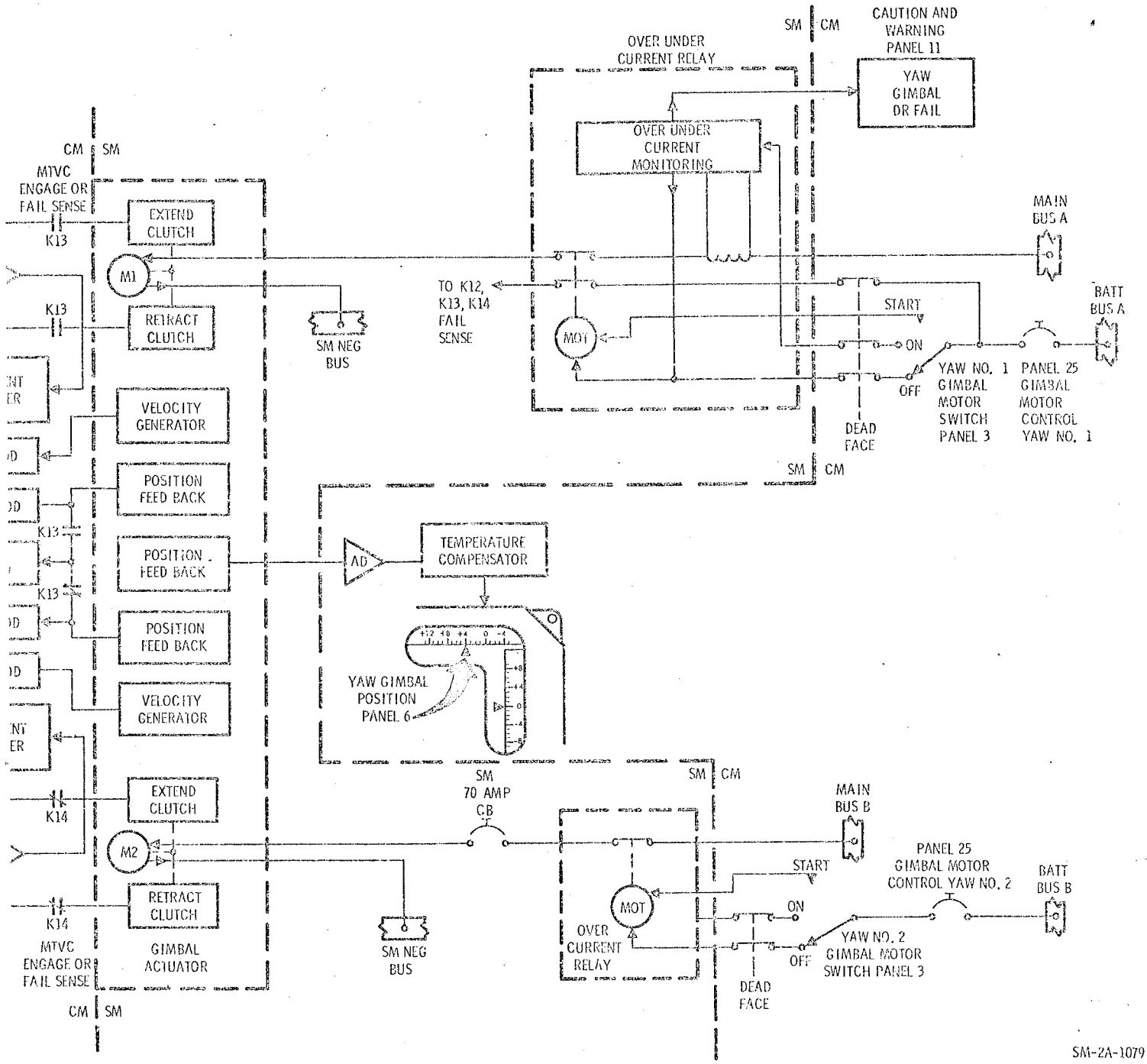
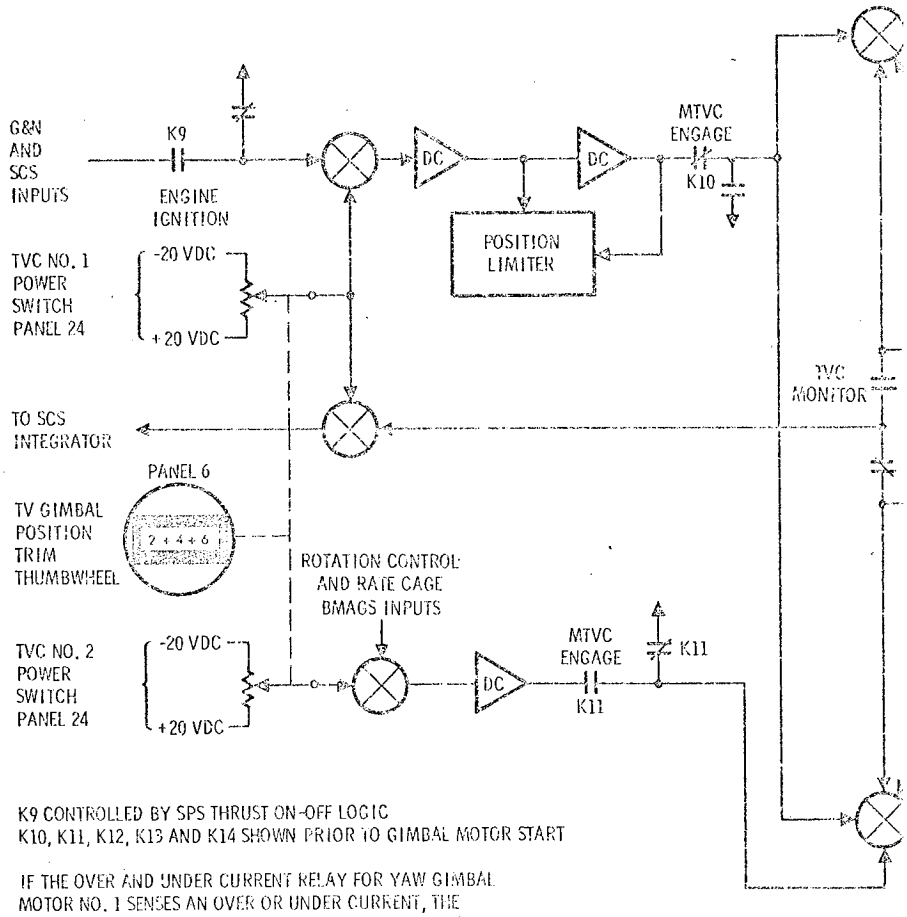


Figure 2.4-4. SPS Yaw Gimbal Actuator Motor and Clutch Control



K9 CONTROLLED BY SPS THRUST ON-OFF LOGIC
K10, K11, K12, K13 AND K14 SHOWN PRIOR TO GIMBAL MOTOR START

IF THE OVER AND UNDER CURRENT RELAY FOR YAW GIMBAL MOTOR NO. 1 SENSES AN OVER OR UNDER CURRENT, THE RELAY SIGNAL OPENS K13 TO CLUTCHES, K13 TOP CONTACT OPENS LOWER CLOSES FOR TLM, K13 CLOSES TO CLUTCHES, K12 TOP CONTACT OPENS, LOWER CLOSES.

K10, K11, K13 and K14 ARE ALSO CONTROLLED BY CLOCKWISE ROTATION OF TRANSLATION CONTROL WITH DELTA V MODE SELECTED REFERRED TO AS MANUAL THRUST VECTOR CONTROL

current is applied to the electro-magnet of the extend and retract clutches when the thrust vector POWER switches, on panel 24, are on, which prevents the engine from moving during the boost phase of the mission with the gimbal motors OFF. A 246 foot-pound force would be required on the engine to overcome the quiescent current (equivalent to 1.53 g) in the clutches. The gimbal motors will be turned on, prior to jettisoning the launch escape tower, to support the SPS abort criteria after the launch escape tower has been jettisoned, and will be turned OFF as soon as possible to reduce the heat problem that occurs due to the gimbal motors driving the clutch housings. With quiescent current applied, it creates a friction force in the clutch housing that creates heat, which if allowed to rise to a high temperature the electro-magnet would loose its magnetism capability; thus rendering that set of clutches inoperative. This problem occurs only during boost, not during the normal SPS burns.

Prior to any thrusting periods the thumbwheels on panel 6 can be used to position the engine. The thrust-on signal may be provided by the G&N through the SCS, or by SCS only. In either mode the current input required (to maintain the engine thrust vector through the center of mass) to the clutches will increase above the quiescent current which increases the current in the electro-magnets that are rotating with the clutch housings. The dry powder magnetic particles have the ability to become magnetized very readily as well as becoming demagnetized as readily. The magnetic particles increase the friction force between the rotating housing and the flywheel, causing the flywheel to rotate. The flywheel arrangement is attached to the clutch output shaft allowing the clutch shaft to drive the bull gear. The bull gear drives a ball nut which drives the actuator jack-shaft to an extend or retract position, depending upon which clutch housing electro-magnet the current input is supplied to. The larger the excitation current, the higher the clutch shaft rotation rate.

Meshed with the ball nut pinion gear are two rate transducers of the tachometer type. When the ball nut is rotated, the rate transducer supplies a feedback into the summing network of the thrust vector control logic to control the driving rates of the jackscrew (acting as a dynamic brake to prevent over or undercorrecting), one transducer for each system.

The jackscrew contains four position transducers, all arranged for linear motion and all connected to a single yoke. One of the position transducers is used to provide a feedback to the summing network of transducer feedback. The two feedbacks to the summing network reduce the output current to the clutch, resulting in a proportional rate change to the desired gimbal angle position and returns to a quiescent current.

One position transducer provides a signal to the visual display on panel 6. One of the position transducers provides a feedback to the redundant summing network of the thrust vector logic for the redundant clutches. The remaining position transducer is not presently utilized.

The spacecraft desired motion, thumbwheel positioning, engine nozzle position, thrust vector position, gimbal position display indicator and actuator ram movement is identified in figure 2.4-5.

A snubbing device provides a hard stop for an additional 1-degree travel beyond the normal gimbal limits.

Manual thrust vector control may be obtained by the crew placing the translation control clockwise. This will open contacts K10 and K13 and close contacts K11 and K14, allowing the rotation control to provide the crew with manual thrust vector control.

2.4.2.10 Propellant Utilization and Gauging Subsystem (PUGS).

The subsystem consists of eight propellant quantity sensors, a propellant utilization valve, a control unit, and a display unit (figures 2.4-6 and 2.4-7).

2.4.2.10.1 Quantity Sensing, Computing, and Indicating System.

Propellant quantity is measured by two separate sensing systems: primary and auxiliary. The primary quantity sensors are cylindrical capacitance probes, mounted axially in each tank. In the oxidizer tanks, the probes consist of a pair of concentric electrodes with oxidizer used as the dielectric. In the fuel tanks, a pyrex glass probe, coated with silver on the inside, is used as one conductor of the capacitor. Fuel on the outside of the probe is the other conductor. The pyrex glass itself forms the dielectric. The auxiliary system utilizes point sensors mounted at intervals along the primary probes to provide a step function impedance change when the liquid level passes their location centerline.

Primary propellant measurement is accomplished by the probes capacitance being a linear function of propellant height.

Auxiliary propellant measurement is accomplished by locating the propellant level with point sensors. Each point sensor consists of concentric metal rings, seven in the storage tanks and eight in the sump tanks. The rings present a variable impedance, depending on whether they are covered or uncovered by the propellants. When the propellants are between point sensors, the propellants remaining are integrated by a rate flow generator which integrates the servos at a rate proportional to the normal flow rate of the fuel and oxidizer. A mode selector senses when the propellant crosses a sensor and changes the auxiliary servos from the flow rate generator mode to the position mode, the system moves to the location specified by the digital-to-analog converter for 3/4 second to correct for any difference. The system then returns to the flow rate generator mode until the next point sensor is reached. Figures 2.4-8 and 2.4-9 illustrate point sensor locations that are covered by propellants. The nonsequential pattern detector functions to detect false or faulty sensor signals. If a sensor has failed, the information from that sensor is blocked from the system, preventing disruption of system computation.

S/C MOTION DESIRED BY THE CREW	THUMB WHEEL POSITIONED ON PANEL ASSEMBLY 6 TO A	ENGINE NOZZLE MOVES TOWARDS THE	THE THRUST VECTOR OF THE ENGINE MOVES TOWARDS THE	GIMBAL POSITION INDICATOR ON PANEL ASSEMBLY 6 MOVES TO A	ACTUATOR RAM
S/C NOSE DOWN (PITCH)	+ NUMERAL (UP)	+ Z AXIS OF THE S/C	- Z AXIS OF THE S/C	+ NUMERAL	PITCH EXTENDS
S/C NOSE UP (PITCH)	- NUMERAL (DOWN)	- Z AXIS OF THE S/C	+ Z AXIS OF THE S/C	- NUMERAL	PITCH RETRACTS
S/C RIGHT (YAW)	- NUMERAL (RIGHT)	+ Y AXIS OF THE S/C	- Y AXIS OF THE S/C	- NUMERAL	YAW RETRACTS
S/C LEFT (YAW)	+ NUMERAL (LEFT)	- Y AXIS OF THE S/C	+ Y AXIS OF THE S/C	+ NUMERAL	YAW EXTENDS

THE ACTUATOR NULL POSITION IN YAW IS 4° OFFSET FROM THE S/C X AXIS DUE TO THE ENGINE MOUNTING PADS IN THE SERVICE MODULE BEING CANTED (BLOCK I VEHICLES)
THE THRUST VECTOR IS 4° TO THE +Y AXIS OF THE S/C AND THE ENGINE NOZZLE IS 4° TO THE -Y AXIS OF THE S/C.
AS A RESULT THE GIMBAL POSITION INDICATOR ON PANEL ASSEMBLY 6 WILL INDICATE A +4° WHEN THE ACTUATORS ARE IN THE NULL POSITION.
TO PARALLEL THE THRUST VECTOR AND THE ENGINE NOZZLE WITH THE X AXIS OF THE S/C, THE YAW THUMB WHEEL ON PANEL ASSEMBLY 6 MUST BE POSITIONED TO 0° AND AS A RESULT THE YAW POSITION INDICATOR ON PANEL ASSEMBLY 6 WILL INDICATE 0°.
IN THIS CASE, THE YAW ACTUATOR IS NO LONGER IN ITS NULL POSITION IN RESPECT TO THE GIMBAL RING.
THE THRUST VECTOR AND THE ENGINE NOZZLE ARE NOW PARALLEL TO THE X AXIS OF THE S/C

THE ACTUATOR NULL POSITION IN PITCH IS 0° (BLOCK I VEHICLES).

P-1073A

Figure 2.4-5. Gimbaling of the Service Propulsion Engine

When a THRUST-ON signal is provided with the SENSOR select switch in the PRIMARY or NORMAL position, the crew display digital readouts, and unbalance display will not change for 4.5±1.0 seconds to allow for propellant settling. However, TLM will receive the same signal as upon completion of the last firing after approximately one second of SPS THRUST-ON.

When the THRUST-ON signal is provided with the SENSOR select switch in AUXILIARY position, the crew display digital readouts and TLM will receive a change in information immediately which is generated from a flow rate integrator that simulates the nominal flow rate and transmits this as quantity information to the crew displays and TLM. The crew digital readouts, unbalance display, and TLM will not be updated to the propellant from a point sensor for 4.5±1.0 seconds after THRUST-ON. When the THRUST-ON signal is provided plus 4.5±1.0 seconds, if a point sensor is uncovered the crew digital readouts, unbalance display, and TLM will be updated to the propellant remaining at that point sensor. The time delay of 4.5±1.0 seconds is to the point sensor system and not to the auxiliary fuel and oxidizer servos. and is to allow for propellant settling.

Any deviation from the nominal oxidizer to fuel ratio (2:1 by mass) is displayed in pounds by the UNBALANCE indicator. The upper half of the indicator is marked INC, and the lower half is marked DEC to identify the required change in oxidizer flow rate to correct any unbalance condition.

When the SENSOR select switch is in the NORMAL position, the outputs of both sensor systems are continually compared in the comparator network. If a discrepancy occurs between total primary and total auxiliary fuel of 300 pounds, or a discrepancy between total primary oxidizer and auxiliary oxidizer of 300 pounds, the caution and warning indicator on panel 11 is illuminated. The output of the oxidizer sump tank servo amplifier and the primary potentiometer of the unbalance indicator are compared in the comparator network, and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached (figure 2.4-10), the caution and warning light on panel 11 is illuminated.

With the SENSOR select switch in the PRIMARY position, the output of the oxidizer sump tank servo amplifier and the output of the primary potentiometer in the unbalance meter are compared in the comparator network and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached, the caution and warning light on panel 11 is illuminated.

With the SENSOR select switch in the AUXILIARY position, the output of the auxiliary oxidizer servo amplifier and the output of the axuiliary potentiometer are compared in the comparator network, and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached (figure 2.4-10), the caution and warning light on panel 11 is illuminated.

G AND INDICATING SYSTEM

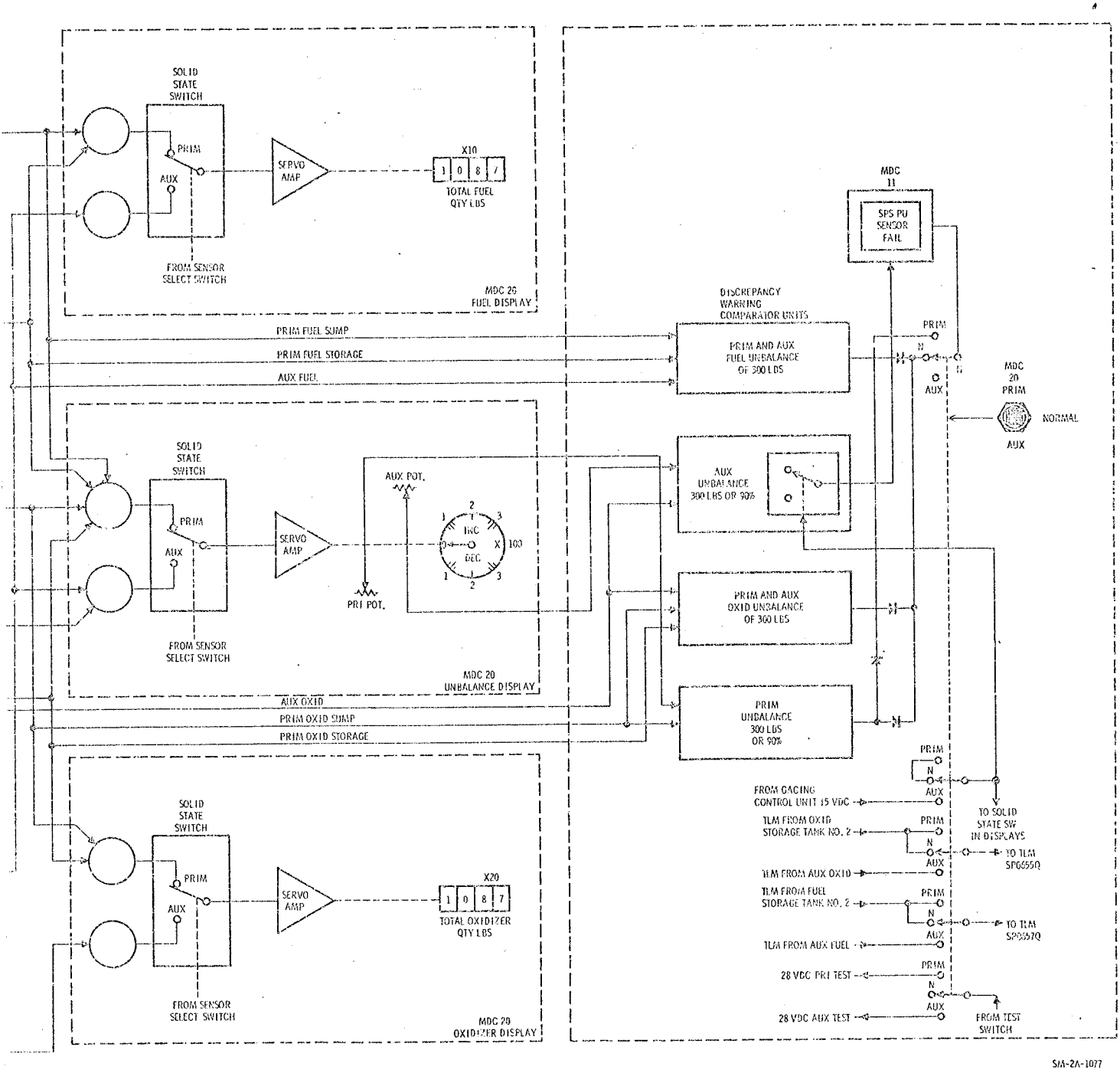
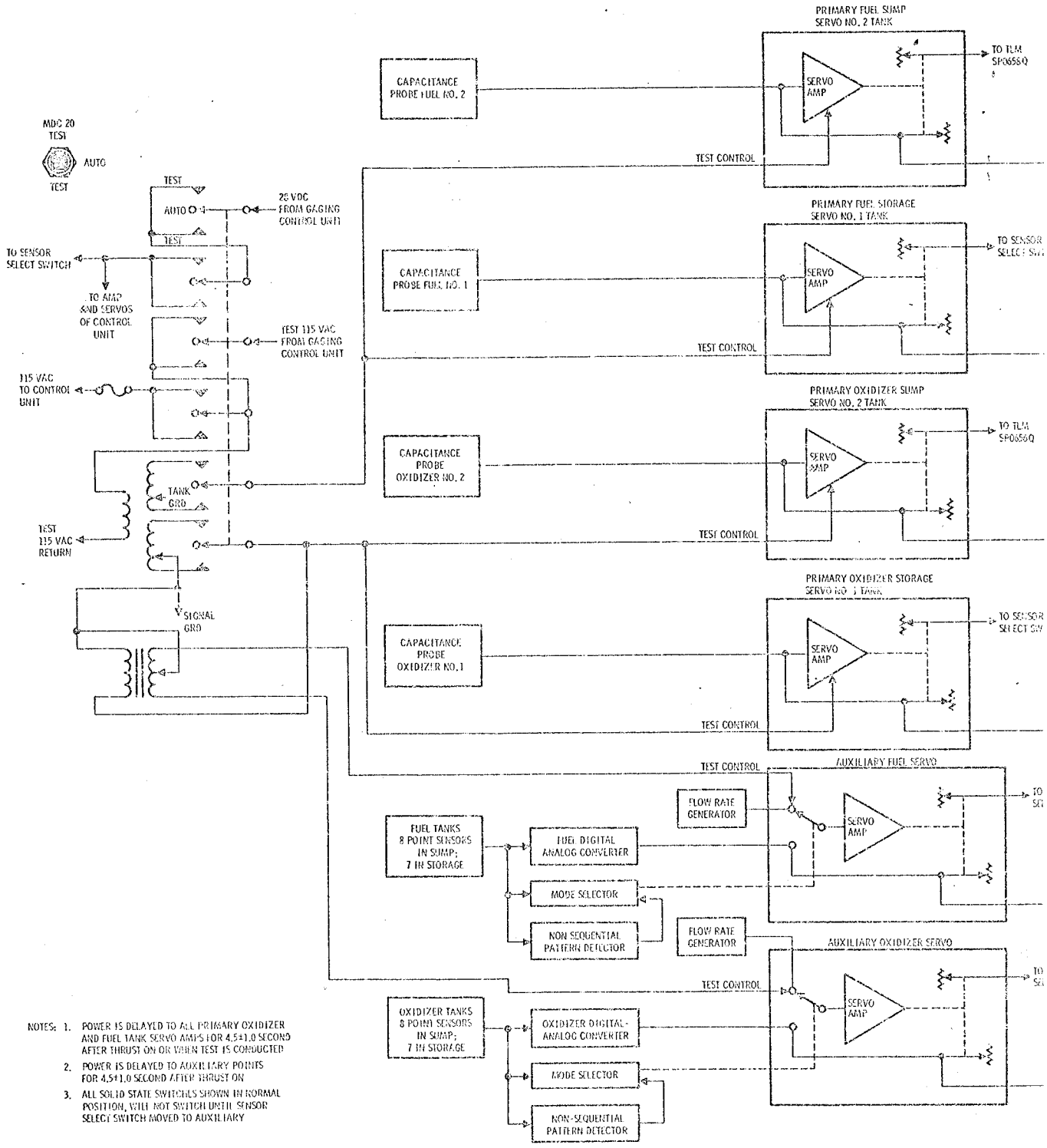


Figure 2.4-6. SPS Quantity Sensing, Computing and Indicating System

SPS QUANTITY SENSING, COMP



NOTES:
1. POWER IS DELAYED TO ALL PRIMARY OXIDIZER AND FUEL TANK SERVO AMPS FOR 4.5±1.0 SECONDS AFTER THRUST ON OR WHEN TEST IS CONDUCTED
2. POWER IS DELAYED TO AUXILIARY POINTS FOR 4.5±1.0 SECOND AFTER THRUST ON
3. ALL SOLID STATE SWITCHES SHOWN IN NORMAL POSITION, WILL NOT SWITCH UNTIL SENSOR SELECT SWITCH MOVED TO AUXILIARY

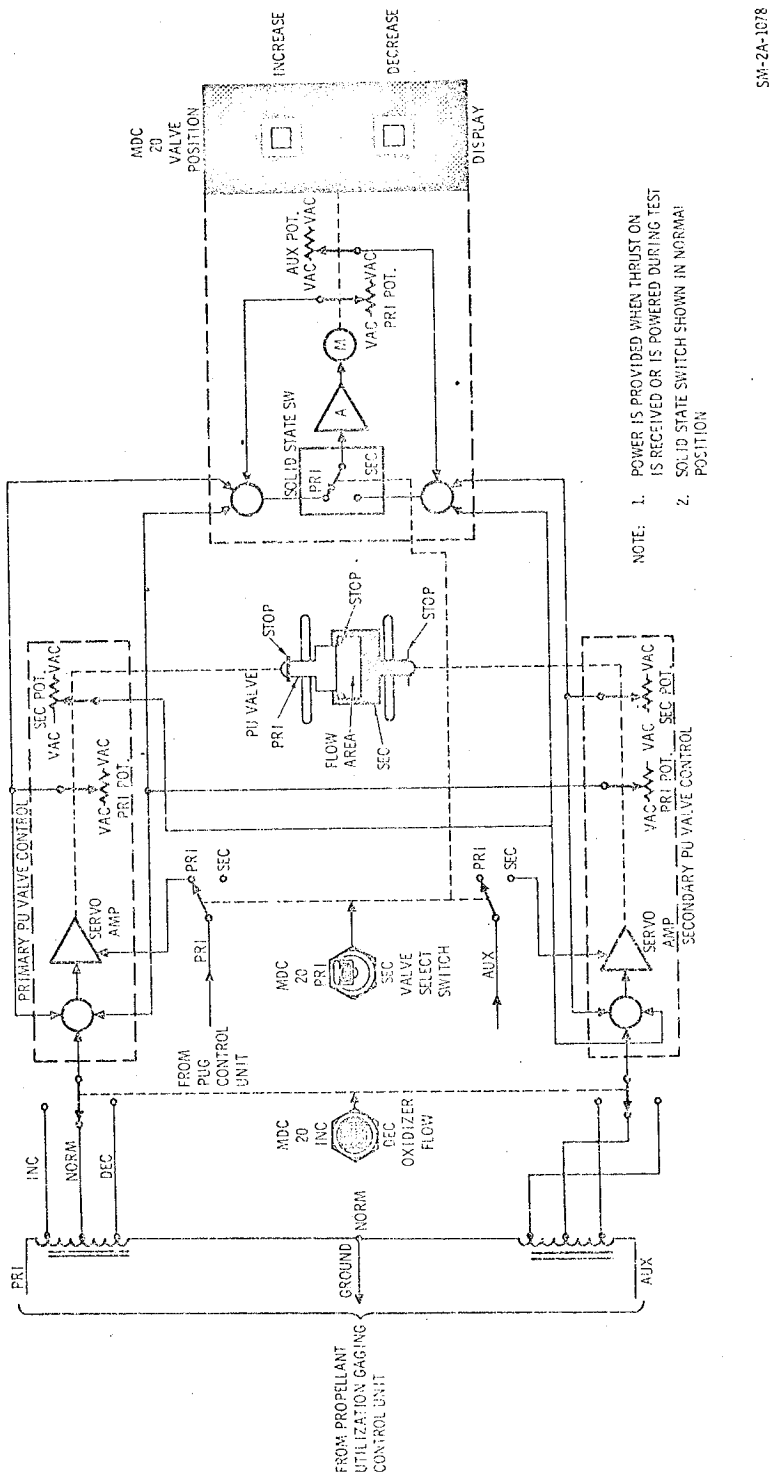


Figure 2.4-7. Propellant Utilization Valve Control and Flag Display.

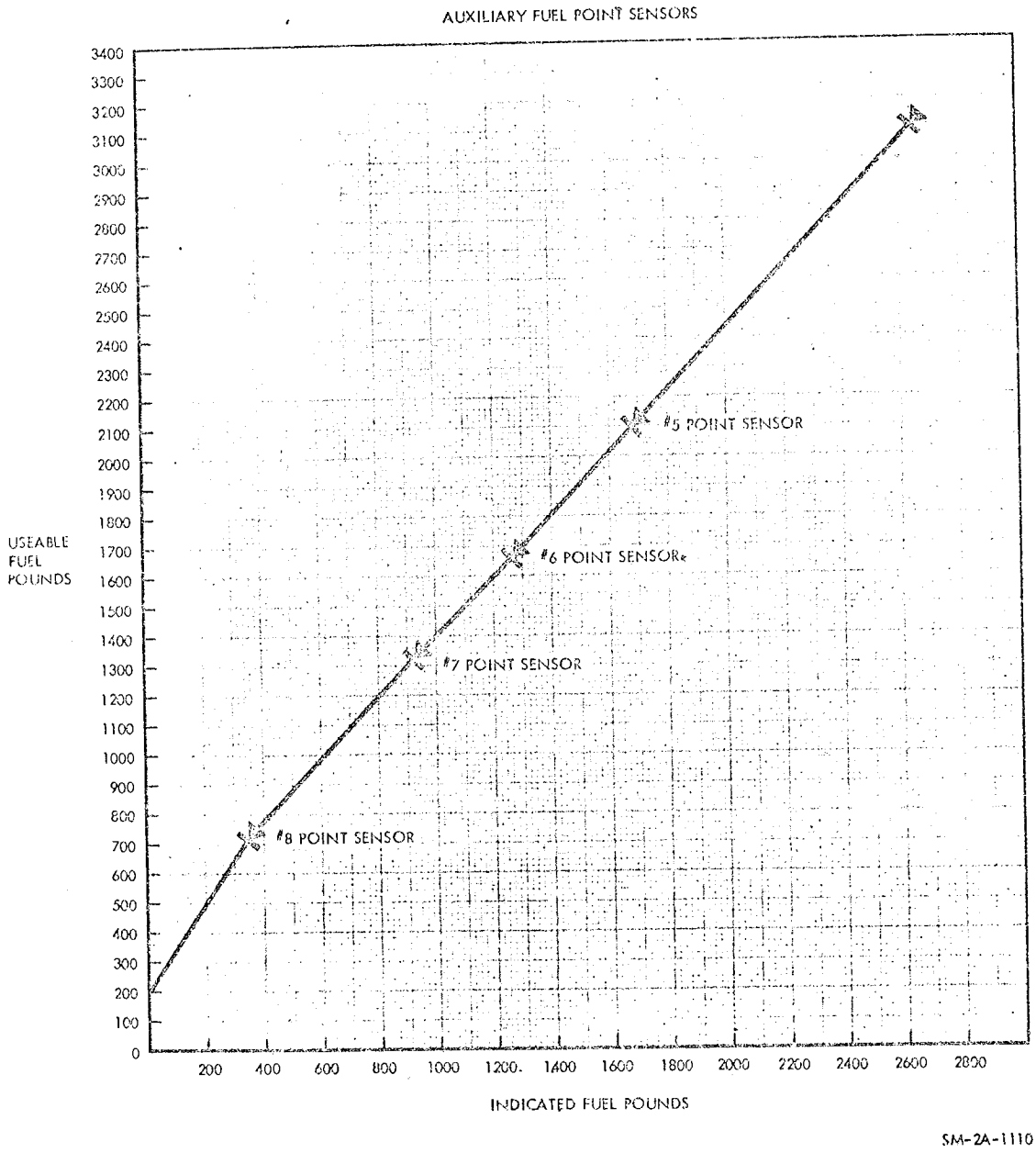


Figure 2.4-8. Auxiliary Fuel Point Sensors

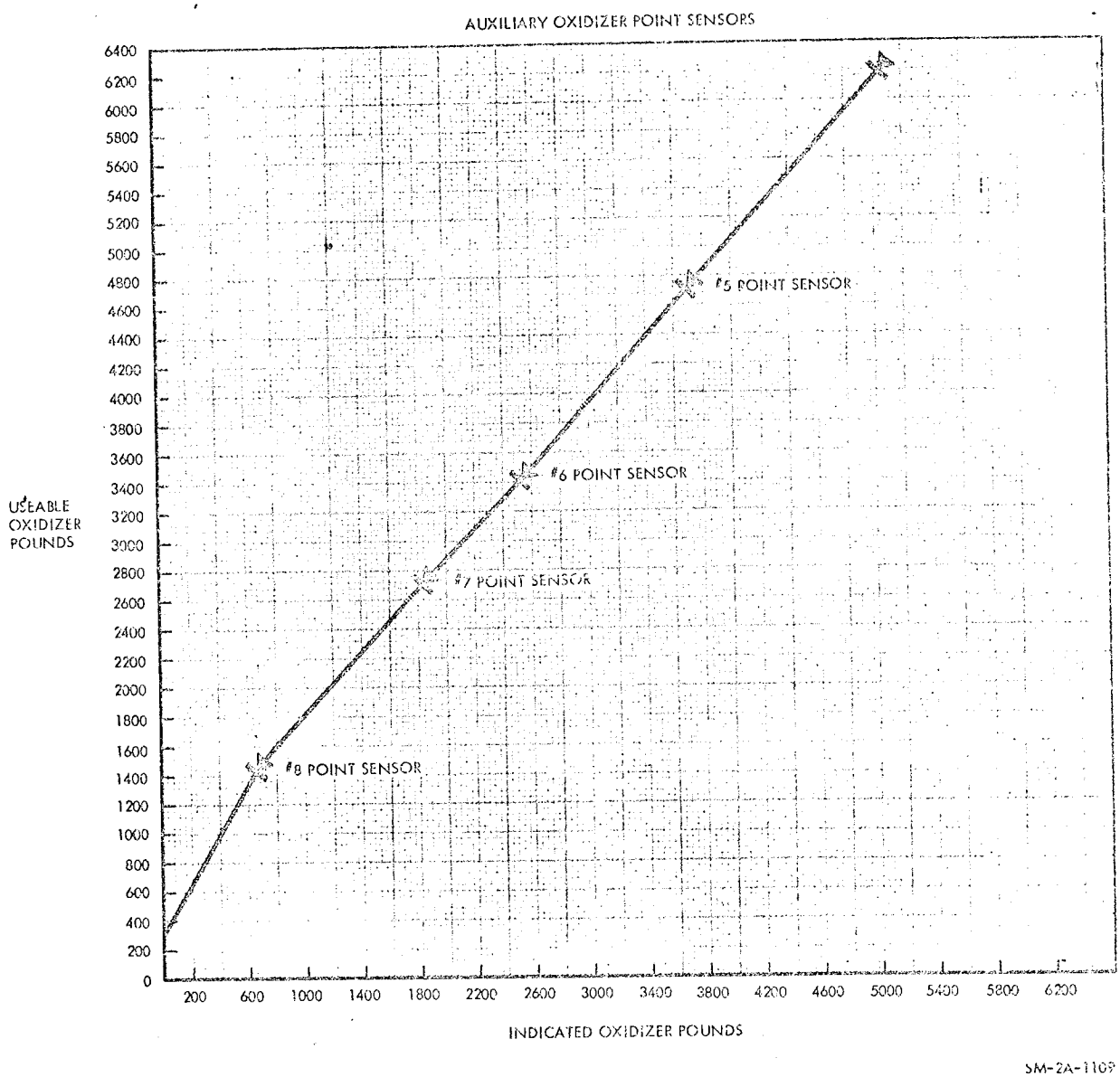


Figure 2.4-9. Auxiliary Oxidizer Point Sensors

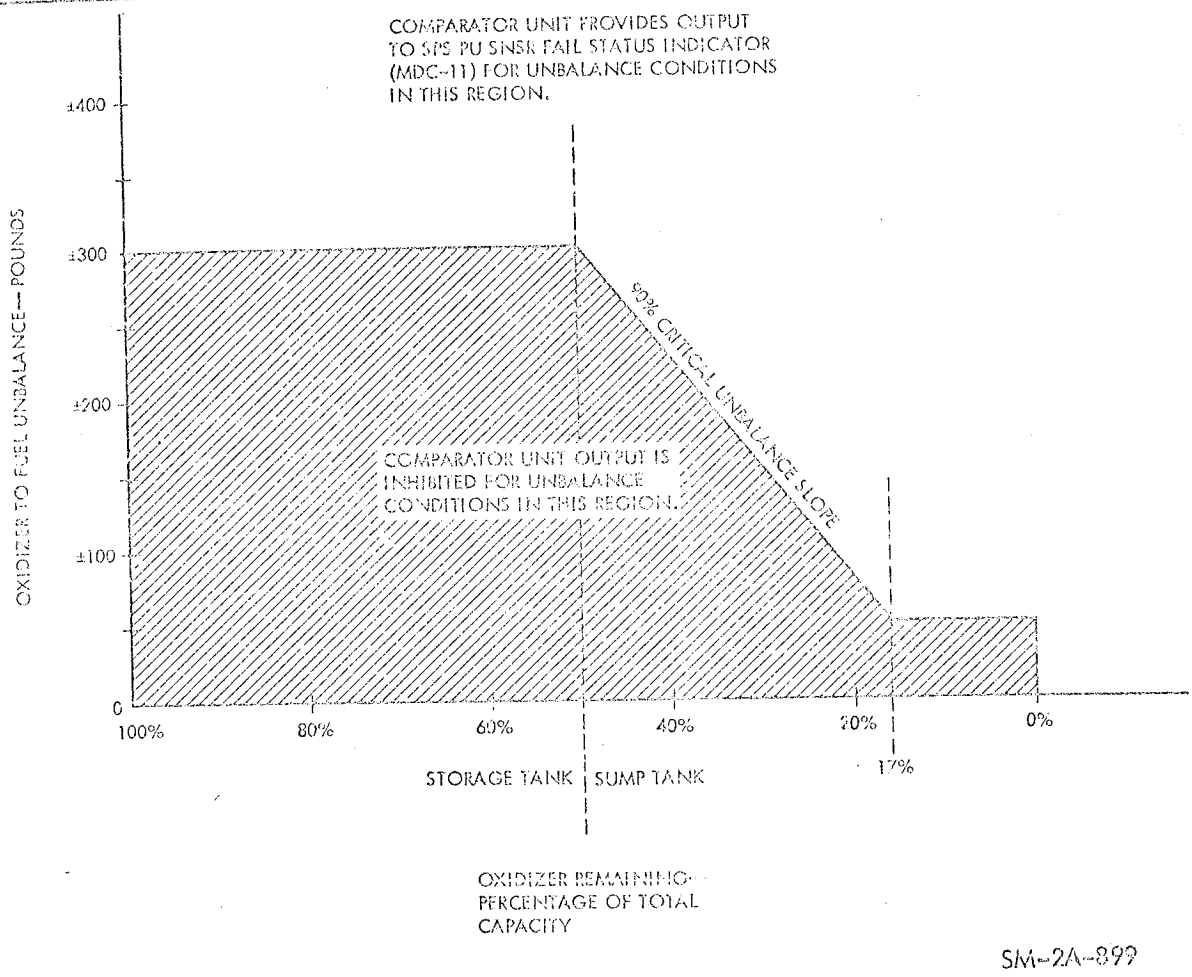


Figure 2.4-10. Propellant Unbalance Warning System Output Chart

Once the warning light is illuminated, the crew can determine whether there is a malfunction within the quantity and indicating systems or if there is a true unbalance condition existing by use of the self-test portion of the system. By observing the response of each system in conjunction with the TEST switch on panel 20, the crew can recognize the malfunction or determine if there is a true unbalance existing.

2.4.2.10.2 Quantity Computing and Indicating System Test.

A test of the sensing systems excluding the point sensors and probes can be implemented during THRUST-ON or -OFF periods.

With the SENSOR select switch in PRIMARY and the TEST switch in the TEST UP position, the test stimuli is applied to the primary system tank servo amplifiers after a 4.5±1.0 second delay. At this time, the test stimuli will drive the fuel and oxidizer displays to an increase reading at

different rates (oxidizer at a rate of approximately 3 digits per second and fuel at a rate of approximately 1.5 digits per second), resulting in an unbalance and indicated on the unbalance display as an INC (clockwise rotation). TLM would receive an increase in propellant quantity from the primary system simultaneously.

Placing the TEST switch in the TEST DOWN position, and after a 4.5±1.0-second delay, will provide test stimuli to the tank servo amplifiers which will drive the fuel and oxidizer displays to a decrease reading, returning the crew displays close to the reading displayed prior to TEST UP, simultaneously TLM would receive a decrease in propellant quantity. If the TEST switch was again placed to TEST DOWN, after a 4.5±1.0-second delay, the fuel and oxidizer crew display readouts would drive to a decrease reading at different rates resulting in an unbalance and indicated on the unbalance display as a DEC (counterclockwise rotation). TLM would receive a decrease in propellant quantity simultaneously. To return to the reading displayed prior to the second TEST DOWN, place the TEST switch to TEST UP and after a 4.5±1.0-second delay, the crew displays would return close to the original displayed readings, simultaneously TLM receives an increase in propellant quantity.

To test the auxiliary system, place the SENSOR select switch to AUXILIARY and utilize the TEST switch up and down positions. There is no time delay involved with the auxiliary system.

The AUTO position removes the electrical test stimuli inputs.

2.4.2.10.3 Propellant Utilization Valve.

If an unbalance condition exists, the crew will use the propellant utilization valve to return the propellants to a balanced condition. The propellant utilization valve housing contains two sliding gate valves within the housing. One of the sliding gate valves is the primary and the remaining is the secondary (figure 2.4-7).

Stops are provided within the valve housing for the full increase or decrease positions of the primary and secondary sliding gate valves.

The secondary propellant utilization valve has twice the travel of the primary propellant utilization valve to compensate for primary propellant utilization valve failure in any position. The secondary valve is selected by the VALVE switch and is controlled by the OXIDIZER FLOW switch in the same manner as the primary.

The propellant utilization valve controls are on panel 20. The VALVE switch selects the primary or secondary propellant utilization valve. Normal position of the VALVE switch is PRIMARY. The OXIDIZER FLOW switch is utilized to position the primary or secondary propellant utilization

sliding gate valve. When the OXIDIZER FLOW switch is in NORMAL, the sliding gate valve is in the nominal flow position and the upper and lower OXID flow position indicator is gray. When the OXIDIZER FLOW switch is placed to the INCREASE position, the sliding gate valve is in the increase flow position and the upper OXID flow position indicator is striped. When the OXIDIZER FLOW switch is placed to DECREASE position, the sliding gate valve is in the decrease flow position, but does not block the oxidizer flow completely and the lower OXID flow indicator is striped.

2.4.2.10.4 Engine THRUST ON-OFF Control.

Figure 2.4-1 illustrates the THRUST ON-OFF logic in the guidance and navigation delta V mode, the stabilization control system delta V mode and the manual direct mode.

The guidance and navigation is the primary delta V mode which provides the most accurate trajectory corrections. The G&N ΔV mode of operation will require G&N gate 2 to be completely enabled. Its required inputs will be an ullage maneuver input which could be supplied by the SPS abort logic or the direct ullage pushbutton or by translation control 1 or 2 placed to the +X, which would satisfy the OR gate 3 function and the holding input after the G&N AND gate 2 is enabled which is processed through NAND gates 1 and 2, with the G&N ΔV mode selected from the SCS control panel and the pulse train converter output of logic one commanded from the G&N computer by the crew. These inputs will enable AND gate 2 and provide the logic one input to inverter 3 which disables AND gate 6. Inverter 4 will provide a logic one signal to the solenoid drivers that provide the ground for the two sets of SPS relays. The two sets of SPS relays provide power to the following:

a. The four solenoid control valves, which allow gaseous nitrogen pressure to be directed to four actuators that position eight of the ball valves in the injector valve assembly of the engine. This is due to INJECTOR PRE VALVE A and B being enabled.

b. The quantity sensing and indicating system and the propellant utilization valve.

c. The systems A and B helium pressurizing valves.

d. When the output of the pulse converter is a logic zero, G&N AND gate 2 is disabled, which terminates a G&N ΔV maneuver and removes ground from the two sets of SPS relays. (Manual backup of the THRUST CONTROL switch to OFF.)

The backup delta V mode, is the stabilization control system delta V mode which has limitations and restrictions that require individual consideration. The SCS ΔV mode of operation will require enabling SCS AND gate 1 to initiate thrusting of the engine. SCS AND gate 1 has three enabling inputs: the input from OR gate 1 indicating a ΔV mode is selected; the output from the DECA indicating a value greater than zero on the ΔV REMAINING display; and the input from the THRUST ON pushbutton light indicator after it is processed through NAND gates 3 and 4. The one logic output from SCS AND gate 1 is inverted by INVERTER 2 to a zero logic which disables AND gate 6 and is inverted by INVERTER 4 to a logic one,

and enables the solenoid drivers that provide ground to the two sets of SPS relays. The two sets of SPS relays provide power to the same functions as in the G&N ΔV mode.

a. When the output of the DECA ΔV REMAINING counter reaches zero velocity, SCS AND gate 1 is disabled. The logic output from AND gate 1 goes to zero and INVERTER 2 goes to a one logic output which enables AND gate 6 to a one logic output and the signal is inverted by INVERTER 4 to a zero logic output, and the solenoid drivers remove ground from the two sets of SPS relays terminating thrust. (Manual backup of the THRUST CONTROL switch to OFF.)

The DIRECT operating mode bypasses all electronics. The DIRECT ON position of the THRUST CONTROL switch provides power to the two sets of SPS relays, the same as in the G&N ΔV mode of SCS ΔV mode.

Thrust would be terminated by placing the THRUST CONTROL switch in the OFF position.

The SPS thrust control logic provides illumination of the talk-back light in the THRUST ON switch. To illuminate the light in a G&N ΔV mode, AND gate 4 must be enabled. It has two inputs which are G&N ΔV mode selected and the presence of a logic one output from the pulse train converter. With AND gate 4 enabled, OR gate 2 will trigger the lamp driver and illuminate the THRUST ON light. To illuminate the light in the SCS ΔV mode, AND gate 3 must be enabled, it will also satisfy OR gate 2 and trigger the lamp driver. The SPS thrust control logic is interlocked so that AND gates 3 and 4 will never be enabled simultaneously because of the THRUST ON switch inhibited to the pulse train converter. Therefore, the THRUST ON light will be illuminated at all times when the thrust is on for normal operation. If the direct function is used to initiate thrusting, it will bypass all electronics and not illuminate the THRUST ON light.

The output from the SPS thrust control logic performs a function other than energize the fuel and oxidizer solenoid valves. It provides the logic switches required to reconfigure the SCS relays for proper thrust vector control. The thrust control switch provides both inputs to OR gate 4 if both dc buses are operational. Either dc bus will enable OR gate 5 to provide the upper input to INHIBIT AND gate 1. AND gate 5 provides the controlling input to the INHIBIT AND gate 1. When the solenoid drivers are not energized and the thrust control switch is in NORMAL, both inputs to AND gate 5 are true. The true input will maintain a logic false output from the INHIBIT AND gate 1 because of the inversion on the input of the gate. When either SPS relay set is activated by a solenoid driver or by the ground contacts of the DIRECT ON switch, AND gate 5 will be disabled by the ground or false input. The input will be inverted by the INHIBIT AND gate 1 input to enable an output to the time delay. The time delay is required to permit thrust buildup from the SPS engine before the ullage maneuver is terminated; however, the pitch and yaw attitude error inputs are inserted into the TVC electronics immediately. This action assures positive g forces

throughout thrust initiation of the SPS engine and gimbaling control of the SPS engine for the entire thrust buildup. The time delay is also active after INHIBIT AND gate 1 is disabled by enabling AND gate 5. AND gate 5 is enabled when both sets of SPS relays are de-energized. The time delay is active for both outputs when the signal is removed to permit continued SPS engine gimbal control, while the residual thrust is present and inhibits RCS operation in pitch and yaw until residual thrust is reduced. This reduces the tumbling induced at thrust termination. The time delay is approximately one second for application and removal of the engine ignition signal.

2.4.3 PERFORMANCE AND DESIGN DATA.

2.4.3.1 Design Data.

The following list contains specific data for the components in the SPS:

HELIUM TANKS (2)	4000±50 psia fill pressure, 4400 maximum operating pressure 70°±10°F, capacity 19.4 cubic feet, inside diameter 40 in. and a wall thickness of 0.46 in.
REGULATOR UNITS (2)	Working regulator - Primary 186±4 psig, secondary 191±4 psig, primary lockup 200 psig, secondary lockup 205 psig. Normally locked by working regulator; primary 181±4 psig, secondary 191±4 psig, primary lockup 195 psig, secondary lockup 205 psig.
PRESSURE TRANSDUCERS (2) ULLAGE PRESSURE (REGULATED HELIUM)	Fuel and oxidizer underpressure setting (SPS PRESS light, panel 11) 160 psia. Fuel and oxidizer overpressure setting (SPS PRESS light, panel 11) 200 psia.
PROPELLANT UTILIZATION	Increase position - 46.65 lbs/second
VALVE CONTROL (2)	Normal position - 45.27 lbs/second at 70°F and 168±4 psig Decrease position - 43.87 lbs/second Response time - Normal to increase or vice-versa, or normal to decrease or vice-versa is 3 to 4 seconds
QUANTITY SENSING SYSTEM ACCURACY	±0.35% of full tank plus ±0.35% of propellant remaining primary system ±0.35% of full tank plus ±0.35% of propellant remaining plus 2.3% of storage tank quantity remaining, auxiliary system.

HELIUM RELIEF VALVE (2)	Diaphragm ruptures at 220±7 psig Filter - 10 microns normal, 25 microns absolute Relief valve relieves at 232±8 psig Relief valve reseats at 212 psig minimum Flow capacity 3 lbs/second minimum at 60 F and 250 psig Bleed device closes at ambient to 100 psi and is manually reset open
OXIDIZER STORAGE AND SUMP TANK	Total tank capacity 30,600 lbs, usable 27,333 lbs. Each tank has a volume of 175 cubic ft. Fill pressure 110 psia. Ullage after filling 2.4 cubic ft in storage and 8.0 cubic ft in sump tank. Ullage after pressurized to 175 psia, 6.8 cubic ft in storage and 5.0 cubic ft in sump tank. Inside diameter 51 in., length 165.4 in., and will elongate to 0.125 in. when pressurized to 240 psi and 120°F for 336 hours. Wall thickness 0.060 in. in continuous areas, 0.069 in. weld buildup areas and 0.031 in. on domes. Fill tolerance of 1/4 of 1% of full tank plus 1/4% of propellant remaining.
FUEL STORAGE AND SUMP TANK	Total tank capacity 15,300 lbs, usable 13,677 lbs. Each tank has a volume of 139.7 cubic ft. Fill pressure 90 psia. Ullage after filling 1.8 cubic ft in storage and 5.8 cubic ft in sump tank. Ullage after pressurized to 175 psia, 6 cubic ft in storage and 3.0 cubic ft in sump tank. Inside diameter 45 in., length 166.8 in., and will elongate to 0.125 in. when pressurized to 240 psi and 120°F for 336 hours. Wall thickness 0.053 in. in continuous areas, 0.061 in. in weld buildup areas, and 0.031 in. on domes. Fill tolerance of 1/4 of 1% full tank plus 1/4% of propellant remaining.

NOMINAL PROPELLANT TANK WORKING PRESSURE	175±4 psia
INTERFACE FLANGE FILTER	500 microns absolute
GASEOUS NITROGEN PROPELLANT VALVE CONTROL SYSTEMS (2)	Storage vessel pressure 2500±50 psi at 68°F, 2900 psi at 130°F. Support 36 valve actuations. Regulator, single stage, 130±7 psi at all flow up to 0.035 lbs/second. 145 psi maximum lockup pressure. Relief valve - relieves at 350±10 psi, reseats at not less than 250 psi Ball valves 1 and 4 dry opening travel time of 0.6 (+0.2, - 0.05) second Ball valves 2 and 3 dry opening travel time of 0.325±0.1 second. Ball valves 1 and 4 dry closing travel time of 0.375±0.05 second Ball valves 2 and 3 dry closing travel time of 0.575±0.1 second
ENGINE	500-second service lift on S/C 014 Capable of 36 restarts Expansion ratio, 6 to 1 at ablative chamber exit area, 62.5 to 1 at nozzle extension exit area. Cooling chamber, ablation and film extension, radiation Injector type, baffled regeneratively, cooled, unlike impingement Oxidizer lead, 8 deg. Length, 152.82 inches

		Nozzle extension exit diameter, 94.4 inches
		Weight, approximately 650 lbs
		Ablative chamber throat temperature sensor, illuminates SPS WALL TEMP HI caution and warning light on panel 11 at 380°F, one sensor per harness.
		SPS P_c transducer, P_c displayed on panel 3 through L/V AOA, SPS P_c switch to L/V AOA, SPS P_c indicator, green range on indicator is 65 to 125%, normal P_c 85 to 125 psia.
	GIMBAL LIMITS	About Z-Z axis ±7 (+1/2, -0) deg with additional 1 deg for snubbing yaw
		About Y-Y axis ±6 (+1/2, - 0) deg with additional 1 deg for snubbing pitch
	GIMBAL MOTOR UNDER AND OVERCURRENT RELAYS	Undercurrent (primary only) below 6 amperes detected for a duration of 250±50 milliseconds or more shall interrupt the flow to the load in less than 100 milliseconds.
		Overcurrent dependent upon temperature during start transient and steady state of gimbal motor on primary. Secondary controlled by 70-amp circuit breaker.
	ACTUATOR CLUTCHES	Quiescent current of 60 (+10, -5) milliamps (Motors off, a 246 ft-lb force required to move engine equivalent to 1.53 g.)
	ACTUATOR PRESSURIZED S/C 012 and 014 SERVO ACTUATOR DEFLECTION RATE	3.5±1.0 psi dry air at -160°F at vendor 0.23 radians per second (13.09° per second)
	FLIGHT COMBUSTION	180 g's peak to peak for 70±20 milliseconds
	STABILITY MONITOR SYSTEM	600 to 5000 cycles per second

2.4.3.2 Performance Data.

Refer to mission modular data book, SID 66-1177.

2.4.3.3 Power Consumption Data.

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Service propulsion						
Propellant utilization valve	VALVE sw and OXIDIZER FLOW sw (Ref. gauging sys)				62.6	16.8
Propellant utilization gauging system	Gauging CB(4) SPS GAUGING AC sw SENSOR sw					
Injector prevalves	He valve CB(2) INJECTOR PREVALVE sw (2)	2		21.0		42.0
He solenoid valves	He PRESSURIZING sw (2) SPS relay	2		28.0		56.0
Feedline heaters	SPS HEATER sw	26		(See figure 2.4-2)		33.0
Pilot valves (SCS)	ECA drivers (2)	4		10.5		42.0
Gimbal actuator motors	Gimbal CB (6) GIMBAL MOTOR sw (4)	Channel I				
		Idle				
		pitch		450*		900
		yaw		450*		
		Boost				
		pitch		511*		1022
		yaw		511*		
		Thrust ON				
		pitch		775*		1550
		yaw		775*		
		Maximum				
		pitch		1800*		3600
		yaw		1800*		
		Channel II				
		Idle				
		pitch		335**		670
		yaw		335**		
		Boost				
		pitch		335**		670
		yaw		335**		
		Thrust ON				
		pitch		335**		670
		yaw		335**		
		Maximum				
		pitch		335**		670
		yaw		335**		

*With quiescent current
**Without quiescent current

Above statements assume channel I is the operating channel and channel II is standby. Channel I operating values applicable to channel II when channel II is commanded. 28-vdc supply values, current draw values not a direct function of an applied voltage.

2.4.3.4 SPS Electrical Power Distribution.

See figure 2.4-11 for electrical power distribution.

2.4.4 OPERATION LIMITATIONS AND RESTRICTIONS.

The operational limitations and restrictions of the SPS are as follows:

a. Propellant quantity gauging subsystem is operational only during engine firing. A 4.5-second firing period is required before propellant quantity information is updated, when SENSOR switch is in the NORM or PRI position. Delay is built-in to allow propellants to settle and stabilize before updating the displays.

b. A one-second time delay between actuation of GIMBAL MOTOR switches (MDC-3) is required, as simultaneous actuation may result in an excessive power drain.

c. Engine design minimum impulse control limit is 0.4 second; however, mission minimum impulse may be longer.

d. Due to adversive temperature effects, engine gimbal drive motors should not be continuously energized for periods in excess of 12 minutes.

e. Single bank mode of operation by the bipropellant valve assembly will result in a 3 percent reduction in thrust.

2.4.5 TELEMETRY MEASUREMENTS.

The following subsequent list is of all SPS telemetry data monitored by flight controllers and ground support personnel.

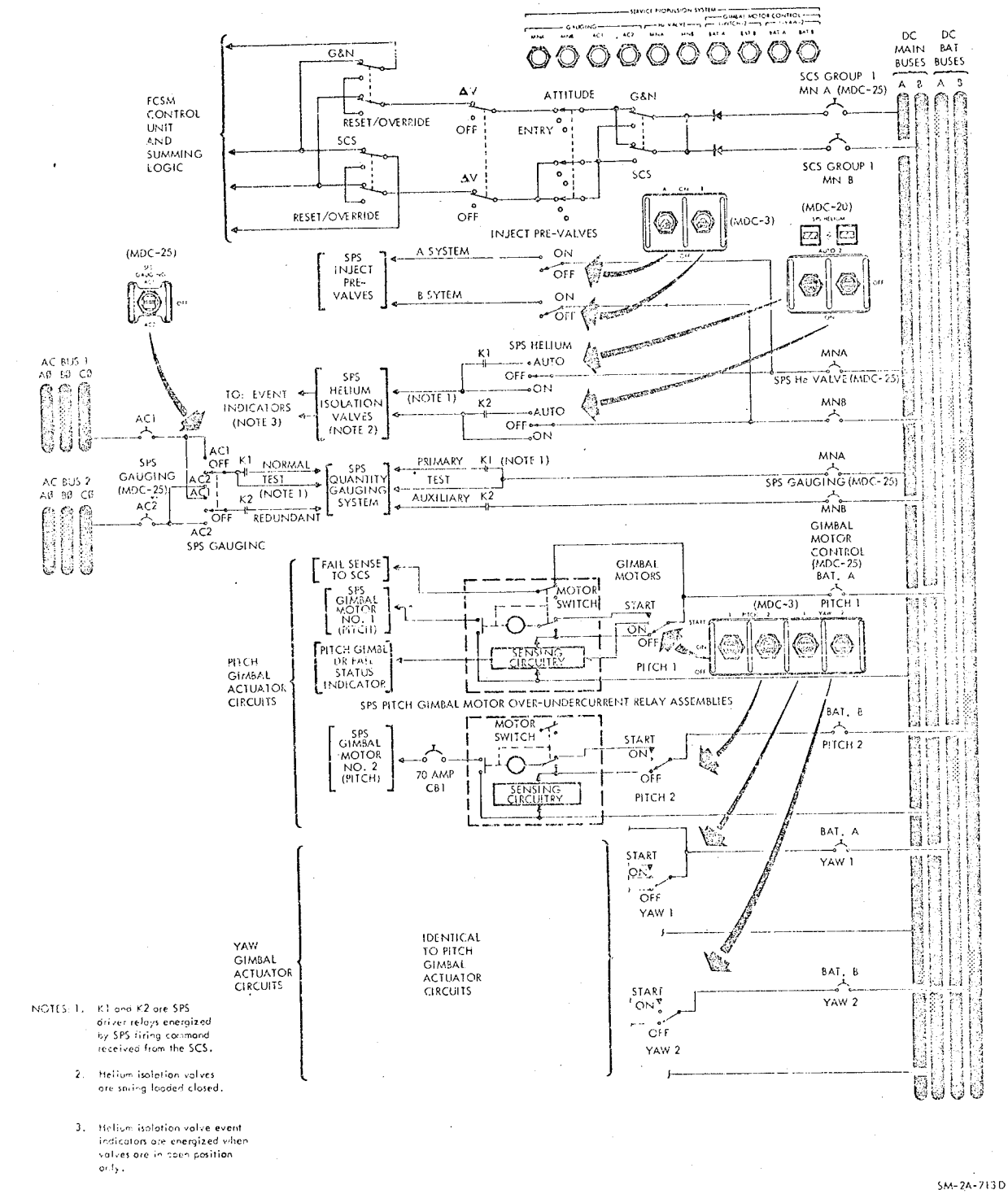


Figure 2.4-11. SPS Electrical Power Distribution Diagram

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 20	2.4-1	Helium Tank Supply Pressure	SP0001P	+0 +5K psia	S28AR3	11A66	H2	PCM	4000±50 psia and decrease with firings
Panels 20 & 11	2.4-1	Regulated Helium Pressure to Fuel Tank	SP0006P	+0 +300 psia	S28AR6	11A70	H2	PCM	170 to 195 psia
Panels 20 & 11	2.4-1	Regulated Helium Pressure to Oxidizer Tank	SP0003P	+0 +300 psia	S28AR5	11A68	H2	PCM	170 to 195 psia
Panels 20 & 11	2.4-1 and 2.4-6	Quantity Sensing System							
		Sensor Select Switch in Normal							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	
		Primary Fuel Storage 1	SP0657Q	+0 +8K lbs		10A92	H1	PCM	
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Primary Oxidizer Storage 1	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
		Sensor Select Switch in Primary							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	
		Primary Fuel Storage 1	SP0657Q	+0 +8K lbs		10A92	H1	PCM	Variable
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Primary Oxidizer Storage 1	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
		Sensor Select Switch in Auxiliary							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Auxiliary Fuel	SP0657Q	+0 +8K lbs		10A92	H1	PCM	
		Auxiliary Oxidizer	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
	2.4-1	Temperature 1 Oxidizer Distribution Line	SP0054T	+0 +200°F					
	2.4-1	Temperature 2 Oxidizer Distribution Line	SP0055T	+0 +200°F					
	2.4-1	Temperature 1 Fuel Distribution Line	SP0057T	+0 +200°F					Variable
	2.4-1	Temperature 2 Fuel Distribution Line	SP0058T	+0 +200°F					
Panel 20	2.4-1	Fuel Inlet Pressure to Fuel Valve	SP0010P	+0 +300 psia	S28AR8	11A77	H2	PCM	135 to 195 psia
Panel 20	2.4-1	Oxidizer Inlet Pressure to Oxidizer Valve	SP0009P	+0 +300 psia	S28AR7	11A76	H2	PCM	135 to 195 psia
Panel 3	2.4-1	Chamber Pressure	SP0061P	+0 +150 psia	S28AR9	12A11	H1	PCM	65 to 125 psia
	2.4-1	Injector Temperature	SP0060T	+0 +200°F		11A109	H1	FQ	Variable
Panel 20	2.4-1	Primary Gaseous Nitrogen Tank Supply Pressure	SP0600P	+0 +5000 psia	S28AR41	10A78	H1	PCM	2500±50 psia and decrease with firings
Panel 20	2.4-1	Secondary Gaseous Nitrogen Tank Supply Pressure	SP0601P	+0 +5000 psia	S28AR42	11A125	H1	PCM	2500±50 psia and decrease with firings
Panel 20	2.4-1	Ball Valve Position 1	SP0022H	+0 +90 deg		11A103	H1	PCM	Open or closed
Panel 20	2.4-1	Ball Valve Position 2	SP0023H	+0 +90 deg		11A105	H1	PCM	Open or closed
Panel 20	2.4-1	Ball Valve Position 3	SP0024H	+0 +90 deg		11A110	H1	PCM	Open or closed

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 20	2.4-1	Ball Valve Position 4	SP0025H	+0 +90 deg		11A11	HI	PCM	Open or closed
	2.4-1	Temperature Oxidizer Engine Feed Line	SP0049T	+0 +200°F					Variable
Panel 20	2.4-1	Temperature Fuel Engine Feed Line	SP0048T	+0 +200°F					+40 to +120°F Variable
	2.4-1	Temperature Engine Valve Body	SP0045T	+0 +200°F					
Panel 11	2.4-1	Temperature Combustion Chamber Outer Skin 1	SP0020T	+0 +500°F	Collins C28-1A5-S28AR60	10A84	HI	PCM	Illuminates C&W light at 380°F
	2.4-1	Temperature Nozzle Outer Skin 1	SP0050T	-260 +2500°F		10A85	HI	PCM	Variable
		Pitch Actuator Case Temperature	SP2055T	+0 +200°F		10A68	HI	FQ	Variable
		Yaw Actuator Case Temperature	SP2054T	+0 +200°F		11A119	HI	FQ	Variable
		SPS Solenoid Driver Out 1	CH4320X			51E-09	E1	PCME	Event
		SPS Solenoid Driver Out 2	CH4321X			51E-10	E1	PCME	
		Yaw Position Feedback	CH1034H	-8.5 +8.5 vdc		51A7	HI	PCM	Variable
		Pitch Position Feedback	CH0034H	-6 +6 vdc		51A3	HI	PCM	

*Analog measurements digitally coded into 8 bit words
Analog measurements - 0 to 5 vdc
FQ - Flight qualification measurements
HI - High bit rate
H2 - High and low bit rate
E1 - High bit rate

Channel code example: 10A68
Significant number - 1
How many zeros after most significant number is amount of samples per second. 0 = 1 sample per second

Analog - A
Event - E
Channel Code - 68

SECTION 2

SUBSECTION 2.5

REACTION CONTROL SYSTEM (RCS)

2.5.1 INTRODUCTION.

The Apollo command service module consists of two separate reaction control systems, completely independent, designated S/M RCS and C/M RCS. The S/M RCS is utilized to control S/C rotation in all three axes, in addition to any minor translation requirements including S-IVB separation, SPS ullage, and C/M-S/M separation maneuvers. The C/M RCS is utilized to control C/M rotation in all three axes after C/M-S/M separation and during entry maneuvers. The C/M RCS does not have translation capabilities.

Both the S/M and C/M RCS are controlled either automatically or manually from the command module. Physical location of the RCS engines is shown in figure 2.5-1. Engine firing sequence for specific maneuvers and individual engine circuit breaker power control are shown in figure 2.5-2.

2.5.2 S/M RCS FUNCTIONAL DESCRIPTION.

The S/M RCS consists of four individual, functionally identical packages, located 90 degrees apart around the forward portion (+X-axis) of the S/M periphery and offset from the S/C Y- and Z-axes by 7 degrees 15 minutes. Each package configuration, called a quad, is such that the reaction engines are mounted on the outer surface of the panel and the remaining components are inside. Propellant distribution lines are routed through the panel skin to facilitate propellant transfer to the reaction engine combustion chambers. The engine combustion chambers are canted approximately 10 degrees away from the panel structure to reduce the effects of exhaust gas on the service module skin. The two roll engines on each quad are offset-mounted to accommodate plumbing in the engine mounting structure.

Each RCS package incorporates a pressure-fed, positive-expulsion, pulse-modulated, bipropellant system to produce the reaction thrust required to perform the various S/M RCS control functions. Acceptable package operating temperature is maintained by internally mounted, thermostatically controlled electric heaters. The S/M RCS propellants consist of nitrogen tetroxide (N_2O_4), used as the oxidizer; monomethylhydrazine (MMH) used as the fuel. Pressurized helium gas is the propellant transferring agent.

P-0081A

Figure 2.5-1. C/M-S/M Engine Locations

BUS POWER	CIRCUIT BREAKER	SM ENGINE				CM ENGINE				SM ENGINE UTILIZATION FOR TRANSLATION MANUEVERS						CHANNEL SWITCHES PANEL 8
		QUAD	MANUEVER	SCS NO.	PROP NO.	SYSTEM	MANUEVER	SCS NO.	PROP NO.	-X	+X	-Y	+Y	-Z	+Z	
MN A	SCS MN A 1 PITCH C15A6CB40 PANEL 25	C A	+P -P	1 2	S19A3B3 S19A1B3	A A	+P -P	1 2	C19B7 C19B11		1 2					PITCH
MN A	SCS MN A 1 YAW C15A6CB32 PANEL 25	B D	+Y -Y	7 8	S19A2B3 S19A4B3	A A	+Y -Y	5 8	C19B9 C19B1	7 8						YAW
MN A	SCS MN A B&D ROLL C15A6CB34 PANEL 25	B B	CW+R CCW-R	9 12	S19A2B2 S19A2B4	A A	CW+R CCW-R	9 12	C19B5 C19B3					12	9	B&D ROLL
MN A	SCS MN A A&C ROLL C15A6CB36 PANEL 25	A A	CCW-R CW+R	16 13	S19A1B2 S19A1B4	DEADFACED AT CM SM SEPARATION OR LES ABORT						16	13			A&C ROLL
MN B	SCS MN B 2 PITCH C15A6CB39 PANEL 25	C A	-P +P	4 3	S19A3B1 S19A1B1	B B	-P +P	4 3	C19B12 C19B8	4 3						PITCH
MN B	SCS MNB 2 YAW C15A6CB31 PANEL 25	B D	-Y +Y	6 5	S19A2B1 S19A4B1	B B	-Y +Y	6 7	C19B2 C19B10		6 5					YAW
MN B	SCS MN B B&D ROLL C15A6CB33 PANEL 25	D D	CCW-R CW+R	10 11	S19A4B4 S19A4B2	B B	CCW-R CW+R	10 11	C19B4 C19B6					11	10	B&D ROLL
MN B	SCS MN B A&C ROLL C15A6CB35 PANEL 25	C C	CCW-R CW+R	14 15	S19A3B2 S19A3B4	DEADFACED AT CM SM SEPARATION OR LES ABORT						15	14			A&C ROLL
MN A	SCS MN A DIRECT CONTROL C15A6CB42 PANEL 25	C D B	+P -Y +Y	1 8 7	S19A3B3 S19A4B3 S19A2B3	A A A	+P -Y +Y	1 8 5	C19B7 C19B1 C19B9	8 7	1					DIRECT RCS SWITCH PANEL 8
		A	CCW-R	16	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		B B	CCW-R CW+R	12 9	S19A2B4 S19A2B2	A A	CCW-R CW+R	12 9	C19B3 C19B5							
		A C	CW+R CW+R	13 15	S19A1B4 S19A3B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		A	-P	2	S19A1B3	A	-P	2	C19B11		2					
MN B	SCS MN B DIRECT CONTROL C15A6CB41 PANEL 25	C A B D D	-P +P -Y +Y CCW-R	4 3 6 5 10	S19A3B1 S19A1B1 S19A2B1 S19A4B1 S19A4B4	B B B B B	-P +P -Y +Y CCW-R	4 3 6 7 10	C19B12 C19B8 C19B2 C19B10 C19B4	4 3	6 5					
		C	CCW-R	14	S19A3B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		D	CW+R	11	S19A4B2	B	CW+R	11	C19B6							

P-2058

Figure 2.5-2. S/M-C/M RCS Engine Power Supplies

The reaction engines may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short-pulse firing permits attitude-hold modes of operation and extremely accurate attitude alignment maneuvers during navigational sightings. CSM attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines on all four quads. However, in the event of a malfunction, complete attitude control can be maintained with only two adjacent quads operating. This two-quad capability does not include the execution of translation and ullage maneuvers.

A functional flow diagram of one S/M RCS quad is shown in figure 2.5-3. The helium storage vessel supplies pressure to two solenoid-operated helium isolation valves that are normally open throughout the mission. This allows helium pressure to the pressure regulators downstream of each helium isolation valve reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through a series parallel combination of four independent check valves. The check valves permit helium pressure to the fuel and oxidizer tanks and prevent reverse flow of propellant vapors or liquid. A pressure-relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure increase.

Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow through the normally open propellant isolation valves.

Oxidizer and fuel is distributed to the eight fuel and oxidizer injector valves by a parallel feed system. The fuel valve on each engine opens 2 milliseconds prior to the oxidizer valve to obtain proper engine operation. Each valve assembly contains orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel impinge, atomize, and ignition due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The injector valves are spring-loaded closed. This system configuration maintains propellants under constant pressure at the engine injector valves providing rapid consistent response rates to thrust on-off commands.

2.5.3 S/M RCS MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The S/M RCS is composed of four separate, individual packages; each package containing the following five major subsystems:

- Pressurization
- Propellant
- Rocket engine

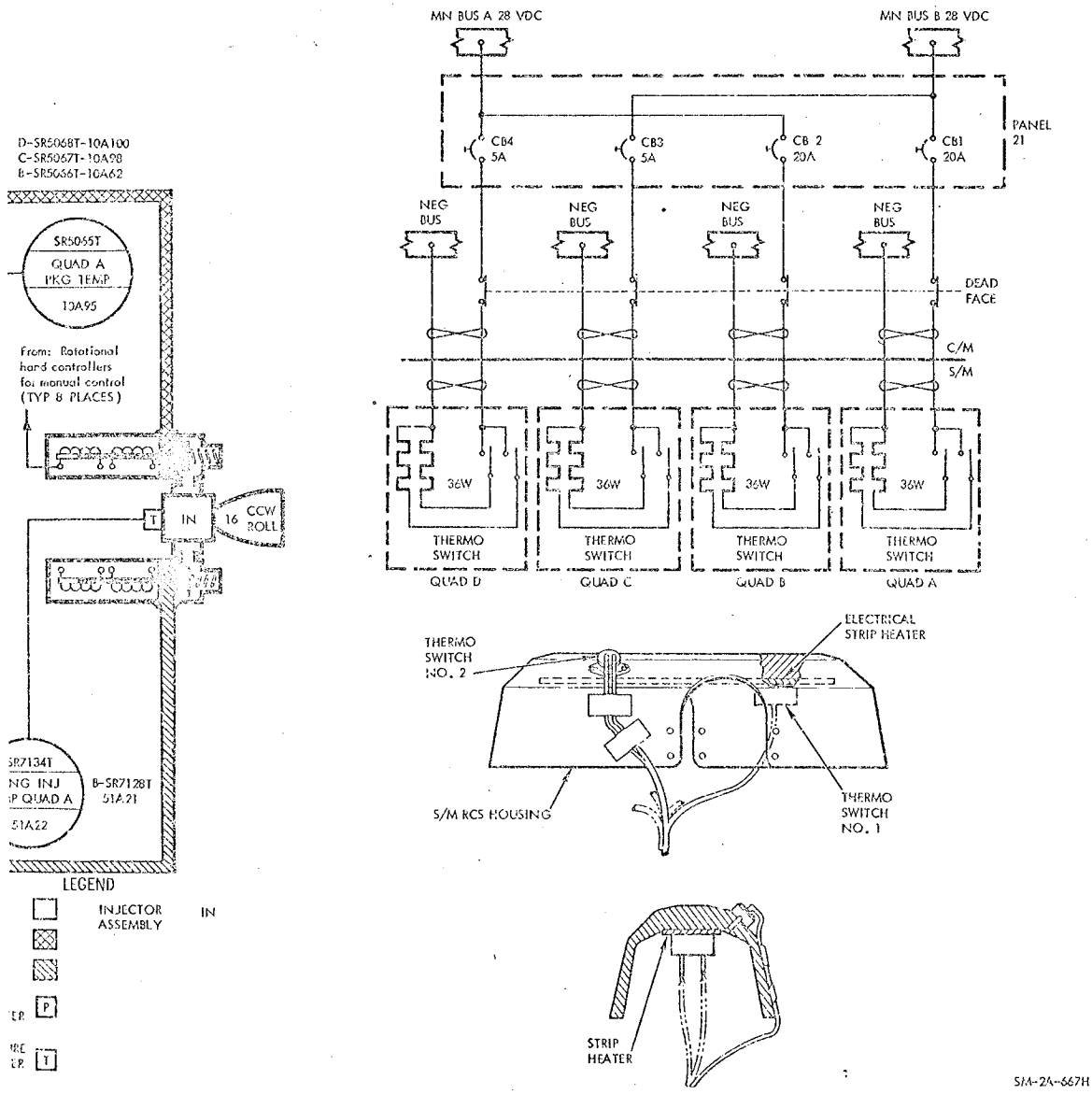
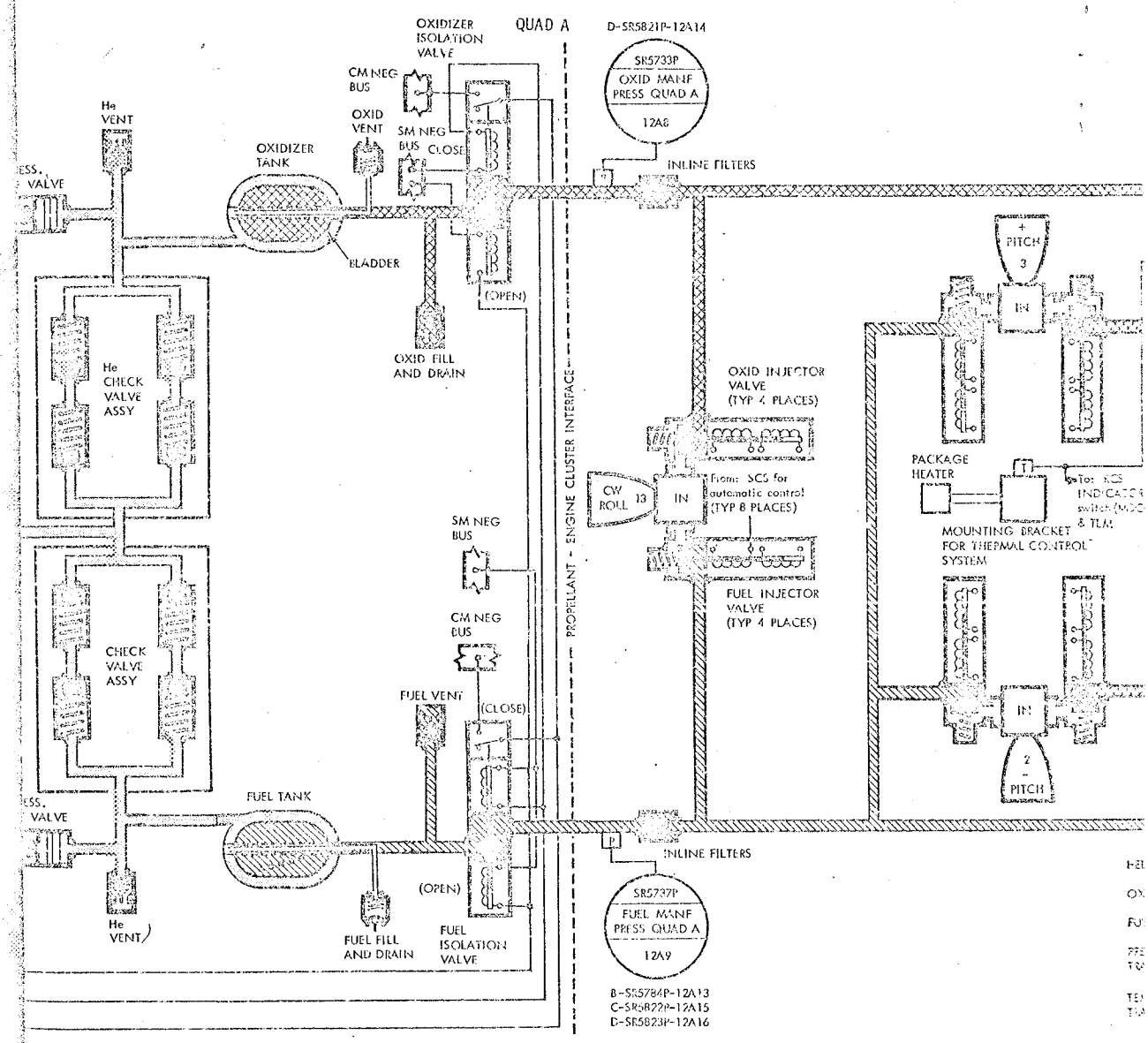
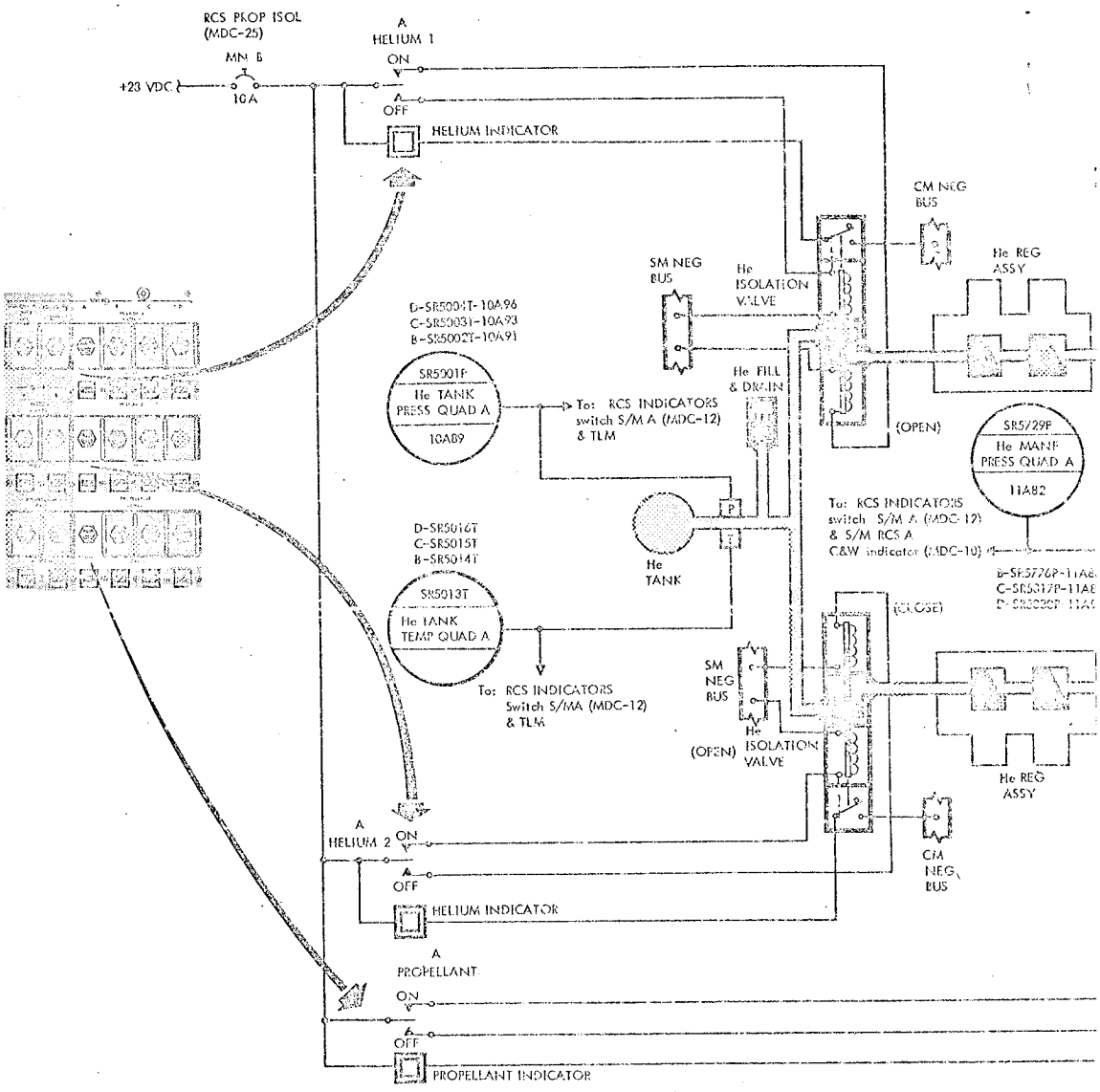
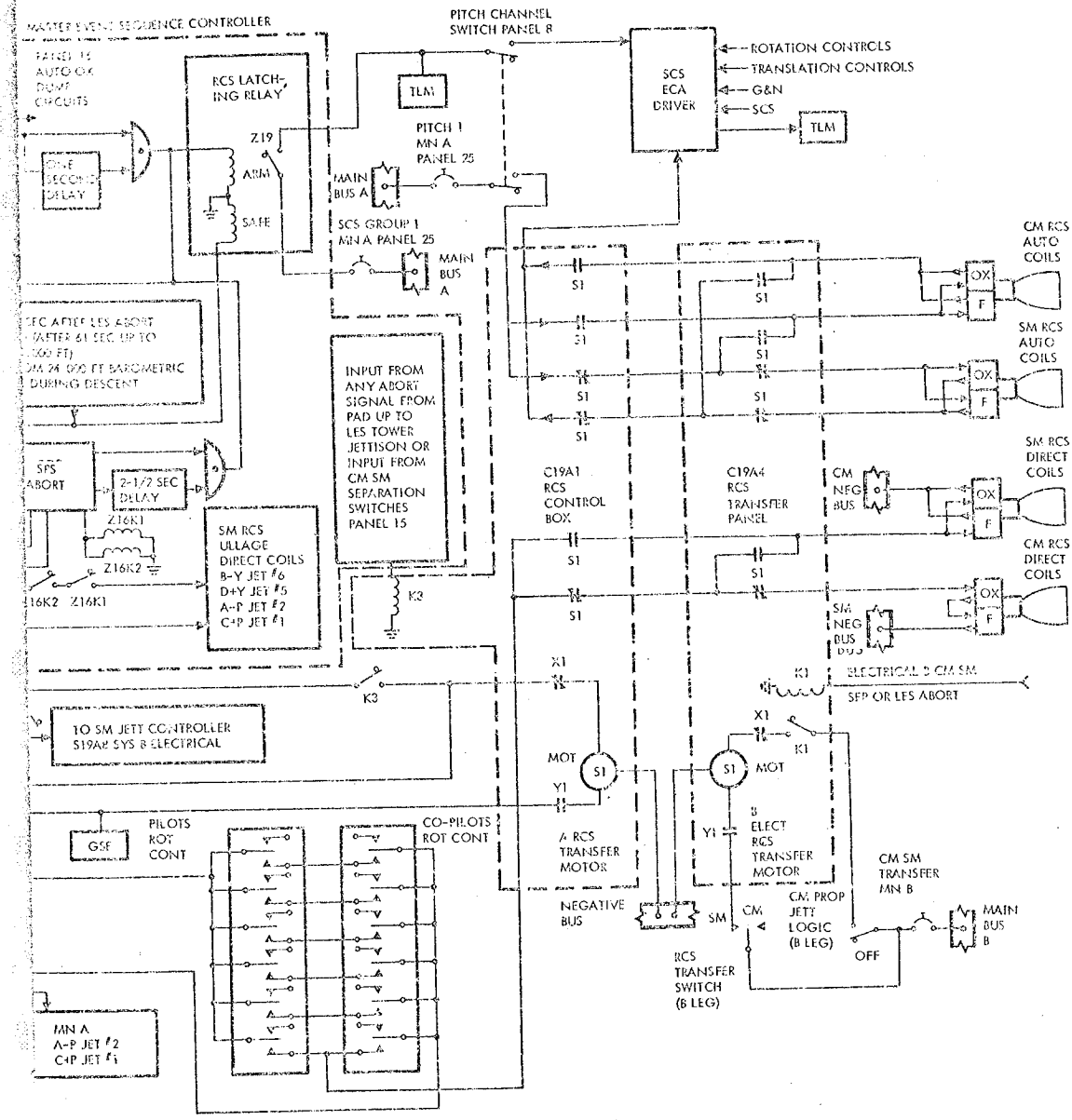
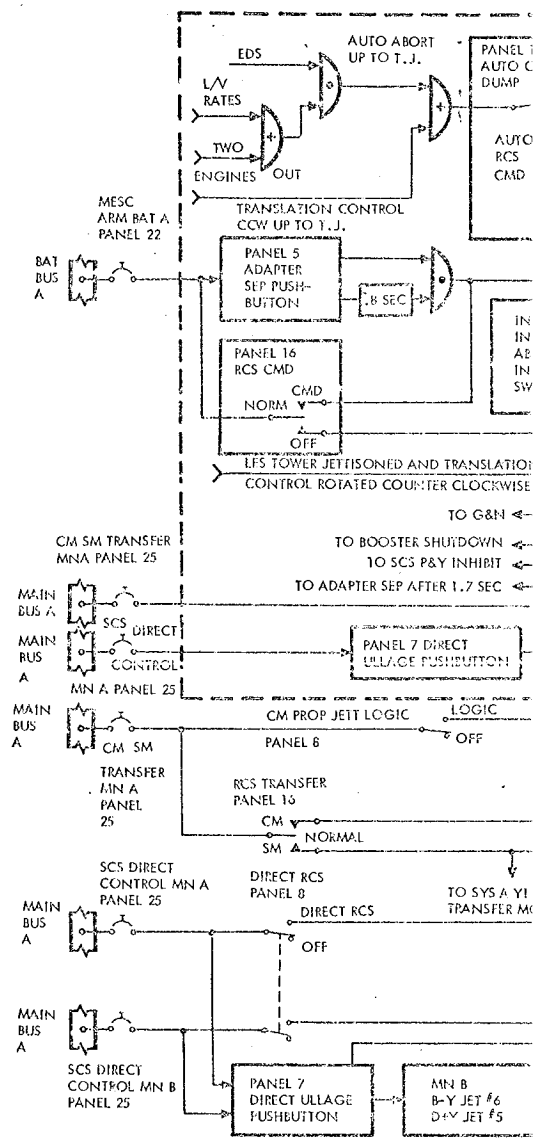


Figure 2.5-3. S/M RCS Functional Flow Diagram (Quad A)


QUAD A
OXIDIZER ISOLATION VALVE
D-SR5821P-12A14
SR5733P
OXID MANF PRESS QUAD A
12A8
CM NEG BUS
OXID VENT
SM NEG BUS
CLOSE
He VENT
OXIDIZER TANK
INLINE FILTERS
BLADDER
(OPEN)
OXID FILL AND DRAIN
He CHECK VALVE ASSY
OXID INJECTOR VALVE (TYP 4 PLACES)
+ PITCH 3
IN
CW ROLL 13
From: SCS for automatic control (TYP 8 PLACES)
PACKAGE HEATER
To: RCS INDICATOR switch (MDC
& TLM
MOUNTING BRACKET FOR THERMAL CONTROL SYSTEM
FUEL INJECTOR VALVE (TYP 4 PLACES)
SM NEG BUS
CM NEG BUS
FUEL VENT
(CLOSE)
CHECK VALVE ASSY
2 - PITCH
FUEL TANK
INLINE FILTERS
(OPEN)
He VENT
FUEL FILL AND DRAIN
FUEL ISOLATION VALVE
SR5737P
FUEL MANF PRESS QUAD A
12A9
PROPELLANT - ENGINE CLUSTER INTERFACE
B-SR5784P-12A13
C-SR5822P-12A15
D-SR5823P-12A16


RCS PROP ISOL (MDC-25)
MN B
+23 VDC
10A
A HELIUM 1
ON
OFF
HELIUM INDICATOR
CM NEG BUS
SM NEG BUS
He ISOLATION VALVE
He REG ASSY
D-SR5004T-10A96
C-SR5003T-10A93
B-SR5002T-10A91
SR5001P
He TANK PRESS QUAD A
10A89
To: RCS INDICATORS switch S/M A (MDC-12) & TLM
He FILL & DRAIN
(OPEN)
SR5129P
He MANF PRESS QUAD A
11A82
To: RCS INDICATORS switch S/M A (MDC-12) & S/M RCS A C&W indicator (MDC-10)
P
T
He TANK
D-SR5016T
C-SR5015T
B-SR5014T
SR5013T
He TANK TEMP QUAD A
To: RCS INDICATORS Switch S/MA (MDC-12) & TLM
(CLOSE)
SM NEG BUS
(OPEN)
He ISOLATION VALVE
He REG ASSY
CM NEG BUS
A HELIUM 2
ON
OFF
HELIUM INDICATOR
A PROPELLANT
ON
OFF
PROPELLANT INDICATOR


MASTER EVENT SEQUENCE CONTROLLER
PANEL 15
AUTO OX DUMP CIRCUITS
RCS LATCHING RELAY
Z19
ARM
SAFE
TLM
PITCH CHANNEL SWITCH PANEL 8
SCS ECA DRIVER
ROTATION CONTROLS
TRANSLATION CONTROLS
G&N
SCS
TLM
PITCH 1 MN A PANEL 25
MAIN BUS A
SCS GROUP 1 MN A PANEL 25
MAIN BUS A
CM RCS AUTO COILS
SM RCS AUTO COILS
OX
F
S1
INPUT FROM ANY ABORT SIGNAL FROM PAD UP TO LES TOWER JETTISON OR INPUT FROM CM SM SEPARATION SWITCHES PANEL 15
SPS ABORT
2-1/2 SEC DELAY
Z16K1
Z16K2
SM RCS ULLAGE DIRECT COILS
B-Y JET #6
D+Y JET #5
A-P JET #2
C+P JET #1
K2
K3
C19A1 RCS CONTROL BOX
C19A4 RCS TRANSFER PANEL
CM NEG BUS
SM NEG BUS
SM RCS DIRECT COILS
CM RCS DIRECT COILS
X1
K1
ELECTRICAL B CM SM SEP OR LES ABORT
TO SM JETT CONTROLLER S19A# SYS B ELECTRICAL
MOT
Y1
A RCS TRANSFER MOTOR
B ELECT RCS TRANSFER MOTOR
GSE
PILOTS ROT CONT
CO-PILOTS ROT CONT
NEGATIVE BUS
SM
CM
CM PROP JETT LOGIC (B LEG)
RCS TRANSFER SWITCH (B LEG)
CM SM TRANSFER MN B
OFF
MAIN BUS B
MN A
A-P JET #2
C+P JET #1


EDS
AUTO ABORT
UP TO T.J.
L/V
RATES
TWO
ENGINES
OUT
MESC
ARM BAT A
PANEL 22
TRANSLATION CONTROL
CCW UP TO T.J.
BAT
BUS
A
PANEL 5
ADAPTER
SEP PUSH-
BUTTON
.8 SEC
PANEL 16
RCS CMD
CMD
NORM
OFF
LES TOWER JETTISONED AND TRANSLATION
CONTROL ROTATED COUNTER CLOCKWISE
TO G&N
TO BOOSTER SHUTDOWN
TO SCS P&Y INHIBIT
TO ADAPTER SEP AFTER 1.7 SEC
CM SM TRANSFER
MNA PANEL 25
MAIN
BUS A
SCS DIRECT
CONTROL
MAIN
BUS
A
MN A PANEL 25
PANEL 7 DIRECT
ULLAGE PUSHBUTTON
MAIN
BUS
A
CM SM
TRANSFER
MN A
PANEL
25
CM PROP JETT LOGIC
PANEL 6
LOGIC
OFF
RCS TRANSFER
PANEL 16
CM
NORMAL
SM
SCS DIRECT
CONTROL MN A
PANEL 25
DIRECT RCS
PANEL 8
DIRECT RCS
OFF
MAIN
BUS
A
MAIN
BUS
A
SCS DIRECT
CONTROL MN B
PANEL 25
PANEL 7
DIRECT ULLAGE
PUSHBUTTON
MN B
B-Y JET #6
D+Y JET #5

- Propellant quantity gauging
- Temperature control system

2.5.3.1 Pressurization Subsystem.

The pressurization and propellant feed stores, regulates, and distributes helium to the propellant tanks, and stores and distributes propellant to the engine assemblies (figure 2.5-3). It consists of storage tanks, isolation valves, pressure regulators, and the lines and valves necessary for filling, draining and distributing the fluids.

2.5.3.1.1 Helium Supply Tank.

The total high-pressure helium supply is contained within a single spherical storage tank. Initial fill pressure is 4150±50 psig at 70°F. The limit working pressure is 5000 psig to accommodate pressure transients during filling. Proof pressure is 6667 psig and the burst pressure is 7500 psig.

2.5.3.1.2 Helium Isolation Valve.

The helium isolation valves are a two-solenoid valves and are mechanically latched open and spring-loaded closed. The helium isolation valves are individually controlled by their own helium switch on panel 15. The valves are normally open in respect to system pressure substantiating the mechanical latching feature for power conservation purposes during the mission, in addition to preventing overheating of the valve coils.

A position switch contained within each valve controls a position indicator below each switch on panel 15. When the valve is open, the position switch is open; and the indicator on panel 15 is grey (same color as the panel) indicating the valve is in its normal position. When the valve is closed, the position switch is closed; and the indicator on panel 15 is diagonal lines indicating the valve is in its abnormal position. The valve is closed in the event of a pressure regulator unit problem and during ground servicing.

2.5.3.1.3 Pressure Regulator Assemblies.

Helium pressure regulation is accomplished by two regulator assemblies connected in parallel, with one assembly located downstream of each helium isolation valve. Each assembly incorporates two (primary and secondary) separate regulators connected in series. The secondary regulator remains open as long as the primary regulator functions properly. In the event of the primary regulator failing open, the secondary regulator will maintain slightly higher, but acceptable pressures.

2.5.3.1.4 Check Valve Assemblies.

Two check valve assemblies, one assembly located downstream of each regulator assembly, permit helium flow in the downstream direction

only. This prevents propellant and/or propellant vapor backflow into the pressurization system if seepage or failure occurs in the propellant tank bladders.

2.5.3.1.5 Pressure Relief Valves.

The helium relief valve contains a burst diaphragm, filter, a bleed device, and the relief valve. The burst diaphragm is installed to provide a more positive seal against helium than that of the actual relief valve. The burst diaphragm ruptures at a predetermined pressure. The burst diaphram is of the nonfragmentation type, but in the event of any fragmentation, the filter filters out any fragmentation and prevents any particles from flowing onto the relief valve seat. The relief valve will relieve at a pressure slightly higher than that of the burst diaphragm rupture pressure and relieve the excessive pressure overboard, protecting the fuel and oxidizer tank. The relief valve will reseat at a predetermined pressure.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage from the diaphragm, or vents the cavity upon completion of performing a checkout of the relief valve from the test port on the relief valve. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure. The bleed device automatically opens when the pressure decreases to the bleed valve opening pressure.

2.5.3.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each RCS quad from the helium storage vessels to the propellant tanks.

2.5.3.2 Propellant Subsystem.

This subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.3.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single titanium alloy hemispherically domed cyclindrical tank. The tank is cradle-mounted to the RCS panel. The tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold, providing expulsion during zero g's. Tank has a working pressure of 248 psig; proof pressure of 331 psig.

2.5.3.2.2 Fuel Tank.

The fuel supply is contained in a single tank that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.3.2.3 Propellant Isolation Shutoff Valve.

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are magnetically latch opened and spring-loaded closed. The valves are normally open in respect to fluid flow. This, again, establishes a power conservation.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel) indicating to the crew that the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines indicating to the crew that the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, runaway thruster, etc.

2.5.3.2.4 Distribution Plumbing.

Propellant distribution plumbing within each quad is functionally identical. Each quad contains separate similar oxidizer and fuel plumbing networks. Propellants within their respective networks are directed from the supply tanks, through manifolds for distribution to the four engines in the cluster.

2.5.3.2.5 Propellant, In-Line Filters.

In-line filters are installed in the fuel and oxidizer manifolds downstream of the propellant shutoff valves and prior to the engine manifold contained within the engine housing. The in-line filters are installed to prevent any particles from flowing into the engine injector valves and engine injector.

2.5.3.3 Engine Assemblies.

The service module reaction control system engines are radiation-cooled, pressure-fed, bipropellant thrust generators which can be operated in either the pulse modulated or the steady state mode. (These modes are defined as a firing of less than one-second duration, and one-second duration or more, respectively.)

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic or manual) generated by the guidance and navigation subsystem and/or stabilization and control subsystem or by the crew; and an injecter

head assembly, which directs the flow of each propellant from the propellant control valves to the combustion chamber where the propellants atomize and ignite (hypergolic) to produce thrust.

2.5.3.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The propellant solenoid injector valves utilize two coaxially wound coils: one for automatic and one for direct manual operation. The automatic coil is used when the thrust command originates from the jet selection logic, which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The manual coils are used when the thrust command originates at the rotation control (direct mode), direct ullage pushbutton, SPS abort, or the C/M S/M SEP switch (figure 2.5-3).

The solenoid valves are spring-loaded closed and energized open. The reaction time of the valves are illustrated in figures 2.5-4 and 2.5-5.

Figure 2.5-4 illustrates a thrusting duration of 15 seconds (steady state). The electrical on signal is received within either the automatic (normal) or manual (backup) coils of the engine injector valves. The solenoid injector valves are energized open allowing fuel and oxidizer to

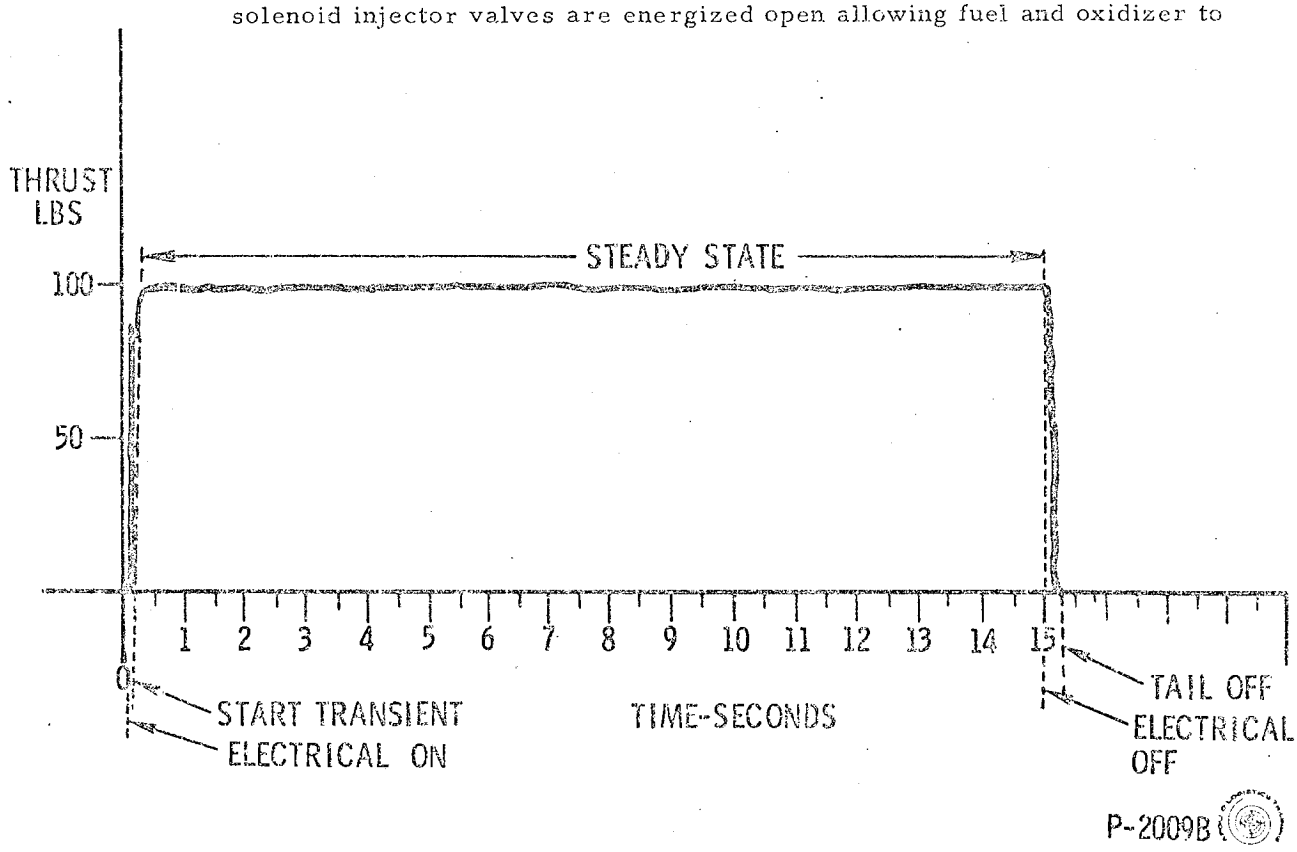


Figure 2.5-4. S/M RCS Steady-State Operation (Typical 15 Seconds)

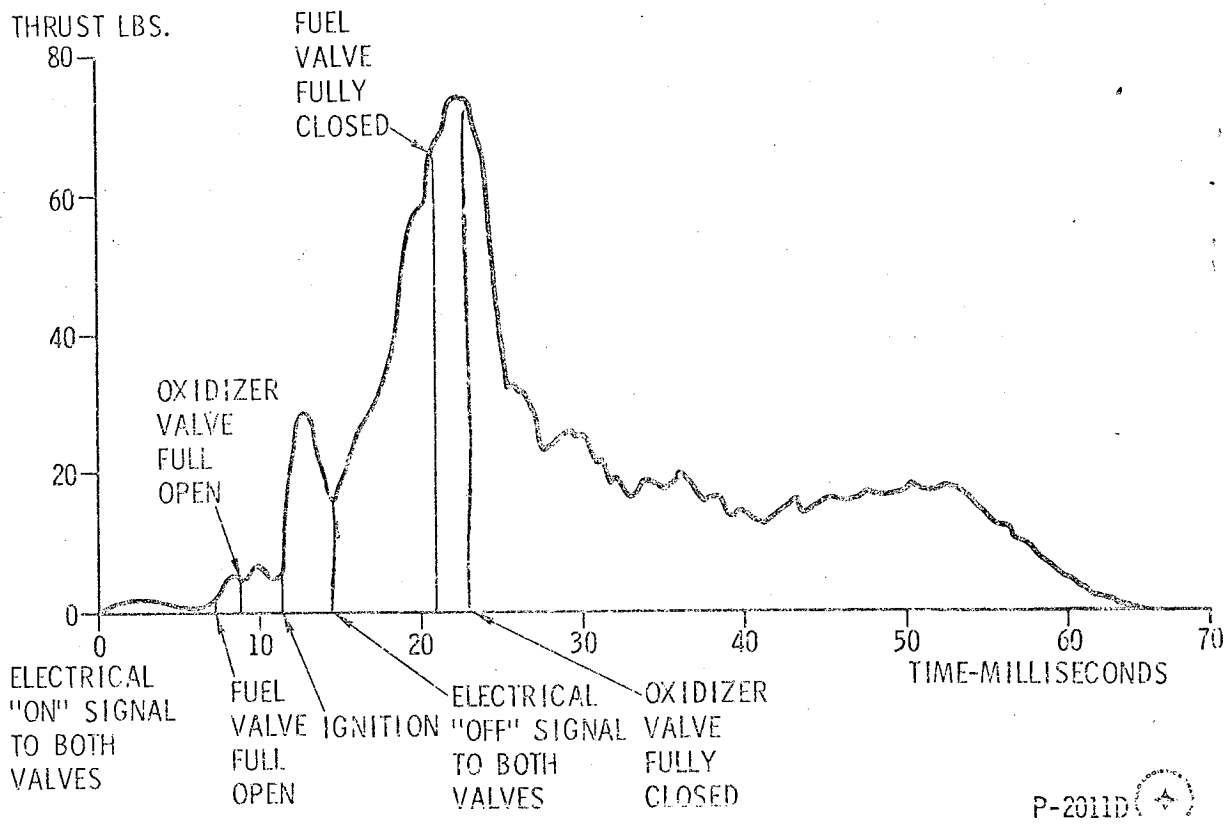


Figure 2.5-5. S/M RCS Engine Minimum Total Impulse (Typical)

flow through the injector into the combustion chamber. The propellants, being hypergolic, ignite, providing the start transient. The engine, as a result of propellant ignition, produces chamber pressure, gas velocity, and thrust. At 15 seconds after the receipt of the thrust-on signal, the automatic or manual coils are de-energized and the injector valves spring-load closed. However, due to the closing time and residual propellant flow downstream of the injector valves into the combustion chamber, thrust output continues until the propellants have burned completely allowing the chamber pressure, gas velocity, and thrust to decay to 0 pounds, establishing the cutoff transient.

Figure 2.5-5 illustrates the minimum electrical signal that can be provided to the automatic coils of the injector valves from the stabilization control subsystem jet selection logic. The following describes the sequence of operation and reasons why.

a. A time of 18±4 milliseconds (14 milliseconds minimum) will elapse before the stabilization control subsystem (SCS) can electrically provide a command-off signal to the automatic coils of the injector valves on the engine.

b. When the automatic coils of the injector valves receive the electrical on signal from the SCS, the injector valves are energized to the open position.

c. The fuel injector automatic coil energizes to the fully open position in 4.5±1.5 milliseconds, and the oxidizer injector automatic coil energizes to the fully open position in 6.0±1.5 milliseconds establishing an approximate 2 millisecond fuel lead. This is accomplished by varying the resistance of the automatic coils in the fuel and oxidizer injector valve.

d. The propellants flow from the injector valves as soon as they both start to open to the premix igniter. However, the fuel will lead the oxidizer by two milliseconds.

e. The propellants start to flow, as soon as the injector valves start to open, into the premix igniter and into the combustion chamber which creates some pressure, gas velocity and thrust, and even though it is very small, the engine is operating in a space environment.

f. The pressure, gas velocity, and thrust continues to increase slightly until the valves reach the fully open position.

g. At approximately 12-1/2 milliseconds, the propellants ignite (hypergolic), producing a spike of thrust upwards into the area of 70 to 80 pounds. At 14 milliseconds minimum, the SCS removes the electrical signal from the automatic coils of the injector valves.

h. The thrust of the engine continues very erratically, while the valves become de-energized and spring-load closed.

i. At approximately 21 milliseconds (closing time of 7.5 milliseconds) on the fuel valve and 23 milliseconds (closing time of 8.0 milliseconds) on the oxidizer valve, the injector valves are fully closed.

j. The residual propellants downstream of the injector valves continue to flow into the combustion chamber, decreasing until complete thrust decay of 0 pounds occurs at approximately 65 milliseconds.

k. In order to determine the total impulse for this time span of operation (figure 2.5-5), everything under the entire thrust curve must be integrated.

The automatic coils are electrically connected in parallel from the SCS. The manual coils in the fuel and oxidizer injector valves provide a manual direct backup to the SCS mode of operation. The manual coils of the injector valves are electrically connected in series. The reasons for the series connection of the manual coils are as follows:

a. Prevent a mismatch between the opening and closing of the valves due to any heat soak-back into the manual coils, which would change the resistance of the manual coils and result in a mismatch if the coils were connected in parallel. The direct manual opening time for fuel is 13 milliseconds and oxidizer is 23 milliseconds. The closing time for fuel and oxidizer is 55±25 milliseconds.

b. The series connection from the fuel manual coil (positive to negative) to the oxidizer manual coil (negative to positive), then to ground, is to increase the arc suppression, reducing the arc at rotation control in the direct RCS mode of operation.

2.5.3.3.2 Injector.

The injector contains a premix igniter. The premix igniter chamber contains a fuel and an oxidizer passage that impinge upon each other (unlike impingement) within the premix igniter chamber. The premix igniter chamber, along with the 2-millisecond fuel lead, provides a smoother start transient primarily in the pulse mode of operation and especially in the area of minimum impulse.

The main chamber portion of the injector will allow eight fuel streams to impinge upon eight oxidizer streams (unlike impingement) for main chamber ignition. There are also eight fuel holes around the outer periphery of the injector, which provides film cooling to the combustion chamber.

2.5.3.3.3 Combustion Chamber.

The combustion chamber is constructed of unalloyed molybdenum, which is coated with a thin layer of molybdenum disilicide to prevent oxidation of the base metal. Cooling of the chamber is by radiation and film cooling.

Nozzle Extension. The nozzle extension is attached to the engine by a Waspolloy nut. The nozzle extension is machined from a cobalt base alloy. The stiffener rings are machined.

2.5.3.3.4 RCS Electrical Heaters.

Each of the RCS engine housings contain an electrical strip heater (figure 2.5-3). The electrical strip heaters provide propellant temperature control by conductance to the engine housing and engine injector valves; thus the propellants. Each heater has two thermo switches that maintain the temperature at a given range.

2.5.3.4 Pressure Versus Temperature Measuring System.

The helium tank supply temperature measurement and helium tank supply pressure measurement (figure 2.5-3) for each quad are utilized by the crew and TLM to determine the quantity of propellants remaining in the respective quad.

The nomogram (figure 2.5-6) depicts how to determine the propellant quantity remaining in percentage. The helium supply pressure is determined in psia on panel 12 by the crew, also the helium supply temperature

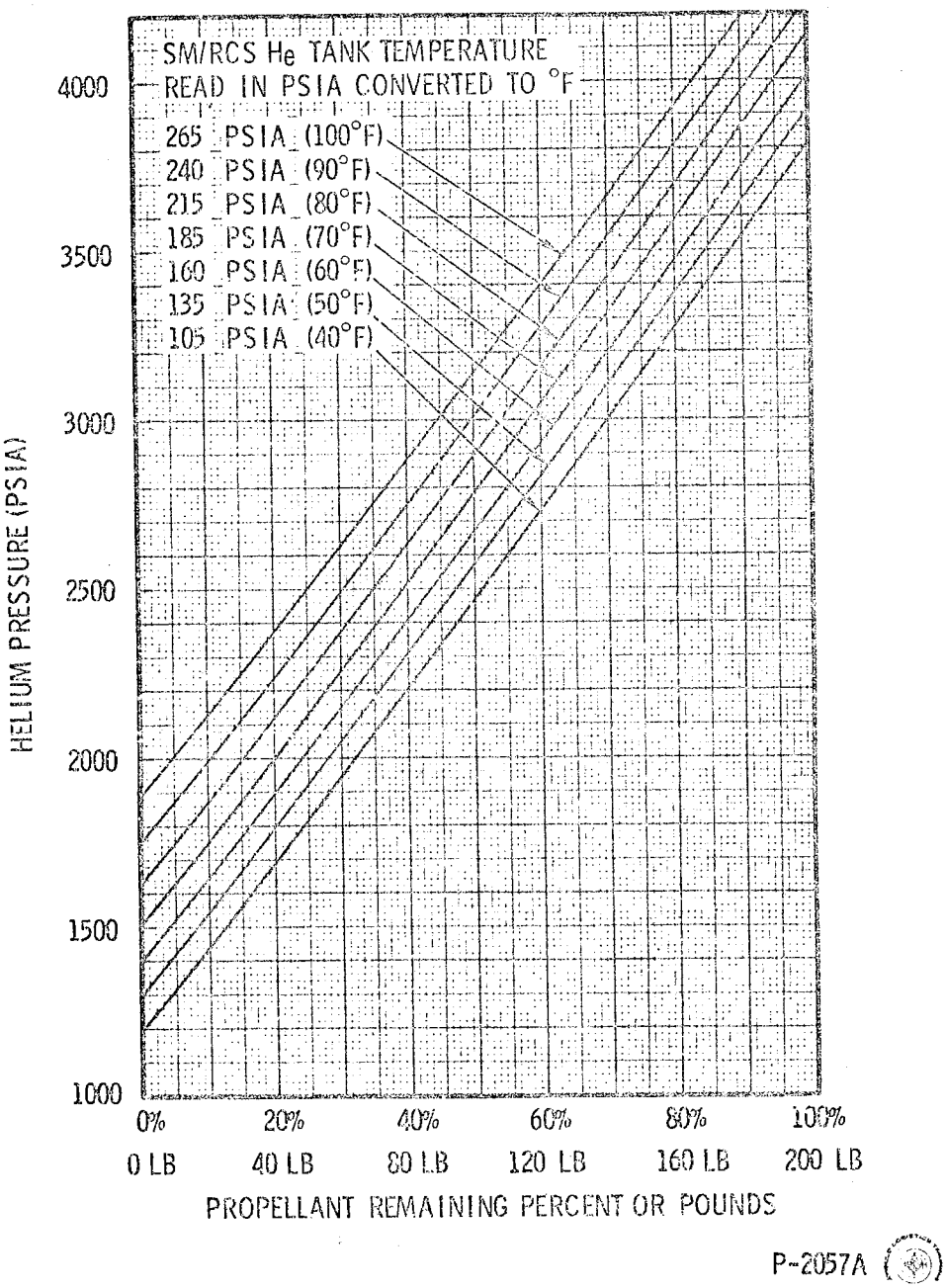


Figure 2.5-6. S/M RCS Nomogram Typical Propellant Remaining

reads in psia. The helium supply temperature readout of 0 psia is equivalent to 0°F and 400 psia is equivalent to 150°F.

As an example, if the crew readout on panel 12 for a given quad reads 3400 psia helium supply pressure and 265 psia helium supply temperature (which is equivalent to 100°F), the quantity of propellants remaining is approximately 60 percent or 120 pounds. The crew would utilize the RCS indicator select switch on panel 12 to select the quad desired in order to obtain the helium tank supply pressure and temperature, and determine the propellant quantity remaining in percent.

2.5.3.5 Engine Thrusting Logic.

In the S/M RCS, the commands from the stabilization and control system cannot be supplied to the SCS channel switches until the contacts of the RCS latching relay are closed. Closing of these contacts for S/M RCS control may be initiated by the following signals (figure 2.5-3):

a. With the launch escape tower jettisoned and the translation control rotated counterclockwise, an S/M abort or a normal S-IVB separation is initiated and the following sequence of events occurs.

1. Inform the G&N system of an abort initiation.
2. Initiate applicable booster shutdown.
3. Inhibit the pitch and yaw automatic jets of the SCS.
4. Initiates an ullage maneuver signal to the required manual coils of the S/M RCS engines (as long as the translation control is in counterclockwise, ullage is terminated when the translation control is returned to the neutral detent).
5. Adapter separation occurs at 1.7 seconds after the abort was initiated.
6. Energizes the RCS latching relay 2-1/2 seconds after the abort was initiated allowing the SCS to provide electrical commands to the automatic coils of the S/M RCS engines. In the event the logic fails to energize the RCS latching relay, the RCS CMD switch on panel 16 is placed to the ON position, providing a manual backup to the automatic function. In addition, if the ADAPTER SEPARATION pushbutton on panel 5 is pressed and held for approximately 1 to 2 seconds, the RCS latching relay is energized.

b. In a backup to the normal S-IVB separation sequence, the RCS CMD switch is momentarily placed to the ON position, energizing the RCS latching relay; the translation control is positioned forward, providing a translation through the SCS to the required automatic coils of the S/M RCS engine for a +X translation; and the ADAPTER SEPARATION pushbutton on panel 5 is held for 2 seconds to initiate adapter separation. (ADAPTER SEPARATION pushbutton pressed and held for approximately 1 to 2 seconds will also energize the RCS latching relay.)

In the event the translation controls are unable to provide an ullage maneuver, the DIRECT ULLAGE pushbutton on panel 7, when depressed

and held, provides the direct ullage signal to the manual coils of the RCS engines, to be energized to provide a +X translation. This provides a manual direct backup to the two translation controls for the ullage maneuver to be performed by the S/M RCS. The ullage maneuver is terminated upon release of the DIRECT ULLAGE pushbutton.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation controls only. When the rotation control is positioned fully to its stops in any direction, the rotation control will energize the required manual coils for the desired maneuver.

If the SCS and/or the jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, it is noted that translation control of the spacecraft is disabled.

2.5.4 S/M RCS PERFORMANCE AND DESIGN DATA.

2.5.4.1 Design Data.

The following list is the design data of the S/M RCS components.

HELIUM TANKS (4)	4150±50 psig at 70±5°F during servicing; after servicing sitting on launch pad 70±10°F. Capacity 0.57 lb, inside diameter 8.84 in., wall thickness 0.105 in., and internal volume 0.205 cu ft.
REGULATOR UNITS (8)	Primary - 181±4 psig with a normal lockup of 183±5 psig. From lockup pressure, not drop below 177 psig or rise above 185 psig and stabilize to 181±2 psig within 2 sec. Secondary - Lockup of 187±5 psig. From lockup pressure, not drop below 177 psig or rise above 194 psig and stabilize at 185±3 psig within 2 sec.
PRESSURE TRANSDUCERS (4) COMMON MANIFOLD	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D). Underpressure 155 psia. Overpressure 215 psia.
HELIUM RELIEF VALVES (8)	Diaphragm rupture at 228±8 psig. Filter - 10 micron nominal, 25 micron absolute.

	Relief valve relieves at 236.5±11.5 psig.
	Relief valve reseats at not less than 220 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device shall reopen when decreasing pressure has reached no less than 20 psig.
FUEL TANK (4)	Combined propellant and ullage volume of 69.0 lbs, initially at 60°F at 30±2 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter maximum 12.62 in., length 23.717 (+0.060, -0.000) in. Wall thickness 0.017 in. to 0.022 in.
	Helium inlet port 1/4 in., fill and drain port 1/2 in.
OXIDIZER TANK (4)	Combined propellant and ullage volume of 137.0 lbs, initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter maximum 12.62 in., length 28.55 (+0.060, -0.000) in.
	Wall thickness 0.017 in. to 0.022 in.
INLINE FILTERS	5-micron nominal; 15-micron absolute - 1000-sec service life, capable of 10,000 operational cycles.
ENGINES (16)	Thrust 100 lbs ±5 percent.
	Expansion ratio 40:1 at nozzle exit.
	Cooling Film and radiation
	Injector type.
	Premix igniter one on one unlike impingement. Eight fuel annulus for film cooling of premix igniter, main chamber eight on eight unlike impingement, eight fuel for film cooling of combustion chamber wall.

	Nozzle extension	L-605 material
	Nozzle exit diameter	5.6 in.
	Fuel lead.	
	Automatic coils - Connected in parallel.	
	Manual coils - Connected in series.	
	Weight - 4.99 lbs.	
	Length - 13.375 in.	
PACKAGE TEMPERATURE TRANSDUCER (4)	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D)	
	Under temperature 63°F.	
	Over temperature 175°F.	
	One in Each Quad	One in Each Quad
HEATERS THERMO-SWITCH	Close at 77 (+10, -7)°F	Close at 115°F
	Open at 104±14°F	Open at 134°F
	36±3.6 watts per heater	36±3.6 watts per heater

2.5.4.2 Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.4.3 Power Consumption Data S/M RCS and C/M RCS.

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Reaction control Service module RCS						
Engine heaters	RCS HEATER CB (4)	8		*36.0		288.0
RCS engine coils	SCS JET SELECTION LOGIC or DIRECT	32		*AUTO = 3.687		118.0
				*DIRECT = 1.062		34.0

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
He isolation valves	He VALVE CB (2) He sw (8)	8		6.750		54.0
Propellant isolation valves	PROP. ISOL. CB (2) PROP. ISOL. sw (4)	8		6.125		49.0
Command module RCS						
Isolation valves	(Ref. S/M/RCS ISOL. CB) PROP. ISOL. sw (2)	4		12.250		49.0
RCS engine coils	SCS JET SELECTION LOGIC OR DIRECT	24		*AUTO = 4.208		105.0
				*DIRECT = 2.187		52.5

*Intermittent operating components.

2.5.4.4 S/M RCS Electrical Power Distribution.

See figure 2.5-7 for electrical power distribution.

2.5.5 S/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Operational limitations and restrictions on the testing of system valves in a dry unserviced propulsion system are as follows:

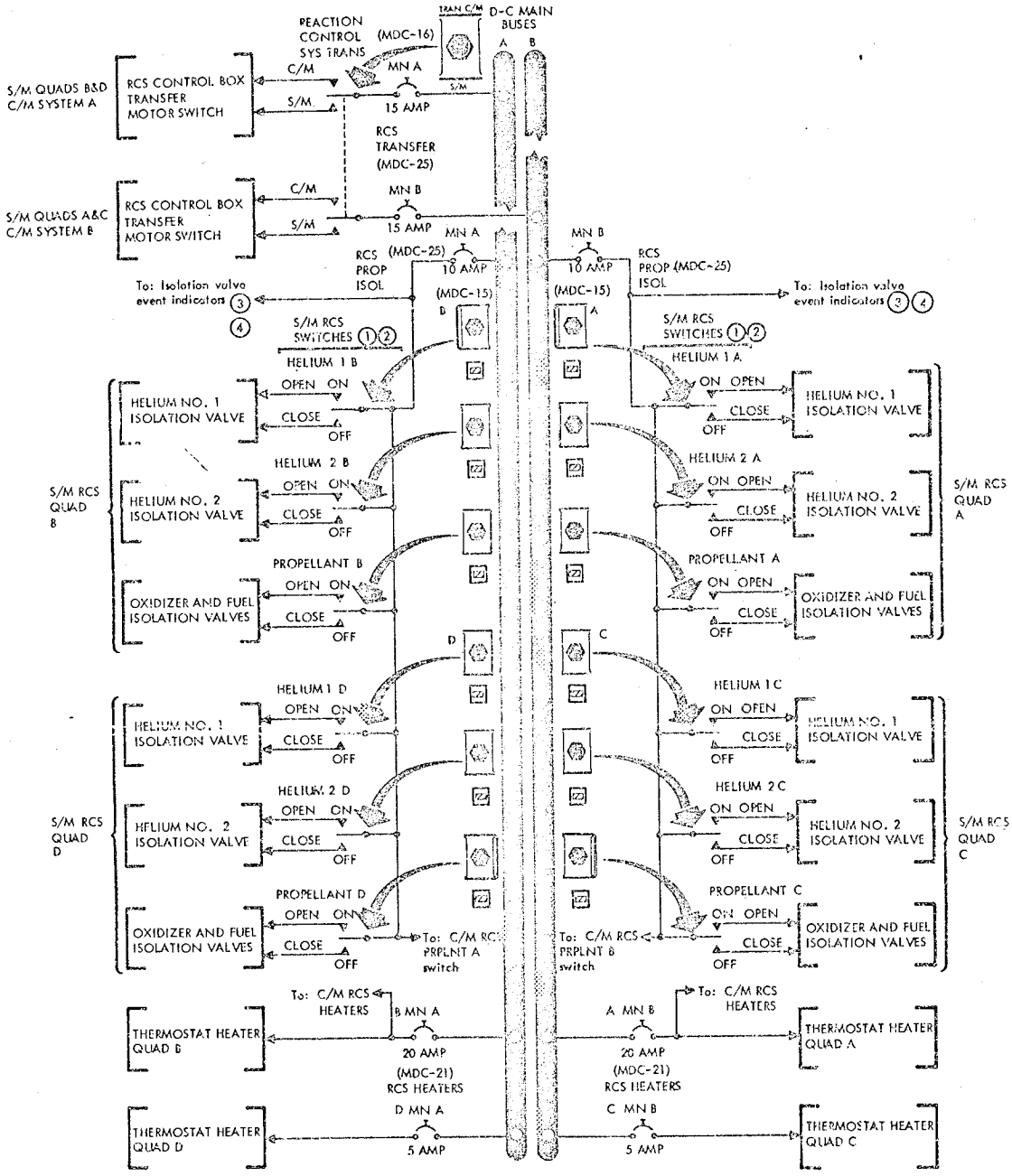
a. Helium isolation valves and propellant isolation valves minimum energization time of 0.2 second and not to exceed 5 seconds.

b. Engine injector valve automatic coil energization not to exceed 2 minutes on time during any 15-minute period with voltage not exceeding 32 vdc.

c. Engine injector valve direct coil energization on time not exceed 45 minutes during any 60-minute period and voltage not exceed 16 vdc to either coil separately or 32 vdc to two coils in series.

2.5.6 S/M RCS TELEMETRY MEASUREMENTS.

The subsequent list is of all S/M RCS telemetry data that is monitored by flight controllers and ground support personnel.



NOTES: 1. Helium isolation valves are mechanically latched open and spring-loaded closed.

2. Propellant isolation valves are magnetically latched open and spring-loaded closed.

3. Each helium isolation valve event indicator is energized when corresponding valve is in closed position only.

4. The propellant isolation valve event indicator is energized if either fuel or oxidizer valve is in the closed position.

SM-2A-715D

Figure 2.5-7. S/M RCS Electrical Power Distribution Diagram

Crew Display	Figure	Measurements	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 12	2.5-3	Helium Tank Temperature A	SR5013T	0 +150°F	S28AR164(S19A1)				70±10°F on launch pad, variable during mission.
Panel 12	2.5-3	Helium Tank Temperature B	SR5014T	0 +150°F	S28AR164(S19A2)				
Panel 12	2.5-3	Helium Tank Temperature C	SR5015T	0 +150°F	S28AR164(S19A3)				
Panel 12	2.5-3	Helium Tank Temperature D	SR5016T	0 +150°F	S28AR164(S19A4)				
Panel 12	2.5-3	Helium Tank Supply Pressure A	SR5001P	+0 +5K psia	S28AR36(S19A1)	10A89	H2	PCM	4150±5°F psia and decreases with engine firings.
Panel 12	2.5-3	Helium Tank Supply Pressure B	SR5002P	+0 +5K psia	S28AR36(S19A2)	10A91	H2	PCM	
Panel 12	2.5-3	Helium Tank Supply Pressure C	SR5003P	+0 +5K psia	S28AR36(S19A3)	10A93	H2	PCM	
Panel 12	2.5-3	Helium Tank Supply Pressure D	SR5004P	+0 +5K psia	S28AR36(S19A4)	10A96	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure A	SR5729P	+0 +400 psia	S28AR44(S19A1)	11A82	H2	PCM	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure B	SR5776P	+0 +400 psia	S28AR44(S19A2)	11A88	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure C	SR5817P	+0 +400 psia	S28AR44(S19A3)	11A89	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure D	SR5830P	+0 +400 psia	S28AR44(S19A4)	11A91	H2	PCM	
	2.5-3	Oxidizer Feed Line Pressure A	SR5733P	+0 +300 psia		12A8	H1	FQ	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
	2.5-3	Fuel Feed Line Pressure A	SR5737P	+0 +300 psia		12A9	H1	FQ	
	2.5-3	Fuel Feed Line Pressure B	SR5784P	+0 +300 psia		12A13	H1	FQ	
	2.5-3	Oxidizer Manifold Pressure D	SR5821P	+0 +300 psia		12A14	H1	FQ	
	2.5-3	Fuel Feed Line Pressure C	SR5822P	+0 +300 psia		12A15	H1	FQ	
	2.5-3	Fuel Feed Line Pressure D	SR5823P	+0 +300 psia		12A16	H1	FQ	
Panel 10 and 12	2.5-3	Temperature Package A + P Engine 3	SR5065T	+0 +300°F	S28AR40(S19A1)	10A95	H1	PCM	Pad 115 to 134°F Flight 115°F to 175°F
Panel 10 and 12	2.5-3	Temperature Package B - Y Engine 6	SR5066T	+0 +300°F	S28AR40(S19A2)	10A62	H1	PCM	

Crew Display	Figure	Measurements	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 10 and 12	2.5-3	Temperature Package C - P Engine 4	SR5067T	+0 +300°F	S28AR40(S19A3)	10A98	H1	PCM	Pad 115 to 134°F Flight 115°F to 175°F
Panel 10 and 12	2.5-3	Temperature Package D + Y Engine 5	SR5068T	+0 +300°F	S28AR40(S19A4)	10A100	H1	PCM	
	2.5-3	Temperature Injector Head B + Y Engine	SR7128T	+0 +500°F		51A21	H1	FQ	Variable
	2.5-3	Temperature Injector Head A CCW R Engine	SR7134T	+0 +500°F		51A22	H1	FQ	Variable
	2.5-3	Direct Ullage On A (Z16 Relay)	CD0140X	OFF ON event		11E12-06	E2	PCME	Event
	2.5-3	Direct Ullage On B (Z16 Relay)	CD0141X	OFF ON event		11E12-08	E2	PCME	Event
	2.5-3	RCS Activate Signal A (Z19 Relay)	CD0170X	OFF ON event		11E13-06	E2	PCME	Event
	2.5-3	RCS Activate Signal B (Z19 Relay)	CD0171X	OFF ON event		11E13-07	E2	PCME	Event
		Tower Jettison A	CD0105X			11E28-02	E2	PCME	Event
		Tower Jettison B	CD0106X			11E28-03	E2	PCME	Event

*Analog measurements digitally coded into 8 bit words.
Analog measurements - 0 to 5 vdc
FQ - Flight qualification measure
H1 - High bit rate
H2 - High and low bit rate
E2 - High and low bit rate

Channel Code Example: 10A89

Significant number - 1
How many zeros after significant number is amount of samples per second - 0 → 1 sample per second

Analog - A
Event - E
Channel code - 89

2.5.7 C/M RCS FUNCTIONAL DESCRIPTION.

The command module reaction control subsystem provides the impulse required for controlling spacecraft attitude during the terminal phases of a mission.

The subsystems are activated normally by the crew placing the C/M-S/M SEPARATION switches to C/M-S/M SEPARATION position or by placing the C/M RCS PRESSURIZE switch to the ON position prior to initiating C/M-S/M separation (C/M RCS PRESSURIZE switch may also be utilized as a manual backup to the C/M-S/M SEPARATION switches). The subsystems are activated automatically in the event of an abort from the pad up to launch escape tower jettison. Separation of the two modules occurs prior to entry (normal mode) or during an abort from the pad up to launch escape tower jettison.

The C/M-S/M consists of two identical and independent subsystems, identified as subsystem A and subsystem B. Both subsystems are operated simultaneously. In the event a malfunction develops in one subsystem, the remaining subsystem has the capability of providing the impulse required to perform necessary pre-entry and entry maneuvers. The C/M RCS is contained entirely within the C/M and each reaction engine nozzle is ported through the C/M skin. The propellants consist of nitrogen tetroxide (N_2O_4) used as oxidizer and monomethylhydrazine (MMH) used as fuel. Pressurized helium gas is the propellant transferring agent.

The reaction jets may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short firing permits attitude modes of operation. C/M attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines of subsystems A and B. However, complete attitude control can be maintained with only one subsystem.

A functional flow diagram of C/M RCS subsystems A and B is shown in figure 2.5-8. The helium storage vessel of each subsystem supplies pressure to two helium isolation squib valves that are normally closed throughout the mission until C/M-S/M separation or C/M RCS pressurize is activated. The helium isolation squib valves in a subsystem are initiated open, allowing pressure to the pressure regulators downstream of each helium isolation squib valve, reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through a series-parallel combination of four independent check valves. The check valves permit helium pressure to the fuel and oxidizer tanks, and prevent reverse flow of propellant vapors or liquids. A pressure-relief is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure increase.

Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders, forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow to valve isolation burst diaphragms, which rupture, and through the propellant isolation valves. Each subsystem supplies fuel and oxidizer to six engines.

Oxidizer and fuel is distributed to the 12 fuel and oxidizer injector valves by a parallel feed system. The fuel and oxidizer injector valves on each engine contain orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel impinge, atomize, and ignite due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The injector valves are spring-loaded closed.

Extremely cold temperature of the C/M exterior is anticipated prior to entry operations; therefore, C/M RCS engine preheating may be necessary before initiating pressurization due to possible freezing of the oxidizer (+11.8°F) upon contact with the engine injector valves. This is accomplished by the crew monitoring the engine temperatures and energizing the injector valve solenoids until acceptable engine temperatures are obtained. The C/M RCS HTRS switch on panel 200 will apply power to the injector valve solenoids for engine preheating.

Since the presence of hypergolic propellants can be hazardous upon C/M impact, the remaining propellants are burned off and the RCS purged with helium prior to C/M landing.

In the event of an abort from the pad up to T + 61 seconds after liftoff, provisions have been incorporated to automatically dump the oxidizer supply overboard, followed by a helium purge of the oxidizer tanks and dumping of the remaining helium supply. The fuel is retained on board due to insufficient time for dumping and the C/M impacts with fuel tanks full, but depressurized.

2.5.8 C/M RCS MAJOR COMPONENTS/SUBSYSTEM DESCRIPTION.

The C/M RCS is composed of two separate, normally independent systems, designated system A and system B. The systems are identical to operation, each containing the following four major subsystems:

- Pressurization
- Propellant
- Rocket engine
- Temperature control system

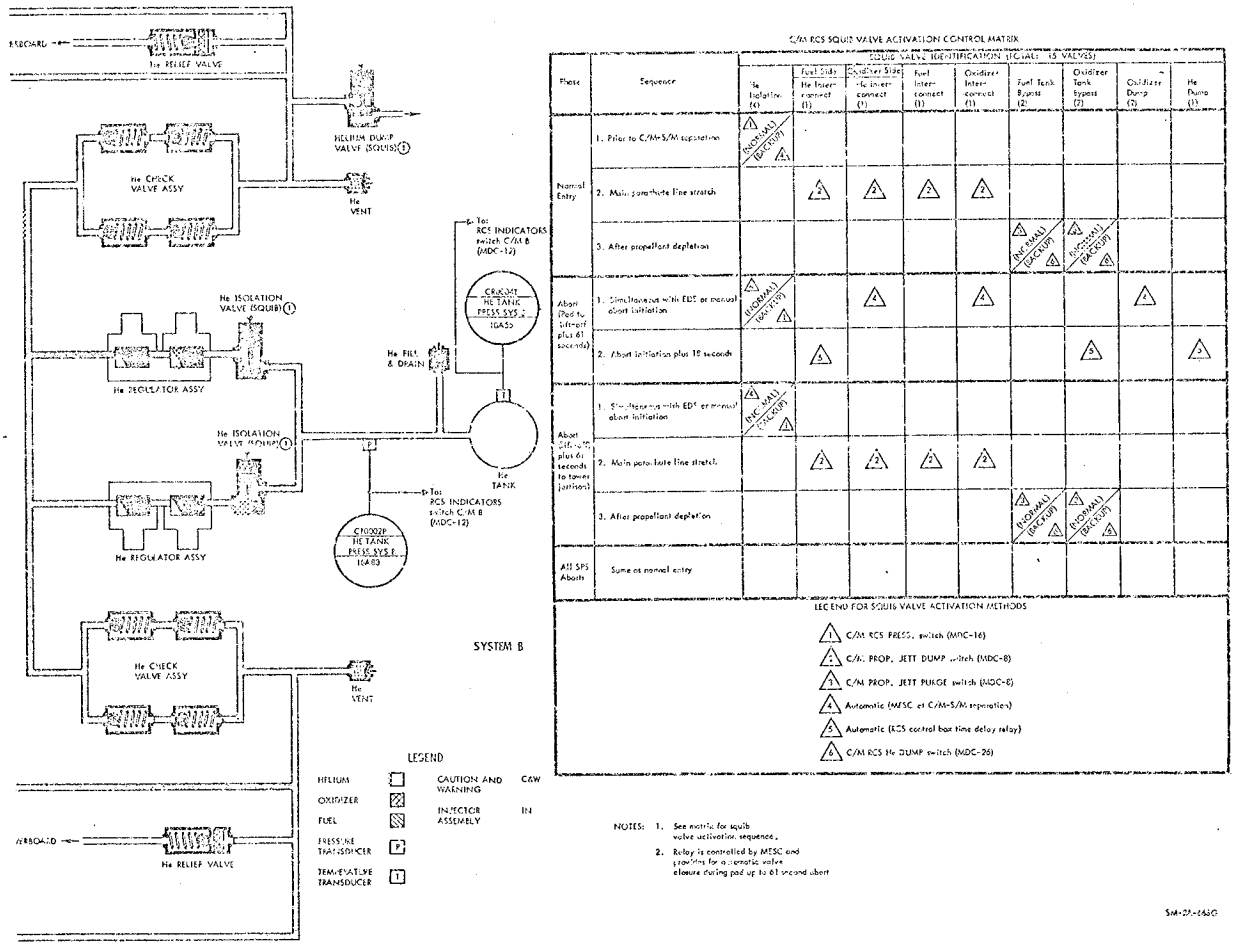
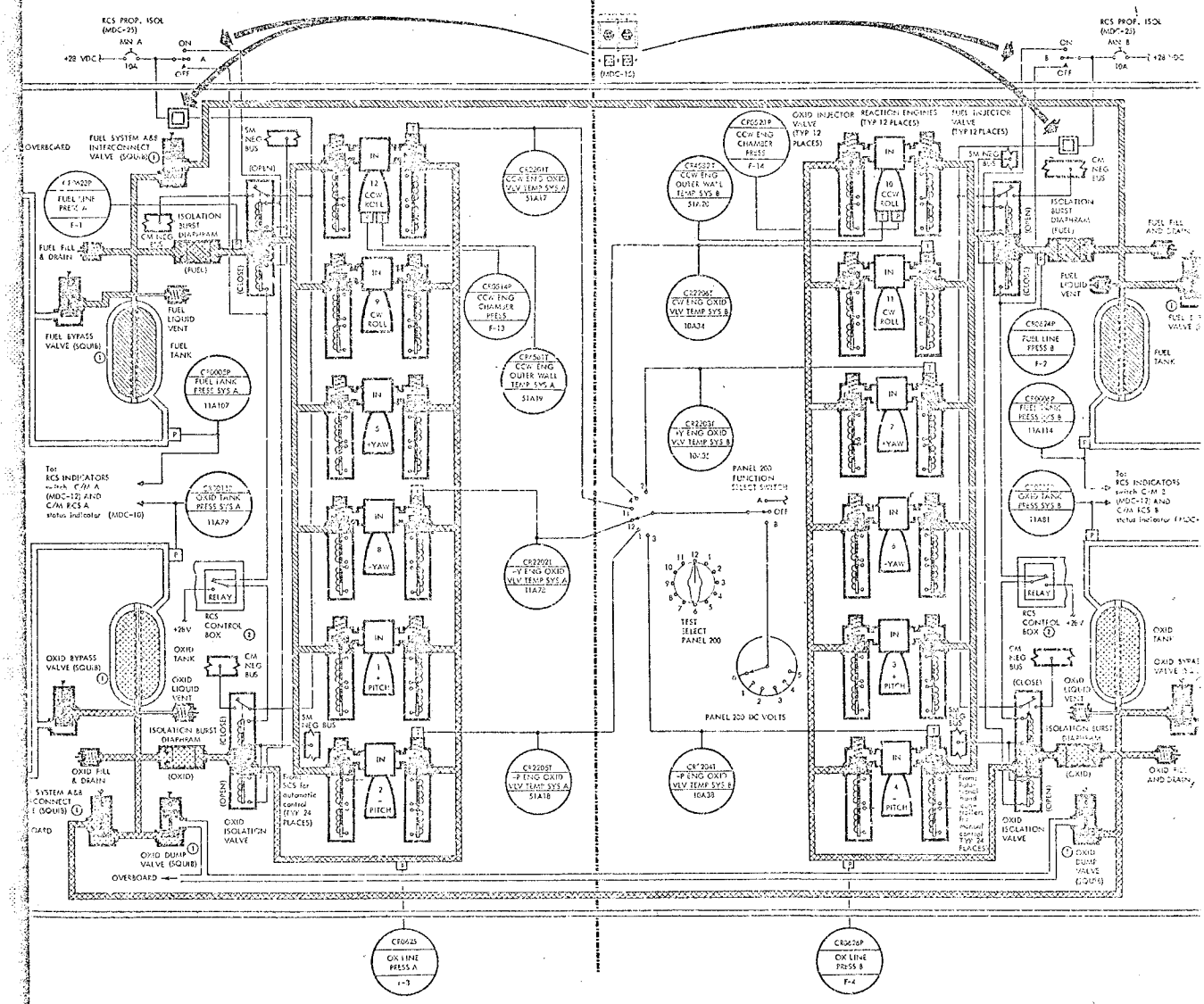
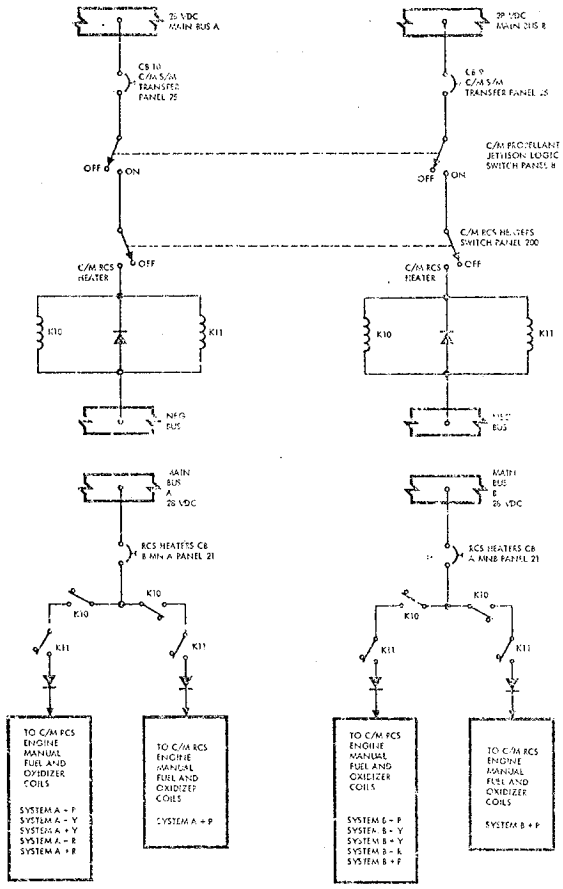
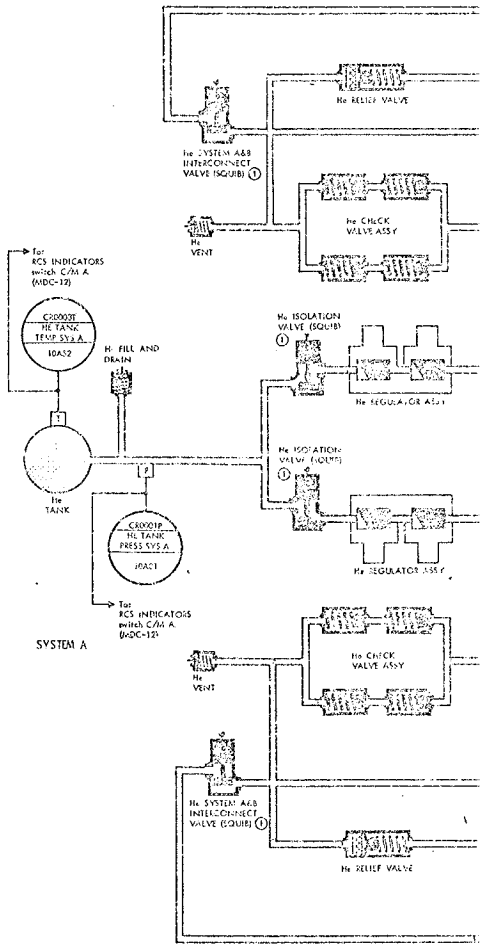


Figure 2.5-8. C/M RCS Functional Flow Diagram


RCS PROP. ISOL (MDC-25)
MN A
ON
A
OFF
+28 VDC
10A
(MDC-15)
RCS PROP. ISOL (MDC-25)
MN B
ON
B
A
OFF
+28 VDC
10A
OVERBOARD
FUEL SYSTEM A&B INTERCONNECT VALVE (SQUIB)
SM NEG BUS
(OPEN)
FT1420P
FUEL LINE PRESS A
F-1
ISOLATION BURST DIAPHRAM
CM NEG BUS
(FUEL)
(CLOSE)
FUEL FILL & DRAIN
FUEL LIQUID VENT
FUEL BYPASS VALVE (SQUIB)
FUEL TANK
CR0002P
FUEL TANK PRESS SYS A
11A107
To RCS INDICATORS via Pitch C/M A (MDC-12) AND C/M RCS A status indicator (MDC-10)
CR2012P
OXID TANK PRESS SYS A
11A79
RELAY
RCS CONTROL BOX
+28V
OXID TANK
CM NEG BUS
OXID LIQUID VENT
OXID BYPASS VALVE (SQUIB)
ISOLATION BURST DIAPHRAM
(OXID)
(CLOSE)
(OPEN)
OXID FILL & DRAIN
SYSTEM A&B CONNECT (SQUIB)
OXID ISOLATION VALVE
OXID DUMP VALVE (SQUIB)
OVERBOARD
Engine SCS for automatic control (TYP 24 PLACES)
SM NEG BUS
IN
12 CCW ROLL
9 CW ROLL
5 +YAW
8 -YAW
1 +PITCH
2 -PITCH
CR0201P
CCW ENG CHAMBER PRESS
F-14
CR2021T
CCW ENG OXID VLV TEMP SYS A
11A17
CR2022T
CCW ENG OUTER WALL TEMP SYS A
11A19
CR2023T
CW ENG OXID VLV TEMP SYS A
11A72
CR2025T
-P ENG OXID VLV TEMP SYS A
11A18
CR0625P
OX LINE PRESS A
F-3
OXID INJECTOR VALVE (TYP 12 PLACES)
REACTION ENGINES (TYP 12 PLACES)
FUEL INJECTOR VALVE (TYP 12 PLACES)
CR0202P
CCW ENG CHAMBER PRESS
F-16
CR2026T
CCW ENG OUTER WALL TEMP SYS B
11A20
CR2027T
CW ENG OXID VLV TEMP SYS B
10A34
CR2028T
+Y ENG OXID VLV TEMP SYS B
10A32
PANEL 200 FUNCTION SELECT SWITCH
A
OFF
B
TEST SELECT PANEL 200
PANEL 200 DC VOLTS
CR2029T
-P ENG OXID VLV TEMP SYS B
10A33
SM NEG BUS
CM NEG BUS
ISOLATION BURST DIAPHRAM
(FUEL)
(CLOSE)
(OPEN)
FUEL FILL AND DRAIN
FUEL LIQUID VENT
CR0624P
FUEL LINE PRESS B
F-2
FUEL TANK
CR0626P
OX LINE PRESS B
F-4
To RCS INDICATORS via C/M 2 (MDC-12) AND C/M RCS B status indicator (MDC-10)
CR2013P
OXID TANK PRESS SYS B
11A81
RELAY
RCS CONTROL BOX
+28 V
OXID TANK
OXID LIQUID VENT
(CLOSE)
(OPEN)
(OXID)
OXID ISOLATION VALVE
OXID DUMP VALVE (SQUIB)
OXID FILL AND DRAIN
OXID BYPASS VALVE
6 -YAW
7 +YAW
11 CW ROLL
10 CCW ROLL
3 +PITCH
4 -PITCH


26 VDC MAIN BUS A
CB 10 C/M S/M TRANSFER PANEL 25
OFF ON
C/M PROPELLANT JETTISON LOGIC SWITCH PANEL B
C/M RCS HEATERS SWITCH PANEL 200
C/M RCS HEATER
OFF
K10
K11
MAIN BUS A 26 VDC
RCS HEATERS CB
K10
K11
TO C/M RCS ENGINE MANUAL FUEL AND OXIDIZER COILS
SYSTEM A + P
SYSTEM A + Y
SYSTEM A + R
SYSTEM A + F
TO C/M RCS ENGINE MANUAL FUEL AND OXIDIZER COILS
SYSTEM A + P
MAIN BUS B 26 VDC
SCS HEATERS CB
TO C/M RCS ENGINE MANUAL FUEL AND OXIDIZER COILS
SYSTEM B + P
SYSTEM B + Y
SYSTEM B + R
SYSTEM B + F
TO C/M RCS ENGINE MANUAL FUEL AND OXIDIZER COILS
SYSTEM B + P


He RELIEF VALVE
He SYSTEM A&B INTERCONNECT VALVE (SQUIB)
He CHECK VALVE ASSY
He VENT
To RCS INDICATORS switch C/M A (MDC-12)
CR0003T HE TANK TEMP SYS A
10AS2
He FILL AND DRAIN
He ISOLATION VALVE (SQUIB)
He REGULATOR ASSY
He TANK
CR0001P HE TANK PRESS SYS A
10AC1
SYSTEM A

2.5.8.1 Pressurization Subsystem.

This subsystem consists of a helium supply tank, two dual-pressure regulator assemblies, two check valve assemblies, two pressure-relief valve assemblies, and associated distribution plumbing.

2.5.8.1.1 Helium Supply Tank.

The total high-pressure helium is contained within a single spherical storage tank. Initial fill pressure is 4150±50 psig. The limit working pressure is 5000 psig to accommodate pressure transients during filling. The proof pressure is 6667 psig and burst pressure is 7500 psig.

2.5.8.1.2 Helium Isolation (Squib-Operated) Valve.

The two squib-operated helium isolation valves are installed in the plumbing from each helium tank to confine the helium to as small an area as possible to reduce helium leakage during the period the system is not in use. Two squib valves are employed in each system to assure pressuriza tion. The valves are opened by closure of the CM PRESS switch on panel 16, the C/M-S/M SEP switches on panel 15, or upon the receipt of an abort signal from the pad up to launch escape tower jettison.

2.5.8.1.3 Helium Pressure Regulator Assembly.

The pressure regulators used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the regulators in the C/M RCS are set at a higher pressure than those of the S/M RCS.

2.5.8.1.4 Helium Check Valve Assembly.

The check valve assemblies used in C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS.

2.5.8.1.5 Helium Relief Valve.

The helium relief valves used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the rupture pressure of the burst diaphragm in the C/M RCS is higher than that of the S/M RCS, and the relief valve relieves at a higher pressure in the C/M RCS than that of the S/M RCS.

2.5.8.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each subsystem from the helium storage vessels to the propellant tanks.

2.5.8.2 Propellant Subsystem.

Each subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.8.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank to each system. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer similar to that of the S/M RCS tank assemblies. The difference is the C/M RCS tank assemblies are smaller in size. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, thus forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold. Working pressure is 360 psig; proof pressure is 480 psig; and the burst pressure is 540 psig.

Fuel Tank. The fuel supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank for each system that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.8.2.2 Diaphragm Burst Isolation Valve.

The burst diaphragms, downstream from each tank are installed to confine the propellants into as small an area as possible throughout the mission. This is to prevent loss of propellants in the event of line rupture downstream of the burst diaphragm or injector valve leakage.

When the helium isolation squib valves are initiated open, regulated helium pressure pressurizes the propellant tanks, creating the positive expulsion of propellants into the respective manifolds to the burst diaphragms, which rupture, allowing the propellants to flow through the propellant isolation valves, to the injector valves on each engine. The diaphragm is of the nonfragmentation type; but, in the event of any fragmentation, a filter is incorporated to prevent any fragments from entering the engine injector valves.

2.5.8.2.3 Propellant Isolation Shutoff Valves.

When the burst diaphragm isolation valves are ruptured, the propellants flow to the propellant isolation valves.

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are

magnetically latched open and spring-loaded closed. The valves are normally open in respect to fluid flow. The C/M propellant switches A and B on panel 15 will be placed to ON after T + 61 seconds and will remain in that position until orbit insertion to ensure that the propellant isolation valves remain open when systems A and B are pressurized upon abort initiation. The switches will also be placed to ON prior to C/M-S/M separation and remain in that position until completion of propellant jettison to again ensure that the valves remain in the open position. The switches are placed to center-neutral position after tower jettison until prior to C/M-S/M separation, removing electrical power from the valves.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel), indicating to the crew the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines, indicating to the crew the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, or runaway thruster, etc. The valve will operate at 0 to 360 psig at both the inlet and outlet ports.

The proof pressure is 540 psig and the burst pressure is 720 psig. The solenoid is a 28-vdc type with a pull-in voltage of not more than 15 volts dc, and the current not to exceed 2 amperes at 30 volts dc. The valve assembly response is 200 milliseconds maximum for one-cycle operation (open-to-closed or closed-to-open).

2.5.8.2.4 Distribution Plumbing.

Brazed joint tubing is used to distribute pressurized helium gas to the propellant positive expulsion tanks in system A and system B. The distribution lines contain 11 explosive-operated (squib) valves which permit changing the helium distribution configuration to accomplish various functions within the C/M RCS. Each squib valve is actuated by an explosive charge detonated by an electrical hotwire igniter. After ignition of the explosive device, the valve remains open permanently. Two squib valves are utilized in each system to isolate the high-pressure helium gas supply to the storage tanks until RCS pressurization is commanded. Two squib valves are utilized to interconnect system A and system B regulated helium supply, which ensures pressurization of both systems during dump-burn and helium purge operations. Two squib valves in each system permit helium gas to bypass the propellant tanks, allowing helium purging of the propellant subsystem. One squib valve is installed in system B regulated helium line to permit helium depressurization in the event of a low-altitude abort (pad to T + 61 second abort).

2.5.8.3 Engine Assembly.

The command module reaction control subsystem engines are ablation cooled, bipropellant thrust generators which can be operated in either the pulse-mode or the steady-state mode.

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic) generated by the guidance and navigation subsystem and/or stabilization control subsystem or by the crew (manually) and an injector head assembly which directs the flow of each propellant from the propellant control valves to the combustion chamber and the combustion chamber in which the propellants are burned to produce thrust. Estimated engine thrust rise and decay is shown in figure 2.5-9.

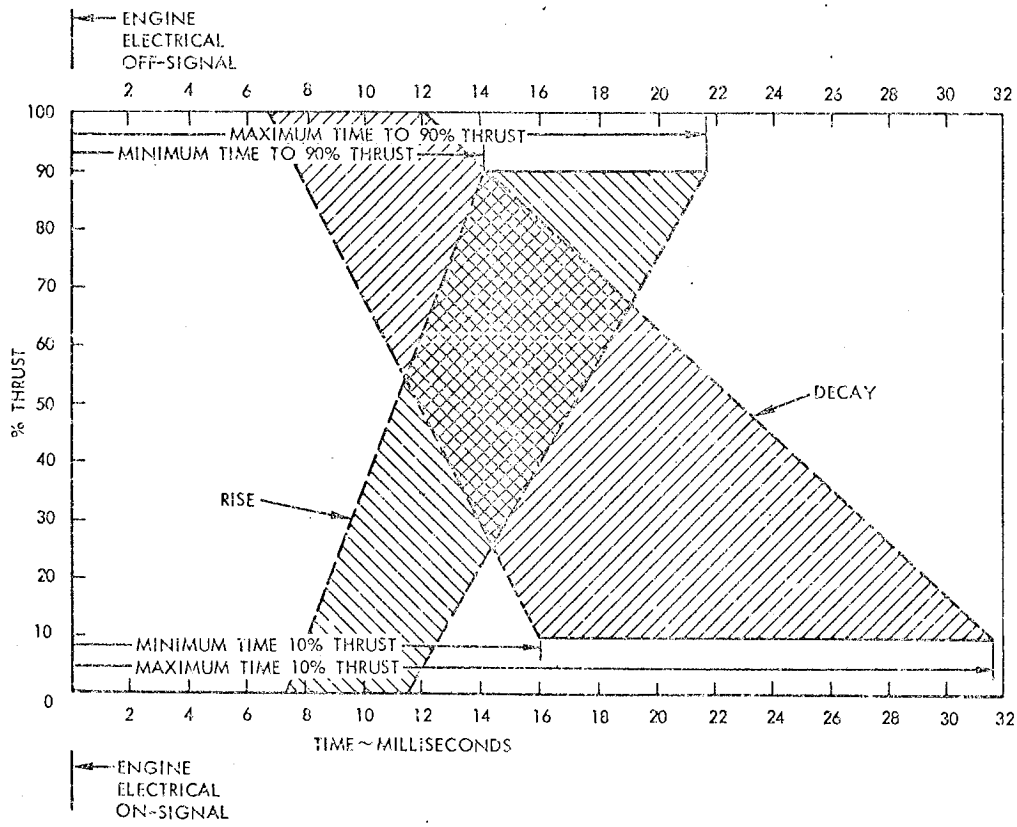


Figure 2.5-9. C/M RCS Engine Thrust Rise and Decay Time (Typical)

2.5.8.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The injector valves utilize two coaxially wound coils: one for automatic and one for direct manual control. The automatic coil is used when the thrust command originates from the jet selection logic. The manual coils are used when the thrust command originates at the rotation control (direct mode).

The solenoid valves are spring-loaded closed and energized open. The reaction time of the valves, pulse mode of operation, reason for pulse mode, and thrust curve generated by the engine is similar to the S/M RCS engines.

The automatic coils in the fuel and oxidizer injector valves are connected in parallel from the SCS. The manual coils in the fuel and oxidizer injector valves provide a manual direct backup to the automatic system. The manual coils are connected in parallel from the rotation controls.

Engine injector valve opening time of 5±2 milliseconds and closing of 6±2 milliseconds for the automatic coils and opening time of 7 milliseconds and closing of 16 to 18 milliseconds for the direct manual coils. The actuation time shall not vary by more than +50 or -25 percent operating time between +40 to +200°F.

2.5.8.3.2 Injector.

The injector, contains a fuel and oxidizer passage that impinge (unlike impingement) upon a splash plate within the combustion chamber. Therefore, the injector pattern is referred to as an unlike impingement splash-plate injector. There are 16 fuel and 16 oxidizer passages in the injector face.

2.5.8.3.3 Thrust Chamber Assembly.

The thrust chamber assembly is fabricated in four segments: the combustion chamber ablative sleeve, the throat insert, the ablative material, and the asbestos and the fiberglass wrap. The engine is ablative cooled.

2.5.8.3.4 Nozzle Extension.

The C/M RCS engines are mounted within the structure of the C/M. The nozzle extensions are required to transmit the gases from the engine out through the structure of the C/M. The nozzle extensions are fabricated of ablative material.

2.5.8.3.5 Engine Solenoid Injector Valve Temperature Control System.

A temperature control system of the C/M RCS engine valves is employed by energizing the manual direct coils on each engine.

Temperature transducers are mounted on the engine injector valve oxidizer solenoids. A temperature transducer is installed on the subsystem. A counterclockwise roll oxidizer valve, negative yaw oxidizer valve, negative pitch oxidizer valve and on subsystem B positive yaw oxidizer valve, negative pitch oxidizer valve, and clockwise roll oxidizer valve. These engine injector solenoid oxidizer valves were selected as the coldest engines.

The temperature transducers have a range from -50°F to +250°F. The temperature transducers from the three subsystem A and B engine oxidizer injector valves provide inputs the the TEST SELECT switch on panel 200, which is located in the lower equipment bay of the command module. With the FUNCTION SELECT switch on panel 200 placed to position B and the TEST SELECT rotary switch on panel 200 placed to positions 1, 2, 3, 4, 11, and 12, respectively, the specific engine oxidizer valve temperature is monitored as a d-c voltage on the 0- to 5-vdc voltmeter. Zero vdc is equivalent to -50°F and 5 vdc is equivalent to +250°F.

A C/M RCS HEATER switch is located on panel 200. The C/M RCS HEATER switch is placed to the ON position when any one of the instrumented engines are below +64°F, approximately 1.80 vdc. This must be accomplished within 26 minutes prior to C/M-S/M separation, providing the C/M propellant jettison LOGIC switch is ON. The fuel and oxidizer injector valve manual coils of all C/M RCS engines are energized open (prior to pressurization of C/M RCS subsystems A and B). A 13-minute heatup time maximum or 100°F, which is monitored on the d-c voltmeter on panel 200 as 2.50 vdc, assures engine injector valve temperature is at +20°F minimum. If +100°F, 2.50 vdc on the d-c voltmeter is reached from the coldest instrumented engine before 13 minutes, the C/M RCS HEATER switch is placed to OFF, which de-energizes the engine injector valves and the injector valves spring-load closed. If a time of 13 minutes is reached before +100°F, 2.50 vdc on the d-c voltmeter, the C/M RCS HEATER switch is placed to OFF. This will prevent the oxidizer from freezing at the engine injector valves upon pressurization of subsystems A and B.

The C/M RCS HEATER switch must be placed to OFF prior to C/M RCS pressurization. The operation of the C/M RCS HEATER switch in conjunction with the d-c voltmeter and/or heating time ensures all other engine valves reach the acceptable temperature levels. The +100°F, 2.50 vdc, or thirteen-minute time limit assures that the warmest engine valve will be less than +200°F.

2.5.8.3.6 Engine Thrust ON-OFF Logic.

All thrust commands for C/M attitude pass through the stabilization and control subsystem and the jet selection logic. These commands may originate at the following:

a. The rotation controls
b. The stabilization and control subsystem
c. The guidance and navigation subsystem.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the C/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation control. When the rotation control is positioned fully to its stops in any direction, the rotation control energizes the required manual coils for the desired maneuver.

When the CM SM SEP switches on panel 15 are placed to CM SM SEP position, the switches automatically energize relays in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) (figure 2.5-10) (providing the CM PROP JETT LOGIC switch on panel 8 is ON) that transfers the SCS and direct manual inputs from the S/M RCS engine th the C/M RCS engines automatically. (These same functions occur on any LES ABORT.)

The transfer motors in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) are redundant to each other in that they ensure the SCS and direct manual inputs are transferred from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS control boxes (C19A1) are automatically activated by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON); in addition, they may also be activated by the manual backup of the RCS TRANSFER switch on panel 16. The transfer motors in the RCS transfer panels (C19A4) are activated automatically only by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON).

As an example, if the RCS transfer motor in C19A1 failed to transfer automatically at CM SM SEP, the RCS transfer motor in C19A4 would still automatically transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines (providing the CM PROP JETT LOGIC switch is ON). In addition, the RCS TRANSFER switch on panel 16 provides a manual backup to the C19A1 RCS transfer motors only.

Another example, the C/M RCS subsystems could be checked out prior to CM SM SEP by placing the RCS TRANSFER switch on panel 16 to CM position, and only the RCS transfer motors (C19A1) in the RCS control boxes would transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS transfer panels (C19A4) would not transfer until C/M S/M SEP (providing the C/M PROP JETT LOGIC switch is ON) and then start the SM jettison controllers.

2.5.8.4 Propellant Jettison.

There are two sequences of propellant jettison. One sequence is employed in the event of an abort while the vehicle is on the launch pad and through the first 61 seconds of flight. The second sequence is employed for all other conditions, whether it be a normal or an abort mode of operation. The sequence of events before and during a normal re-entry is as follows:

a. The crew will place the C/M S/M SEPARATION switches to the C/M S/M SEPARATION position on panel 15 or place the C/M RCS PRESS switch on panel 16 to the ON position, prior to initiating C/M S/M separation. The C/M RCS PRESS switch or the C/M S/M SEP switches initiates the helium isolation squib valves in C/M RCS subsystems A and B, thus pressurizing both subsystems (figures 2.5-8 and 2.5-10). The C/M RCS PRESS switch provides a backup to the C/M S/M SEP switches and the RCS LOGIC switch on panel 8 must be ON, prior to initiating C/M-S/M separation to provide an automatic RCS transfer.

b. The C/M continues to descend after re-entry into the earth atmosphere. At 24,000 feet, barometric switch is activated which unlatches the RCS latching relay, inhibiting any commands from the SCS to the jet selection logic (figure 2.5-3) (manual backup of RCS CMD switch panel 16).

c. At main parachute line stretch, the RCS propellant jettison DUMP switch on panel 8 is placed to the DUMP position as a normal manual function by the crew, initiating the following functions, simultaneously. The RCS LOGIC switch on panel 18 must be ON prior to placing DUMP switch to DUMP position.

1. Initiates the two helium interconnect squib valves
2. Initiates the fuel interconnect squib valve
3. Initiates the oxidizer interconnect squib valve
4. The fuel and oxidizer injector valve manual coils are energized on all of the C/M RCS engines, excluding the + pitch engines. The + pitch engines are not energized due to their location being adjacent to the steam vent. The propellants are jettisoned by burning the propellants remaining in 10 of the 12 engines. The length of time to burn the remaining propellants will vary, depending upon the amount of propellants remaining in the fuel and oxidizer tanks at 24,000 feet. If an entire propellant load remained, as an example, a nominal burn time would be 88 seconds through 10 of the 12 engines. In the worst case of only 5 of the 12 engines (manual coils energized), a nominal burn time would be 155 seconds.

d. Upon completion of propellant burn, the C/M propellant jettison PURGE switch on panel 8 is placed to the PURGE position as a normal manual function by the crew. When the PURGE switch is on, the switch initiates the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, thus purging the manifolds through 10 of the 12 engines. Purging requires approximately 15 seconds or until helium depletion.

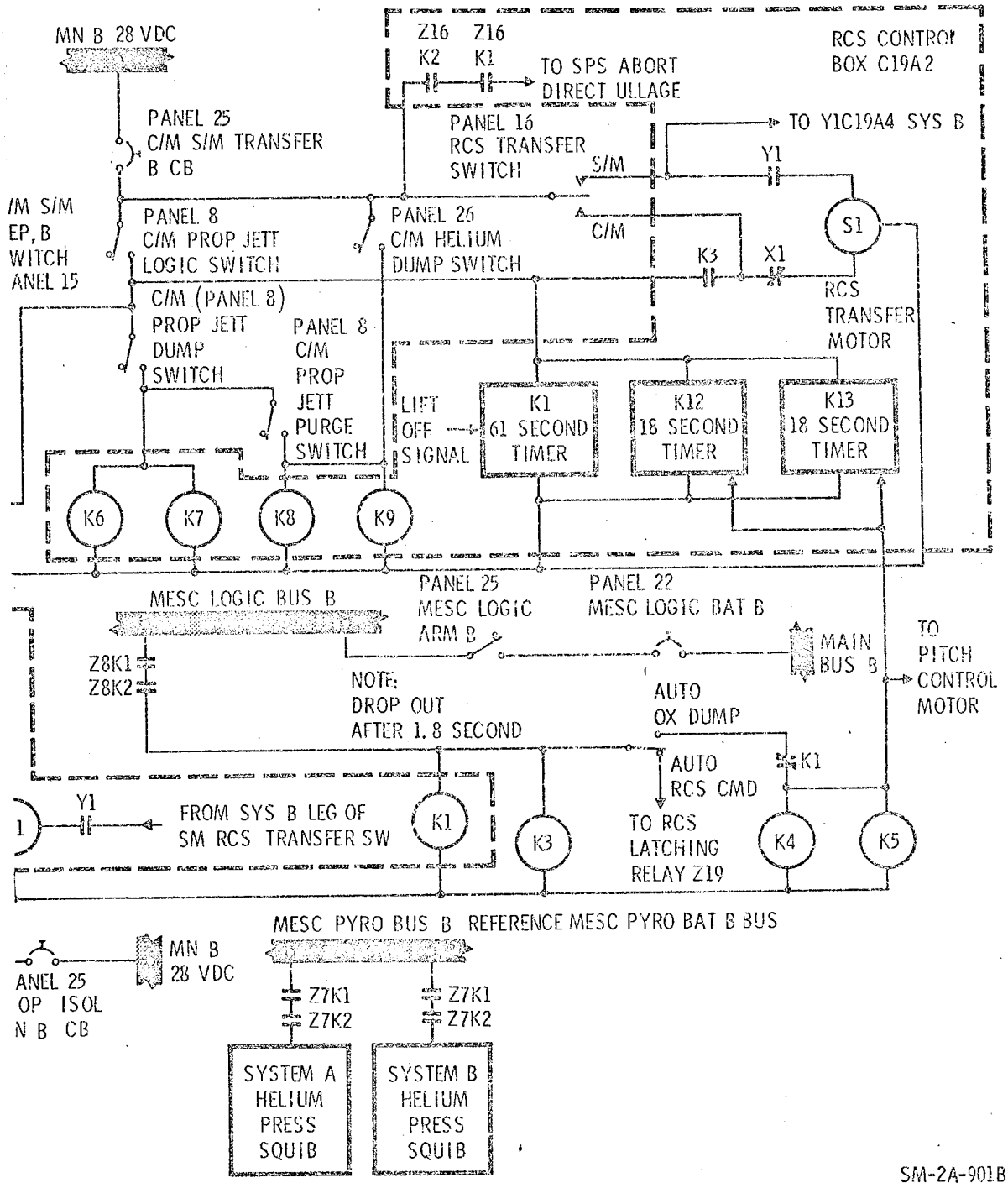
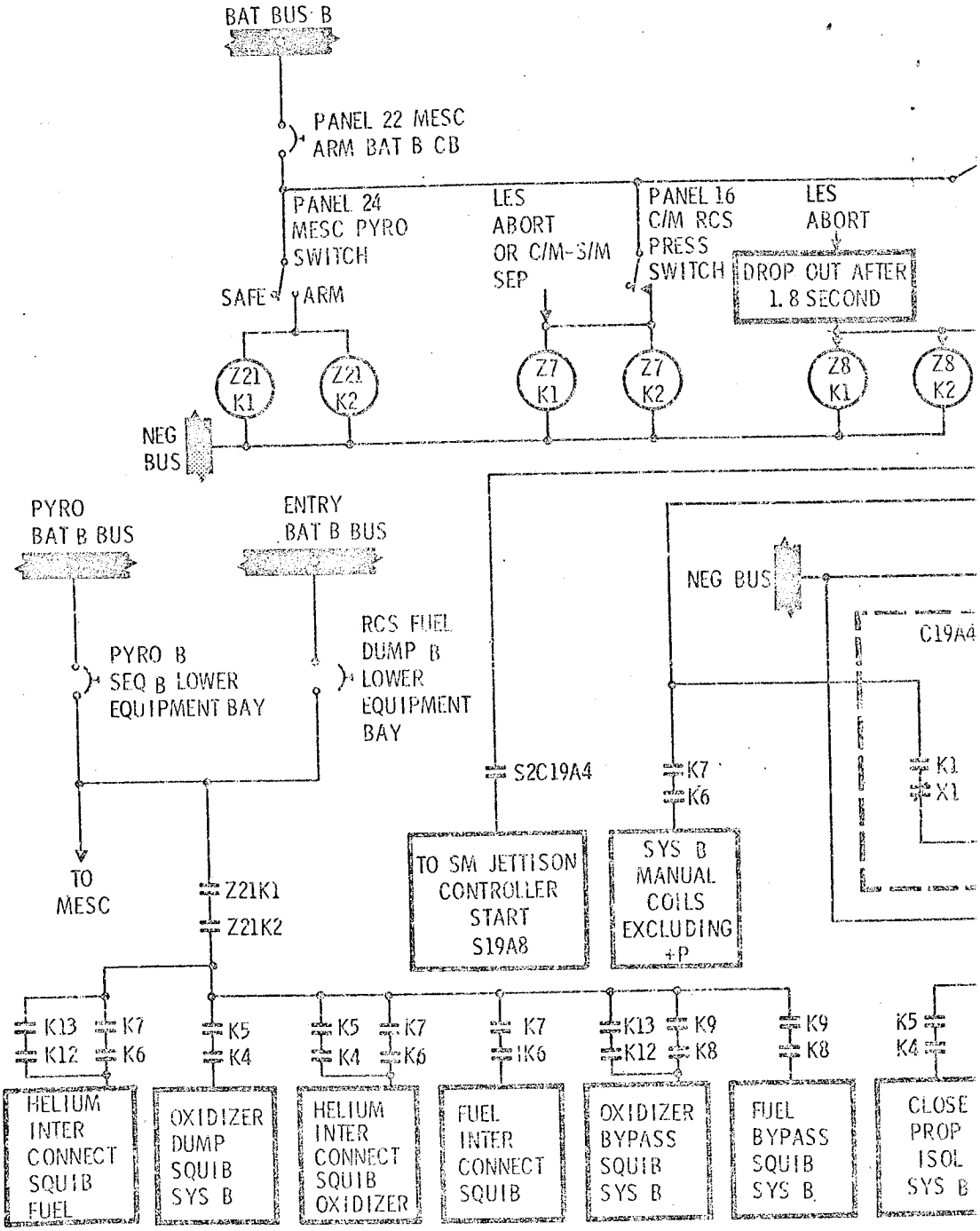
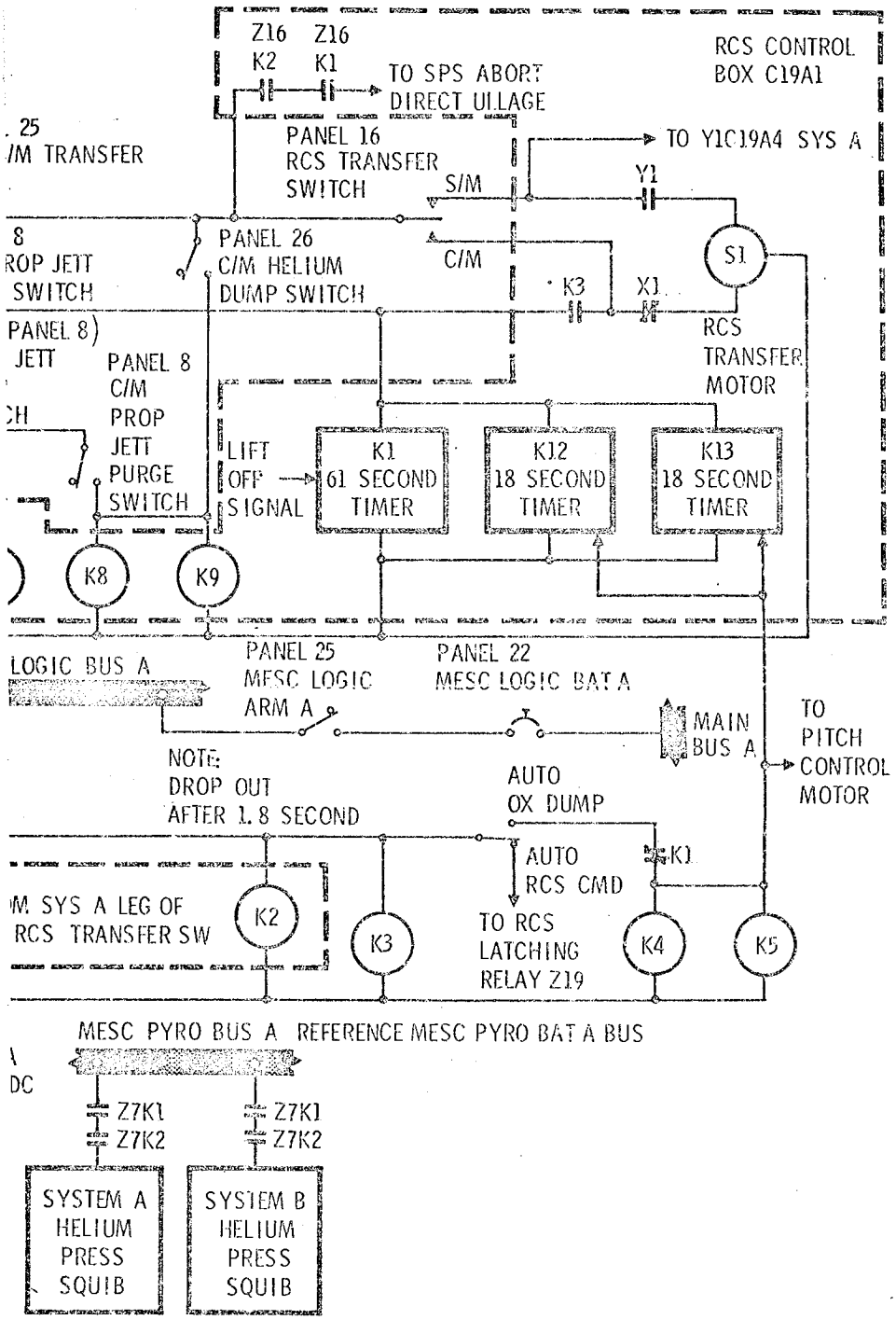
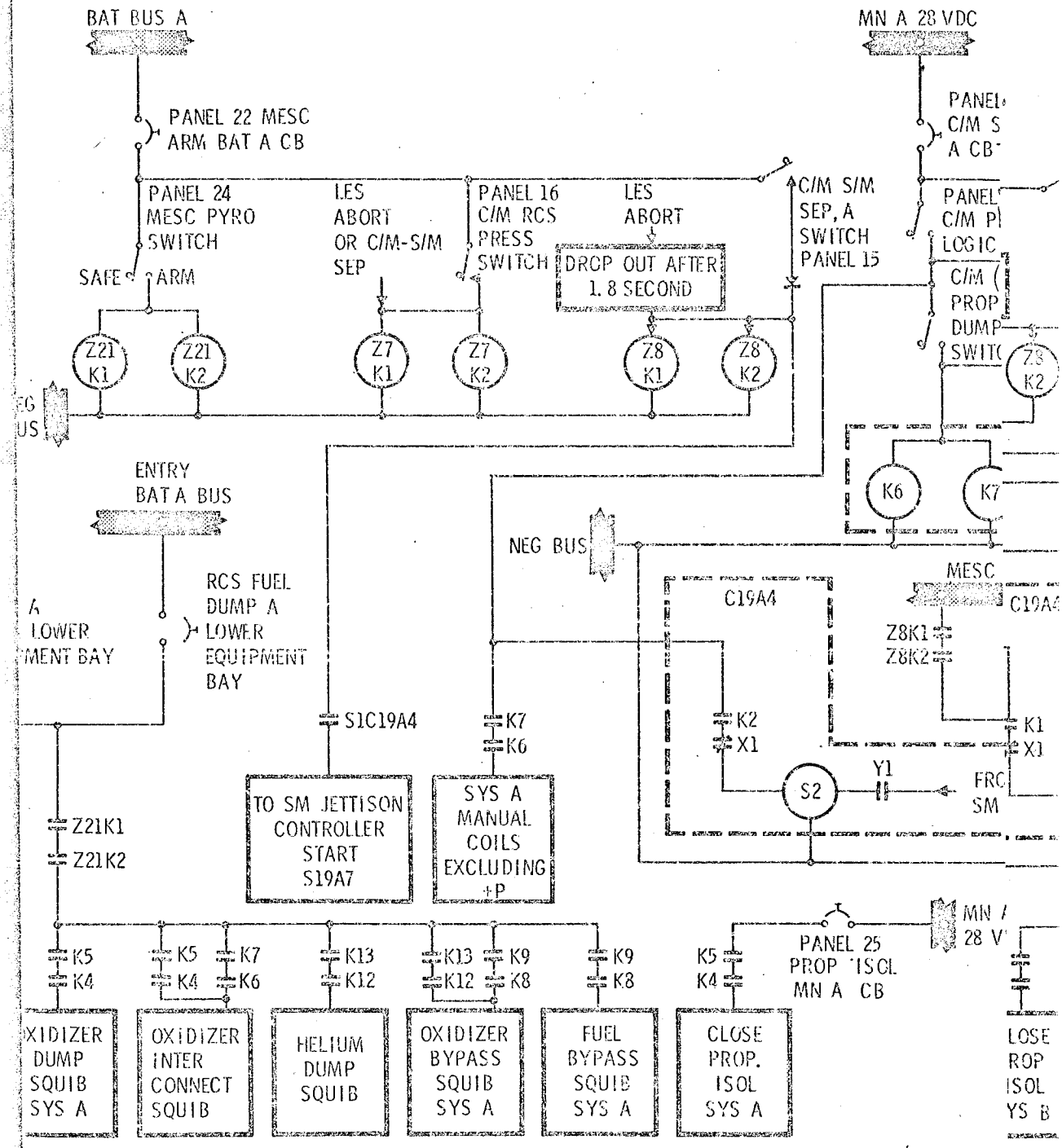
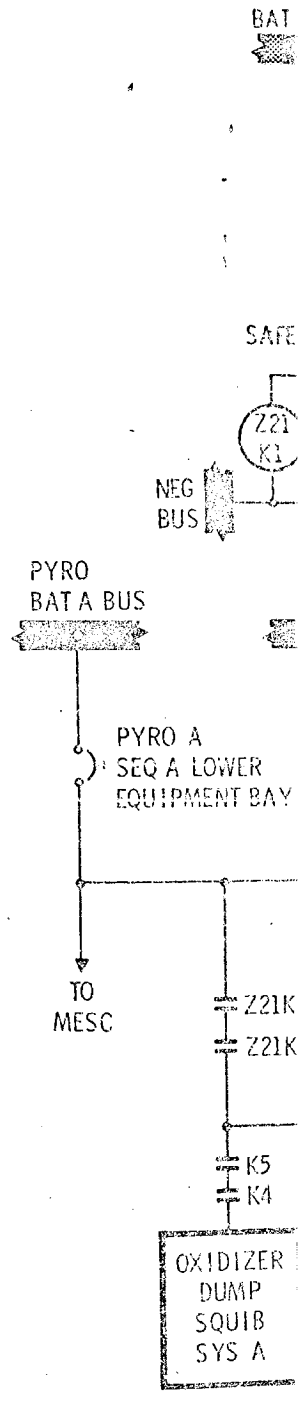


Figure 2.5-10. C/M RCS Squib Valve Power Control Diagram


BAT BUS B
PANEL 22 MESC ARM BAT B CB
PANEL 24 MESC PYRO SWITCH
SAFE
ARM
LES ABORT OR C/M-S/M SEP
PANEL 16 C/M RCS PRESS SWITCH
LES ABORT
DROP OUT AFTER 1.8 SECOND
Z21 K1
Z21 K2
Z7 K1
Z7 K2
Z8 K1
Z8 K2
NEG BUS
PYRO BAT B BUS
ENTRY BAT B BUS
PYRO B SEQ B LOWER EQUIPMENT BAY
RCS FUEL DUMP B LOWER EQUIPMENT BAY
NEG BUS
C19A4
K1
X1
S2C19A4
K7
K6
TO MESC
Z21K1
Z21K2
TO SM JETTISON CONTROLLER START S19A8
SYS B MANUAL COILS EXCLUDING +P
K13 K12
K7 K6
K5 K4
K5 K4
K7 K6
K7 IK6
K13 K12
K9 K8
K9 K8
K5 K4
HELIUM INTER CONNECT SQUIB FUEL
OXIDIZER DUMP SQUIB SYS B
HELIUM INTER CONNECT SQUIB OXIDIZER
FUEL INTER CONNECT SQUIB
OXIDIZER BYPASS SQUIB SYS B
FUEL BYPASS SQUIB SYS B
CLOSE PROP ISOL SYS B


Z16 K2
Z16 K1
TO SPS ABORT
DIRECT ULLAGE
RCS CONTROL BOX C19A1
. 25
/M TRANSFER
PANEL 16
RCS TRANSFER
SWITCH
S/M
TO Y1C19A4 SYS A
Y1
8
ROP JETT
SWITCH
PANEL 26
C/M HELIUM
DUMP SWITCH
C/M
S1
K3
X1
PANEL 8)
JETT
PANEL 8
C/M
PROP
JETT
PURGE
SWITCH
RCS
TRANSFER
MOTOR
CH
LIFT
OFF
SIGNAL
K1
61 SECOND
TIMER
K12
18 SECOND
TIMER
K13
18 SECOND
TIMER
K8
K9
LOGIC BUS A
PANEL 25
MESC LOGIC
ARM A
PANEL 22
MESC LOGIC BAT A
MAIN
BUS A
TO
PITCH
CONTROL
MOTOR
NOTE:
DROP OUT
AFTER 1.8 SECOND
AUTO
OX DUMP
AUTO
RCS CMD
K1
M SYS A LEG OF
RCS TRANSFER SW
K2
K3
TO RCS
LATCHING
RELAY Z19
K4
K5
MESC PYRO BUS A
REFERENCE MESC PYRO BAT A BUS
DC
Z7K1
Z7K2
Z7K1
Z7K2
SYSTEM A
HELIUM
PRESS
SQUIB
SYSTEM B
HELIUM
PRESS
SQUIB


BAT BUS A
MN A 28 VDC
PANEL 22 MESC ARM BAT A CB
PANEL 24 MESC PYRO SWITCH
SAFE
ARM
LES ABORT OR C/M-S/M SEP
PANEL 16 C/M RCS PRESS SWITCH
LES ABORT
DROP OUT AFTER 1.8 SECOND
C/M S/M SEP, A SWITCH PANEL 15
Z21 K1
Z21 K2
Z7 K1
Z7 K2
Z8 K1
Z8 K2
K6
K7
ENTRY BAT A BUS
NEG BUS
RCS FUEL DUMP A LOWER EQUIPMENT BAY
S1C19A4
K7
K6
C19A4
MESC
Z8K1
Z8K2
K2
X1
K1
X1
S2
Y1
Z21K1
Z21K2
TO SM JETTISON CONTROLLER START S19A7
SYS A MANUAL COILS EXCLUDING +P
K5
K4
K13
K12
K9
K8
PANEL 25 PROP ISOL MN A CB
OXIDIZER DUMP SQUIB SYS A
OXIDIZER INTER CONNECT SQUIB
HELIUM DUMP SQUIB
OXIDIZER BYPASS SQUIB SYS A
FUEL BYPASS SQUIB SYS A
CLOSE PROP. ISOL SYS A


BAT
SAFE
Z21
K1
NEG
BUS
PYRO
BAT A BUS
PYRO A
SEQ A LOWER
EQUIPMENT BAY
TO
MESC
Z21K
Z21K
K5
K4
OXIDIZER
DUMP
SQUIB
SYS A

e. In the event of the C/M propellant jettison LOGIC switch and/or DUMP switch failure, the remaining propellants may be burned by placing the DIRECT RCS switch on panel 8 to ON and positioning the two rotation controllers to CCW, CW, -Y, +Y and -P (excluding +P) position, energizing the manual fuel and oxidizer injector valve solenoid coils of 10 of the 12 C/M RCS engines burned. At the completion of propellant burn, the C/M RCS HELIUM DUMP switch on panel 26 would be placed ON initiating the four bypass squib valves, allowing the regulation helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines providing the two rotation controllers are positioned to CCW, CW, -Y, +Y and -P (excluding +P).

f. In the event the C/M propellant jettison LOGIC switch and DUMP switch on panel 8 function correctly and the PURGE switch fails, the C/M HELIUM DUMP switch on panel 26 would be placed to ON; thus initiating the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines.

g. Prior to water impact the LOGIC switch on panel 8 may be placed to the OFF position, which would de-energize the manual coils of the engine injector valves allowing the engine injector valves to spring-load closed, preventing sea water from entering the manifolds through the engine. The DUMP switch placed to the OFF position will accomplish the same function.

The sequence of events involving an abort from the pad up to 61 seconds is as follows:

a. The OXIDIZER DUMP switch on panel 16 is placed in the AUTO OX DUMP position, and the RCS LOGIC switch on panel 8 is placed in the ON position at some time in the countdown prior to T=0.

b. The following events occur simultaneously upon the receipt of the abort signal. The command may be generated automatically by the sequence events controller subsystem or by manually rotating the translation control counterclockwise.

1. When the abort signal is received, the two squib-operated helium isolation valves in each system are initiated open, pressurizing subsystems A and B. Manual backup of the C/M PRESS switch, panel 16.
2. The squib-operated helium interconnect valve for the oxidizer tanks is initiated open. If only one of the two squib helium isolation valves was initiated open, both systems are pressurized as a result of the helium interconnect squib valve interconnect.
3. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed to prevent fuel and oxidizer from flowing to the thrust chamber assemblies.
4. The squib-operated oxidizer interconnect valve is initiated open. If only one of the two oxidizer overboard dump squib valves was initiated open, the oxidizer manifolds of each system are common as a result of the oxidizer interconnect squib valve.

5. The squib-operated oxidizer overboard dump valves route the oxidizer to a blow-out plug in the aft heat shield of the C/M which shears a pin due to the pressure buildup and blows the plug out, dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 to 15 seconds.

6. The RCS latching relay will not energize in the event of an abort from 0 to +61 seconds due to the position of the AUTO OX DUMP switch (figures 2.5-3 and 2.5-10). Thus, no commands are allowed into the jet selection logic from the SCS.

7. The C/M-S/M RCS transfer motor-driven switches are automatically driven upon the receipt of the abort signal, allowing electrical signals to be supplied to the C/M RCS engine injector valves. Manual backup of RCS transfer switch, panel 16.

c. Eighteen seconds after the abort signal is initiated, the following events automatically occur simultaneously:

1. The helium interconnect squib valve between the fuel tanks is initiated open.

2. The helium overboard dump squib valve is initiated open, dumping the helium pressure overboard into the aft equipment compartment, releasing the helium pressure from both fuel tanks.

3. The bypass squib valve to the subsystems A and B oxidizer tank is initiated open, purging both oxidizer systems out through the overboard dump in the aft heatshield.

4. Fuel remains onboard at impact with no pressure on the fuel tanks.

The sequence of events of an abort, initiated after 61 seconds up to launch escape tower jettison, are as follows:

a. At 61 seconds after lift-off, the crew as a normal manual function will place the AUTO OX DUMP switch on panel 16 to the AUTO RCS CMD position.

b. The RCS LOGIC switch was placed to the ON position prior to T+0.

1. Initiate both helium isolation squib valves in C/M RCS, subsystems A and B. Manual backup of C/M RCS PRESS switch on panel 16; thus, pressurizing C/M RCS subsystems A and B.

2. Drives the C/M S/M RCS transfer motors to the C/M RCS position. Manual backup of RCS TRANSFER switch on panel 16 for C19A1 RCS transfer motors only.

3. RCS latching relay energized one second after receipt of the abort signal.

d. At main parachute line stretch, as a normal manual function, the RCS propellant and jettison DUMP switch on panel 8 is placed to the DUMP position initiating functions the same as a normal entry.

2.5.9 C/M RCS PERFORMANCE AND DESIGN DATA.

2.5.9.1 Design Data.

The following list contains data of the CM/RCS components:

HELIUM TANKS (2)	4150±50 psig at 70°±5°F during servicing, setting on launch pad 70°±10°F. Capacity 0.57 lbs, inside diameter 8.84 in., wall thickness 0.105 in. and internal volume of 365±5 cubic in. at 4150±50 psig.
HELIUM ISOLATION SQUIB VALVE FILTER	Remove 98 percent of all particles whose two smallest dimensions are greater than 40 microns. Remove 100 percent of all particles whose two smallest dimensions are greater than 74 microns.
REGULATOR UNITS (4)	Primary - Initial of 291±6 psig and stabilize within 2 seconds to 291±4 psig. Lockup pressure minimum of 284 psig and not exceed 302 psig. Secondary - Lockup 287 to 308 psig and stabilize at 294.5±7.5 psig within 2 seconds.
HELIUM RELIEF VALVES (4)	Diaphragm rupture at 340±8 psi Filter - 10 microns nominal, 25 microns absolute Relief valves relieves at 346±14 psig Relief valve reseats at no less than 327 psig Flow capacity 0.3 lb/min at 60°F and 346±14 psig Bleed device closes when increasing pressure has reached no more than 179 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed and relief valve assemblies combined. The bleed device shall reopen when decreasing pressure has reached no less than 20 psig.

PRESSURE TRANSDUCERS FUEL AND OXIDIZER	Illuminates caution and warning light on panel 10 (C/M RCS A or B)
	After helium isolation, underpressure 265 psia
	Squib valve actuation, overpressure 325 psia
FUEL TANKS (2)	Combined propellant and ullage volume of 45.2 lbs, initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Length 17.329 (+0.040, -0.000) in., outside diameter maximum 12.62 in., wall thickness 0.022 in. to 0.027 in.
OXIDIZER TANK (2)	Combined propellant and ullage volume of 89.2 pounds initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 85°F. Length 19.907 (+0.040, -0.000) in., maximum outside diameter 12.62 in., wall thickness 0.022 to 0.027 in.
VALVE ISOLATION BURST DIAPHRAGM (4)	Rupture at 241±14 psig, within 2 seconds after rupture pressure is reached at any temperature between 40° to 105°F.
	Filter 75 microns nominal, 100 microns absolute.
ENGINE	200-second service life, 3000 operational cycles
	Nominal thrust, 93 pounds
	Expansion ratio, 9 to 1
	Cooling, ablation
	Injector type, 16 on 16 splash plate
	Combustion chamber refrasil ablative sleeve and graphite base throat insert.

		Automatic and manual coils - connected in parallel
		Weight, 8.3 lbs
		Length, 11.65 in. maximum
		Nozzle exit diameter, 2.13 inches
		Nozzle extensions, ablative refrasil
	OXIDIZER DUMP BLOWOUT PLUG	Pin shears at 100 psig

2.5.9.2 Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.9.3 Power Consumption Data.

Refer to paragraph 2.5.4.3.

2.5.10 C/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

A propellant isolation valve switch must be placed to ON momentarily prior to lift-off and returned to neutral. At T+61 seconds after lift-off the switches must be placed to ON until orbit insertion to ensure that the valves will remain open if an LES abort is initiated; then at orbit insertion, the switches may be placed to neutral. The switches must be placed to ON prior to C/M RCS pressurization to ensure valves remain open throughout entry.

2.5.10.1 C/M RCS Electrical Power Distribution.

See figure 2.5-11 for electrical power distribution.

2.5.11 C/M RCS TELEMETRY MEASUREMENTS.

The following is a complete list of the C/M RCS telemetry data that is monitored by the flight controllers and ground support personnel.

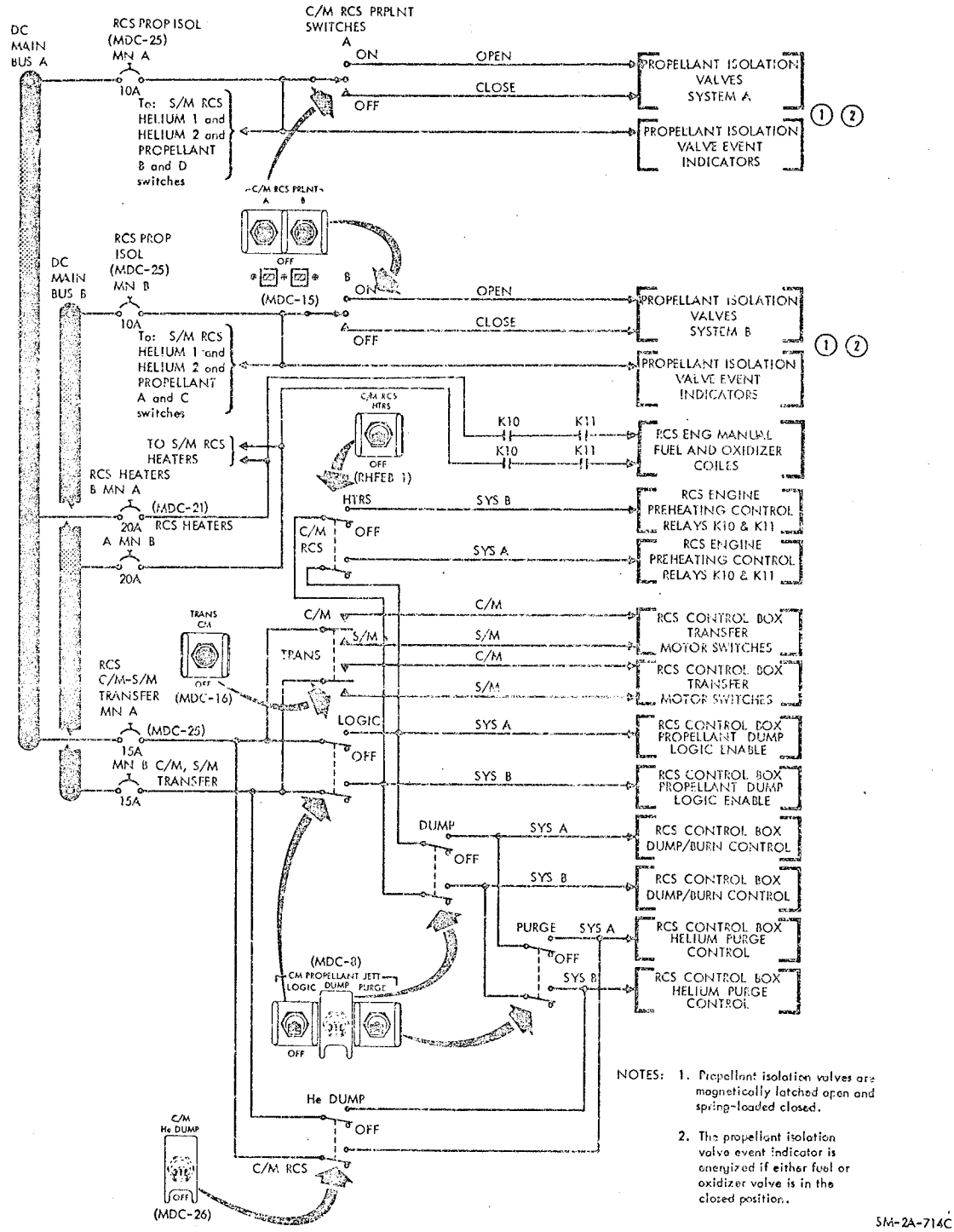


Figure 2.5-11. C/M RCS Electrical Power Distribution Diagram

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 12	2.5-7	Helium Tank Supply Pressure A	CR0001P	+0 +5K psia	C28AR31	10A81	H2	PCM	4150±50 psia and decrease during mission.
Panel 12	2.5-7	Helium Tank Supply Pressure B	CR0002P	+0 +5K psia	C28AR32	10A83	H2	PCM	
Panel 12	2.5-7	Helium Tank Supply Temperature A	CR0003T	+0 +300°F	C28AR33	10A52	H1	PCM	70±10°F on launch pad variable during mission.
Panel 12	2.5-7	Helium Tank Supply Temperature B	CR0004T	+0 +300°F	C28AR34	10A55	H1	PCM	
Panels 10 and 12	2.5-7	Fuel Tank A Pressure	CR0005P	+0 +400 psia	C28AR35	11A107	H2	PCM	After pressurization 287 to 308 psia until propellant purge
Panels 10 and 12	2.5-7	Fuel Tank B Pressure	CR0006P	+0 +400 psia	C28AR36	11A114	H2	PCM	
Panels 10 and 12	2.5-7	Oxidizer Tank A Pressure	CR0011P	+0 +400 psia	C28AR38	11A79	H2	PCM	
Panels 10 and 12	2.5-7	Oxidizer Tank B Pressure	CR0012P	+0 +400 psia	C28AR39	11A81	H2	PCM	
	2.5-7	Fuel Line Pressure A	CR0623P	+0 +400 psia		F-1		FQ	Flight recorder.
	2.5-7	Fuel Line Pressure B	CR0624P	+0 +400 psia		F-2		FQ	
	2.5-7	Oxidizer Line Pressure A	CR0625P	+0 +400 psia		F-3		FQ	
	2.5-7	Oxidizer Line Pressure B	CR0626P	+0 +400 psia		F-4		FQ	
Panel 97	2.5-7	Temperature Oxidizer Valve CCW R Engine A	CR2201T	-50 +250°F	C28AR295	51A17	H1	PCM	Variable during mission, prior to separation turn heaters on if below +64°F, turn off in 13 minutes time or 100°F, whichever is reached first.
Panel 97	2.5-7	Temperature Oxidizer Valve -Y Engine A	CR2202T	-50 +250°F	C28AR296	11A78	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine A	CR2205T	-50 +250°F	C28AR299	51A18	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve +Y Engine B	CR2203T	-50 +250°F	C28AR297	10A35	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine B	CR2204T	-50 +250°F	C28AR298	10A38	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve CWR Engine B	CR2206T	-50 +250°F	C28AR300	10A34	H1	PCM	
	2.5-7	CCW Roll Engine Chamber Pressure A	CR0614P	+0 +250 psia		F-13		FQ	Flight recorder.
	2.5-7	CCW Roll Engine Chamber Pressure B	CR0620P	+0 +250 psia		F-14		FQ	
	2.5-7	CCW Roll Engine Wall Temperature A	CR4361T	+0 +1000°F		51A19	H1	FQ	Variable

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
	2.5-7	CCW Roll Engine Wall Temperature B	CR4582T	+0 +1000°F		51A20	H1	FQ	Variable
	2.5-9	C/M-S/M SEP Relay Close A (Z9 to Z7)	CD0023X	OFF ON event		11E12-03	E2	PCME	Event
	2.5-9	C/M-S/M SEP Relay Close B (Z9 to Z7)	CD0024X	OFF ON event		11E12-04	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal A (Z9 to Z7)	CD0002X	OFF ON event		11E12-01	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal B (Z9 to Z7)	CD0062X	OFF ON event		11E12-07	E2	PCME	Event
	2.5-9	RCS Actuate Signal A (Z19)	CD0170X	OFF ON event		11E13-06	E2	PCME	Event
	2.5-9	RCS Activate Signal B (Z19)	CD0171X	OFF ON event		11E13-07	E2	PCME	Event
	2.5-9	C/M Pressurize Signal A (Z9 to Z7)	CD0173X	OFF ON event		11E13-08	E2	PCME	Event
	2.5-9	C/M Pressurize Signal B (Z9 to Z7)	CD0174X	OFF ON event		11E14-01	E2	PCME	Event
	2.5-9	Barometric Switch Lock In Close Relay A	CE0007X	CLOSE OPEN event		11E14-08	E2	PCME	Event
	2.5-9	Barometric Switch Relay Lock In Close Relay B	CE0008X	CLOSE OPEN event		11E15-01	E2	PCME	Event
	2.5-9	Lift-Off Signal A	BS0060X			11E25-03	E2	PCME	Event
	2.5-9	Lift-Off Signal B	BS0061X			11E25-04	E2	PCME	Event

*Analog measurements digitally coded into 8 bit words.
Analog measurements -0 (+0.15 -0) vdc to 5 (+0, -0.15) vdc
FQ - Flight qualification measurements
H1 - High bit rate
H2 - High and low bit rate
E2 - High and low bit rate

Channel Example: 10A81

Significant number - 1
How many zeros after significant number is amount of samples per second - 0

1 sample per second

SECTION 2

SUBSECTION 2.6

ELECTRICAL POWER SYSTEM (EPS)

2.6.1 INTRODUCTION.

The electrical power system (figure 2.6-1) supplies all electrical power required by the spacecraft to complete its scheduled mission. D-C electrical power is provided by three fuel cell power plants, two S/M jettison controller batteries located in the service module, and five batteries (2 pyro and 3 entry) located in the command module. A-C electrical power is provided by one, or two, of the three inverters located in the lower equipment bay of the command module. Controls and displays for the EPS are positioned in the command module near the astronaut responsible for controlling and monitoring the system. The EPS can be divided into four subsystems as follows:

- Energy storage: cryogenic storage; pyrotechnic, entry, and S/M jettison controller batteries
- Power generation: fuel cell power plants
- Power conversion: solid state inverters, battery charger
- Power distribution: d-c power distribution, a-c power distribution, sensing circuits, controls and displays.

2.6.2 FUNCTIONAL DESCRIPTION.

2.6.2.1 Energy Stowage.

The primary source of energy for the EPS is provided by the cryogenic storage system. There are two hydrogen (fuel) and two oxygen (oxidizer) cryogenic storage tanks. Each tank has its associated controls, heaters, and fans designed to give, in an automatic mode, a single-phase reactant to its load throughout the tank-density range, when operating at normal pressures.

A secondary source of energy storage is provided by batteries. The batteries supply sequencer logic and pyro power at all times, supplemental d-c power for high-peak loads, and all electrical power required during the entry and postlanding phases after CSM separation.

2.6.2.2 Power Generation.

Three Bacon-type fuel cell power plants in the service module generate the d-c power required for spacecraft systems. The fuel cell power plants are activated prior to launch and operate continuously throughout the mission until CSM separation. Normally, fuel cell power plant 1 is connected to main d-c bus A, power plant 3 to main d-c bus B, and power plant 2 to both main d-c buses A and B. However, the capability is provided to also connect fuel cell power plant 1 to main d-c bus B and fuel cell power plant 3 to main d-c bus A.

Each fuel cell is rated to produce 29±2 volts dc between 563 and 1420 watts of power. Two fuel cell power plants are capable of providing the normal power requirements of all spacecraft systems. If two fuel cell power plants malfunction, some of the electrical components must be shut down to conserve power, and the remaining power plant with battery backup will supply sufficient power to carry the load and insure successful mission termination. One fuel cell with complete battery backup can provide maximum power required by mission burns, if the cryogenics are available and fuel cell temperature is above 425°F.

2.6.2.3 Power Conversion.

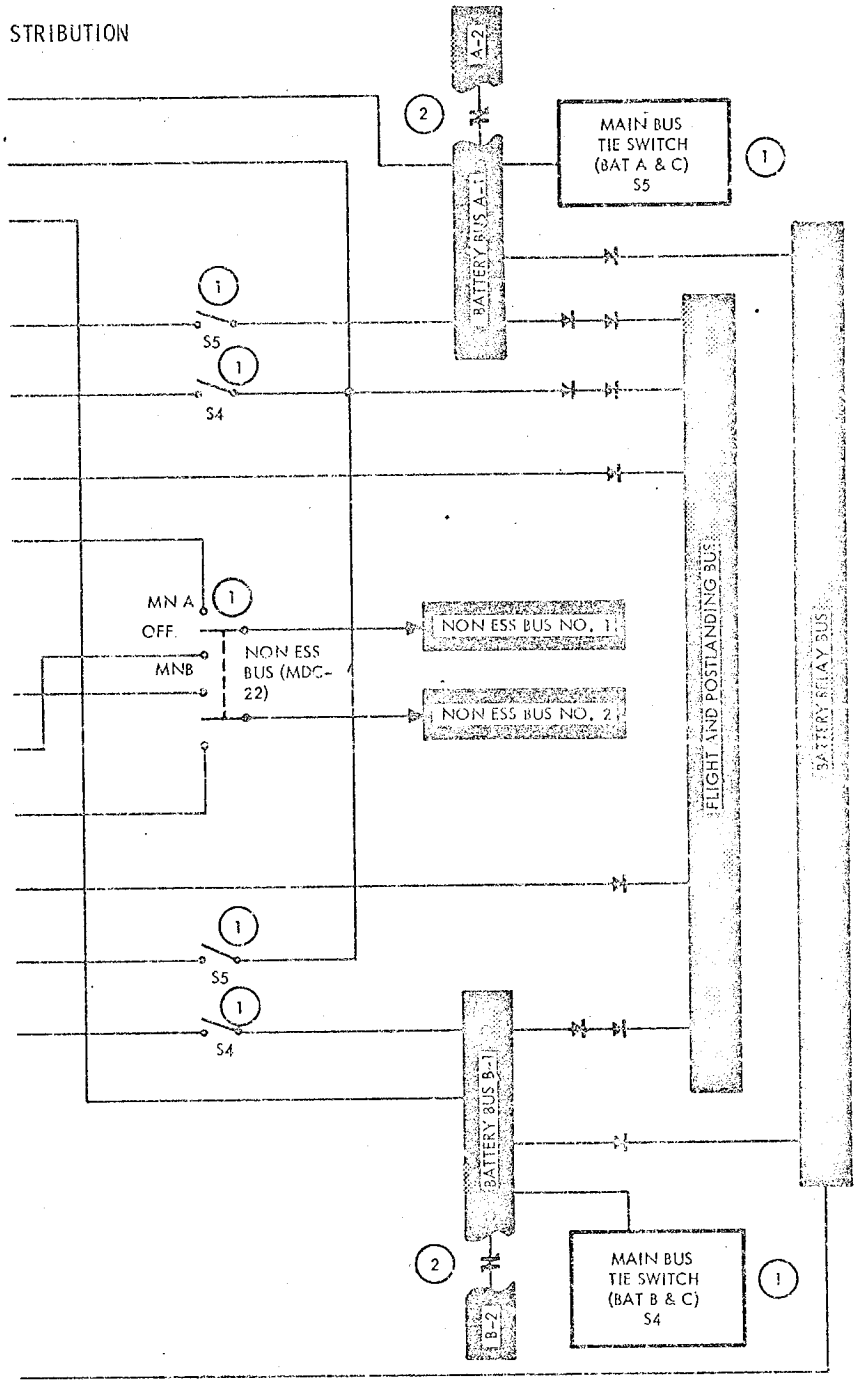
Primary d-c power is converted into a-c power by solid-state inverters. The inverters provide 115-volt 400-cps 3-phase a-c power up to 1250 volt-amperes each. The a-c power is connected to the two a-c buses which supply power to a-c loads. During normal operation, one inverter will power both a-c buses while the two remaining inverters act as redundant sources. For peak loads, each a-c bus will be powered by a separate inverter. In case of an a-c or d-c bus failure, the inverters and remaining buses can be isolated. Inverter switching circuits prevent connecting two inverters on one bus, but simultaneous operation of two inverters is possible if each is connected to a separate bus. A phase synchronizing unit provides in-phase power when a separate inverter is powering each bus.

The battery charger is a secondary power conversion unit, which is used to keep entry batteries charged. The charger is a solid-state device converting a-c power from the inverters and using d-c power from the fuel cells to provide charging voltage.

2.6.2.4 Power Distribution.

Distribution of primary d-c power is accomplished by two redundant d-c buses in the command module. Additional buses consist of two separate nonessential buses for servicing nonessential loads, a battery relay bus for power distribution switching, two battery buses, and a flight and postlanding bus to service certain communications and the postlanding circuits. A-C power is distributed by two redundant a-c buses.

STRIBUTION

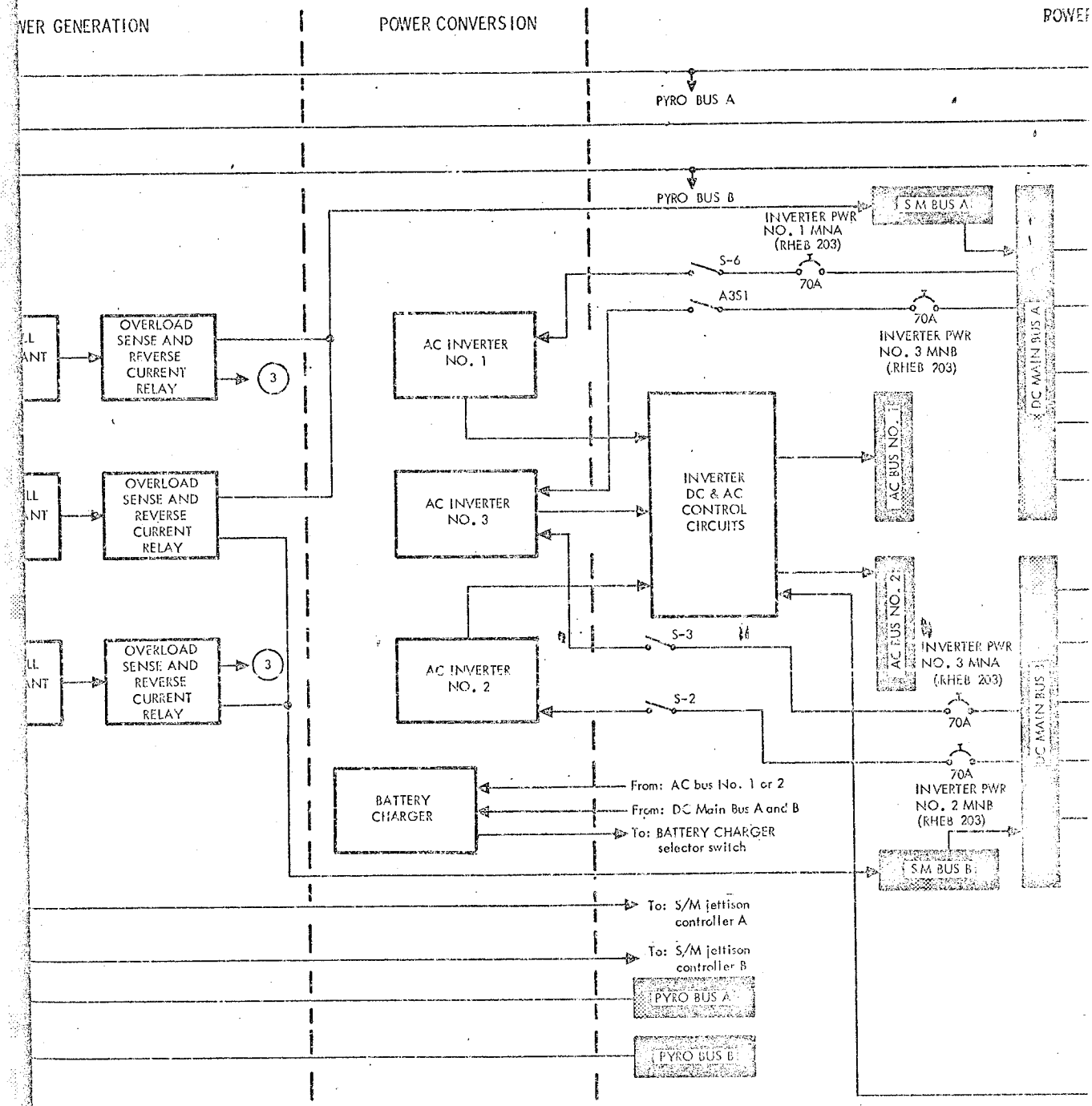


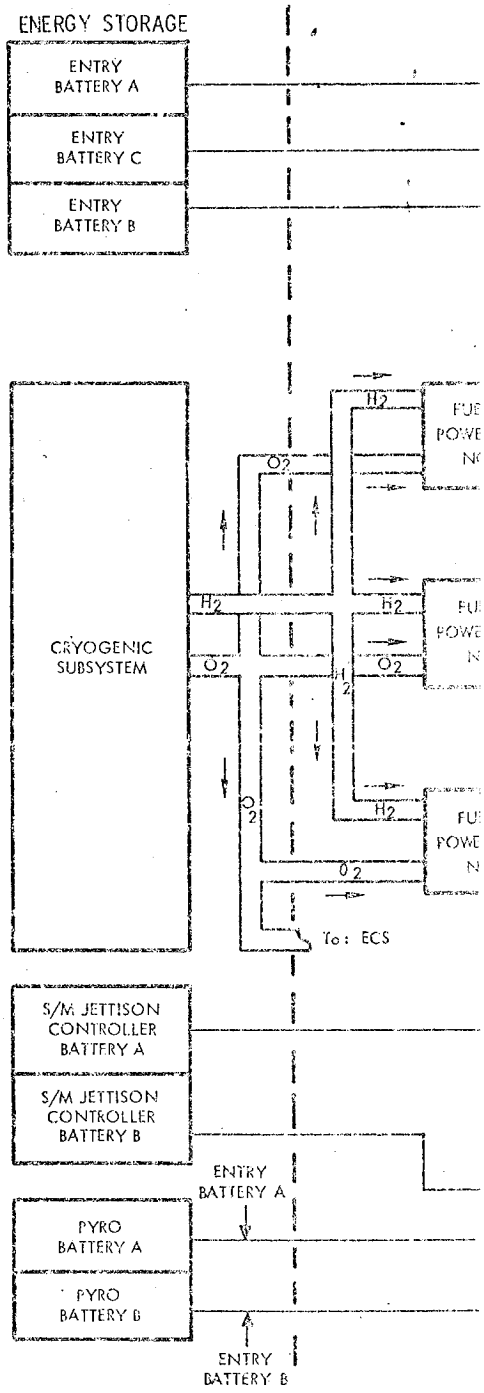
NOTES:

1. Meter switch contacts close when main bus tie switches are set to bat A&C and bat B&C
2. Battery bus contacts remain closed on manned S/C.
3. F/C 1 can be connected to SM Bus B & F/C 3 to SM Bus A.
4. DC Bus control circuit breakers are illustrated in Figure 2.6-11.

SM-2A-633K

Figure 2.6-1. Electrical Power System Block Diagram


WER GENERATION
POWER CONVERSION
POWER
PYRO BUS A
PYRO BUS B
INVERTER PWR NO. 1 MNA (RHEB 203)
S-6
70A
A351
70A
INVERTER PWR NO. 3 MNB (RHEB 203)
S M BUS A
DC MAIN BUS A
OVERLOAD SENSE AND REVERSE CURRENT RELAY
3
AC INVERTER NO. 1
AC INVERTER NO. 3
AC INVERTER NO. 2
INVERTER DC & AC CONTROL CIRCUITS
AC BUS NO. 1
AC BUS NO. 2
S-3
S-2
INVERTER PWR NO. 3 MNA (RHEB 203)
70A
70A
INVERTER PWR NO. 2 MNB (RHEB 203)
DC MAIN BUS B
S M BUS B
BATTERY CHARGER
From: AC bus No. 1 or 2
From: DC Main Bus A and B
To: BATTERY CHARGER selector switch
To: S/M jettison controller A
To: S/M jettison controller B
PYRO BUS A
PYRO BUS B


ENERGY STORAGE
ENTRY BATTERY A
ENTRY BATTERY C
ENTRY BATTERY B
CRYOGENIC SUBSYSTEM
H2
O2
To: ECS
S/M JETTISON CONTROLLER BATTERY A
S/M JETTISON CONTROLLER BATTERY B
ENTRY BATTERY A
PYRO BATTERY A
PYRO BATTERY B
ENTRY BATTERY B

reactant temperature. With design pressures in the tanks, single-phase reactant is available independent of downstream system transfer.

The manual mode of operation simply bypasses the pressure switches. It can be used in case of control failure or when operating with quantity unbalanced depletion. To avoid excessive temperatures, a thermal sensitive interlock device is in series with each heater element in the O_2 and H_2 tanks. These open the heater circuits when internal temperatures reach 80°F and close when temperatures decrease to 70°F. Tank pressures and quantities are monitored on meters located on MDC-13. O_2 tank relief valves initially vent at 983 psig and reseat at 970 psig. H_2 relief valves vent at 273 psig and reseat at 268 psig. The C&W system will alarm when oxygen pressure in either tank exceeds 950 psia, or goes below 800 psia. The hydrogen system alarms the C&W system when pressure in either tank exceeds 270 psia, or goes below 220 psia.

Individual tank pressures, quantities, and reactant temperatures are telemetered to MSFN.

2.6.3.2 Batteries.

A total of seven silver oxide-zinc storage batteries are incorporated in the EPS. Five of these batteries are located in the C/M lower equipment bay, the other two in sector IV of the S/M.

Three entry batteries (A, B, and C) provide the primary source of power after CSM separation and during postlanding operations. Prior to CSM separation, the entry batteries provide a secondary source of power while the fuel cells provide the primary source. The entry batteries are used for the following purposes:

- Provide C/M power after CSM separation
- Supplement fuel cell power during peak load periods (SPS gimbal motor operation)
- Provide power during emergency operations (failure of two fuel cells)
- Provide power for EPS control circuitry (relays, indicators, etc.)
- Provide sequential logic power
- Provide power for recovery aids during postlanding phase
- Batteries A and B can power pyro circuits upon selection.

The entry batteries can be recharged in flight.

2.6.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

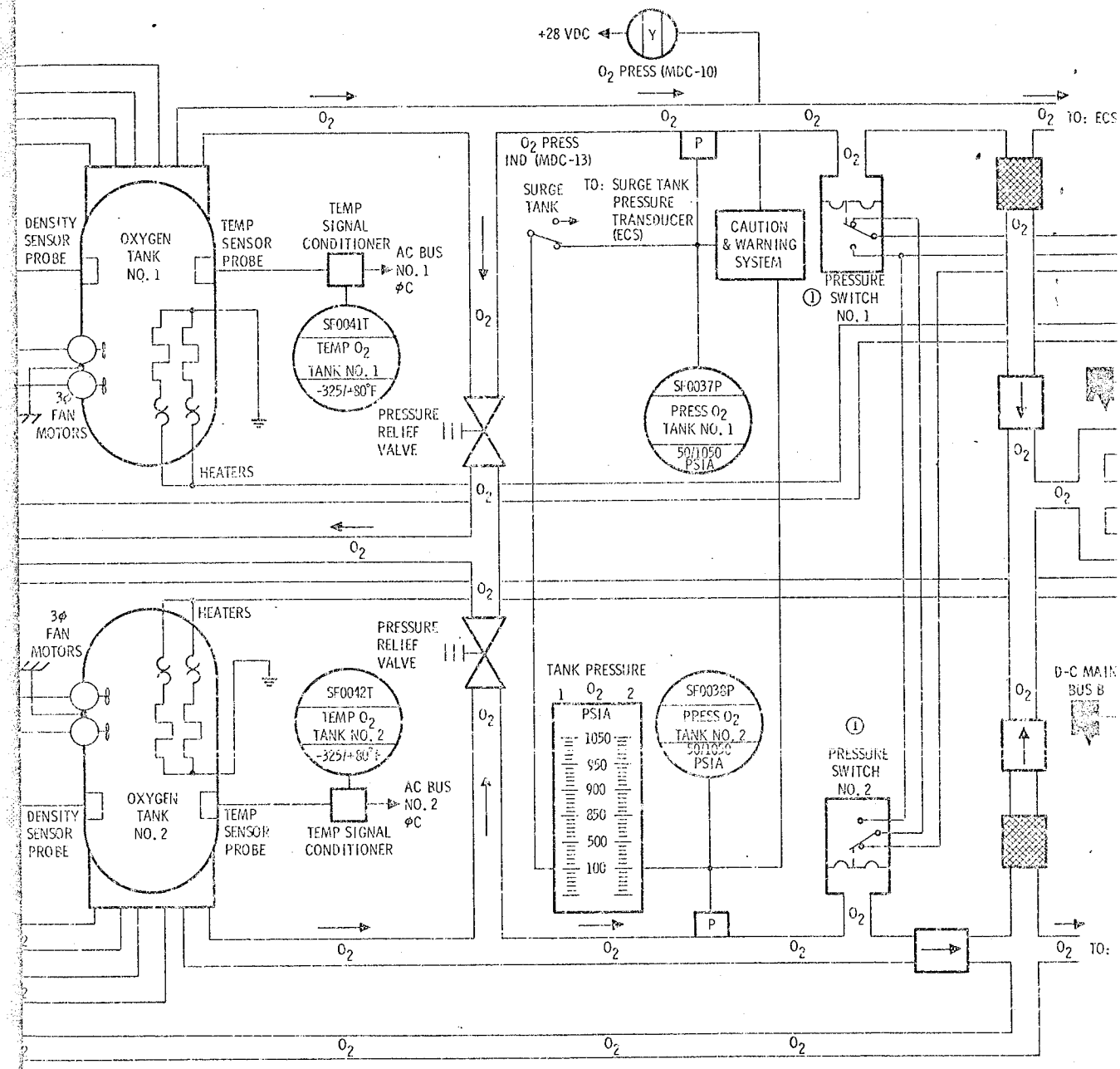
2.6.3.1 Cryogenic Storage.

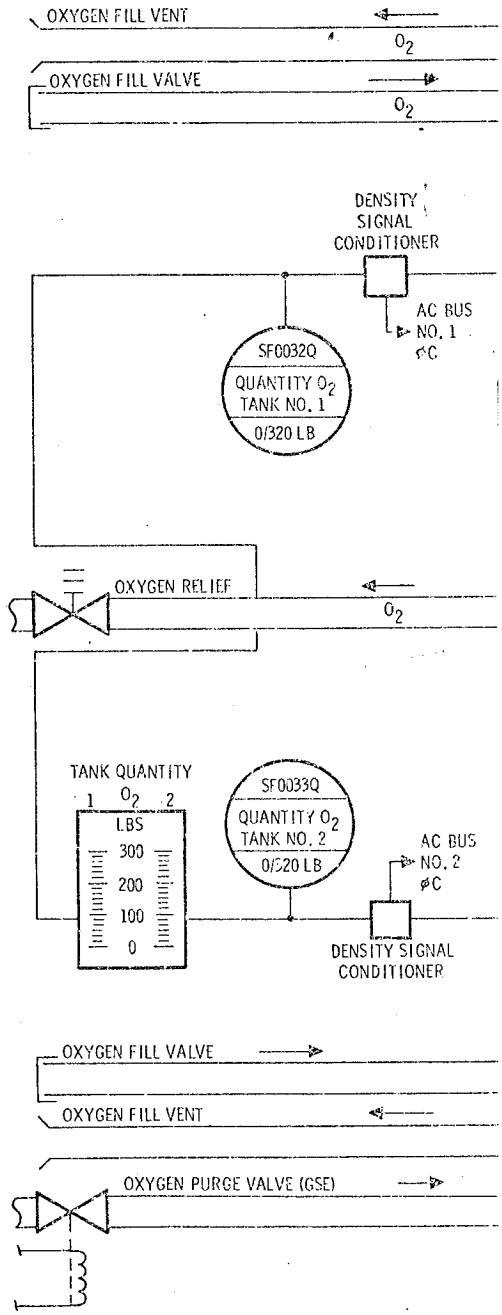
The cryogenic storage system (figure 2.6-2) supplies oxygen and hydrogen reactants to the spacecraft. Hydrogen is supplied to the EPS and oxygen is supplied to both EPS and ECS. The design functions of the two storage systems are identical. The physical data for the cryogenic storage system is given in the following list.

Tank Number	Wt of Usable Cryogenics	Flow Rate at Min dq/dm	Design Storage Press. (Psia)	Min Allowable Operating Pressure	Approx Tank Qtys at Min Heater & Fan Cycling
LO 12	320 lb	0.676 lb/hr	900±35	150 psia	131 to 82 lbs
XTA 0006	320 lb	0.713 lb/hr	900±35	150 psia	131 to 82 lbs
LH 23	28 lb	0.070 lb/hr	245 (+15, -20)	100 psia	14.5 to 7.3 lbs
LH 25	28 lb	0.066 lb/hr	245 (+15, -20)	100 psia	14.5 to 7.3 lbs

The automatic control mode is designed to give a single-phase reactant flow into the F/C and ECS feedlines at design pressures. This control is achieved in effect by controlling the heat transfer within the system. The heat required to maintain constant pressure varies with density. Fill density for oxygen is a little above 70 lbs/ft^3. As depletion proceeds from 70 lbs/ft^3, or 100 percent quantity, to approximately 28 lbs/ft^3, or 40 percent quantity, the cycling of the fans and heaters for repressurization will extend until they cycle least at quantities between 131 and 82 lbs. In the hydrogen system, least amount of heater and fan cycling will occur at quantities between approximately 14.5 and 7.3 lbs. With the system in automatic operation, tank quantities should remain within 15 pounds of each other for oxygen and within one pound difference for hydrogen. The pressure switches activating the heaters and fans are in series. The oxygen switches activate when pressure drops to 865 psia in both tanks. They deactivate when pressure reaches 935 psia in one of the tanks. Keeping the design pressure permits depletion to follow predictable tank densities and respective heat requirements.

When the systems reach the point where the heater and fan cycling is at a minimum, the heat leak of the tank becomes sufficient to maintain design pressures, provided flow is within min dq/dm values as shown in the preceding list. This realm of operation is referred to as being in the minimum dq/dm region. The minimum dq/dm point for oxygen is 23.5 lbs/ft^3 at the nominal operating pressure of 900 psia. The value for hydrogen is 1.87 lbs/ft^3 at 250 psia. The heat required for densities less than the above rises abruptly for both oxygen and hydrogen. The intrinsic flow output of the systems is a maximum at the point where minimum heat is required to maintain pressure. The time-rate of arriving at the minimum dq/dm point is dependent on load demands, tank pressure, and


+28 VDC
Y
O_2 PRESS (MDC-10)
O_2
O_2 PRESS IND (MDC-13)
P
SURGE TANK
TO: SURGE TANK PRESSURE TRANSDUCER (ECS)
CAUTION & WARNING SYSTEM
PRESSURE SWITCH NO. 1
TO: ECS
DENSITY SENSOR PROBE
OXYGEN TANK NO. 1
TEMP SENSOR PROBE
TEMP SIGNAL CONDITIONER
AC BUS NO. 1 φC
SF0041T
TEMP O_2 TANK NO. 1
-325/+80°F
3φ FAN MOTORS
PRESSURE RELIEF VALVE
SF0037P
PRESS O_2 TANK NO. 1
50/1050 PSIA
HEATERS
3φ FAN MOTORS
HEATERS
PRESSURE RELIEF VALVE
SF0042T
TEMP O_2 TANK NO. 2
-325/+80°F
TANK PRESSURE
1 O_2 2
PSIA
1050
950
900
850
500
100
SF0038P
PRESS O_2 TANK NO. 2
50/1050 PSIA
PRESSURE SWITCH NO. 2
D-C MAIN BUS B
DENSITY SENSOR PROBE
OXYGEN TANK NO. 2
TEMP SENSOR PROBE
TEMP SIGNAL CONDITIONER
AC BUS NO. 2 φC
TO:


OXYGEN FILL VENT
O_2
OXYGEN FILL VALVE
O_2
DENSITY SIGNAL CONDITIONER
AC BUS NO. 1 ϕC
SF0032Q
QUANTITY O_2 TANK NO. 1
0/320 LB
OXYGEN RELIEF
O_2
TANK QUANTITY
1 O_2 2
LBS
300
200
100
0
SF0033Q
QUANTITY O_2 TANK NO. 2
0/320 LB
AC BUS NO. 2 ϕC
DENSITY SIGNAL CONDITIONER
OXYGEN FILL VALVE
OXYGEN FILL VENT
OXYGEN PURGE VALVE (GSE)

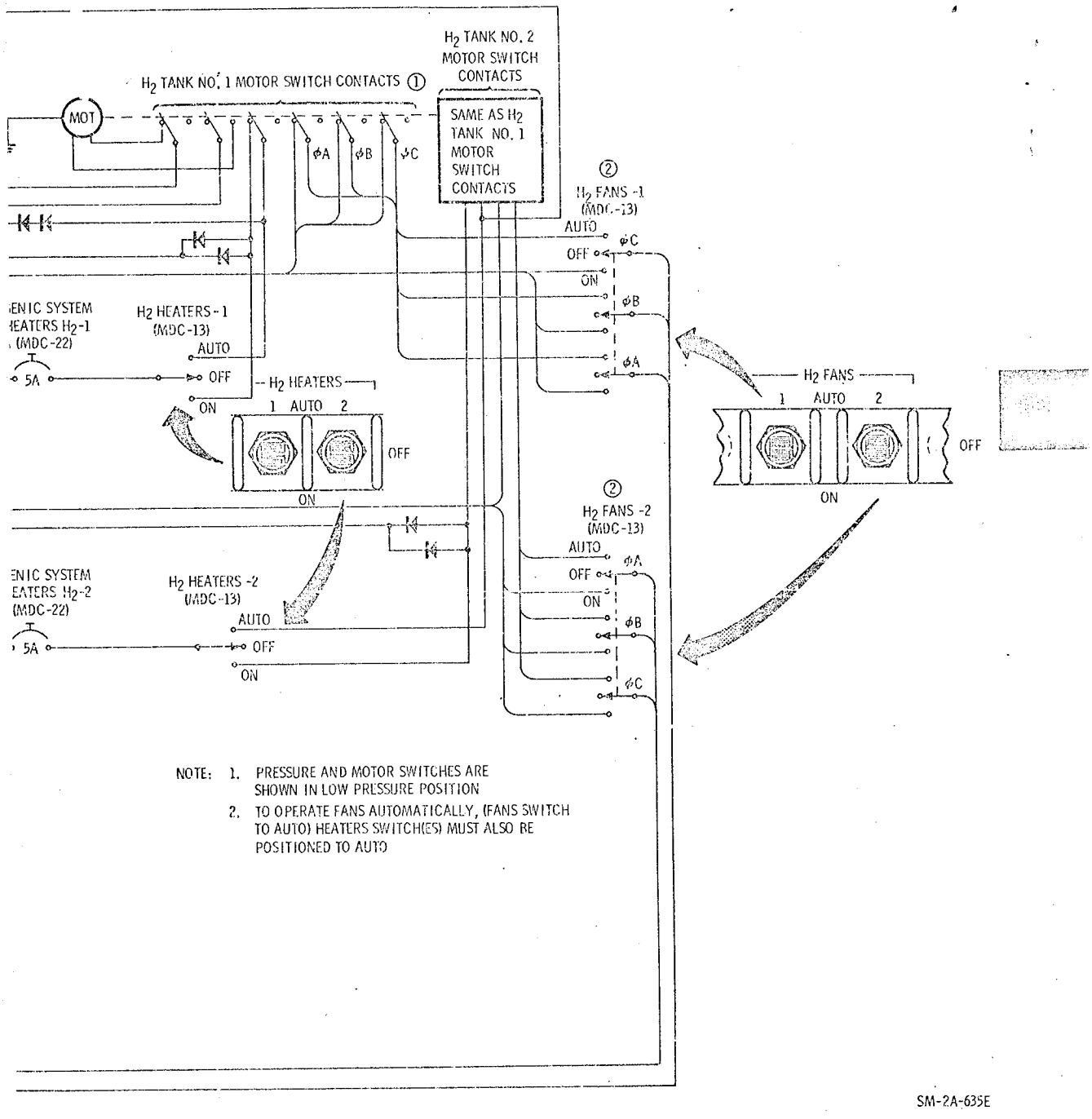
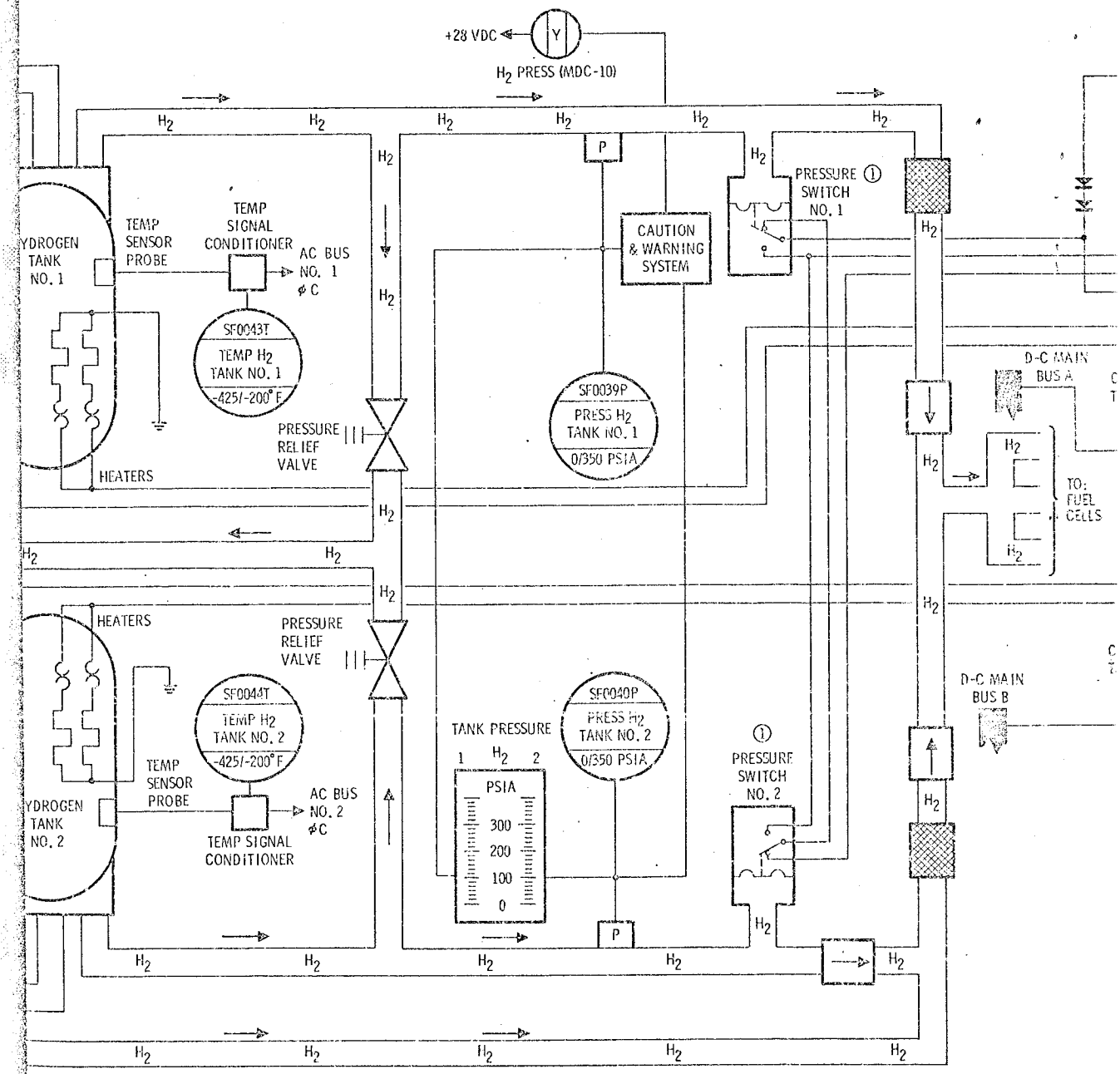
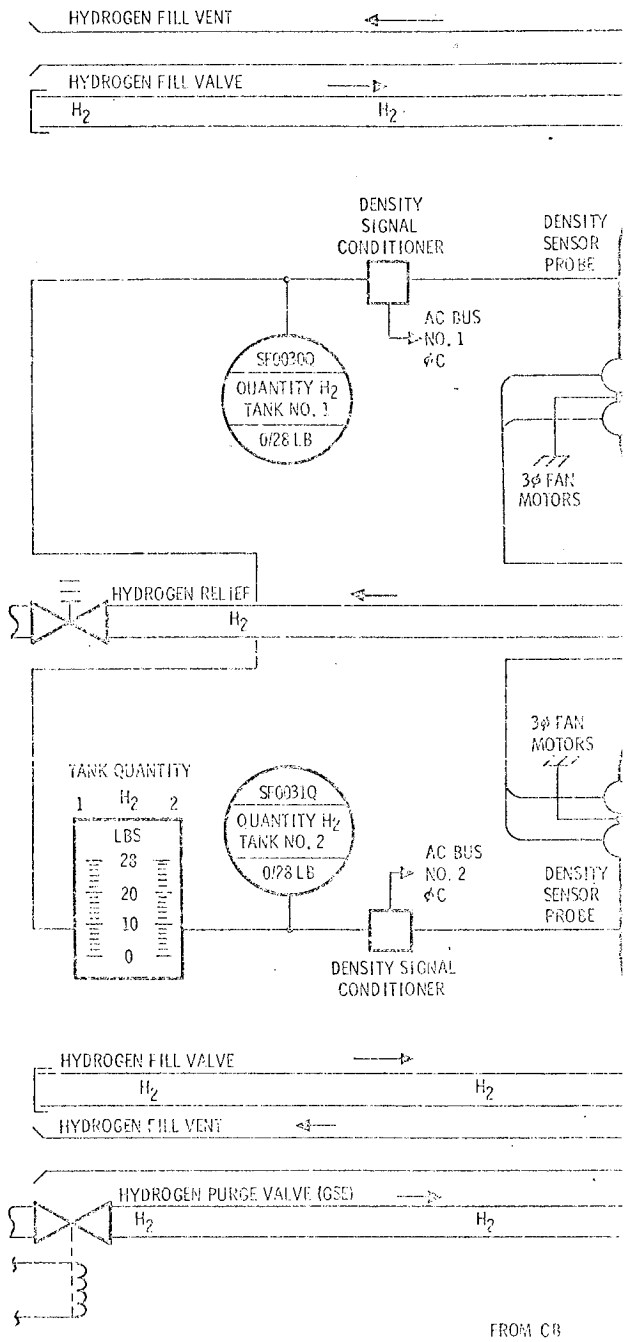


Figure 2.6-2. Cryogenic Storage System (Sheet 2 of 2)


+28 VDC
Y
H2 PRESS (MDC-10)
H2
P
PRESSURE ①
SWITCH
NO. 1
CAUTION
& WARNING
SYSTEM
TEMP
SENSOR
PROBE
TEMP
SIGNAL
CONDITIONER
AC BUS
NO. 1
ϕC
SF0043T
TEMP H2
TANK NO. 1
-425/-200°F
SF0039P
PRESS H2
TANK NO. 1
0/350 PSIA
PRESSURE
RELIEF
VALVE
HEATERS
D-C MAIN
BUS A
TO:
FUEL
CELLS
SF0044T
TEMP H2
TANK NO. 2
-425/-200°F
SF0040P
PRESS H2
TANK NO. 2
0/350 PSIA
TANK PRESSURE
1
2
PSIA
300
200
100
0
D-C MAIN
BUS B
PRESSURE
SWITCH
NO. 2
AC BUS
NO. 2
ϕC



FROM CB
2 - CRYOGENIC TANK FAN MOTORS A
1 - CRYOGENIC TANK FAN MOTORS A

Each entry battery is mounted within a vented plastic case. The battery cells are individually encased in plastic containers which contain relief valves that open at 40±10 psig, venting pressure and hydrogen gas into the battery case. Each battery case is vented overboard through a manifold leading to a manually operated valve (BATTERY VENT VALVE), which is connected to the ECS dump line. With the valve at its normal position of VENT, the battery cases are vented overboard through the ECS urine/water dump line. In a failure mode, this would prevent hydrogen gas from entering the crew compartment. With the battery vent valve closed, which would be the position after fracture of a battery case, the possibility exists for pressure buildup in the battery manifold due to outgassing of the batteries. The vent valve will be opened at pressures slightly below CM pressure and allow the built-up pressure to vent overboard. Battery manifold pressure can be monitored using the auxiliary DC VOLTS meter, located on panel 200 in the RHFEB, and is telemetered.

The two pyrotechnic batteries supply power to initiate ordnance devices in the S/C. The pyrotechnic batteries are isolated from the rest of the EPS to prevent the high power surges in the pyrotechnic system from affecting the EPS and to ensure source power when required. These batteries shall not be recharged in flight. Entry battery A or B can be used as a redundant source of power for initiating pyro circuits in the respective A or B pyro system, if either pyro battery fails.

The two S/M jettison controller batteries, located in the S/M, supply power to two jettison sequencers to sustain the S/M RCS retrofire, as well as firing the S/M positive roll RCS engines two seconds after CSM separation. These batteries are isolated from the rest of the EPS and cannot be recharged or monitored in flight.

Performance characteristics of each S/C battery are as follows:

Battery	Capacity per Battery	No. of Cells per Battery	Open Circuit Voltage (Max.)	Nominal Voltage	Minimum Voltage	Ambient Battery Temperature
Entry A, B, and C (3)	40-amp-hrs (25 ampere rate)	20	37.8 vdc (37.2 vdc in flight)	29.0 vdc (35 amps load)	27.0 vdc (35 amps load)	50° to 110°F
Pyro A and B (2)	75 amps for 36 seconds	20	37.8 vdc (37.2 vdc in flight)	23.0 vdc (75 amps load)	20.0 vdc (75 amps load) (35.0 vdc open circuit)	60° to 110°F

Battery	Capacity per Battery	No. of Cells per Battery	Open Circuit Voltage (Max.)	Nominal Voltage	Minimum Voltage	Ambient Battery Temperature
S/M jettison controller A and B (2)	75 amps for 36 seconds	20	37.8 vdc (not measurable in S/C or by telemetry)	23.0 vdc (75 amps load)	20.0 vdc (75 amps load)	60° to 110°F

NOTE Pyro battery load voltage is not measurable due to the extremely short time they power pyro loads.

2.6.3.3 Fuel Cell Power Plants.

Each fuel cell power plant consists of 31 single cells, connected in series, and an accessory section. Each single cell generates approximately 1 volt. The accessory section consists of a nitrogen pressurization system, an oxygen feed, a hydrogen feed, a primary (hydrogen) loop, and a secondary (glycol) loop (figure 2.6-3). The primary and secondary loops control the temperature within the fuel cell power plant. The primary loop also extracts potable water from the power plant for use by the crew. The secondary loop radiates heat from the power plant into space through radiators located on the exterior of the S/M.

The nitrogen system establishes a reference pressure in the fuel cell. There is approximately 0.44 lbs of N_2 contained in the nitrogen tank under a pressure of 1500 psia. The nitrogen regulator reduces this pressure to 52 psia, which is used to pressurize the glycol accumulator, the electrolyte (KOH) in the cells, and as a reference pressure for the oxygen and hydrogen regulators.

Oxygen, stored in a cryogenic state at a pressure of 900±35 psia, is supplied to the fuel cell power plants. Due to the low-flow rate, the oxygen absorbs heat while flowing through the lines, absorbs additional heat in the preheater, flows to the oxygen regulator, and reaches the fuel cell power plants in a gaseous form at temperatures above +100°F. The regulator is designed to maintain a pressure differential of 10.5 psia above the nitrogen pressure, supplying the oxygen to the fuel cell at a nominal 62.5 psia. The oxygen in the system is approximately 99.99 percent pure. Over a period of time, the impurities accumulate in the reactant compartment and decrease fuel cell efficiency. This is noted by a drop in fuel cell performance. To eliminate the impurities, the fuel cell is purged. Normally a fuel cell will be purged every 24 hours; however, the actual purge cycle will be determined by the predicted mission power profile and the purity of the reactant as it is calculated to be after

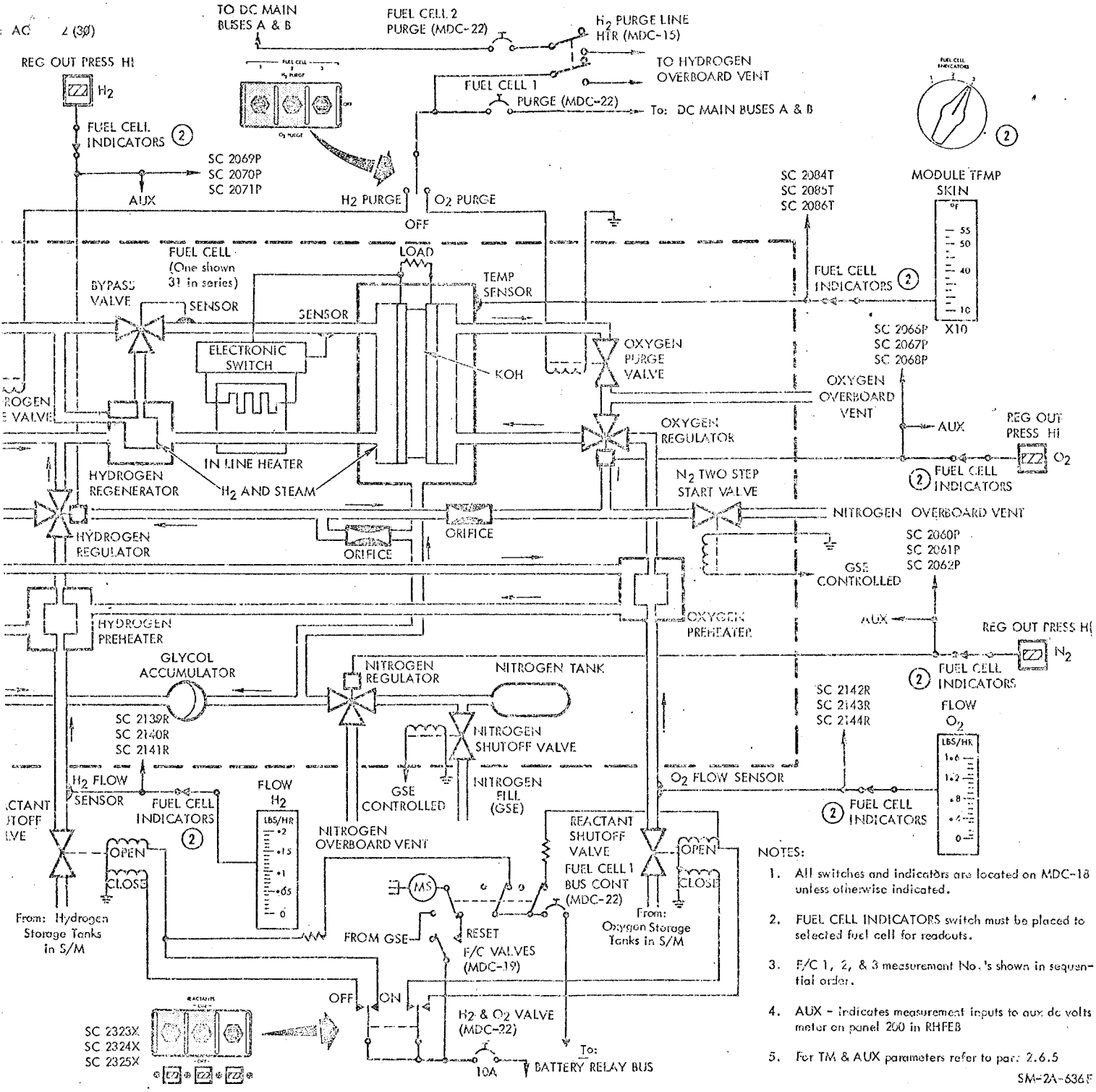
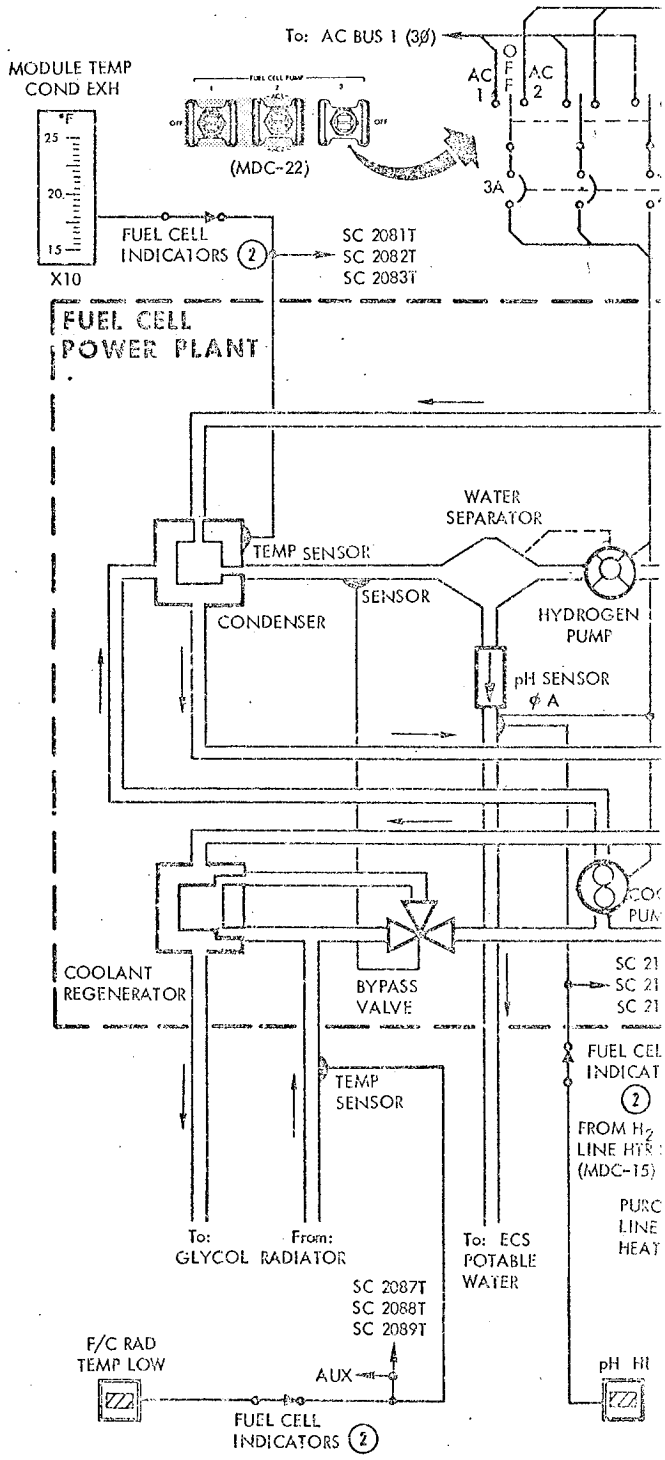


Figure 2.6-3. Fuel Cell Power Plant Flow Diagram


To: AC BUS 1 (3Ø)
MODULE TEMP
COND EXH
°F
25
20
15
X10
(MDC-22)
AC 1
OFF
AC 2
3A
FUEL CELL
INDICATORS (2)
SC 2081T
SC 2082T
SC 2083T
FUEL CELL
POWER PLANT
WATER
SEPARATOR
TEMP SENSOR
SENSOR
CONDENSER
HYDROGEN
PUMP
pH SENSOR
ϕ A
COOLANT
REGENERATOR
BYPASS
VALVE
TEMP
SENSOR
To:
GLYCOL
From:
RADIATOR
To: ECS
POTABLE
WATER
SC 2087T
SC 2088T
SC 2089T
F/C RAD
TEMP LOW
AUX
FUEL CELL
INDICATORS (2)
pH HI

completion of S/C cryogenic tank fill. Time required for oxygen purge is 2 minutes for each power plant. Activating the O_2 purge valve allows an additional flow of up to 0.6 lb per hr. An emergency purge can be performed if steady state current output of a power plant decreases by approximately 3 amps. Power plant parameters (primarily voltage, current, and skin temperature) must be considered to determine if an emergency purge is required.

Hydrogen, stored in a cryogenic state at a pressure of 245 (+15, -20), psia and regulated down to a pressure of 60.5 psia, flows into the hydrogen regenerator loop, passing through an in-line heater and into the fuel cell. The in-line heater is an automatic device which aids the fuel cell power plant in sustaining operating temperature at low-power operating levels. The hydrogen, or primary regenerator loop, is used for fuel cell thermal control and permits water removal from the fuel cell. The heat generated by the reaction is transferred to the saturated H_2 fluid. The hot, saturated hydrogen is drawn into the hydrogen exhaust line by the H_2 pump. A sensor in this line provides an input to an electronic switch which controls activation of the H_2 in-line heater. Activation of this heater is accomplished automatically at a hydrogen exhaust temperature of 385±5°F, supplying additional heat to hydrogen gas flowing to the fuel cell power plant. The in-line heater is automatically deactivated at a temperature of 390±5°F. After passing the in-line heater sensor, the saturated hydrogen flows to a sensor-controlled bypass valve. This valve controls the amount of exhaust gas flowing through the H_2 regenerator. The sensor closes the bypass valve at 425°F, allowing all exhaust gas to flow through the regenerator. This heats the returning hydrogen and sustains operating temperature of the fuel cell. With the bypass valve in a full regenerative position (temperatures 425° or lower), if fuel cell power plant temperature continues to decrease, the in-line heater will be activated to supply additional heat. If power plant temperature is above 425°F, the sensor causes the bypass valve to open proportionately (fully open at 495°F) allowing exhaust gas to flow directly to the condenser. A transfer of heat from the hydrogen and steam to the glycol takes place in the condenser. The temperature of the hydrogen and steam is lowered to between 155° and 175°F, thus liquifying some of the water vapor. A sensor in the condenser exhaust, controls a glycol regenerator bypass valve in the glycol radiator return line which regulates the temperature of the glycol. This, in turn, helps control fuel cell temperature and maintains the temperature of the condenser exhaust within the desired range of 155° to 175°F. The liquid water and hydrogen then flows through a centrifugal water separator pump which extracts the water and delivers it to the ECS potable water storage tank in the C/M. The amount of water produced by each fuel cell is in direct relation to the reactants consumed which is related to power output. (See figure 2.6-4.)

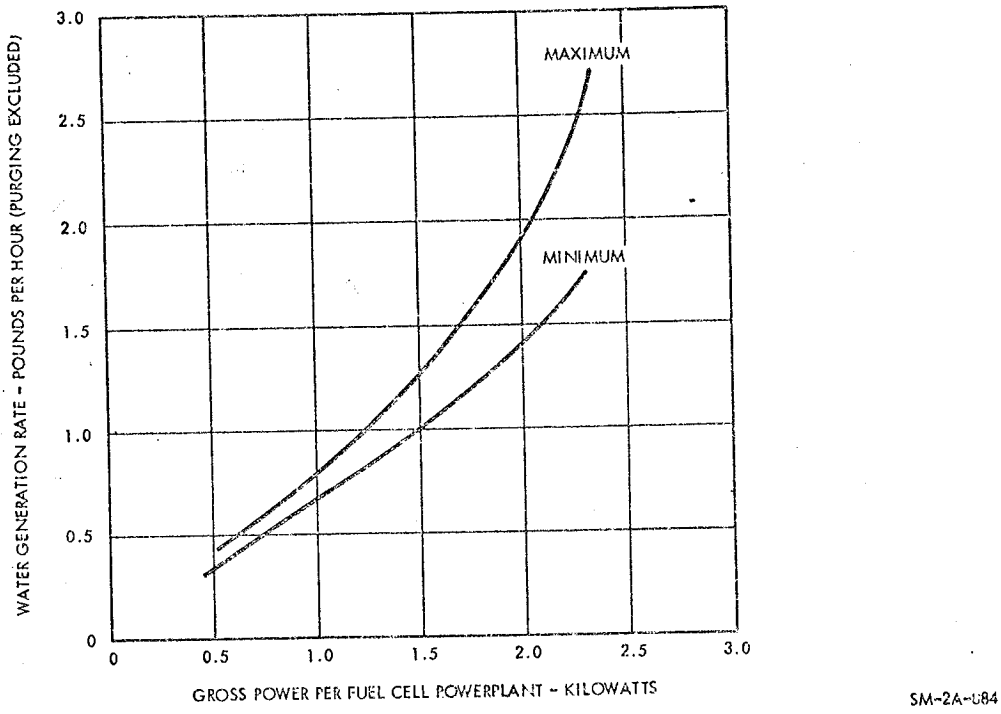


Figure 2.6-4. Water Production Rate vs Power Output

The hydrogen pump circulates the remaining slightly moist fluid through the regenerator and back to the fuel cell. In order to maintain the desired ratio of water to KOH in the fuel cell, the condenser exhaust temperature is regulated at a level so that some moisture is left in the returning hydrogen as it flows back into the cell. The hydrogen in the cryogenic system is approximately 99.94 percent pure. H_2 purge valve activation allows an additional flow of up to 0.75 lbs per hour, and will normally be performed for a period of 80 seconds per power plant every 24 hours. The actual H_2 purge cycle will also depend on the predicted power profile and reactant purity as calculated after cryogenic tank fill. The performance degradation participation by the H_2 electrode is negligible and cannot be seen with on-board instrumentation (with normal degradation). If degradation is suspected to remain after an emergency O_2 purge, an H_2 purge may be warranted. There is some indication that periodic H_2 purging may be eliminated altogether, thereby only performing the degradation purge whenever it may be required. Thirty minutes prior to H_2 purging, the H_2 PURGE LINE HTR switch (MDC-15) is placed in the up position to energize the H_2 fuel cell vent line heater and preclude any freezing of the moist exhaust gas in the vent line.

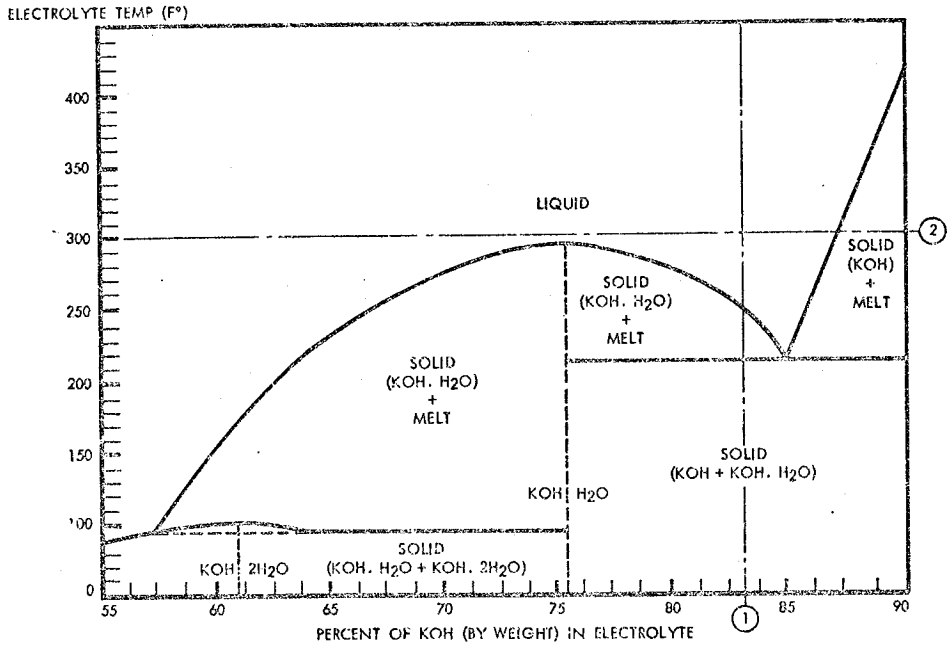
The secondary loop contains a 62.5 to 37.5 mixture of ethylene glycol and water, respectively. This loop serves to preheat the reactants and to transport waste heat to the space radiators. An accumulator, pressurized by the nitrogen, pressurizes the glycol loop and also acts as a buffer for the expansion and contraction of the coolant as it varies in temperature. Glycol flow through the regenerator is controlled by a bypass valve which operates in conjunction with the condenser exhaust sensor. When the condenser exhaust is at 155°F, the glycol is routed through the regenerator to increase glycol temperature and effect minimum heat transfer in the condenser. The glycol bypass valve is completely open at a condenser exhaust temperature of 175°F, routing the glycol through the pump to the condenser and on to the oxygen and hydrogen preheaters. Since the glycol temperature is lower, a maximum transfer of heat in the condenser lowers the condenser exhaust temperature. The condenser exhaust temperature sensor regulates coolant temperature which affects the amount of water removed from the power plant. The 155° to 175°F operating range will best maintain the desired ratio of water to KOH in the fuel cell.

A 400-cps 3-phase a-c gear pump maintains glycol flow at the rate of 35 to 80 lbs per hour, raising the pressure 6 psi. After the oxygen and hydrogen preheaters, the glycol is routed through the glycol regenerator and to the space radiators, where heat is radiated into the space environment.

Each fuel cell contains electrolyte (KOH) which consists by weight of 83 percent potassium hydroxide and 17 percent water on initial fill, and has a critical temperature of 300°F (figure 2.6-5). The electrolyte remains a solid to an approximate temperature of 220°F; with a temperature increase to 300°F, the electrolyte becomes a liquid and the fuel cell electrochemical reaction becomes effective. Bringing the fuel cell to critical temperature is accomplished using GSE, and cannot be performed from S/C power sources. Placing a load on the power plant will maintain it above this critical temperature.

2.6.3.4 Inverters.

Each inverter (figure 2.6-6) is composed of a clock oscillator, an eight-stage digital countdown section, a d-c line filter, two silicon-controlled rectifiers, a magnetic amplifier, a buck-boost amplifier, a demodulator, two d-c filters, an eight-stage power inversion section, a harmonic neutralization transformer, an a-c output filter, current sensing transformers, a Zener diode reference bridge, a low-voltage control, and an overcurrent trip circuit. The inverter normally uses a 6.4-kc square wave synchronizing signal from the central timing equipment (CTE) which maintains inverter output at 400±2 cps. If this external signal is completely lost, the oscillator within the inverter will provide pulses that will maintain inverter output within ±7 cps. The internal



NOTES:
1. Percent (83) of KOH in electrolyte at initial fill.
2. Critical temperature (300°F) of electrolyte at which electrochemical reaction begins, on initial start-up of fuel cell.

SM-2A-803A

Figure 2.6-5. KOH H_2O Phase Diagram

oscillator is normally synchronized by the external pulse which is provided through the phase synchronizing unit. The phase synchronizer will provide these pulses to the inverter after a maximum of two seconds. The following paragraphs describe the function of the various stages of the inverter.

The 6.4-kc negative square wave provided by the central timing equipment is applied through the phase synchronizer and the oscillator to the eight-stage digital countdown section. The oscillator has two divider circuits which provide a 1600-pps signal to the magnetic amplifier and two silicon-controlled rectifiers.

The eight-stage digital countdown section uses the 6.4-kc square wave signal to produce a series of eight 400-cycle square waves, each mutually displaced one pulse time from the preceding and following wave. Once pulse time is 156 microseconds and represents 22.5 electrical degrees. This series of square waves is applied to the eight-stage power inversion section.

The eight-stage power inversion section, using a controlled voltage from the buck-boost amplifier, amplifies the series of 400-cycle square waves produced by the eight-stage digital countdown section. The amplified square waves, still mutually displaced 22.5 electrical degrees, are applied to the harmonic neutralization transformer, which is described in a subsequent paragraph.

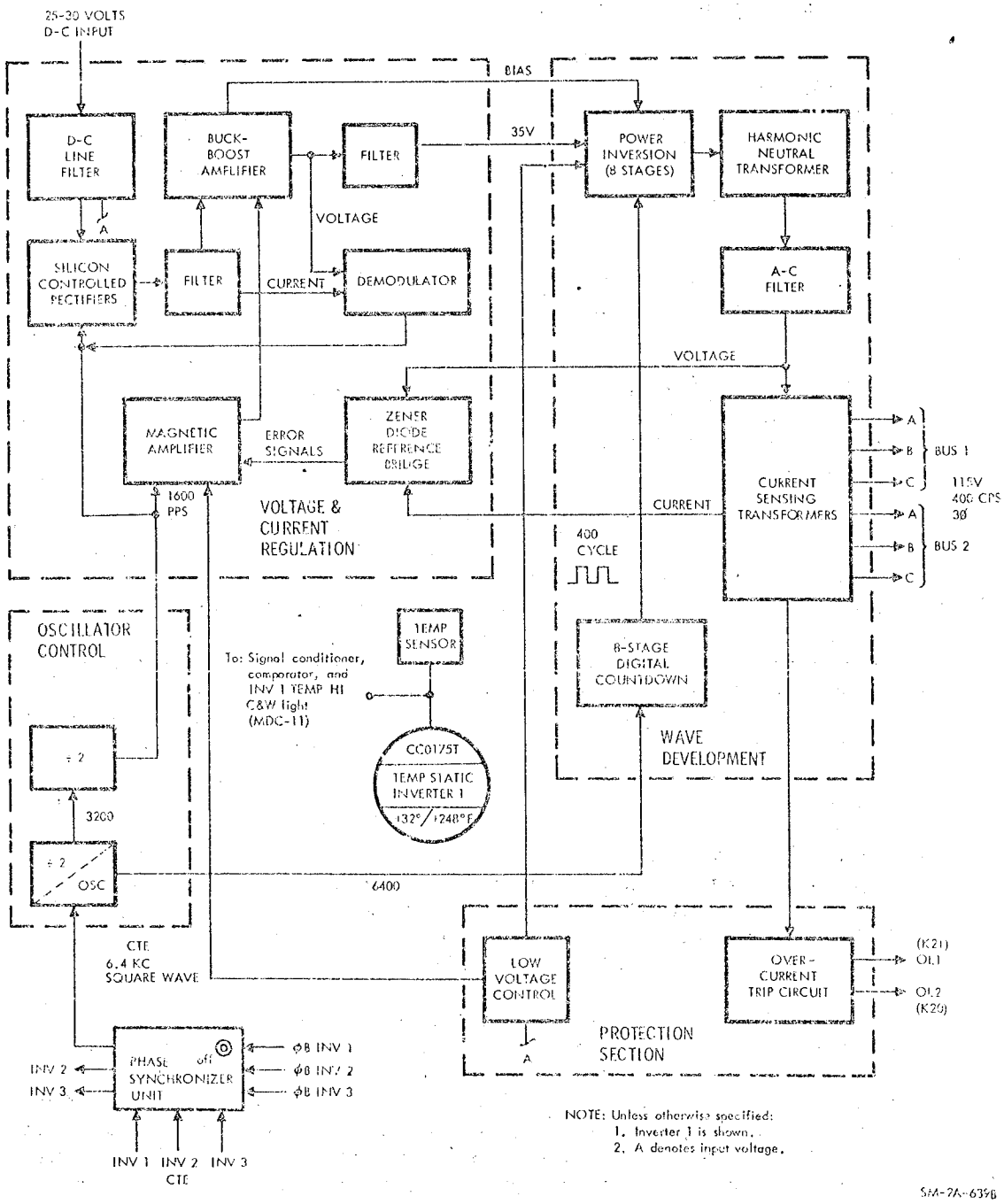


Figure 2.6-6. Inverter Block Diagram

D-C power to the inverter is supplied from the main d-c buses through the d-c line filter. This filter reduces the high frequency ripple in the input, and the 25 to 30 vdc is applied to the silicon-controller rectifiers and buck-boost amplifier.

The silicon-controlled rectifiers, using the filtered d-c power and the 1600-pps signal from the clock oscillator, produce a d-c square wave with an on-time of greater than 90 degrees from each rectifier. This is filtered and supplied to the buck-boost amplifier where it is coupled with the amplified 1600-pps output of the magnetic amplifier to develop a filtered 35 volts dc which is used for amplification in the power inversion stages.

The buck-boost amplifier, using the 1600-pps signal from the magnetic amplifier, the filtered d-c power from the main duc buses, and an error signal feedback from the Zener diode reference bridge, provides a variable bias voltage to the eight-stage power inversion section. The amplitude of this voltage is controlled by the amplitude and phase of the feedback signal from the Zener diode reference bridge. This bias signal is varied by the error signal to regulate inverter voltage and current output.

The demodulator compensates for any low-frequency ripple in the d-c input to the inverter. The high-frequency ripple is attenuated by the filters. The demodulator senses the 35-volt d-c output of the buck-boost amplifier and the current input to the buck-boost amplifier. It compensates for ripple in the 10- to 1000-cps range. An input voltage drop or increase will be reflected in a drop or increase in the 35-volt d-c output of the buck-boost amplifier as well as a drop or increase in current input to the buck-boost amplifier. A sensed decrease in the buck-boost amplifier voltage output would be compensated for a demodulator output, transformer coupled, to the silicon-controlled rectifiers, causing them to conduct for a longer time, thus increasing their filtered output. A sensed increase in buck-boost amplifier voltage output, caused by an increase in the d-c input to the inverter, would cause the demodulator to produce a signal causing the silicon-controlled rectifiers to conduct for shorter periods, producing a lower filtered output to the buck-boost amplifier. In this fashion, the 35-volt d-c input to the power inversion section is maintained at a relatively constant level.

The low-voltage control samples the input voltage to the inverter and can terminate inverter operation. Since the buck-boost amplifier provides a boost action during a decrease in input voltage to the inverter, in an attempt to maintain a constant 35 volts dc to the power inversion section, the high boost required during a low-voltage input would tend to overheat the buck-boost amplifier. As a precautionary measure, the low-voltage control will terminate inverter operation by disconnecting operating voltage to the magnetic amplifier and a power inversion stage when input voltage decreases to between 16 and 19 volts dc.

The harmonic neutralization section, using the 400-cycle, square-wave output of the eight-stage power inversion section, transforms it into a 3-phase 400-cycle 115-volt sine wave signal. The manner in which these transformers are wound produces flux cancellation which eliminates all harmonics up to and including the fifteenth of the fundamental frequency. The 22.5 electrical degree displacement of the square wave provides a means of electrically rotating the square wave excited primary windings around the 3-phase, wye-connected, secondary windings, thus producing the 3-phase 400-cycle sine wave output. This 115-volt signal is then applied to the a-c output filter.

The a-c output filter eliminates the remaining higher harmonics. Since the lower harmonics were eliminated by the harmonic neutralization section, the size and weight of this output filter was reduced. Circuitry in this filter also produces a rectified signal which is applied to the Zener diode reference bridge. The amplitude of this signal is a function of the amplitude of a-c output voltage. After filtering, the 3-phase 115-volt a-c 400-cycle sine wave is applied to the a-c buses through current-sensing transformers.

The current-sensing transformer section produces a rectified signal, the amplitude of which is in direct function of inverter output current magnitude. This d-c signal is applied to the Zener diode reference bridge to regulate inverter current output. It is also applied to an overcurrent trip circuit.

The Zener diode reference bridge receives a rectified d-c signal, representing voltage output, from the circuitry in the a-c output filter. A variance in voltage output unbalances the bridge providing an error signal of proper polarity and magnitude to the buck-boost amplifier via the magnetic amplifier. When inverter current output reaches 200 to 250 percent of rated current, the rectified signal applied to the bridge from the current sensing transformers is of sufficient magnitude to provide an error signal and cause the buck-boost amplifier to operate in the same manner as during an overvoltage condition. The bias output of the buck-boost amplifier, being controlled by the error signal, will be varied to correct for any variation in inverter voltage or current output. When inverter current output reaches 250 percent of rated current, the over-current trip circuit is activated.

The overcurrent trip circuit monitors a rectified d-c signal representing current output. When total inverter current output exceeds 250 percent of rated current, this circuit will effect an inverter disconnect in 15±5 seconds. If current output of any single phase exceeds 300 percent of rated current, this circuit will effect an inverter disconnect in 5±1 second.

A phase synchronizer unit (PSU), located in the RHEB (panel 208), establishes inverter outputs so they are in phase when using a separate inverter on each of the two a-c buses. The two inverter configuration is prevelant during delta V's as a safety precaution in case of a single failure in thrust vector control.

The use of two inverters during delta V's retains redundancy in the stabilization and control subsystem, since power through a-c bus 1 is used for automatic thrust vector control and power through a-c bus 2 is used for manual thrust vector control.

Central timing equipment (CTE) trigger pulses, used for inverter operation, are supplied to the inverters through the PSU. The PSU samples ϕB from each inverter output, and when an in-phase relationship is established, supplies the 6400-cps CTE trigger pulse to the inverters being used. The ϕB input also supplies power for PSU circuitry.

The in-phase relationship is acquired by initially providing out-of-phase trigger pulses (6080 to 6400 cps) until the two inverters are synchronized, at which time the CTE signal is coupled to the inverters. Phase lock, with a maximum displacement of ±10 degrees, is acquired in a maximum of two seconds.

The synchronizer provides this function for any combination of pairs of the three available inverters. A two-position toggle switch on the PSU, when positioned to OFF, allows for direct input of CTE signals to the inverters in the event of failure of the synchronizer unit. However, in this situation, the in-phase relationship would not be realized.

A temperature sensor with a range of +32° to +248°F is installed in each inverter to provide MSFN the capability of monitoring inverter temperature. It also provides an input to the C&WS which will illumine a light at an inverter overtemperature of 226°F.

2.6.3.5 Battery Charger.

A constant voltage, solid-state battery charger (figure 2.6-7), located in the C/M lower equipment bay, is incorporated into the EPS. The battery charger selector switch (MDC-18) controls power input to the charger, as well as connecting the charger output to the selected battery (figure 2.6-11). When the BATTERY CHARGER selector switch is positioned to entry battery A, B, or C, a relay (K4) is activated, completing circuits from a-c and d-c power sources to the battery charger. Also, the battery charger output is connected to the selected battery to be charged through the MAIN BUS TIE switches (MDC-22). Positioning the MAIN BUS TIE switch (A&C or B&C) to OFF, for the selected batteries, will disconnect main bus loads from the batteries and also complete the circuit from the charger to the battery. Only one battery can be charged at a time.

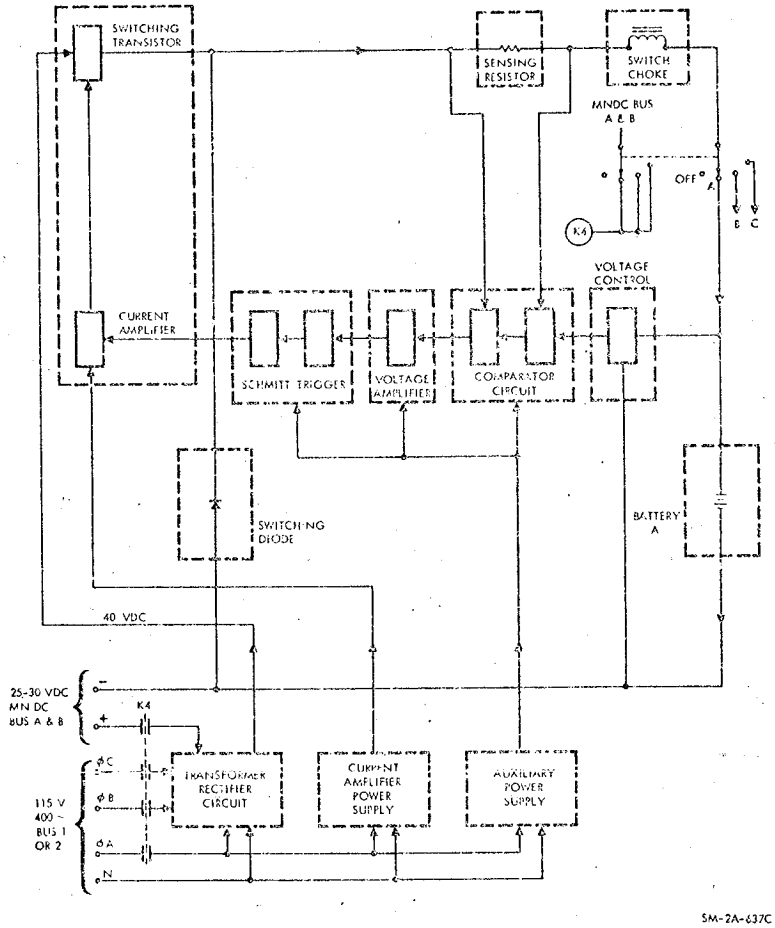


Figure 2.6-7. Battery Charger Block Diagram

The battery charger uses 25 to 30 volts dc from the main d-c buses and 115 volts 400-cps, 3-phase ac from either of the a-c buses. All three phases of ac are used to boost the 25 to 30-volt d-c input to produce 40 volts dc for charging. In addition, phase A of the ac is used to supply power for the rest of the charger circuitry. The logic network in the charger, which consists of a two-stage differential amplifier (comparator), a two-stage Schmitt trigger, a current sensing resistor, and a voltage amplifier will set up the initial condition for operation. The first stage of the comparator is in the on mode, with the second stage in the off mode, placing the Schmitt trigger first stage in the on mode with the second stage off. This condition provides maximum base drive to the current amplifier which turns the switching transistor to the on mode. With the switching transistor on, current flows from the transformer rectifier through the switching transistor, current sensing resistor, and switch

choke to the battery being charged. As current flow increases, the voltage drop across the sensing resistor increases. The voltage across the sensing resistor builds to a level which turns the first stage of the comparator to the off mode and the second stage to the on mode. This condition turns off the voltage amplifier which reverses the operation of the Schmitt trigger to first stage off and second stage on. This places the current amplifier off, which turns off the switching transistor. The switching transistor in the off mode will stop current flow from the power source, causing the field in the choke to continue collapsing and discharging into the battery through the switching diode and the current sensing resistor. As the EMF in the choke decreases, the current through the sensing resistor decreases, reducing the voltage drop across the resistor. At some point, the decrease in voltage drop across the sensing resistor, reverses the operation of the comparator circuit, setting up the initial condition and completing one cycle of operation. The output load current, due to the action of the choke, remains relatively constant except for the small variation through the sensing resistor. This variation is required to switch the switching transistor and Schmitt trigger through the action of the comparator.

Battery charger output is regulated by the sensing resistor until the battery voltage reaches approximately 36 volts. At this time, the voltage control network is activated and, in conjunction with the sensing resistor, provides a signal for cycling the battery charger. As the battery voltage increases, the internal impedance of the battery increases, decreasing current flow from the charger. At 39 volts, the battery is fully charged and current flow becomes negligible. (See figure 2.6-8.) Battery charger disconnect will be effected at a current output of approximately 0.6 amps.

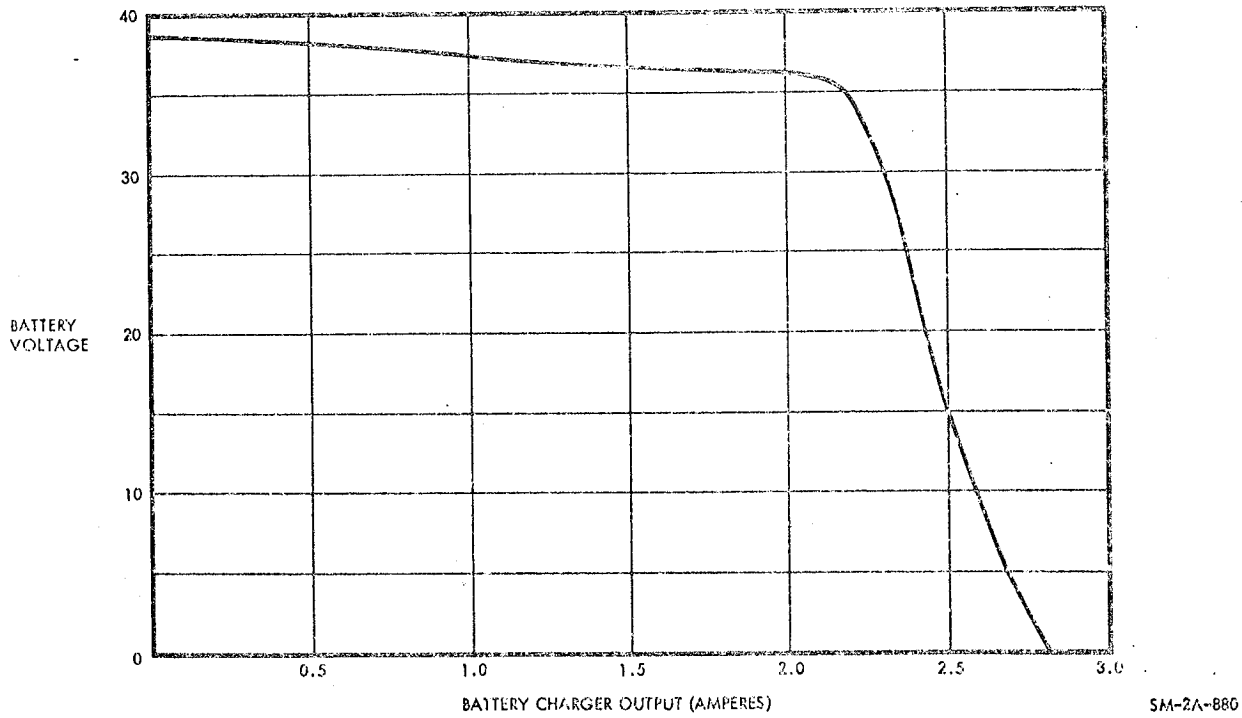


Figure 2.6-8. Battery Charging Rate Chart

Battery input will be monitored by MSFN through the normal battery telemetry measurements.

2.6.3.6 Power Distribution.

D-C and a-c power distribution to components of the EPS is provided by two redundant buses in each system. A single-point ground on the spacecraft structure is used to eliminate ground loop effects. Sensing and control circuits are provided for monitoring and protection of each bus system.

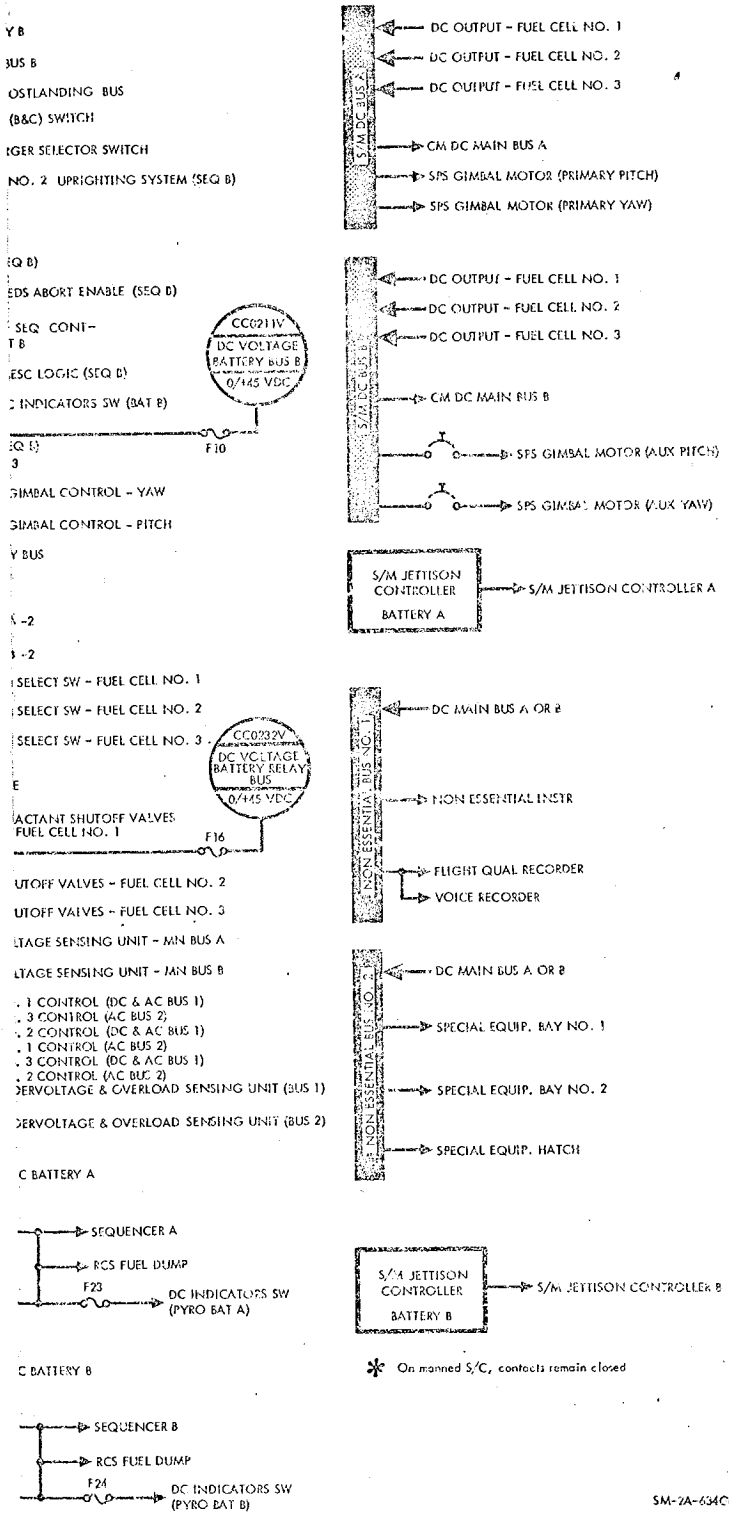
Distribution of d-c power (figure 2.6-9) is accomplished with a two-wire system and a series of interconnected buses, individual switches, circuit breakers, and isolation diodes. The buses consist of the following:

- Two redundant main d-c buses (A and B) powered by the three fuel cells and/or entry batteries A, B, and C.
- Two battery buses (A and B) each powered by its respective entry battery A and B.
- Flight and postlanding bus, powered through the main d-c buses, and/or the three entry batteries, A, B, and C.
- Two nonessential buses, powered through either d-c main bus A or B.
- Battery relay bus, powered by entry batteries A and B through individual battery buses.
- Pyro buses, which are isolated from the main electrical power system when powered by the pyro batteries. A capability is provided to connect entry battery A or B to the respective A or B pyro system in case of loss of a pyro battery.
- S/M jettison controllers, powered by S/M jettison controller batteries, which are completely isolated from the main electrical power system.

Power from the fuel cell power plants is connected to the main d-c buses through six motor switches (part of overload/reverse current circuits in the S/M which are controlled by switches in the C/M located on MDC-18. Fuel cell power can be connected to either or both of the main d-c buses. Six event indicators show when fuel cell output is connected. When an overload condition occurs, the overload-reverse current sensing circuits automatically disconnect the fuel cell power plants from the overloaded bus and provide visual displays for isolation of the trouble. A reverse current condition will disconnect the malfunctioning power plant from the d-c system. D-C undervoltage sensing circuits (figure 2.6-10) are also provided to indicate bus low voltage conditions. If voltage drops

below 26.25 volts dc, an applicable d-c undervoltage light on the caution and warning panel (MDC-11) will illuminate. Since each bus is capable of handling all EPS loads, an undervoltage condition should not occur except in an isolated instance, if too many electrical units are placed on the bus simultaneously or if a malfunction exists in the EPS. A voltmeter, on MDC-18, is provided to monitor bus voltage. An ammeter is provided on MDC-18 to monitor current output of fuel cells 1, 2, 3, batteries A, B, C, and the battery charger. During extreme power loads or emergencies, power to the main d-c buses can be supplied from entry batteries A and B by way of battery buses and directly from battery C (figure 2.6-11). Each battery bus is separated physically into two parts (e.g., battery bus A is A-1 and A-2), but remain connected electrically by motor switch contacts which are not opened on manned S/C. A switch to two nonessential buses permits isolating nonessential equipment during a shortage of power (two fuel cell power plants out). The postlanding bus supplies power to some of the telecommunications equipment, float bag No. 1 and No. 3 controls, and the ECS postlanding vent control. In flight and up to CSM separation, the postlanding bus receives power from the fuel cells and/or entry batteries through the main d-c buses. After CSM separation, the entry batteries supply power to the postlanding bus through the main d-c buses or directly through individual circuit breakers. Motor switch contacts which close when the MAIN BUS TIE switches are positioned ON, complete the circuit between the entry batteries and the main d-c buses and open the connection from the battery charger. The battery relay bus provides d-c power to the d-c and a-c sensing units, and the fuel cell and inverter control circuits. The pyrotechnic batteries supply power to initiate ordnance devices for separation of the LES, forward heat shield, S/M from C/M, and for deployment of the drogue and main parachutes during a pad abort, high-altitude abort, or normal mission progression. The S/M jettison controller batteries, supply power through the S/M jettison controllers for the CSM separation maneuver. To operate recovery communications and other aids after landing, power is provided by the entry batteries through three circuit breakers (figure 2.6-11) which are normally open until just prior to CSM separation.

Distribution of a-c power (figure 2.6-12) is accomplished with a four-wire system via two redundant buses, a-c bus No. 1 and a-c bus No. 2. The a-c neutral bus is connected to the single-point ground. A-C power is provided by the solid-state 115/200-volt 400-cps 3-phase inverters. D-C power is routed to the inverters through the main d-c buses. Inverter No. 1 can be powered through d-c main bus A, inverter No. 2 through d-c main bus B, and inverter No. 3 through either d-c main bus A or B by switch selection. Each of these circuits has a separate circuit breaker and a power control motor switch. Switches for applying power to the motor switches are located on MDC-18. All three inverters are identical and are provided with overtemperature circuitry. A light indicator, in the caution/warning group on MDC-11, illuminates to indicate an over-temperature situation. Inverter operating temperature is telemetered



D-C Power Distribution

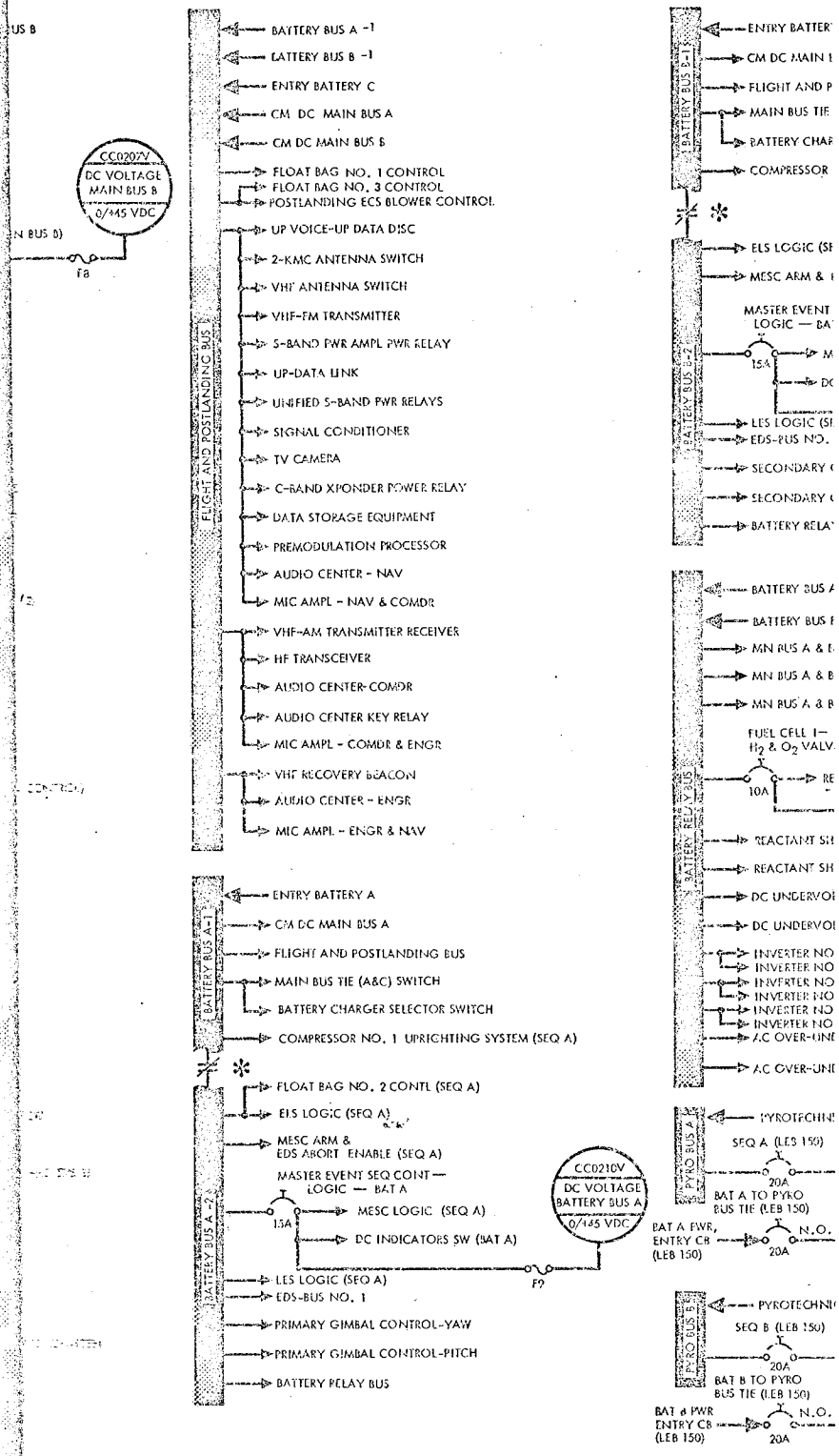
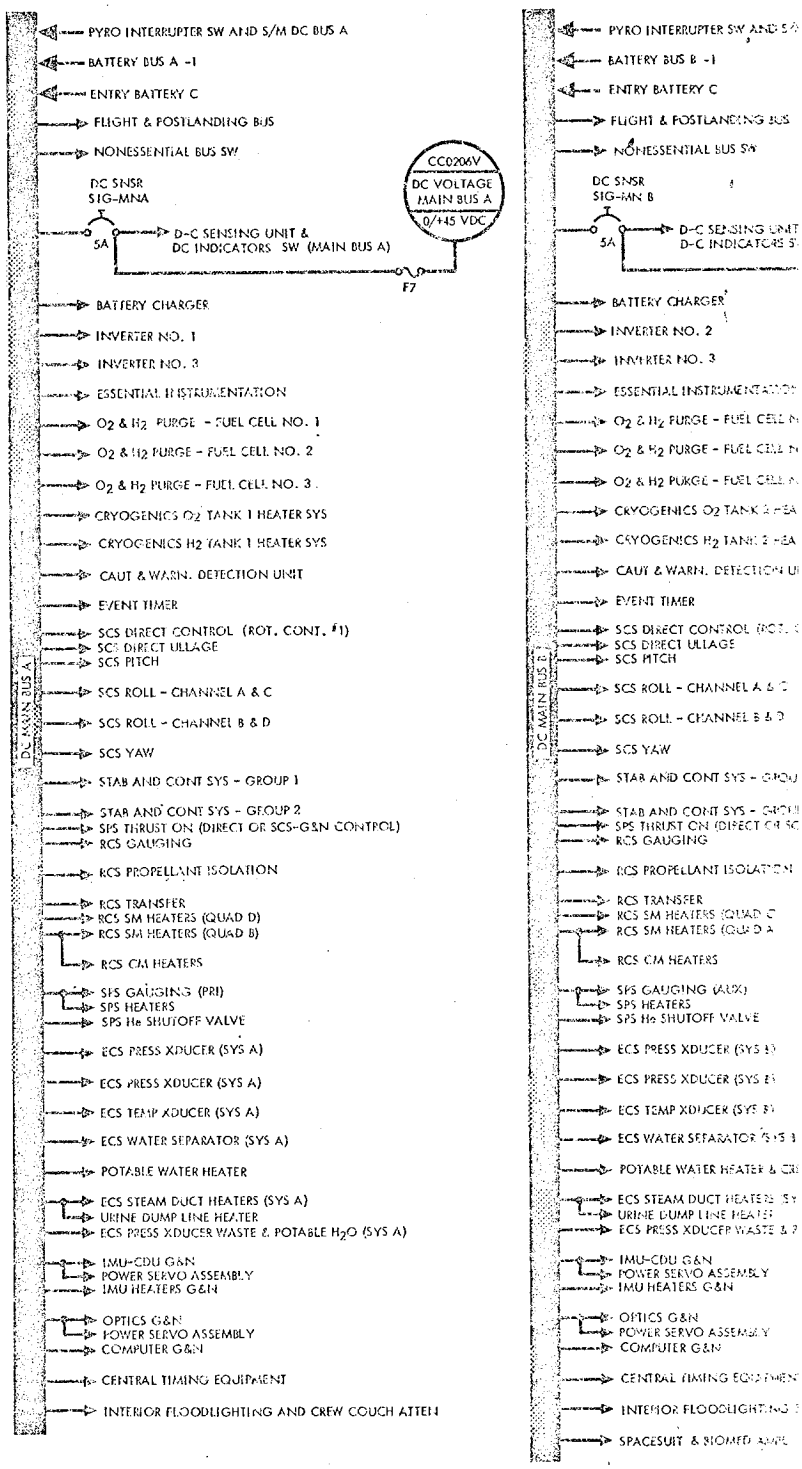

US B
CC0207V
DC VOLTAGE
MAIN BUS B
0/145 VDC
N BUS B)
F8
BATTERY BUS A -1
BATTERY BUS B -1
ENTRY BATTERY C
CM DC MAIN BUS A
CM DC MAIN BUS B
FLOAT BAG NO. 1 CONTROL
FLOAT BAG NO. 3 CONTROL
POSTLANDING ECS BLOWER CONTROL
UP VOICE-UP DATA DISC
2-KMC ANTENNA SWITCH
VHF ANTENNA SWITCH
VHF-FM TRANSMITTER
S-BAND PWR AMPL PWR RELAY
UP-DATA LINK
UNIFIED S-BAND PWR RELAYS
SIGNAL CONDITIONER
TV CAMERA
C-BAND XPONDER POWER RELAY
DATA STORAGE EQUIPMENT
PREMODULATION PROCESSOR
AUDIO CENTER - NAV
MIC AMPL - NAV & COMDR
VHF-AM TRANSMITTER RECEIVER
HF TRANSCEIVER
AUDIO CENTER-COMDR
AUDIO CENTER KEY RELAY
MIC AMPL - COMDR & ENGR
VHF RECOVERY BEACON
AUDIO CENTER - ENGR
MIC AMPL - ENGR & NAV
FLIGHT AND POSTLANDING BUS
ENTRY BATTERY A
CM DC MAIN BUS A
FLIGHT AND POSTLANDING BUS
MAIN BUS TIE (A&C) SWITCH
BATTERY CHARGER SELECTOR SWITCH
COMPRESSOR NO. 1 UPRIGHTING SYSTEM (SEQ A)
FLOAT BAG NO. 2 CONTL (SEQ A)
ELS LOGIC (SEQ A)
MESC ARM &
EDS ABORT ENABLE (SEQ A)
MASTER EVENT SEQ CONT —
LOGIC — BAT A
MESC LOGIC (SEQ A)
15A
DC INDICATORS SW (BAT A)
CC0210V
DC VOLTAGE
BATTERY BUS A
0/145 VDC
F9
LES LOGIC (SEQ A)
EDS-BUS NO. 1
PRIMARY GIMBAL CONTROL-YAW
PRIMARY GIMBAL CONTROL-PITCH
BATTERY RELAY BUS
ENTRY BATTER
CM DC MAIN
FLIGHT AND P
MAIN BUS TIE
BATTERY CHAR
COMPRESSOR
ELS LOGIC (SE
MESC ARM &
MASTER EVENT
LOGIC — BA
15A
LES LOGIC (SE
EDS-BUS NO.
SECONDARY
SECONDARY
BATTERY RELA
BATTERY BUS A
BATTERY BUS B
MN BUS A & B
MN BUS A & B
MN BUS A & B
FUEL CELL 1—
H2 & O2 VALV
10A
REACTANT SE
REACTANT SE
DC UNDERVOL
DC UNDERVOL
INVERTER NO
INVERTER NO
INVERTER NO
INVERTER NO
INVERTER NO
INVERTER NO
A.C OVER-UNI
A.C OVER-UNI
PYROTECHNI
SEQ A (LEB 150)
20A
BAT A TO PYRO
BUS TIE (LEB 150)
BAT A PWR,
ENTRY CB
(LEB 150)
N.O.
20A
PYROTECHNI
SEQ B (LEB 150)
20A
BAT B TO PYRO
BUS TIE (LEB 150)
BAT B PWR
ENTRY CB
(LEB 150)
N.O.
20A

Figure 2.6-9.


PYRO INTERRUPTER SW AND S/M DC BUS A
BATTERY BUS A -1
ENTRY BATTERY C
FLIGHT & POSTLANDING BUS
NONESSENTIAL BUS SW
CC0206V
DC VOLTAGE
MAIN BUS A
0/+45 VDC
DC SNSR
SIG-MNA
5A
D-C SENSING UNIT &
DC INDICATORS SW (MAIN BUS A)
F7
BATTERY CHARGER
INVERTER NO. 1
INVERTER NO. 3
ESSENTIAL INSTRUMENTATION
O2 & H2 PURGE - FUEL CELL NO. 1
O2 & H2 PURGE - FUEL CELL NO. 2
O2 & H2 PURGE - FUEL CELL NO. 3
CRYOGENICS O2 TANK 1 HEATER SYS
CRYOGENICS H2 TANK 1 HEATER SYS
CAUT & WARN. DETECTION UNIT
EVENT TIMER
SCS DIRECT CONTROL (ROT. CONT. #1)
SCS DIRECT ULLAGE
SCS PITCH
SCS ROLL - CHANNEL A & C
SCS ROLL - CHANNEL B & D
SCS YAW
STAB AND CONT SYS - GROUP 1
STAB AND CONT SYS - GROUP 2
SPS THRUST ON (DIRECT OR SCS-G&N CONTROL)
RCS GAUGING
RCS PROPELLANT ISOLATION
RCS TRANSFER
RCS SM HEATERS (QUAD D)
RCS SM HEATERS (QUAD B)
RCS CM HEATERS
SPS GAUGING (PRI)
SPS HEATERS
SPS He SHUTOFF VALVE
ECS PRESS XDUCER (SYS A)
ECS PRESS XDUCER (SYS A)
ECS TEMP XDUCER (SYS A)
ECS WATER SEPARATOR (SYS A)
POTABLE WATER HEATER
ECS STEAM DUCT HEATERS (SYS A)
URINE DUMP LINE HEATER
ECS PRESS XDUCER WASTE & POTABLE H2O (SYS A)
IMU-CDU G&N
POWER SERVO ASSEMBLY
IMU HEATERS G&N
OPTICS G&N
POWER SERVO ASSEMBLY
COMPUTER G&N
CENTRAL TIMING EQUIPMENT
INTERIOR FLOODLIGHTING AND CREW COUCH ATTEN
DC MAIN BUS A
PYRO INTERRUPTER SW AND S/A
BATTERY BUS B -1
ENTRY BATTERY C
FLIGHT & POSTLANDING BUS
NONESSENTIAL BUS SW
DC SNSR
SIG-MN B
5A
D-C SENSING UNIT
D-C INDICATORS S
BATTERY CHARGER
INVERTER NO. 2
INVERTER NO. 3
ESSENTIAL INSTRUMENTATION
O2 & H2 PURGE - FUEL CELL N
O2 & H2 PURGE - FUEL CELL N
O2 & H2 PURGE - FUEL CELL N
CRYOGENICS O2 TANK 2 HEA
CRYOGENICS H2 TANK 2 HEA
CAUT & WARN. DETECTION U
EVENT TIMER
SCS DIRECT CONTROL (ROT.
SCS DIRECT ULLAGE
SCS PITCH
SCS ROLL - CHANNEL A &
SCS ROLL - CHANNEL B &
SCS YAW
STAB AND CONT SYS - GROU
STAB AND CONT SYS - GROU
SPS THRUST ON (DIRECT OR SC
RCS GAUGING
RCS PROPELLANT ISOLATION
RCS TRANSFER
RCS SM HEATERS (QUAD C
RCS SM HEATERS (QUAD A
RCS CM HEATERS
SPS GAUGING (AUX)
SPS HEATERS
SPS He SHUTOFF VALVE
ECS PRESS XDUCER (SYS B)
ECS PRESS XDUCER (SYS B)
ECS TEMP XDUCER (SYS B)
ECS WATER SEPARATOR (SYS B
POTABLE WATER HEATER & CR
ECS STEAM DUCT HEATERS (SY
URINE DUMP LINE HEATER
ECS PRESS XDUCER WASTE & P
IMU-CDU G&N
POWER SERVO ASSEMBLY
IMU HEATERS G&N
OPTICS G&N
POWER SERVO ASSEMBLY
COMPUTER G&N
CENTRAL TIMING EQUIPMENT
INTERIOR FLOODLIGHTING
SPACESUIT & BIOMED AMPL
DC MAIN BUS B

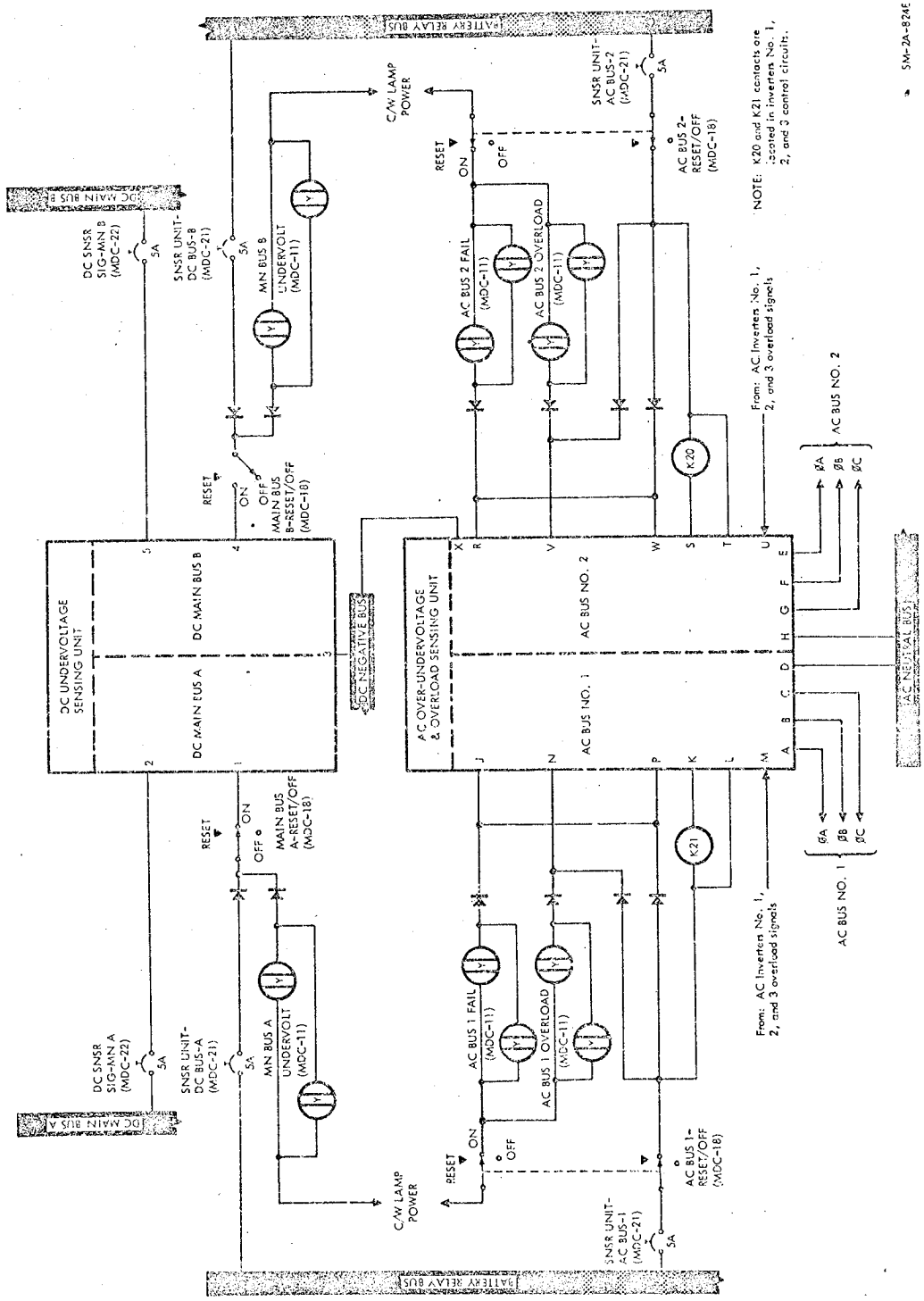


Figure 2.6-10. DC and AC Sensing Circuits

to the MSFN. Inverter output is routed through a series of control motor switches to the a-c buses. Six switches on MDC-18 control motor switches which operate contacts to connect or disconnect the inverters from the a-c buses. The motor switches are designed to prevent connecting two inverters to the same a-c bus at the same time. AC loads are powered through the redundant a-c buses. In some instances, one phase is used for operation of equipment; in others two, and in others all three. Over-undervoltage and overload sensing circuits (figure 2.6-11) are provided for each bus. A-C bus voltage fail and overload lights in the caution/warning group on MDC-11 provide a visual indication of these malfunctions. Monitoring of voltage and frequency of each phase on each bus is accomplished by selection with the AC INDICATORS switch. Readings are displayed on separate AC VOLTS and FREQUENCY meters located on MDC-18. Each phase voltage and ØA frequency is telemetered to MSFN stations.

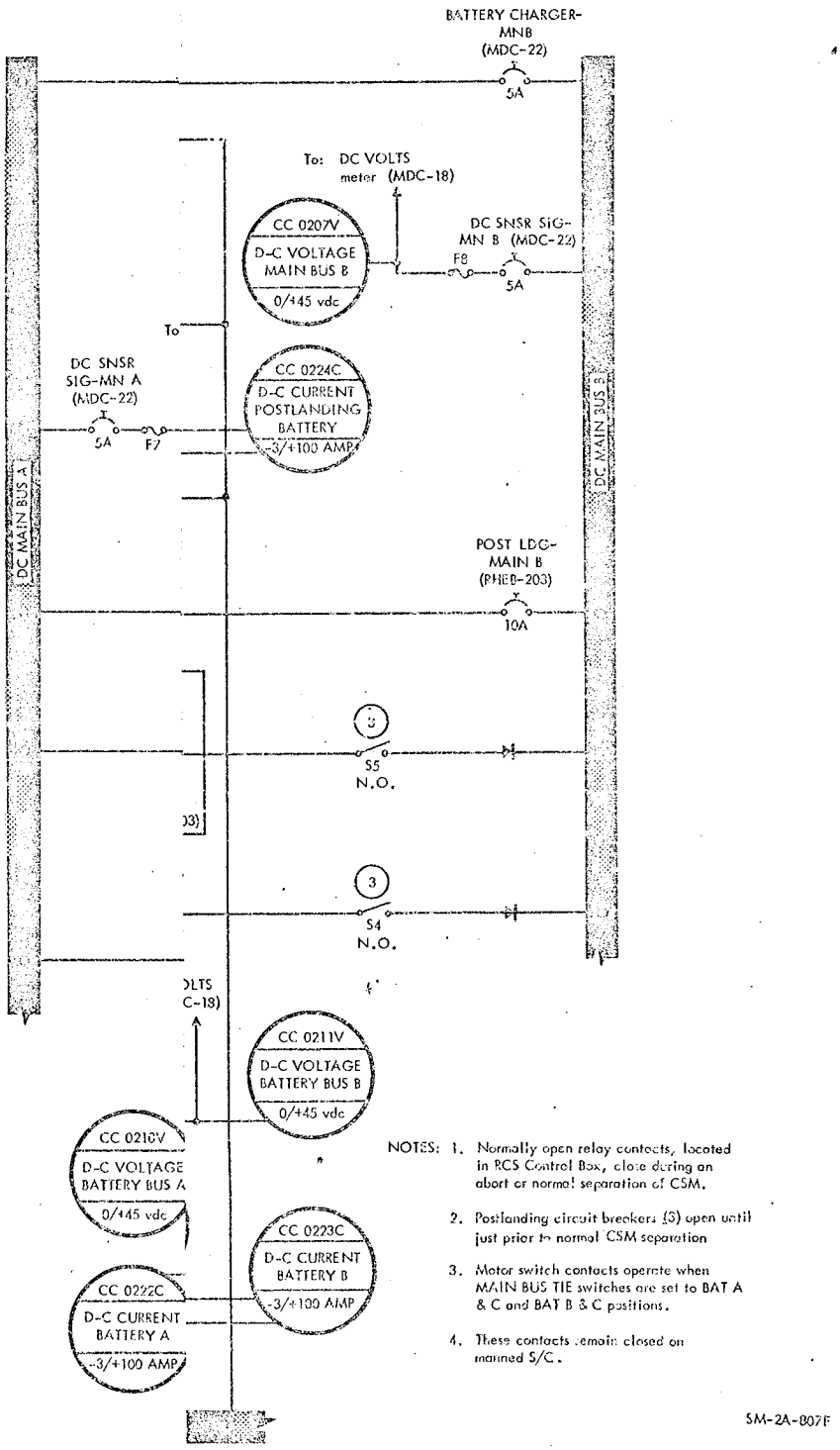
2.6.4 PERFORMANCE AND DESIGN DATA.

2.6.4.1 AC and DC Data.

AC and DC performance and design data for the EPS is as follows:

AC

Phases	3
Displacement	120± 2 degrees
Steady-state voltage	115±2 vac (average of 3 phases)
Transient voltage	115 (+35, -65) vac
Recovery	To 115±10v within 15 ms, steady state within 50 ms
Unbalance	2 vac (worst phase from average)
Frequency limits	
Normal (synchronized to central timing equipment)	400±2 cps
Emergency (loss of central timing equipment)	400±7 cps
Wave characteristics (sine wave)	
Maximum distortion	5 percent
Highest harmonic	4 percent
Crest factor	1.414±10 percent
Rating	1250 va



:ger and CM D-C Bus Control Circuits

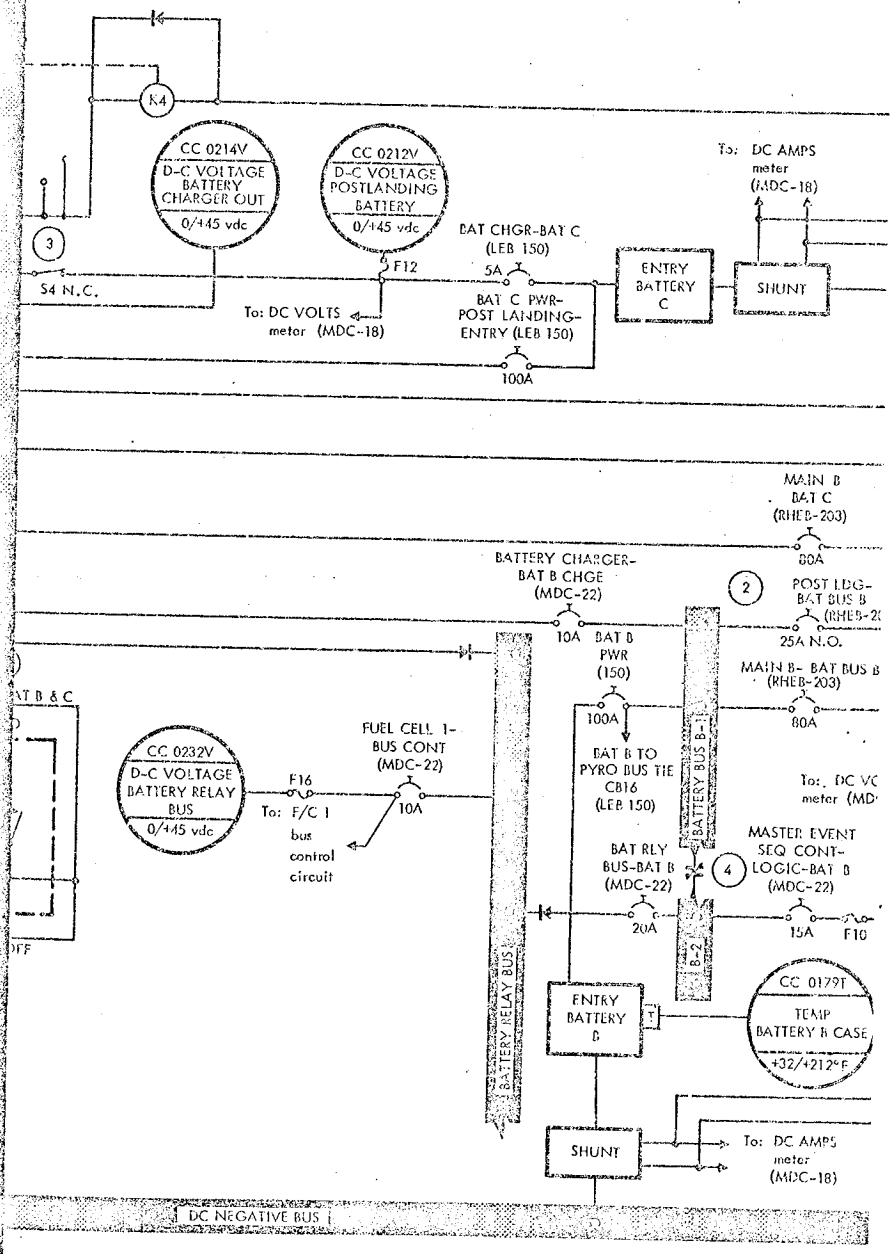
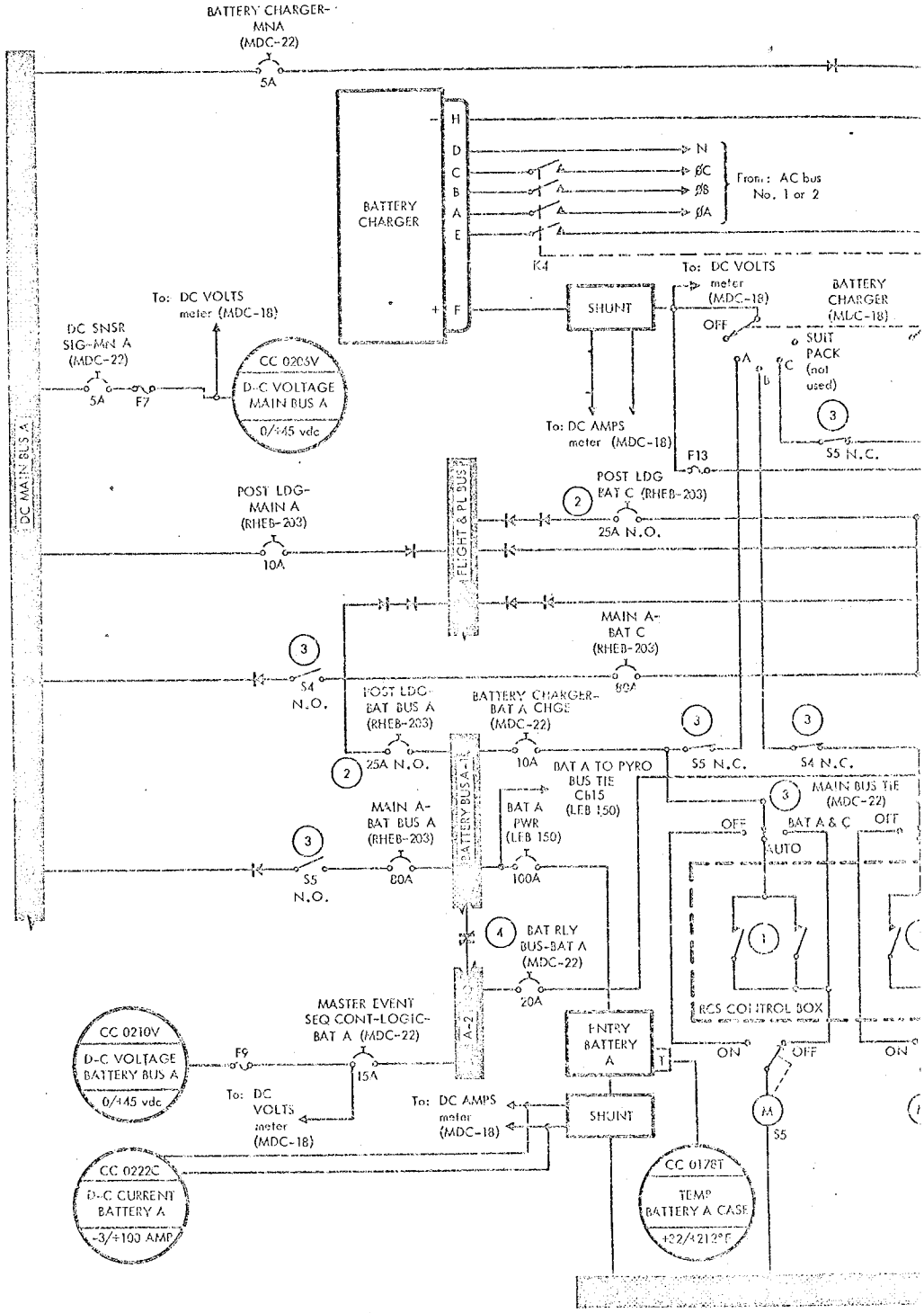


Figure 2.6-11: Battery Char


BATTERY CHARGER-MNA (MDC-22)
5A
DC MAIN BUS A
BATTERY CHARGER
H
D
C
B
A
E
F
N
βC
βB
βA
From: AC bus No. 1 or 2
K4
To: DC VOLTS meter (MDC-18)
SHUNT
To: DC AMPS meter (MDC-18)
OFF
BATTERY CHARGER (MDC-18)
SUIT PACK (not used)
S5 N.C.
F13
DC SNSR SIG-MN A (MDC-22)
5A
F7
CC 0206V
D-C VOLTAGE MAIN BUS A
0/+45 vdc
POST LDG-MAIN A (RHEB-203)
10A
FLIGHT & PL BUS A
POST LDG BAT C (RHEB-203)
25A N.O.
MAIN A-BAT C (RHEB-203)
80A
S4 N.O.
POST LDG-BAT BUS A (RHEB-203)
BATTERY CHARGER-BAT A CHGE (MDC-22)
10A
S5 N.C.
S4 N.C.
BAT A TO PYRO BUS TIE CB15 (LEB 150)
MAIN BUS TIE (MDC-22)
BAT A & C
OFF
AUTO
MAIN A-BAT BUS A (RHEB-203)
BAT A PWR (LEB 150)
100A
S5 N.O.
BATTERY BUS A-1
BAT RLY BUS-BAT A (MDC-22)
20A
RCS CONTROL BOX
ENTRY BATTERY A
ON
OFF
MASTER EVENT SEQ CONT-LOGIC-BAT A (MDC-22)
CC 0210V
D-C VOLTAGE BATTERY BUS A
0/+45 vdc
F9
15A
A-2
To: DC VOLTS meter (MDC-18)
To: DC AMPS meter (MDC-18)
SHUNT
S5
CC 0222C
D-C CURRENT BATTERY A
-3/+100 AMP
CC 0178T
TEMP BATTERY A CASE
+32/+212°F

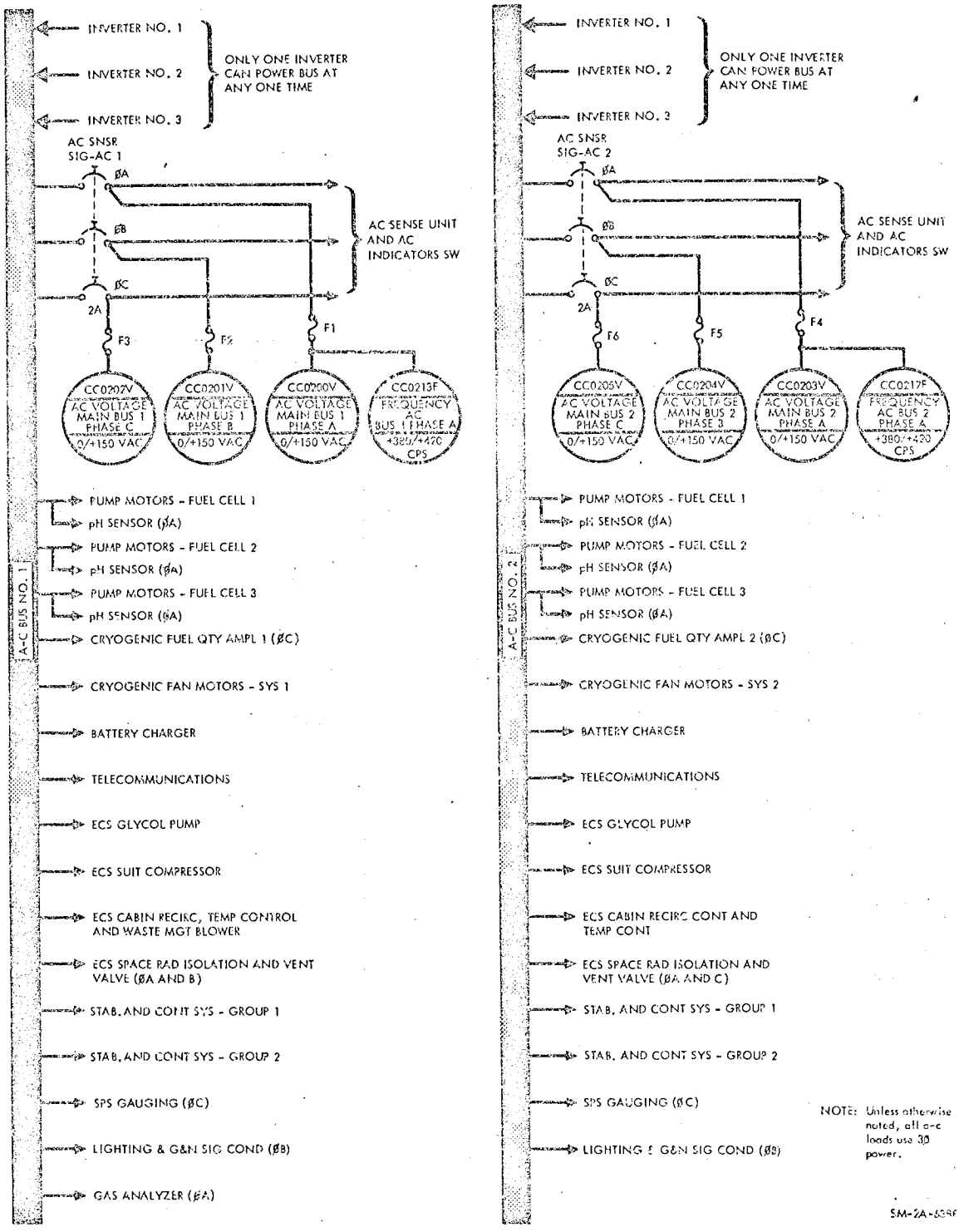


Figure 2.6-12. A-C Power Distribution

DC

Steady-state voltage limits Normal	29±2.0 vdc
During postlanding and preflight checkout periods	27 to 30 vdc
Ripple voltage	1v p-p

2.6.4.2 Power Requirements.

Power requirements for the EPS are as follows:

Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
FUEL CELLS						
Hydrogen pump	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22)	3	100.0		300.0	
Glycol pump	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22)	3	20.0		60.0	
pH indicator	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22) and FUEL CELL INDICATORS sw (MDC-18)	3	2.0		6.0	
Power factor correction for above items		3	2.5		7.5	
Total including pf correction					373.5	
Pressure transducers	FUEL CELL INDICATORS sw (MDC-18)	9		2.0		18.0
H_2 flowmeter circuits	FUEL CELL INDICATORS sw (MDC-18)	3		1.0		3.0

Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
O_2 flowmeter circuits	FUEL CELL INDICATORS sw (MDC-18)	3		1.0		3.0
H_2 purge line heater	H_2 PURGE LINE HEATER (MDC-15)	2		2.0		4.0
Purge solenoid	FUEL CELL-1, -2, -3, and H_2 PURGE/O_2 PURGE sw (MDC-18)	6		17.5		105.0
Fuel cell inline heater	None (Automatic on at +385±5°F) (Automatic off at +390±5°F)	3		160.0		480.0
CRYOGENICS						
H_2 tank heater	H_2 HEATERS-1 and -2 sw (MDC-13)	2		20.0		40.0
O_2 tank heater	O_2 HEATERS-1 and -2 sw (MDC-13)	2		155.0		310.0
H_2 tank fan	H_2 FANS-1 and -2 sw (MDC-13)	4	5.0		20.0	
O_2 tank fan	O_2 FANS -1 and -2 sw (MDC-13)	4	14.5		58.0	
Pressure transducer	ESSENTIAL-3 (153) C/B	4		1.5		6.0
Signal conditioner	CRYOGENIC SYSTEM-QTY AMPL-1 and -2-ØC C/B (MDC-22)	4	4.0		16.0	
BATTERY CHARGER	BATTERY CHARGER selector sw (MDC-18)	1			55.0 max	84.0 max

SYSTEMS DATA

Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
SENSING UNITS						
D-C under-voltage sensing unit (2 circuits)	MAIN BUS A and B-RESET/OFF sw (MDC-18)	1				0.5
A-C under and overvoltage and overload sensing unit (2 circuits)	AC BUS 1 and 2-RESET/OFF sw (MDC-18)	1				1.0
PHASE SYNCHRONIZER UNIT	INV PHASE LOCK (panel 208)	1	7.5		7.5	
INVERTERS (See note)	AC INVERTER-1, -2, and -3 sw (MDC-18)					

NOTE With a 28-volt d-c input, each inverter will operate at air efficiency of 76 percent minimum with a 1250 volt-ampere load, 0.9 power factor, and 74 percent minimum with a 625 volt-ampere load, 0.9 power factor.

2.6.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.6.5.1 Fuel Cell Power Plants.

Fuel cell power plants are designed to function under atmospheric and high vacuum conditions. Each must be able to maintain itself at sustaining temperatures and minimum electrical loads at both environment extremes. To function properly, fuel cells must operate under the following limitations and restrictions:

- External nonoperating temperature -20° to +140°F
- Operating temperature inside S/M +30° to +130°F
- External nonoperating pressure Atmospheric
- Normal voltage 27 to 31 vdc

• Minimum operating voltage Emergency operation	20.5 vdc at 2295 watts (gross power level)
Normal operation	27 vdc
• Maximum operating voltage	31 vdc
• Fuel cell disconnect (overload and reverse current relay)	75 amperes for over 15 minutes, 112 amperes for 25 to 300 seconds
Maximum reverse current	1 second minimum
• Minimum sustaining power/fuel cell power plant (with in-line heater off)	563 watts
In-line heater	160 watts
• H_2 purge line heater	4 watts
• Maximum gross power under emergency conditions	2295 watts
• Nitrogen pressure	52 to 70 psia
• Reactant pressure Oxygen Hydrogen	 62 to 75 psia 60.5 to 75 psia

• Reactant consumption/fuel cell power plant

Power Level	563W	2295W
Hydrogen	0.0476	0.262 lb/hr
Oxygen	0.378	2.08 lb/hr

• Electrolyte water concentration	24.3 to 28.2 percent
• Minimum stack temperature for self-sustaining operation	+385°F
• Approximate external environment temperature range outside S/C (for radiation)	-260° to +400°F
• Fuel cell power plant operating skin temperature	+385° to +500°F
• Condenser exhaust operating temperature	+155° to +175°F

• Purging frequency	Nominally every 24 hrs. (dependent on reactant purity after tank fill)
O_2 switch ON time	2 minutes
H_2 switch ON time	80 seconds
• Additional flow rate while purging	
O_2	Up to 0.6 lb/hr
H_2	Up to 0.75 lb/hr

2.6.5.2 Cryogenic Storage Subsystem.

The cryogenic storage subsystem must be able to meet the following requirements for proper operation of the fuel cell power plants and the ECS:

• Minimum usable quantity	
Oxygen	320 lb each tank
Hydrogen	28 lb each tank
• Temperature at time of fill	
Oxygen	-297°F (approx)
Hydrogen	-423°F (approx)
• Operating pressure range	
Oxygen	865 to 935 psia
Hydrogen	225 to 260 psia
• Temperature probe range	
Oxygen	-325° to +80°F
Hydrogen	-425° to -200°F
• Maximum allowable difference in quantity balance between tanks	
Oxygen tanks No. 1 and 2	15 lb
Hydrogen tanks No. 1 and 2	1 lb
• Pressure relief valve operation	
Crack pressure	
Oxygen	998 psia
Hydrogen	288 psia
Reseat pressure	
Oxygen	980 psia
Hydrogen	283 psia
Full flow, maximum relief	
Oxygen	1025 psia
Hydrogen	300 psia

2.6.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all EPS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
CC 0175 T	Temp static inverter 1	+32/+248°F	+40° to +140°F	INV 1 TEMP HI C&W light
CC 0176 T	Temp static inverter 2	+32/+248°F	+40° to +140°F	INV 2 TEMP HI C&W light
CC 0177 T	Temp static inverter 3	+32/+248°F	+40° to +140°F	INV 3 TEMP HI C&W light
*CC 0178 T	Temp battery A case	+32/+212°F	+50° to 110°F (200°F entry)	None
*CC 0179 T	Temp battery B case	+32/+212°F	+50° to 110°F (200°F entry)	None
*CC 0188 P	Press bat compartment (Manif)	Zero/+18 psia	Zero	Auxiliary DC VOLTS meter
CC 0200 V	AC voltage main bus 1 phase A	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0201 V	AC voltage main bus 1 phase B	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0202 V	AC voltage main bus 1 phase C	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
CC 0203 V	AC voltage main bus 2 phase A	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0204 V	AC voltage main bus 2 phase B	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0205 V	AC voltage main bus 2 phase C	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
CC 0206 V	DC voltage main bus A	Zero/+45 vdc	27 to 31 vdc	DC VOLTS meter
CC 0207 V	DC voltage main bus B	Zero/+45 vdc	27 to 31 vdc	DC VOLTS meter
*CC 0210 V	DC voltage battery bus A	Zero/+45 vdc	35 to 37 vdc open circuit	DC VOLTS meter
*CC 0211 V	DC voltage battery bus B	Zero/+45 vdc	27 to 29 vdc on load	DC VOLTS meter

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CC 0212 V	DC voltage post landing battery	Zero/+45 vdc	35 to 37.2 vdc open circuit 27 to 29 vdc on load	DC VOLTS meter
*CC 0213 F	Frequency ac bus 1 phase A	+380/+420 cps	393 to 407 cps	FREQUENCY meter
*CC 0214 V	DC voltage bat charger out	Zero/+45 vdc	37 to 39 vdc	DC VOLTS meter
*CC 0217 F	Frequency ac bus 2 phase A	+380/+420 cps	393 to 407 cps	FREQUENCY meter
*CC 0222 C	DC current battery A	-3/+100 amp	-3 to 30 amps	DC AMPS meter
*CC 0223 C	DC current battery B	-3/+100 amp	-3 to 30 amps	DC AMPS meter
*CC 0224 C	DC current post landing battery	-3/+100 amp	-3 to 30 amps	DC AMPS meter
CC 0232 V	DC voltage battery relay bus	Zero/+45 vdc	25 to 36.5 vdc	None
*SC 2060 P	N_2 pressure F/C 1 regulated	Zero/+75 psia	50 to 54 psia	F/C 1 C&W light, REG OUT PRESS HI-N_2 event indicator, and auxiliary DC VOLTS meter.
*SC 2061 P	N_2 pressure F/C 2 regulated	Zero/+75 psia	50 to 54 psia	F/C 2 C&W light, REG OUT PRESS HI-N_2 event indicator, and auxiliary DC VOLTS meter
*SC 2062 P	N_2 pressure F/C 3 regulated	Zero/+75 psia	50 to 54 psia	F/C 3 C&W light, REG OUT PRESS HI-N_2 event indicator, and auxiliary DC VOLTS meter
*SC 2066 P	O_2 pressure F/C 1 regulated	Zero/+75 psia	59 to 65 psia	F/C 1 C&W light, REG OUT PRESS HI-O_2 event indicator, and auxiliary DC VOLTS meter
*SC 2067 P	O_2 pressure F/C 2 regulated	Zero/+75 psia	59 to 65 psia	F/C 2 C&W light, REG OUT PRESS HI-O_2 event indicator, and auxiliary DC VOLTS meter

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*SC 2068 P	O_2 pressure F/C 3 regulated	Zero/+75 psia	59 to 65 psia	F/C 3 C&W light, REG OUT PRESS HI-O_2 event indicator, and auxiliary DC VOLTS meter
*SC 2069 P	H_2 pressure F/C 1 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 1 C&W light, REG OUT PRESS HI-H_2 event indicator, and auxiliary DC VOLTS meter
*SC 2070 P	H_2 pressure F/C 2 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 2 C&W light, REG OUT PRESS HI-H_2 event indicator, and auxiliary DC VOLTS meter
*SC 2071 P	H_2 pressure F/C 3 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 3 C&W light, REG OUT PRESS HI-H_2 event indicator, and auxiliary DC VOLTS meter
SC 2081 T	Temp F/C 1 cond exhaust	+150/+250°F	+157° to +172°F	F/C 1 C&W light, and MODULE TEMP COND-EXH indicator
SC 2082 T	Temp F/C 2 cond exhaust	+150/+250°F	+157° to +172°F	F/C 2 C&W light, and MODULE TEMP COND-EXH indicator
SC 2083 T	Temp F/C 3 cond exhaust	+150/+250°F	+157° to +172°F	F/C 3 C&W light, and MODULE TEMP COND-EXH indicator
SC 2084 T	Temp F/C 1 skin	+80/+550°F	+385° to +460°F	F/C 1 C&W light and MODULE TEMP-SKIN indicator
SC 2085 T	Temp F/C 2 skin	+80/+550°F	+385° to +460°F	F/C 2 C&W light and MODULE TEMP-SKIN indicator

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2086 T	Temp F/C 3 skin	+80/+550°F	+385° to +460°F	F/C 3 C&W light and MODULE TEMP-SKIN indicator
SC 2087 T	Temp F/C 1 radiator outlet	-50/+300°F	-30° to +300°F	F/C 1 C&W light, F/C RAD TEMP LOW event indicator and auxiliary DC VOLTS meter
SC 2088 T	Temp F/C 2 radiator outlet	-50/+300°F	-30° to +300°F	F/C 2 C&W light, F/C RAD TEMP LOW event indicator and auxiliary DC VOLTS meter
SC 2089 T	Temp F/C 3 radiator outlet	-50/+300°F	-30° to +300°F	F/C 3 C&W light, F/C RAD TEMP LOW event indicator and auxiliary DC VOLTS meter
SC 2113 C	DC current F/C 1 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2114 C	DC current F/C 2 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2115 C	DC current F/C 3 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2120 X	Fuel cell 1 bus A disconnect	Off/on event	Connected	F/C BUS DISCONNECT C&W light and FUEL CELL-1-MAIN BUS A switch event indicator
SC 2121 X	Fuel cell 2 bus A disconnect	Off/on event	Connected	F/C BUS DISCONNECT C&W light and FUEL CELL-2-MAIN BUS A switch event indicator
SC 2122 X	Fuel cell 3 bus A disconnect	Off/on event	Disconnected	F/C BUS DISCONNECT C&W light and FUEL CELL-3-MAIN BUS A switch event indicator

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2125 X	Fuel cell 1 bus B disconnect	Off/on event	Disconnected	F/C BUS DISCONNECT C&W light and FUEL CELL-1-MAIN BUS B switch event indicator
SC 2126 X	Fuel cell 2 bus B disconnect	Off/on event	Connected	F/C BUS DISCONNECT C&W light and FUEL CELL-2-MAIN BUS B switch event indicator
SC 2127 X	Fuel cell 3 bus B disconnect	Off/on event	Connected	F/C BUS DISCONNECT C&W light and FUEL CELL-3-MAIN BUS B switch event indicator
*SC 2139 R	Flow rate H_2 F/C 1	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 1 C&W light and FLOW-H_2 indicator
*SC 2140 R	Flow rate H_2 F/C 2	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 2 C&W light and FLOW-H_2 indicator
*SC 2141 R	Flow rate H_2 F/C 3	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 3 C&W light and FLOW-H_2 indicator
*SC 2142 R	Flow rate O_2 F/C 1	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 1 C&W light and FLOW-O_2 indicator
*SC 2143 R	Flow rate O_2 F/C 2	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 2 C&W light and FLOW-O_2 indicator
*SC 2144 R	Flow rate O_2 F/C 3	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 3 C&W light and FLOW-O_2 indicator
*SC 2160 X	pH factor water condition F/C 1	Normal/high event	Normal	F/C 1 C&W light and pH HI event indicator
*SC 2161 X	pH factor water condition F/C 2	Normal/high event	Normal	F/C 2 C&W light and pH HI event indicator
*SC 2162 X	pH factor water condition F/C 3	Normal/high event	Normal	F/C 3 C&W light and pH HI event indicator

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2323 X	Fuel cell 1 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SC 2324 X	Fuel cell 2 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SC 2325 X	Fuel cell 3 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SF 0030 Q	Quantity H_2 tank 1	Zero/+28 lb	+28 lbs to zero	TANK QUANTITY-H_2-1 indicator
SF 0031 Q	Quantity H_2 tank 2	Zero/+28 lb	+28 lbs to zero	TANK QUANTITY-H_2-2 indicator
SF 0032 Q	Quantity O_2 tank 1	Zero/+320 lb	+320 lbs to zero	TANK QUANTITY-O_2-1 indicator
SF 0033 Q	Quantity O_2 tank 2	Zero/+320 lb	+320 lbs to zero	TANK QUANTITY-O_2-2 indicator
SF 0037 P	Press O_2 tank 1	+50/+1050 psia	865 to 935 psia	O_2 PRESS C&W light and TANK PRESSURE-O_2-1 indicator
SF 0038 P	Press O_2 tank 2	+50/+1050 psia	865 to 935 psia	O_2 PRESS C&W light and TANK PRESSURE-O_2-2 indicator
SF 0039 P	Press H_2 tank 1	Zero/+350 psia	225 to 260 psia	H_2 PRESS C&W light and TANK PRESSURE-H_2-1 indicator
SF 0040 P	Press H_2 tank 2	Zero/+350 psia	225 to 260 psia	H_2 PRESS C&W light and TANK PRESSURE-H_2-2 indicator
SF 0041 T	Temp O_2 tank 1	-325/+80°F	-284° to -140°F	None
SF 0042 T	Temp O_2 tank 2	-325/+80°F	-284° to -140°F	None
SF 0043 T	Temp H_2 tank 1	-425/-200°F	-417° to -340°F	None
SF 0044 T	Temp H_2 tank 2	-425/-200°F	-417° to -340°F	None

The auxiliary DC VOLTS meter, FUNCTION SELECT and TEST SELECT switches, located on panel 200 in the C/M RHFEB, provide a means of monitoring various telemetered measurements within the S/C and verifying certain parameters displayed only by event indicators. The following list presents the measurements test can be monitored using the auxiliary DC VOLTS meter, their respective switch positions, and the range of each sensor . Normal operating parameters of measurable items are covered in the telemetry listing.

Auxiliary DC VOLTS Meter Indication (Telemetry Identity) and Code No.)	Switch Positions		Sensor Range
	Function Select	Test Select	
N_2 pressure, psia F/C 1 SC 2060 P F/C 2 SC 2061 P F/C 3 SC 2062 P	A	1 2 3	0 to 75 psia
O_2 pressure, psia F/C 1 SC 2066 P F/C 2 SC 2067 P F/C 3 SC 2068 P		4 5 6	0 to 75 psia
H_2 pressure, psia F/C 1 SC 2069 P F/C 2 SC 2070 P F/C 3 SC 2071 P		7 8 9	0 to 75 psia
EPS radiator outlet temp F/C 1 SC 2087 T F/C 2 SC 2088 T F/C 3 SC 2089 T		10 11 12	-50° to +300°F
C/M-RCS oxidizer valve temp -P engine, sys A CR 2205 T +Y engine, sys B CR 2203 T -P engine, sys B CR 2204 T CW engine, sys B CR 2206 T CCW engine, sys A CR 2201 T -Y engine, sys A CR 2202 T	B	1 2 3 4 11 12	-50° to +250°F
PIPA temp CG 2300 T		5	+125° to +135°F
IRIG temp CG 2301 T		6	+128.5° to +138.5°F

SYSTEMS DATA

Auxiliary DC VOLTS Meter Indication (Telemetry Identity) and Code No.)	Switch Positions		Sensor Range
	Function Select	Test Select	
IMU current Heater CG 2302 C Blower CG 2303 C		7 8	0 to 5 amps
Battery manifold Pressure, psia CC 0188 P		9	0 to 18 psia
ECS radiator inlet Temp SF 0665 T		10	+60° to +150°F

The conversion of the previously listed telemetry measurements to the auxiliary DC VOLTSmeter indication is presented as follows:

Auxiliary DC VOLTS Meter Display	N_2, O_2, H_2 Pressure (PSIA)	EPS Radiator Outlet Temp (°F)	C/M-RCS Oxidizer Valve Temp (°F)	PIPA Temp (°F)	IRIG Temp (°F)	IMU Heater and Blower Current (Amps)	Battery Manifold Pressure (PSIA)	ECS Radiator Inlet Temp (°F)
0.0	0	-50	-50	+125.0	+128.5	0.0	0.00	+60.0
0.2	3	-36	-38	+125.4	+128.9	0.2	0.72	+63.6
0.4	6	-22	-26	+125.8	+129.3	0.4	1.44	+67.2
0.6	9	-8	-14	+126.2	+129.7	0.6	2.16	+70.8
0.8	12	+6	-2	+126.6	+130.1	0.8	2.88	+74.4
1.0	15	+20	+10	+127.0	+130.5	1.0	3.60	+78.0
1.2	18	+34	+22	+127.4	+130.9	1.2	4.32	+81.6
1.4	21	+48	+34	+127.8	+131.3	1.4	5.04	+85.2
1.6	24	+62	+46	+128.2	+131.7	1.6	5.76	+88.8
1.8	27	+76	+58	+128.6	+132.1	1.8	6.48	+92.4
2.0	30	+90	+70	+129.0	+132.5	2.0	7.20	+96.0
2.2	33	+104	+82	+129.4	+132.9	2.2	7.92	+99.6
2.4	36	+118	+94	+129.8	+133.3	2.4	8.64	+103.2
2.6	39	+132	+106	+130.2	+133.7	2.6	9.36	+106.8
2.8	42	+146	+118	+130.6	+134.1	2.8	10.08	+110.4
3.0	45	+160	+130	+131.0	+134.5	3.0	10.80	+114.0
3.2	48	+174	+142	+131.4	+134.9	3.2	11.52	+117.6
3.4	51	+188	+154	+131.8	+135.3	3.4	12.24	+121.2
3.6	54	+202	+166	+132.2	+135.7	3.6	12.96	+124.8
3.8	57	+216	+178	+132.6	+136.1	3.8	13.68	+128.4
4.0	60	+230	+190	+133.0	+136.5	4.0	14.40	+132.0

SYSTEMS DATA

Auxiliary DC VOLTS Meter Display	N_2, O_2, H_2 Pressure (PSIA)	EPS Radiator Outlet Temp (°F)	C/M-RCS Oxidizer Valve Temp (°F)	PIPA Temp (°F)	IRIG Temp (°F)	IMU Heater and Blower Current (Amps)	Battery Manifold Pressure (PSIA)	ECS Radiator Inlet Temp (°F)
4.2	63	+244	+202	+133.4	+136.9	4.2	15.12	+135.6
4.4	66	+258	+214	+133.8	+137.3	4.4	15.84	+139.2
4.6	69	+272	+226	+134.2	+137.7	4.6	16.56	+142.8
4.8	72	+286	+238	+134.6	+138.1	4.8	17.28	+146.4
5.0	75	+300	+250	+135.0	+138.5	5.0	18.00	+150.0

SECTION 2

SUBSECTION 2.7

ENVIRONMENTAL CONTROL SYSTEM (ECS)

2.7.1 INTRODUCTION.

The environmental control system (ECS) is designed to provide a controlled environment for three crewmen within the Apollo C/M for missions up to 14 days. The system also supplies several of the metabolic requirements, as well as functioning in the removal of by-products resulting from the normal metabolic process. The controlled environment consists of a pressure suit circuit for use during normal or emergency conditions, and a shirtsleeve atmosphere within the C/M cabin, for use when normal conditions prevail. Oxygen and thermally controlled water are supplied for crew consumption; whereas, carbon dioxide and odors, water-production, and heat output are removed. In addition, the ECS disperses equipment heat loads and provides for venting the waste storage compartment. Controls and displays are located in several areas within the C/M cabin; these, in conjunction with automatically functioning components, and sensing and protective devices, aid the crew in the operation of the system. The five subsystems composing the ECS are the oxygen supply, pressure suit circuit, cabin pressure and temperature control, water-glycol coolant, and water supply.

The oxygen supply subsystem controls the inflow of oxygen for the entire Apollo mission. This function is accomplished by pressure regulator, demand regulators, storage tanks, check valves, and manual shutoff valves. The pressure suit subsystem automatically controls the flow, pressure, temperature, and composition of the pressure suit gas. In conjunction with the C/M pressure and temperature control subsystem, it also controls the environment conditions in the cabin when one, or all of the crew are out of their pressure suits. These functions are provided by water separators, temperature controls, a suit heat exchanger, a debris trap, gas compressor, CO_2-odor absorbers, and a water glycol-to-gas heat exchanger.

The cabin pressure and temperature control subsystem automatically maintains the pressure and temperature of the cabin within specified limits. This function is accomplished in conjunction with the pressure suit subsystem by means of regulated oxygen inflow, recirculation blowers, a heat exchanger, a temperature control and sensors, vent valves, and other valves and controls required. The water-glycol subsystem is an intermediate heat transfer loop which permits excess heat to be transferred from the C/M interior to the space radiators where it is rejected to the cosmic sink. This function is accomplished by pumps, heat exchangers,

cold plate networks, valves, and controls. The water supply subsystem collects, stores, and provides water for supplemental heat transfer operation, and collects and stores potable water for consumption by the crew. These functions are accomplished by utilizing water tanks, pressure controls, cyclic accumulators, and valves.

Other than the circuitry required for controls and displays or electrical power, three points of interface exist between the ECS and other S/C systems. All oxygen supplied to the ECS flows from the cryogenic storage tanks, which are considered a part of the EPS. The fuel cells, also a part of the EPS, furnish the onboard supply of potable water that is stored by the ECS. The third interface point is with the waste management system, which connects into the ECS overboard dump line.

2.7.2 FUNCTIONAL DESCRIPTION.

The ECS requires a minimum amount of crew time be spent for normal system operation. In addition to periodically monitoring system indicators, the crew is responsible for the accomplishment of several normal tasks on an infrequent basis. For conditions other than normal, the duties of the crew will increase. Electrical and manual override and backup capabilities exist throughout the ECS to maintain the required reliability level of the system.

The oxygen supplied to the ECS from the storage tanks in the S/M is used to carry out a variety of system functions. Upon reaching the ECS, oxygen is automatically regulated and manually routed to various subsystem components by a system of valves and lines. Also incorporated are automatically functioning components to maintain suit and/or cabin pressure in the event of cabin decompression of equipment malfunction.

The atmosphere of the pressurized cabin, as well as that of the pressure garment assemblies (PGA), is routed through the suit circuit for contaminant removal and humidity control. The flow, pressure, and temperature control within the suit circuit, are maintained by other components of the subsystem. This is accomplished automatically by using transducers, sensors, and control units to regulate these functions. Mechanical-type oxygen pressure regulators automatically maintain cabin pressure within prescribed limits. The temperature of the cabin is controlled by an automatic unit that regulates the output of the cabin heat exchanger with the aid of sensors and anticipators.

Carbon dioxide and odors are removed from the suit circuit and cabin gases by routing the gas flow through two filters in the CO_2-odor absorber canisters. Each filter contains sufficient lithium hydroxide (CO_2 removal) and activated charcoal (odor removal) for a 12-hour duty period for a crew of three. The suit circuit and cabin atmospheres are also sampled by a gas chromatograph that will identify up to 28 gas components that may be present.

Heat, generated by the crew and the many items of electrical equipment located in the cabin, is absorbed by recirculating water-glycol. The heat is transferred to the water-glycol as it flows through the suit heat exchanger, the cabin heat exchanger, and the cold plate network for the electrical equipment. The warm water-glycol is then routed through space radiators in the S/M, where the heat is radiated to space. Supplementing the radiators and/or as a backup mode, water evaporators are employed for any additional temperature control of suit gases or insufficiently cooled water-glycol.

Potable and waste water are generated on-board the S/C. The potable water is a by-product of the EPS fuel cells and flows to the ECS where it is stored. Cold potable water is available to the crew for drinking, and hot or cold potable water is available for food reconstitution. Waste water is derived from the moisture that condenses in the water separator of the suit exchanger. It is collected and stored by the ECS and used for evaporative cooling in the suit heat exchanger evaporator and the water-glycol evaporator.

2.7.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

Pertinent design data in regard to components, their function within each subsystem, and how they interface is contained under major component/subsystem description. The description follows the logical flow, component by component, through each subsystem of the ECS.

2.7.3.1 Oxygen Supply Subsystem.

Two cryogenic oxygen storage tanks (part of the electrical power system) supply 900±35 psia oxygen flow to the ECS. Each tank contains 320 pounds of oxygen, and of the total supply, approximately one-third is consumed by the ECS. Oxygen flows unrestricted in parallel lines from the S/M supply tanks into the C/M. In the C/M, oxygen flows in each supply line through a filter, a capillary restrictor, and a check valve upstream to their connection to a common distribution line. To assure uniform flow, the capillary restrictors are coiled around a warm water-glycol line to increase the oxygen temperature. Each restrictor allows a maximum flow of 4.5 pounds per hour into the ECS to limit the demands placed on the cryogenic oxygen storage tanks and enable the tank heaters to maintain the prescribed tank pressures. The minimum flow rate will not decrease below 3.4 pounds per hour as the oxygen density decreases due to usage. Illustrated in the ECS integrated schematic (figure 2.7-13) the manual S/M supply shutoff valve, located on the LHEB panel 307, is normally in the ON position and placed to OFF prior to SCM separation for the entry phase of the mission. Downstream of the S/M shutoff valve 900±35 psia oxygen is distributed to a surge tank, an entry O_2 tank, a PLSS fill valve, and the main pressure regulator assembly. Oxygen flows to the surge tank through a manual surge tank isolation valve, located on the LHEB panel 307. The surge tank provides a reservoir of O_2 for the entry mission modes, and during flow requirements above the 0.9 pound per hour maximum

allowable by the capillary restrictors. Approximately 3.7 pounds of oxygen is available at nominal inlet pressure of 900±35 psia. A surge tank pressure transducer output is displayed by the TANK PRESS O_2 1 indicator, located on MDC panel 13. The indicator input must be selected by the switch position, SURGE TANK, located below the indicator. To reduce the demand loads on the cryogenic storage system, high flow rates from the surge tank will maintain cabin pressure from 5 to 3.5 psia for 5 minutes, with a 0.5-inch-diameter puncture in the cabin. The flow rate into the cabin is a function of regulator valves downstream of the surge tank. The 5-minute period allows unsuited crewmembers to don PGAs. When isolated by the surge tank manual shutoff valve, the tank is protected by a pressure relief and manual shutoff valve assembly. The relief portion is set between 1020 and 1070 psig. Should the relief valve fail or not reseat properly, the manual shutoff valve will isolate the relief valve function from the system.

Downstream O_2 supply is also stored in a one-pound entry O_2 tank, through a manual three-way selector valve, a check valve, and a check valve bypass. When the manual selector valve is in the FILL position, the entry O_2 supply tank receives high pressure O_2 through the check valve bypass. When the tank is charged, the selector valve may be positioned to OFF to isolate the tank supply, or to ON whereby the O_2 tank supply may augment the surge tank function. The check valve prevents a reverse flow in case of entry O_2 tank damage. An isolation check valve between the two tanks prevents reverse flow and a manual valve permits charging PLSS oxygen tanks from the ECS.

The 900±35-psig oxygen supply, from the cryogenic tanks, is regulated to 100±10 psig by the main pressure regulator assembly illustrated in figure 2.7-1. The main pressure regulator assembly consists of a manual selector valve, two regulators, and two relief and check valves. NORMAL position of the manual selector valve parallels the regulators. Position No. 1 or No. 2 selects its regulator respectively. The OFF position isolates all O_2 supply for the crew and cabin. Should a regulator fail open, the relief valve for that regulator will limit the pressure to 140 psig downstream and vent a maximum flow of 0.75 pounds per minute into the cabin. This fault should be corrected by selecting the alternate regulator only.

An oxygen flow transducer, downstream of the main regulator, provides a signal to the flow indicator, located on the main display console panel 13, and the O_2 FLOW HI light. Although short periods of flow in excess of 0.45 pounds per hour are considered normal, a continuous flow rate between 0.45 and 1.0 pound per hour should not be tolerated. Flow rates above 1.0 pounds per hour and for a period of 15 seconds and above activate the red O_2 FLOW HI warning light located on the caution and warning (C&W) panel 11. The 15-second time delay prevents the O_2 FLOW HI light from lighting during O_2 flow requirements of the cyclic accumulators that remove water from the suit heat exchanger, and during transient conditions. Continued flow rates in this range are indicative of cabin leakage, O_2 supplied subsystem leakage, or subsystem mismanagement.

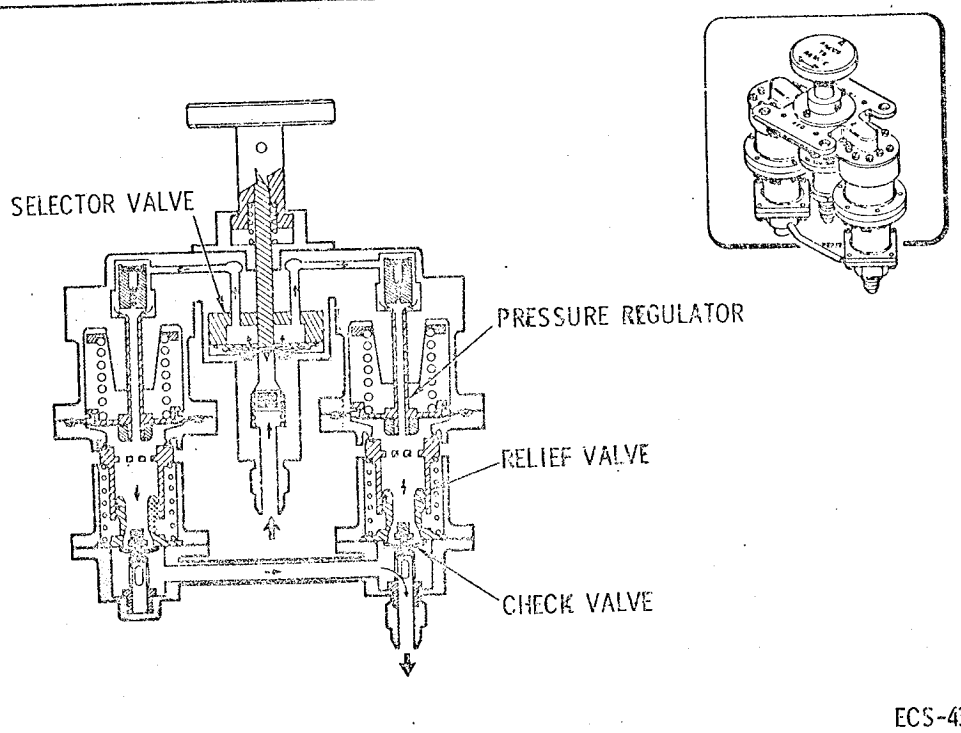


Figure 2.7-1. Main Oxygen Pressure Regulator

Connected to the 100±10-psig regulated pressure line is a fluid tank pressure regulator and relief valve assembly, located on the OXYGEN CONTROL PANEL No. 314. It consists of redundant pressure regulators and relief valves which provide oxygen at regulated pressure to the expulsion bladders installed in the potable water tank, waste water tank, and the water-glycol (W/G) reservoir. Two four-position selector valves are employed at the inlet and outlet, and enable isolation of malfunctioning elements or complete shutoff as desired. The pressure regulator is a normally opened, diaphragm-operated poppet metering valve which functions to reduce 100±10-psig supply pressure to 20±2-psig O_2 pressure to the fluid tanks, in relation to cabin pressure. The relief valve incorporated in the assembly outlet chamber functions to relieve O_2 pressure in excess of 25±2 psig into the cabin.

Should a regulator diaphragm rupture, and is isolated by the inlet manual selector valve, the manual outlet selector valve must also be positioned to isolate the relief portion of the failed regulator. This prevents a feedback from the alternate regulator flowing oxygen through the ruptured diaphragm of the failed regulator into the cabin.

Should the selector inlet valve of the assembly be placed to position 1, the selector outlet valve must also be placed to position 1 (or NORMAL). If instead, the selector outlet valve were placed to position 2, the valve port to pressurize the tanks would be closed, and the port to the relief

valve would remain open. This permits the pressure relief function of the valve to remain operative but prohibits subsequent tank pressurization. Conversely, when the selector outlet valve is set to position 2, the selector inlet valve must also be set to position 2 (or NORMAL). The OFF position of the inlet and outlet selector valves is normally for ground checkout; however, if both pressure regulators malfunction during flight, the selector inlet valve must be set to the OFF position. This eliminates the tank pressurization function, but does not affect the pressure relief function. In response to the possibility of both relief valves malfunctioning, the selector outlet valve must be set to the OFF position. This action will eliminate both the pressurization and pressure relief functions.

The 100±10-psig oxygen supply is controlled by the emergency cabin pressure regulator, located on panel 314, to provide increased oxygen flow to the cabin, and prevent rapid decompression. The emergency cabin pressure regulator consists of dual aneroid-operated, normally closed valves to prevent overpressurization of the aneroids, and a manual four-position selector valve with positions designated No. 1, No. 2, NORMAL, and OFF. A PRESS-TO-TEST button, which closes the cabin pressure sense port allows a fix bleed of 100 cc per min to pressurize an aneroid chamber and drive the valve open. Normally the 100±10-psig oxygen supply to the cabin is controlled by the cabin pressure regulator assembly. It consists of dual, aneroid-absolute type normally closed valves, and each will deliver a minimum of 0.2 pound per hour oxygen flow at a cabin pressure of 5.0±0.2 psia. Failure mode of the valve is normally closed. A manual control valve may be opened and allow a minimum 6 pounds per hour flow of O_2 directly into the cabin for repressurization from 0.0 to 5.0 psia within one hour. The cabin pressure regulator and the emergency cabin pressure regulator are associated with the cabin pressure and temperature control subsystem (paragraph 2.7.3.3). Oxygen distribution at 100±10 psig is routed to a manually operated metering valve, for direct flow into the suit inlet duct. In the full open position, oxygen will flow from 0.6 to 0.7 pound per minute.

Downstream the dual suit demand pressure regulator and relief valve, located on LHEB panel 310, compares suit compressor inlet pressure to cabin ambient pressure. When the compressor inlet pressure is 2.5 to 3.5 inches of water pressure below cabin pressure, the demand regulator controls O_2 flow into the suit circuit at flow rates up to 0.007 pound per minute. When the compressor inlet pressure is above 2 to 9 inches of water pressure above cabin pressure, the relief valve vents the suit circuit gases to the cabin at a maximum flow rate of 0.66 pound per minute. Normally the compressor inlet manifold is regulated to an average of 6.10 inches of water above cabin ambient pressure. When cabin ambient pressure is less than 4 psia, a 100 ccm bleed within the demand regulator is used to maintain the suit circuit pressure at 3.75±0.25 psia. With cabin ambient pressure below 3.5 psia and a 0.66 pound per minute suit leakage, the demand regulator should sustain suit circuit pressure at 3.75±0.25 psia. A four-position manual selector valve with control positions designated as No. 1, No. 2, both, and OFF provides isolation of a fault. The demand pressure regulator and relief valve are described in paragraph 2.7.3.3.

Oxygen regulated at 100±10-psig pressure is used as a motive force in the removal of waste water from the suit circuit and then expelled into the suit heat exchanger.

2.7.3.2 Pressure Suit Circuit Subsystem.

The pressure suit subsystem is a loop or circuit designed to supply a conditioned atmosphere for a crew of three, whether they be in or out of their PGAs. The circuit provides for ventilation and cooling for the crew, the removal of carbon dioxide and odors, and the control of relative humidity. Suit circuit pressure is maintained by controlling the amount of oxygen entering the subsystem.

A supply-return hose assembly is connected between each crewman's PGA and a suit hose connector assembly. This assembly consists of a combined supply-return connection. A three-position suit flow control valve, which diverts oxygen into the cabin when a crewmember is unsuited, and a check valve prevents return flow from the cabin. Normal operation is to disconnect the hose at the suit. There is also a venturi-type flow limiter, located upstream in each supply line, to limit flow to any one suit to a maximum of 0.7 pound per minute. During the time a crewmember is in the shirtsleeve mode, the flow control valve is positioned to permit suit circuit flow into the C/M cabin, through the suit hose, which is removed at the PGA connection. The return section of the suit hose is capped to prevent cabin gas flowing into the suit circuit when crewmen remove their suits.

Cabin gases are returned to the suit circuit for removal of carbon dioxide, odors, heat, and moisture. These gases enter at the suit circuit return air valve assembly, which consists of two check valves in series, and a manual shutoff valve for isolating the suit circuit if the cabin becomes contaminated. The combined cabin and suit circuit atmosphere first flows through the debris trap, where small particles of solid matter are removed. The trap contains a bypass valve in the event the filter screen becomes clogged.

Two suit compressors, connected in parallel, maintain circulation within the suit circuit. Normally only one compressor is operated at a time; however, both may be operated for a small advantage in sensible heat removal with a large increase in power consumption in all cases except prelaunch, or when the three crewmembers are unsuited in a 5-psia pressurized cabin. A differential pressure transducer between the inlet and outlet manifolds of the compressor supplies signals for indication on the main display console (panel 13). Compressor output is dependent on the mode of operation. In normal space operation, the operating compressor delivers approximately 35 cubic feet per minute of suit gas at a pressure rise of 10 inches of water within the condition of 4.93 psia and 88°F. When the cabin is unpressurized, the operating compressor delivers approximately 34.5 cubic feet per minute suit gas at a pressure rise of 6.9 inches of water when inlet conditions are 3.51 psia at 85°F.

The suit demand pressure regulator (figure 2.7-2) controls suit circuit pressure in normal and emergency modes. It supplies oxygen to the suits whenever the suit circuit is isolated from the cabin, and during depressurized operations. It also relieves excess gas to prevent over-pressurizing the suits.

The regulator consists essentially of two redundant demand regulators, and a relief valve. A selector valve is provided for selecting either or both regulators. Normally both are in operation.

Each regulator section consists of an aneroid control, and a differential diaphragm housed in a reference chamber. The diaphragm is connected by a rod to the demand valve. The demand valve will be opened whenever a pressure differential is sensed across the diaphragm. In operation there is a constant bleed flow of oxygen from the supply into the reference chamber,

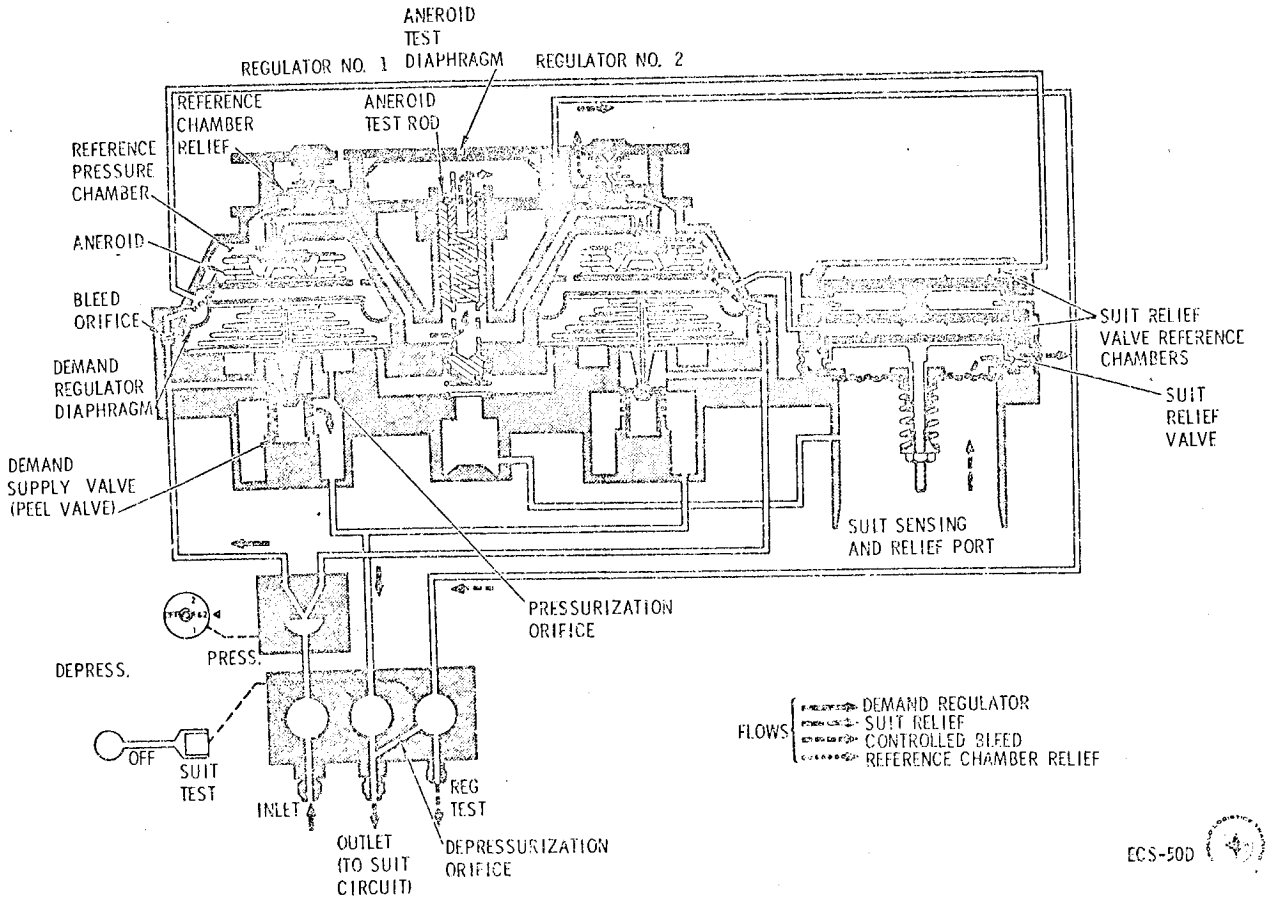


Figure 2.7-2. Oxygen Demand Pressure Regulator and Relief Valve

around the aneroid, and out through the control port into the cabin. As long as the cabin pressure is greater than 3.75 psia, the flow of oxygen through the control port is virtually unrestricted, so that the pressure within the reference chamber is essentially that of the cabin. This pressure acts on the upper side of the diaphragm, while suit pressure is applied to the underside. The diaphragm can be made to open the demand valve by either increasing the reference chamber pressure, or by decreasing the sensed suit pressure.

The increased pressure mode occurs during depressurized operations. As the cabin pressure decreases the aneroid expands. At 3.75 psia the aneroid will have expanded sufficiently to restrict the outflow of oxygen through the control port, thus increasing the reference chamber pressure.

Decreased suit pressure mode occurs whenever the suit circuit is isolated from the cabin, and cabin pressure is above 5 psia. In the process of respiration the crew will exhale carbon dioxide and water vapor. In circulating the suit gases through the CO_2-odor absorber and the suit heat exchanger, the CO_2 and water are removed. The removal reduces the pressure in the suit circuit, which is sensed by the regulator on the underside of the diaphragm. When the pressure drops approximately 2 inches H_2O below cabin pressure, the diaphragm will open the demand valve.

The regulator assembly contains a poppet-type relief valve which is integral with the suit pressure sense port. During operations when the cabin pressure is above 3.75 psia, the relief valve is loaded by a coil spring which allows excess suit gas to be vented whenever suit pressure rises 2 to 9 inches H_2O above cabin pressure. When the cabin pressure decreases to 3.75 psia, the reference chamber pressure is increased by the throttling effect of the expanding aneroid. The reference chamber pressure is applied through ducts to two relief-valve loading chambers which are arranged in tandem above the relief valve poppet. The pressure in the loading chambers acts on tandem diaphragms which are forced against the relief valve poppet. The relief portion of the valve is thus increased to 3.75 psia plus 2 to 9 inches H_2O.

Two parallel CO_2-odor absorber canisters, downstream of the suit compressors, function in the removal of carbon dioxide and odors. A removable filter within each canister contains sufficient lithium hydroxide (for CO_2 removal) and activated charcoal (for odor removal) to last 1.5 man-days of operation. This operational limit requires each filter be changed, on an alternating basis, every 12 hours. An internal bypass is incorporated within each filter to furnish the required flow during the ECS emergency mode (cabin depressurized), but will also increase the flow under normal conditions. Although 50 percent of the flow is permitted to bypass the lithium hydroxide, the total flow must pass through the charcoal filter.

The CO_2-odor absorber filter change sequence involves numerically identified filters and alphabetically identified filter stowage containers. Although the filters are replaced in numerical sequence, the stowage containers are not opened in alphabetical sequence relative to filter replacement. Odd-numbered filters will always be installed in suit circuit canister A (upper) and even-numbered filters installed in canister B (lower). After the proper filter stowage container is located by the crewman, the correct filter is obtained and the filter change accomplished. The used filter is then stowed in the container from which the unused replacement came. Where two filters are stowed one above the other, the used filter will always be placed below the remaining unused filter. This provides a more readily accessible unused filter at the next 12-hour replacement period. Filter replacement data, such as filter number and mission time, is recorded by the crew in the flight log.

A diverter valve located at the canisters inlet is normally positioned to direct gas flow through both filters. In conjunction with check valves, located at each canister outlet, repositioning the diverter valve isolates an expended filter. A manually operated vent valve for each canister allows equalization to cabin pressure prior to the removal of a filter.

Suit circuit gases, upon leaving the CO_2-odor absorber canister assembly, are at a higher temperature and humidity level than at any other point in the suit circuit. Heat has been generated in flowing through the compressors and the canister assembly. Also, the already humid gases have picked up additional moisture due to chemical reaction between the carbon dioxide and lithium hydroxide. The suit heat exchanger removes this heat and humidity from the suit gases.

Normally the heat transfer fluid, water-glycol, flowing through the suit heat exchanger removes the suit circuit heat loads to space through space radiators. A water-glycol evaporator supplements heat transfer when the space radiators are inadequate. A suit evaporator (part of the suit heat exchanger) is provided and used only in the event of an emergency. Under all other conditions the suit evaporator controls are to remain in the OFF position. The control switch (SUIT EVAP, AUTO - MAN, located on panel 13) controls electrical power to the system. This operational change will not impose added constraints on the mission; however, if the water-glycol evaporator should fail when it is required for cooling of electronics, etc., this would be sufficient cause to terminate the mission.

Should the ability of the suit evaporator system demonstrate proper operation, the control switch would be placed to the AUTO position. When water-glycol inlet temperatures to the suit heat exchanger exceed 52°F or the outlet temperatures of the suit circuit gases from the heat exchanger exceed 60°F, the suit heat exchanger is bypassed by the water-glycol flow through a diverter valve. When the automatic-controlled diverter valve is in the full bypass position, an integral switch in the diverter valve assembly is activated. The diverter valve switch activates the suit evaporator steam pressure control unit. The correct steam duct pressure is automatically

established for a given temperature error by the steam pressure control unit, pressure transducer, and the steam pressure control valve. Initial opening of the steam pressure control valve causes a switch in that valve assembly to activate the wetness control unit. Water inlet through a solenoid valve to the suit evaporator is automatically controlled by sensing the suit evaporator wetness and the temperature of the suit gases at the heat exchanger outlet. When suit gas temperatures return to normal, the evaporator mode is sequencially deactivated and water-glycol flow is re-established. By overriding the suit gases temperature sensor at the outlet of the heat exchanger the system may also be activated, providing the SUIT EVAP control switch is in the AUTO position. Simulated high heat load is initiated by the SUIT HT EXCH switch (LHEB-310).

As the moisture-laden suit gases are cooled, condensation takes place within the heat exchanger. This moisture is absorbed by a wick-like material, removed by capillary action and the suction of the H_2O accumulator, and pumped into the waste water system.

The two accumulators are automatically controlled, self-cycling, reciprocating pumps. Oxygen at 100±10 psig periodically activates the pumps on the expulsion stroke, while a return spring is utilized for the suction stroke. Only one accumulator can be operated at a time with the second for standby use in the event of a malfunction. A manual backup mode of accumulator operation is also incorporated. Following the discharge of suit circuit gases from the suit heat exchanger, the normal flow is to the three suit hose connector assemblies. A suit flow relief valve is incorporated in the bypass line between the outlet of the suit heat exchanger and the inlet to the suit compressor. The valve opens at a ΔP of 5.0±0.2 in. H_2O and automatically maintains a nearly constant flow in the event of suit circuit flow resistance fluctuations.

2.7.3.2.1 CO_2 Sensor.

The CO_2 sensor, situated between the inlet and outlet manifolds of the suit circuit, is a compact unit that operates on the infrared absorption principle. The unit measures the amount of infrared energy absorbed by the CO_2 in the atmospheric sample passing through the sensor. This is accomplished by comparing two different wavelengths in the infrared spectrum. One wavelength is absorbed by CO_2, while the other acts as a reference. This establishes a ratio signal which is amplified and reads out as a d-c voltage proportional to the partial pressure of CO_2 in the sample gas.

The sensor is divided into the optics section and the electronics section. The optics section includes an infrared energy source (a small tungsten filament lamp), and optical lenses and mirror for focusing the beam through two wavelength filters and the atmospheric sample onto a detector. Both wavelength filters (4.3 microns for sampling and 4.0 microns for reference) are attached to a tuning fork which vibrates at

600 cycles per second. The filters move back and forth across the focused light beam, alternately transmitting energy at the sample and reference wavelengths.

The basic purpose of the electronics section is to detect and transform signal information. Miniaturized components are mounted on seven printed circuit boards, which accomplish all the electrical functions. These functions include supplying the power for the infrared source lamp and the operation of the tuning fork, the detector, and the various preamplifiers and amplifiers. The output signal activates the CO_2 PP HI systems status light (MDC-11) and the CO_2 PART PRESS indicator (MDC-13).

2.7.3.2.2 Gas Chromatograph.

The gas chromatograph is an item of GFE that is installed in several of the Apollo Block I spacecraft for flight qualification purposes. The unit is capable of identifying and measuring the concentrations of 28 gas components, and the resulting data is then telemetered to MSFN. This compact item of equipment is installed in the LEB, and it interfaces the inlet and outlet manifolds of the suit circuit in the LHEB.

The gas chromatograph operates on the basic principle of routing samples of the suit circuit and/or cabin atmosphere through three separate capillary columns and detectors. Low-pressure helium is used as the carrier gas for the sample streams. The helium supply, even under continuous demand, will last the length of any proposed mission. The helium is stored in a reservoir at 6000 psig and is regulated to its normal working pressure of 42 psia. In the event of regulator malfunction, pressure relief is provided by a 200-psig rupture disc. Each capillary column and detector identifies a specific number of gas components. One column-detector will identify five of the permanent gases; namely, hydrogen, nitrogen, oxygen, methane, and carbon monoxide. Another is concerned only with the separation and detection of ammonia, carbon dioxide, and water. The third column-detector identifies 20 trace contaminants listed as follows: Freon II, methyl alcohol, methylene chloride, ethyl alcohol, benzene, P-dioxane, acetone, hydrochloric acid, hydrogen sulfide, ethylene oxide, isoprene, diethyl sulphide, nitrogen dioxide, ethylene glycol, vinylidene chloride, methyl chloroform, acetylene, dimethyl sulfide, Freon 114, and 1, 1 trichloroethane.

Cross-section ionization-type detectors are used in conjunction with the three columns for gas component identification. The output current of the detectors produces a minimum-strength signal that must be greatly amplified, then conditioned for telemetry. The capillary columns, the detectors, and the electrometer amplifiers are housed in an oven, the temperature of which is maintained within a very close tolerance. The balance of the electronics, installed in a separate package, consist of a transformer, a programmer, and a regulated power supply. Solid-state circuitry is used exclusively throughout the electronics of the unit.

The gas chromatograph will complete one identification cycle in approximately 80 minutes, regardless of the sampling mode selected. Samples are taken from the suit circuit atmosphere, the cabin atmosphere, or from each atmosphere on alternating cycles depending on the positioning of a selector switch located on the LEB panel 120. The selector switch may be positioned to CABIN AIR/AUTO/SUIT AIR by command.

The gas chromatograph is serviced and installed by ground support personnel prior to flight crew ingress.

A three-position START/OFF/PREHEAT switch, controls power for operation, and must be placed to the PREHEAT position for a minimum of 80 minutes before switch is set to START. A push-type switch, AMPL-CAL, for bench calibration only and the START/OFF/PREHEAT switch, are located on panel 120.

During the mission, the flight crew will not be required to make control adjustments to the unit unless directed to do so by MSFN. During descent, the remaining helium in the reservoir is dumped into the cabin by the action of a pyro valve inside the unit. A full tank (abort condition) can be emptied in a maximum of 3 minutes. Pyro valve initiation is simultaneous with the C/M-RCS propellant purge operation.

2.7.3.3 Cabin Pressure and Temperature Control Subsystem.

The pressurization and temperature control of the C/M cabin are primarily automatic functions with manual backup and override modes provided. Cabin pressurization is maintained by the cabin pressure regulator assembly (figure 2.7-3). This unit consists of dual regulators and a manual repressurization valve operated by a knurled knob. Both regulators operate simultaneously as there is no selector valve incorporated and no off position. The regulators automatically maintain the cabin at 5±0.2 psia during normal conditions and at a maximum oxygen flow rate of 1.3 pounds per hour. If the cabin should become depressurized for any reason, the regulators close at a pressure of 3.5 psia to conserve oxygen. The manual valve, with a maximum flow rate of 7.2 pounds per hour, may be adjusted to maintain cabin pressure in event of regulator malfunction. However, it is primarily used to repressurize the cabin following decompression, requiring approximately 1 hour to raise the cabin pressure back to 5.0±0.2 psia.

An emergency cabin pressure regulator assembly (figure 2.7-4) will flood the cabin with oxygen to prevent rapid decompression in the event of cabin wall puncture. As cabin decompression is hazardous to life only when a crewman is in the shirtsleeve mode, the regulators are not selected for use until just prior to a crewman removing his PGA. The regulator

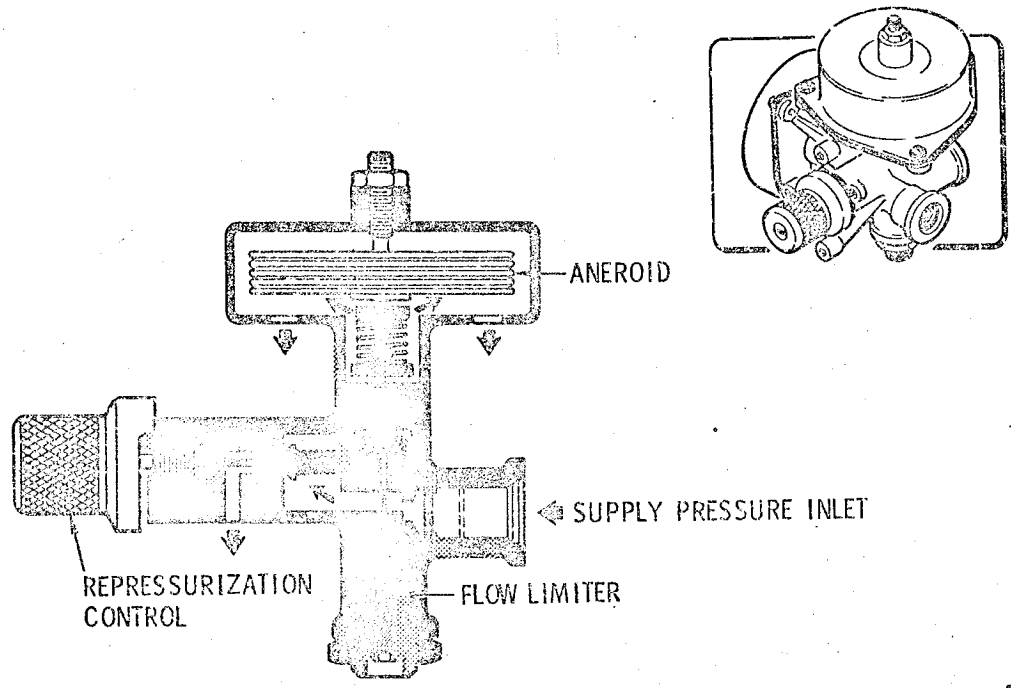


Figure 2.7-3. Cabin Pressure Regulator

assembly consists of a four-position manual selector valve and two redundant regulators which, when selected for use, automatically open when the cabin pressure drops to 4.5±0.1 psia. The emergency cabin pressure mode of 3.5 psia is contingent upon Apollo design limits and meteorite tests and allows unsuited crewmen time to don their PGAs. This minimum pressure can be maintained for 5 minutes, providing that meteorite holes do not exceed the total equivalent area of a hole 0.5 inch in diameter. At the end of this time, the pressure will drop more rapidly, going to 2.0 psia in 10 minutes and to 1.0 psia in 15 minutes.

The dual cabin pressure relief valve (figure 2.7-5) provides positive and negative pressure relief for the cabin throughout the entire mission. Although they function automatically, cable-operated manual override controls, located on panel 307, are provided for adjustments during flight to close relief valves for a malfunction, or to prevent sea water inflow during postlanding phase and ground checkout procedures. When the cabin pressure becomes higher than the external ambient pressure, the relief valves limit the differential pressure to 6 (+0.2, -0.4) psi. During the ascent phase, this differential pressure may go as high as 7.0 psi for a short period of time. Conversely, when the cabin pressure becomes lower than the external ambient pressure (as during descent), the relief valves limit the differential pressure to a maximum of 25 inches of water. The assembly is located in the steam duct overboard line which provides the means of venting the positive and negative cabin pressures.

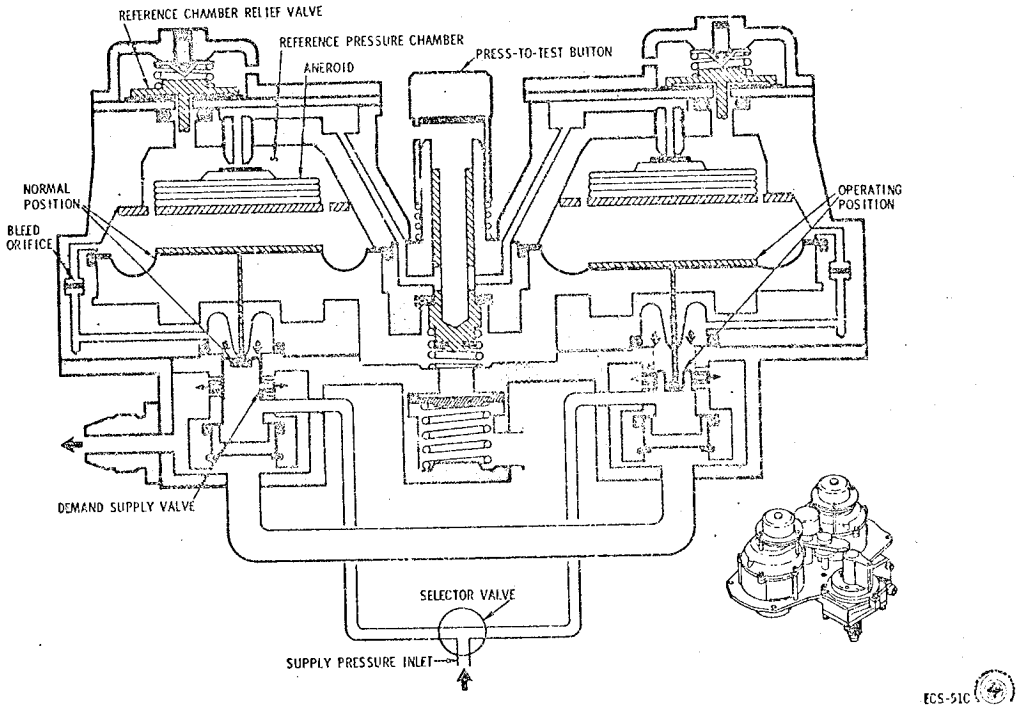


Figure 2.7-4. Emergency Inflow Regulator

Ventilation within the C/M is provided by dual fans, which circulate cabin gases through the cabin heat exchanger. Normally, both cabin air fans are selected by the crew for simultaneous operation. If either fan malfunctions or is shut down for any reason, a closure (cover) is manually installed over the inlet of the inoperative fan to prevent backflow. A cabin air control louver, located at the outlet of the cabin heat exchanger, is manually adjusted for directional flow of gases within the cabin.

Although cabin temperature control is normally an automatic function, resort to manual backup and override modes of operation may be utilized. Cabin gases are heated or cooled by their circulation through the cabin heat exchanger, which uses water-glycol as the heat transfer medium. A cabin temperature control unit compares a desired temperature, selected by the crew, to the temperature that is sensed at the inlet to the cabin air fans. Any difference results in a signal that repositions the motor-operated cabin temperature control valve. This valve regulates the amount of hot or cold water-glycol flowing into the cabin heat exchanger. At each end of valve full travel, the total hot or cold flow is routed through the heat exchanger; whereas, at intermediate valve positions, the water-glycol flow through the heat exchanger varies. A cabin temperature anticipator, located at the cabin air control louver discharge, senses the temperature rate of change and signals the cabin temperature control unit, preventing overcorrection by the control valve.

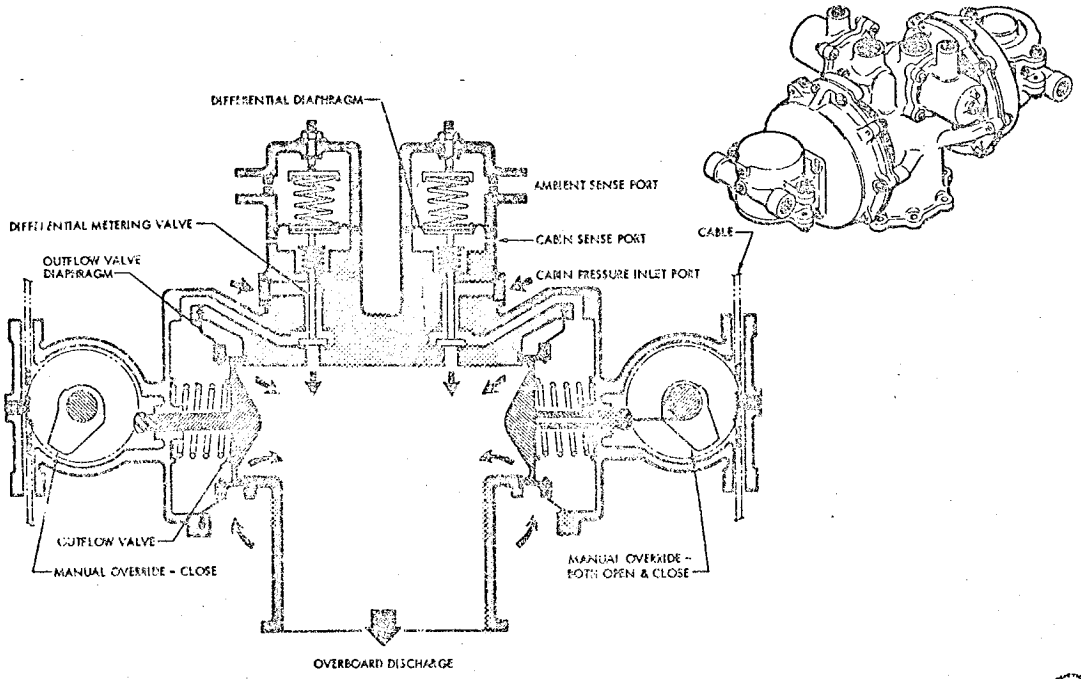


Figure 2.7-5. Cabin Pressure Relief Valve

Ventilation during the postlanding phase is accomplished by circulating outside ambient air through the cabin. All of the equipment necessary to carry out this function (other than controls) is located on the C/M forward tunnel cover. Outside air is drawn into the cabin through an inlet duct containing a shutoff valve and fan. The inlet duct includes a flexible extension for promoting more efficient ventilation. After circulating within the cabin, the air is expelled overboard through an adjacent outlet duct and shutoff valve. Both motor-operated shutoff (vent) valves and the vent fan are controlled by the VENT FAN switch on MDC-25. High- or low-speed fan operation is available, and either switch position will simultaneously activate the fan and open the cabin vent valves. An assembly consisting of a pendulum-type attitude sensing switch and an adjacent override control switch (PLVC) are installed in the LHEB. The pendulum is free to move only in the Z-axis. Should the C/M roll beyond a specified limit or become inverted (stable II condition), the attitude sensing switch activates the cabin vent valves to the closed position to prevent water ingestion. If all efforts to return the C/M to the upright (stable I) condition should fail, the PLVC switch (LHEB-141) is set to OPEN. This overrides the closing action of the attitude sensing switch by opening both cabin vent valves and flooding the forward portion of the C/M. The pressure on the tunnel hatch then becomes equalized, thus allowing its removal for the escape of the crew. The PLVC switch may also be used to open the cabin vent valves if the attitude sensing switch should fail after having closed the valves. In order to prevent the inadvertent opening of the vent valves in flight, two precautions are taken. A lockpin is installed in each vent valve, and the circuit

breaker applying power to the PLV system is not engaged during flight. Therefore, before the PLV system can be operated, the lockpins must be removed (pulled out approximately 0.5 in.) prior to CSM separation and the applicable circuit breaker engaged after landing.

2.7.3.4 Water-Glycol Coolant Subsystem.

The water-glycol coolant subsystem is a closed loop through which an aqueous ethylene-glycol mixture (water-glycol) is continuously circulated. The mixture ratio by weight consists of 62.5 parts of glycol to 37.5 parts of water. Basically, the subsystem provides a heat transport fluid loop for the cabin atmosphere, the suit circuit atmosphere, the electronic equipment, and a portion of the potable water. It also serves as a source of heat for the cabin atmosphere when required. All of the unwanted heat absorbed by the water-glycol is transported either to the space radiators, where it is radiated to space, or to the water-glycol evaporator, where it is rejected by the evaporation of water.

The water-glycol (W/G) evaporator outlet temperature must be maintained between 40° and 43°F (nominal 41.5°F). Sensed at the W/G evaporator inlet from the space radiators W/G temperatures between 42.9° and 45.9°F (nominal 45°F) activates the automatic mixing valve control system (figure 2.7-6). High-temperature W/G from the water-glycol pump is mixed with the lower W/G temperature from the space radiators to maintain the evaporator outlet nominal temperature of 41.5°F. The manual override for the mixing valve is located on the coolant control panel 311 (GLYCOL EVAP TEMP IN) and a switch located on panel 13 allows selection of AUTO or MAN operation.

Three lines from the water-glycol pump assembly are paralleled to the water-glycol evaporator inlet. The aforementioned oxygen supply capillary restrictors are wound around the line routed to the space radiators and relief valves. The other line is routed to the mixing valve. To insure proper operation of the oxygen supply restrictors, in the line between the cryogenic O_2 storage in the S/M to the surge tanks in the C/M during cabin repressurization, full water-glycol flow through the line to the space radiators is required. Sufficient heat must be available to prevent cryogenic oxygen entering the C/M oxygen system and preclude the possibility of freezing the water-glycol. To achieve this, the mixing valve must be manually placed to the full closed position 15 to 30 minutes before repressurization and remain closed until the surge tank returns to maximum pressure after repressurization of the C/M.

High-temperature water-glycol between 48° and 50.5°F from the space radiators and sensed at the evaporator inlet initiates the water-glycol evaporator temperature control system. Once the evaporator mode is initiated by the evaporator inlet sensor, an evaporator outlet sensor supplies the controlled variable signals to the controller. If a heating temperature error is sensed by the evaporator outlet sensor, the steam pressure valve begins to open and repositions at a velocity proportional to

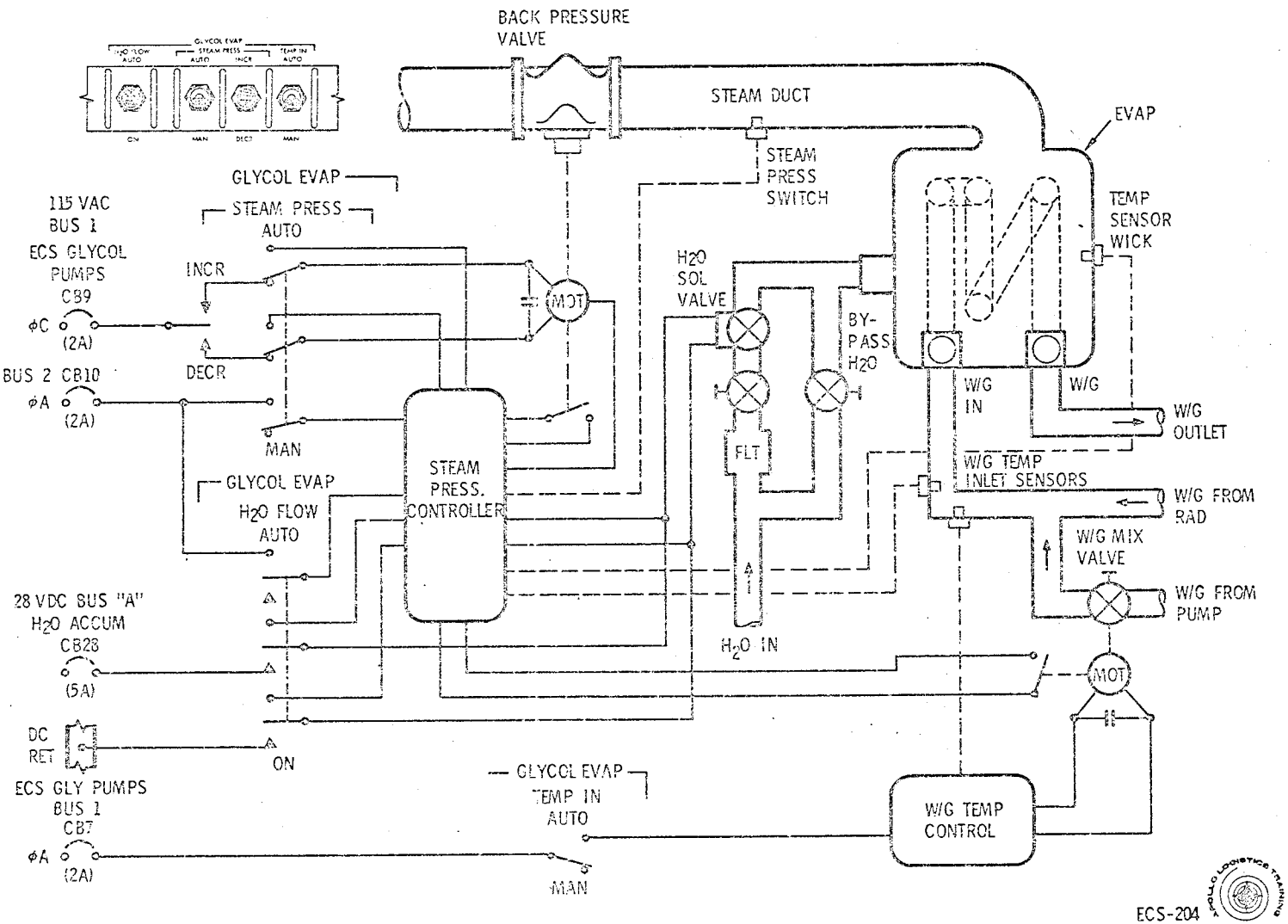


Figure 2.7-6. Water-Glycol Evaporator Temperature Control

the temperature error. Evaporator wicks are maintained in a wet condition to provide immediate boiling when the steam pressure valve is opened. Should the steam pressure drop below 5.0±0.2 mm Hg abs, a pressure switch overrides the temperature signal and closes the steam pressure valve. The override pressure switch provides adequate pressure margin above the freezing pressure of 4.58 mm Hg abs. A switch in the steam pressure valve assembly is activated when the valve is initially cracked open. The switch activates the wetness control for replenishing water to the evaporator through a water-solenoid control valve. Signals from the wick temperature sensor are indicative of the relative wetness of the evaporator wicks. As water evaporates, the wick sensor temperature increases and exceeds an evaporator inlet reference sensor signal and cycles the water control valve open. The reference input sensor varies the control as a function of heat load to maintain the desired wick temperature with no water carryover into the steam duct. When the evaporator wicks become replenished with water, the wick sensor temperature decreases and approaches the saturation temperature corresponding to the steam pressure and cycles the water control valve closed. The water control valve continues to cycle as long as water-glycol cooling by water evaporation is required.

The steam pressure control valve can be electrically repositioned to control the steam pressure for 40° to 43°F outlet glycol temperature using the pressure monitor indicator (panel 13, GLY EVAP-OUTLET TEMP). The control switches (GLYCOL EVAP - STEAM PRESS) must be placed to the MAN position, and then to INCR for open and DECR for closing the steam pressure valve. The H_2O FLOW switch (panel 13) should be in the AUTO position for the automatic wetness control to be effective. Should the wetness control fail, the water inlet control valve can be energized open by placing the H_2O FLOW switch to ON. When operating in this mode, a portable indicating unit should be used to prevent water carryover into the steam duct. The portable indicating unit consists of a four-position selector switch for selecting OFF, WICK TEMP., EVAP INLET TEMP. AND NUL. The unit has its own 175-hour battery-operated power supply. WICK TEMPERATURE indicator markings are 40° to 70°F, WATER-GLYCOL INLET TEMPERATURE indicator markings are 40° to 100°F, and the NUL indicator markings are a red line across the midlength section of the dial face and is marked above the red line on the dial WATER ON, and below on dial WATER OFF. A water control tabulation chart (figure 2.7-7) for operation of W/G evaporator in the manual mode, is provided showing wick temperature versus inlet glycol temperature. The portable indication unit should also be used when manual water bypass control valve (GLY EVAP WATER CONTROL BYPASS panel 317) is used. The portable indicator unit will connect to J39 (panel 311). The main water-glycol flow next enters the cabin temperature control valve, where it is routed either to the cabin heat exchanger or to the remaining thermal coldplates. The action is dependent upon the temperature control unit, which automatically controls the movements of the motor-operated cabin temperature control valve. The valve is so constructed that in the cabin full cooling mode, the total flow of cool water-glycol (167 pounds per hour) is routed first through the cabin

Evaporator Inlet Temperature Sensor (°F)	Wick Temperature Sensor (°F)	Evaporator Inlet Temperature Sensor (°F)	Wick Temperature Sensor (°F)
40	41.62	71	54.63
41	42.13	72	54.96
42	42.65	73	55.28
43	43.15	74	55.60
44	43.65	75	55.91
45	44.14	76	56.21
46	44.63	77	56.51
47	45.11	78	56.80
48	45.58	79	57.08
49	46.04	80	57.37
50	46.50	81	57.66
51	46.95	82	57.93
52	47.39	83	58.19
53	47.82	84	58.46
54	48.25	85	58.71
55	48.67	86	58.96
56	49.08	87	59.21
57	49.49	88	59.46
58	49.89	89	59.71
59	50.30	90	59.94
60	50.39	91	60.17
61	51.07	92	60.40
62	51.45	93	60.63
63	51.83	94	60.85
64	52.20	95	61.06
65	52.56	96	61.28
66	52.92	97	61.49
67	53.27	98	61.69
68	53.62	99	61.90
69	53.96	100	62.10
70	54.30		

Figure 2.7-7. Water Flow Control Chart

heat exchanger and then through the thermal coldplates. In the cabin full heating mode, the total flow is routed through the thermal coldplates first, where the water-glycol absorbs heat, and from there flows through the cabin heat exchanger. The intermediate valve positions are for the partial cooling or partial heating modes. In the intermediate positions, the quantity of cool or warm water-glycol flowing through the heat exchanger is reduced in proportion to the demand for cooling or heating. Although the amount of water-glycol flowing through the cabin heat exchanger will vary, the total flow through the thermal coldplates will always be 200 pounds per hour. (See figure 2.7-8.) An orifice restrictor is installed between the cabin temperature control valve and the inlet to the coldplates. Its purpose is to maintain a constant flow rate through the coldplates by reducing the

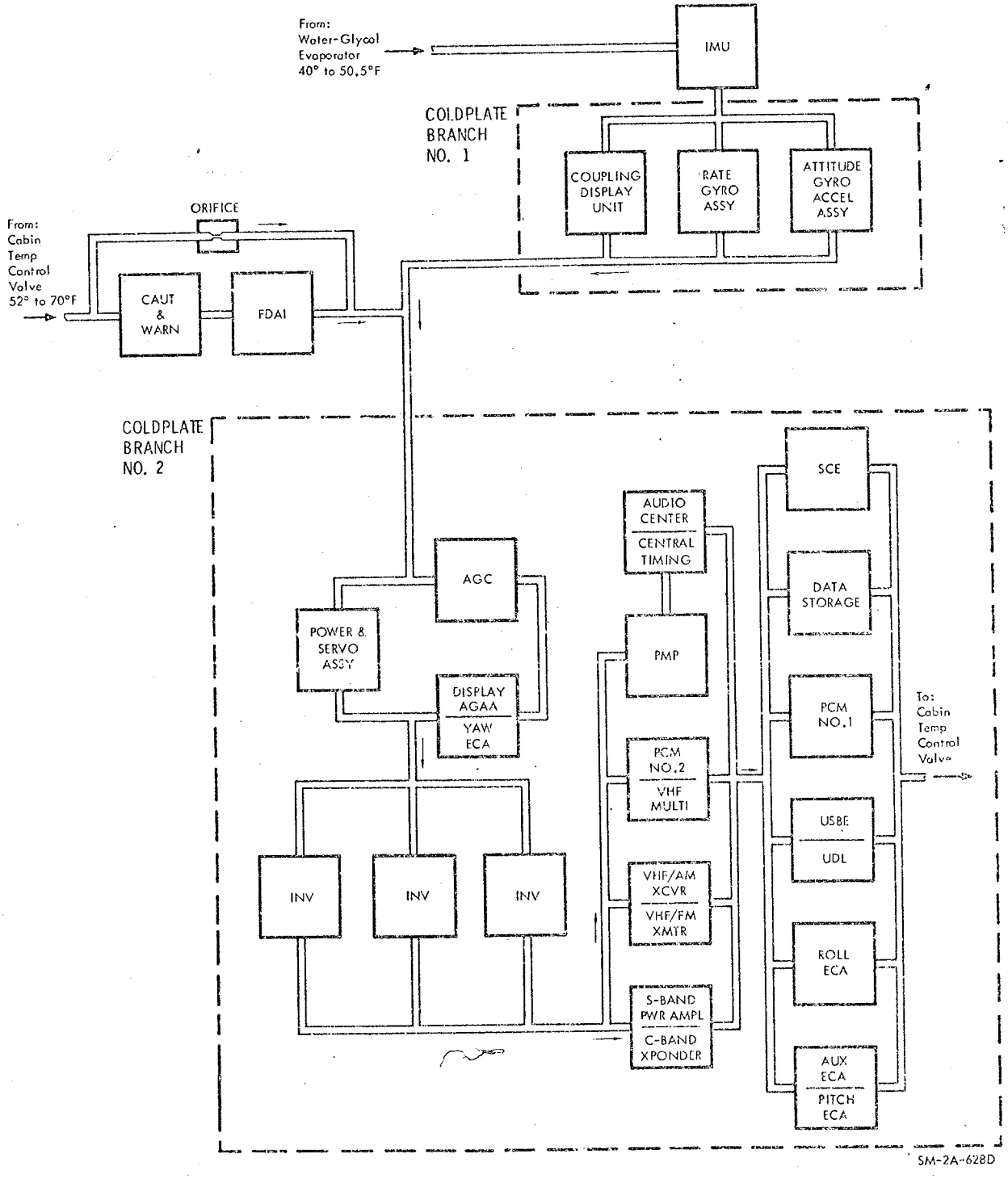


Figure 2.7-8. Equipment Coldplate Flow Diagram

heating mode flow rate to that of the cooling mode flow rate. Another orifice restrictor, located in the coolant line from the IMU, maintains a constant flow rate through this component regardless of system flow fluctuations.

The total flow leaving the cabin temperature control valve enters the water-glycol pump assembly which provides the continuous coolant circulation within the subsystem. The assembly consists of two water-glycol pumps, two pump outlet check valves, a full-flow filter, an accumulator, and an accumulator isolation shutoff valve. The two pumps, mounted in parallel, can only be operated one at a time with the second pump for standby redundancy. Each pump outlet check valve prevents coolant backflow through the nonoperating pump. Water-glycol entering the assembly first passes through the full-flow filter before reaching the pumps. There is also a side passage that leads to the accumulator.

The purpose of the accumulator is to maintain correct pump inlet pressure and to compensate for small amounts of leakage and/or thermal expansion/contraction. The manual shutoff valve in the side passage is closed to isolate the accumulator in case of a punctured bellows, which would permit the coolant to leak into the cabin, causing contamination. If the water-glycol accumulator quantity indicator on the main display console shows a steady decay to zero, a leak in the water-glycol system is the probable cause. However, an indication showing a slow steady decrease, which stops at a point above zero, is probably due to thermal contraction indicating the water-glycol temperature is below the nominal range. Located downstream of the pump assembly is the water-glycol pump outlet pressure transducer which measures the static pressure of the water-glycol at the pump outlet, thus giving an indication of pump performance.

At this point in the subsystem, the temperature of the water-glycol has greatly increased due to the absorption of the various heat loads. The total flow of hot water-glycol is routed through a passage in the steam pressure control valve to prevent ice from forming within the valve opening. Icing at this location could result in valve malfunction and/or blocking of the steam duct. To prevent ice from forming at the outlet of the steam duct, two redundant electric heaters are used. The two 3-watt heater elements inside the duct extend approximately 8 inches upstream from the outlet.

The water-glycol next flows to the water-glycol evaporator inlet temperature control valve (previously described). The hot water-glycol that is not used for mixing by this valve is routed to the space radiators for cooling. Any pressure losses in the space radiator circuit, regardless of the number of radiators in operation, will be limited by the action of the dual water-glycol pressure relief valves. These two valves are in parallel and are located between the inlet and outlet lines of the radiator circuit. Just upstream of each pressure relief valve is a manual shutoff valve. By controlling the shutoff valves, one relief valve at a time is normally selected for use with the second for standby redundancy. When a ΔP of

11 psi is reached, the relief valves open to bypass coolant to the radiator return line, closing at a ΔP of 8.5 psi. In order to preserve the water-glycol closed loop, the relief valves function as a bypass when all space radiator isolation valves are closed or when the water-glycol radiator shutoff valve is closed. This is a manual shutoff valve that controls the flow of water-glycol from the C/M to the S/M. It is placed to the closed position shortly before CSM separation to prevent the coolant in the C/M from flowing overboard after separation.

Two space radiators with an area of 30 square feet each are located on opposite sides of the S/M in sectors II and V. Each radiator panel contains two separate sets of tubes. The flow of water-glycol through the four tube circuits is individually regulated by a motor-operated radiator isolation valve located on the inlet side of each tube circuit. The four valves are remotely controlled from the C/M and give the crew some degree of latitude in their selection of cooling area. However, the primary purpose of the valves is to isolate tube circuits should they develop leaks. A check valve in each tube circuit outlet line prevents the backflow of coolant from entering any radiator tube circuit that is leaking. Freezing within the radiators is the point at which flow ceases, and may be prevented by maintaining the inlet temperature above 75°F. This temperature is obtained on the AUX DC VOLTS meter (RHFEB-200) or from MSFN if the crew is unable to leave the couches.

The water-glycol, after leaving the space radiators and re-entering the C/M, flows through a capillary restrictor. This is placed in the line to make the pressure drop through the radiators compatible with that through the water-glycol temperature control valve during the mixing mode. Upon leaving the restrictor, the water-glycol flows through two check valves in series. These valves prevent coolant from flowing overboard following CSM separation. A temperature sensor, located between these check valves, gives an indication on the main display console of the temperature of the coolant leaving the radiators. The indicator is located on MDC-13.

Under normal space flight conditions the water-glycol reservoir is isolated from the coolant subsystem by the proper positioning of three glycol reservoir manual shutoff valves. The water-glycol reservoir inlet and outlet valves are closed, and the reservoir bypass valve between the inlet and outlet lines is opened. During the prelaunch and ascent phases, however, the position of these three valves is reversed to permit coolant flow through the reservoir. The one gallon of water-glycol contained in the reservoir is then utilized as a heat sink, which becomes necessary during the ascent phase. The space radiators are not effective during ascent and evaporative cooling takes place only after the ambient pressure reaches 0.05 psia, which is approximately 150,000 feet altitude (T + 2 minutes and 10 seconds).

If a water-glycol leak should occur, the coolant subsystem may be refilled from the limited supply in the water-glycol reservoir after the leak is isolated. The glycol reserve shutoff valve, located in the line from

the reservoir to the inlet side of the pump, is used for this purpose. As the reservoir contains a bladder that is under 20±2 psig oxygen pressure, positive expulsion of the coolant is assured. The pressurized reservoir may also serve as an accumulator for the coolant subsystem, if the regular water-glycol accumulator becomes inoperative and is isolated. The flow of water-glycol, either through the reservoir or bypassing it, next enters the water-glycol evaporator (previously described), thus completing the coolant loop.

During prelaunch operations, the flow of temperature-controlled water-glycol is furnished by GSE through lines connected to the fill and vent couplings in the S/M. The solenoid-operated water-glycol shutoff valve, upstream of the outlet coupling, is controlled at the GSE and is opened to permit coolant flow through the spacecraft loop and back to the GSE.

2.7.3.5 Water Supply Subsystem.

The primary function of the water supply subsystem is the storage and collection of potable and waste water. Potable water produced by the fuel cells and waste water recovered from the suit heat exchanger water separator are stored in separate tanks in the C/M. Supplementing this supply are two water tanks in the S/M that contain potable water for refilling the C/M potable water storage tank. The water supply subsystem also supplies hot and cold potable water to the crew and waste water to the water-glycol evaporator and suit heat exchanger for evaporative cooling.

The water produced by the fuel cells in the S/M is a steady source of potable water and is stored in a 36-pound capacity tank located in the aft compartment of the C/M. The tank, which contains a bladder, is pressurized with oxygen at 20±2 psig by the tank pressure regulator and relief valve assembly, thus assuring positive expulsion of fluid. Fuel cell water flows into the tank at a potential pressure of approximately 61.5 psia, which is high enough to overcome the tank pressure. The potable water tank may be serviced before flight by the manually operated servicing valve, which is also in the aft compartment and not accessible to the crew. A quantity indicator on the main display console gives the measurements obtained by the tank quantity transducer. Located in a water line between the fuel cells and the potable water tank is a check valve and the potable tank inlet shutoff valve. The check valve prevents any reverse flow of potable water. The shutoff valve, when closed, prevents fuel cell water that has become contaminated from entering the C/M potable water network.

Temperature-controlled potable water is available to the crew from two components within the C/M. Cold water, which is maintained to 50°F (at the water chiller), is available at both the food preparation water supply unit and the water delivery unit. Hot water, however, is available only at the food preparation water supply unit. This component utilizes a small tank with an electric heater to raise the water temperature to 154°±4°F. By selecting the proper valve, hot or cold water is metered out for food reconstitution or other crew needs. The water delivery unit is used by the

crew exclusively for drinking purposes. It consists of a housing containing a coiled flexible tube and a water delivery valve for use with the individual mouthpieces of the three crewmen. Upstream of this unit is the drinking water supply shutoff valve that is closed if the water delivery valve should leak.

Waste water collected from moisture condensate within the suit heat exchanger is drawn into one of the cyclic accumulators and from there pumped into the waste water network. If, however, there is a water demand by either the water-glycol evaporator or the suit heat exchanger evaporator, the waste water flows directly to the water control valve of the appropriate evaporator. The 56-pound capacity waste water tank contains the pressurization and quantity measuring features of the potable water tank. A servicing valve is located on the water control panel in the C/M cabin and, therefore, is accessible to the crew, if necessary.

Although waste water never enters the potable water network, potable water may enter the waste water network under certain conditions. If the potable tank becomes full, the differential pressure between the networks will eventually overcome the 6.0±0.5 psi at the waste tank inlet valve, thus permitting water flow. Potable water also enters the waste water network if the waste tank is empty and there is a water demand by either evaporator. The low pressure created by this water demand is responsible for waste tank inlet valve activation. The valve also incorporates a manual shutoff feature for use if the relief valve portion malfunctions. Closing the valve thus prevents the premature dumping of potable water into the waste water network. A check valve, located downstream of the relief valve, separates the potable and waste water networks by permitting flow in one direction only.

To prevent overpressurizing the water supply subsystem, a pressure relief assembly is installed downstream of the check valves that separate the potable and waste water networks. The assembly consists of a selector valve and two redundant pressure relief valves in parallel. When the potable and waste water tanks are full, the continued supply of water produced by the fuel cells will be dumped overboard by these relief valves. Normally, both valves are selected for simultaneous use, and dumping occurs when the water pressure reaches approximately 32 psi above the outside ambient pressure. Another line, with two check valves in series, bypasses fuel cell water output directly to the pressure relief assembly. However, this action will take place only in event the waste tank inlet valve fails closed. The bypass prevents fuel cell water flow from being blocked, thereby preventing total fuel cell failure due to flooding within the cells.

To provide sufficient water for a maximum duration earth orbital mission, two 56-pound water tanks are installed in the S/M. These tanks are similar to the C/M waste water tank but lack the quantity measuring capability. A separate tank pressurizing system is used for positive expulsion of the water. Nitrogen at 900 psig is stored in a small tank that is protected against overpressure by a relief valve set at 1045±25 psig. In

addition to a nitrogen fill valve, there is a pressure regulator and relief valve to reduce and regulate nitrogen pressure in the water tanks. These tanks are pressurized at 40±2 psig, and the relief valve will function at 44 to 48 psig.

At the water outlet of each tank, there is a manual fill valve and a solenoid shutoff valve. The shutoff valves are controlled by the WASTE H_2O TK REFILL switch in the C/M. These valves control the flow of water from the tanks to a common line in the S/M that subsequently connects into the potable water line from the fuel cells. When the C/M potable water tank quantity is low, it will be refilled from these S/M water tanks at a flow rate of 2.92 pounds per minute.

2.7.3.6 ECS-Waste Management System Interface.

Although the waste management system (WMS) and C/M battery venting network are not subsystems of the ECS, they will be covered as such in the AOH because of system interface. The interface mentioned is in reference to the ECS water overflow line. All of the urine and the fecal odors of the WMS, as well as gas pressure from the C/M batteries, are also routed overboard through this single ECS water dump line. Incorporated at the outlet of the dump line (urine/water) is a 0.055 inch orifice nozzle that restricts gas flow to a maximum of 1 cfm and liquid flow to less than 1 cfm. The gas flow is limited to prevent excessive loss of cabin atmosphere during fecal canister usage. The restriction on liquid flow, in conjunction with a 5.7-watt, continuously operating dump nozzle heater, prevents the formation of ice at the nozzle, which could block all flow.

The function of controlling and/or disposing of waste solids, liquids, and gases is accomplished by the WMS. Except for the fecal canister and other items of stowed equipment, the major portion of the system is located in the RHEB. The WMS is basically divided into the urine/fecal and the vacuum cleaner subsystems. Several components that are no longer functional have not been removed from the WMS, as shown in figure 2.7-9. This is due to recent modifications that would not permit their removal because of schedule impact.

The components for the urine portion of the urine/fecal subsystem consist of a separate urine sample volume measuring system unit (USVMS) for each crewmember. (Refer to section 5.) The unit is used for each urination in order to provide a urine sample, with the remainder of the contents being dumped overboard in the following manner. The USVMS is first attached by quick-disconnect to an inline filter, which remains attached (by quick-disconnect) to the waste management dump line. The USVMS valve is set to the DUMP position, followed by setting the WASTE MANAGEMENT-SELECTOR valve on RHEB-201 to URINE FECES and the adjacent OVBD DRAIN valve to DUMP. A 5-psi differential pressure, provided by the valve settings, will empty the contents of the collection bag overboard through the urine/water dump line. Should a USVMS unit fail, direct overboard urination may be accomplished by using the urine

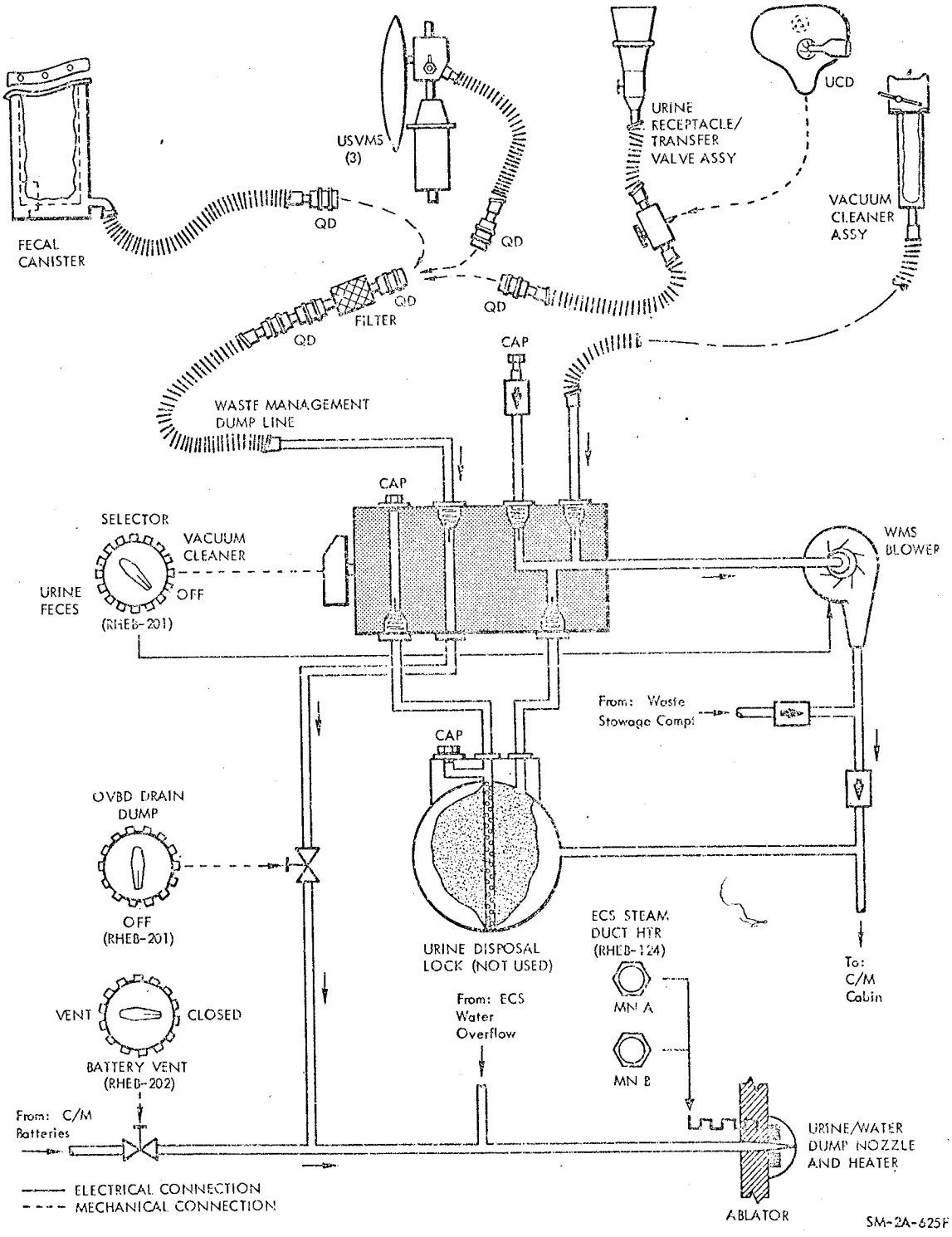


Figure 2.7-9. WMS Functional Flow Diagram

receptacle, which is a backup component. The PHA urine collection device (UCD) may be used during prelaunch, and if so, is emptied in much the same way. The transfer valve (of the urine receptacle/transfer valve assembly) is inserted into the UCD after it is removed from the PGA. The urine receptacle is then attached by quick-disconnect to the filter on the waste management dump line. The WASTE MANAGEMENT-SELECTOR and OVBD DRAIN valves are set to the URINE FECES and DUMP positions respectively, emptying the contents overboard. Upon completion, the PGA UCD is stowed in the PGA stowage bag. Although the WMS blower will operate whenever the SELECTOR valve is set to the URINE FECES position, functional operation of the blower is for vacuum cleaning only.

For the fecal portion of the urine/fecal subsystem, components consist only of the fecal canister and hose assembly. Normally stowed out of the way, the canister is secured to the center CO_2-odor absorber filter storage container at the LEB. The hose is then attached by quick-disconnect to the filter on the waste management dump line. The WASTE MANAGEMENT-SELECTOR valve is set to URINE FECES and the OVBD DRAIN valve is set to DUMP. Differential pressure of 5 psi is thus created, routing the odors overboard through the urine/water dump line.

The vacuum cleaner subsystem is made up of the vacuum assembly and an 8-foot flex hose, which are stowed in the vacuum stowage compartment. After removing the vacuum cleaner from the storage compartment, it is placed in operation by setting the WASTE MANAGEMENT-SELECTOR valve to VACUUM CLEANER. This single action activates the WMS blower and opens the valve port that connects the vacuum cleaner line to the blower. The WMS blower provides a gas flow of 5 cfm at a ΔP of -4.9 inches H_2O to effectively remove debris, either solid or liquid. A porous bag, inserted into the vacuum assembly, traps the debris while the gases are exhausted into the C/M cabin.

The C/M battery venting network consists of a manifold, a BATTERY VENT valve (RHEB-202), and lines that are routed to connect into the urine/water dump line. The vent valve is to remain in the VENT position during normal operation to provide unrestricted flow for intermittent battery relief valve operation. Only in event of a battery case rupture or vent manifold leakage will the vent valve be closed. This prevents loss of cabin atmosphere overboard, thereby, conserving oxygen.

2.7.3.7 Electrical Power Distribution.

The types of electrical power required for the operation of the ECS are 28 volts dc and 115/200-volts 400-cycles 3-phase ac. (See figure 2.7-10.) The larger motors of the system utilize 200-volt 3-phase power, whereas the smaller motors and control circuits operate from a single phase of the ac at 115 volts. Except for the postlanding ventilation system, those components using 28 volts dc will receive power from the fuel cells before CSM separation and from batteries after separation. The postlanding ventilation system will operate from batteries, exclusively.

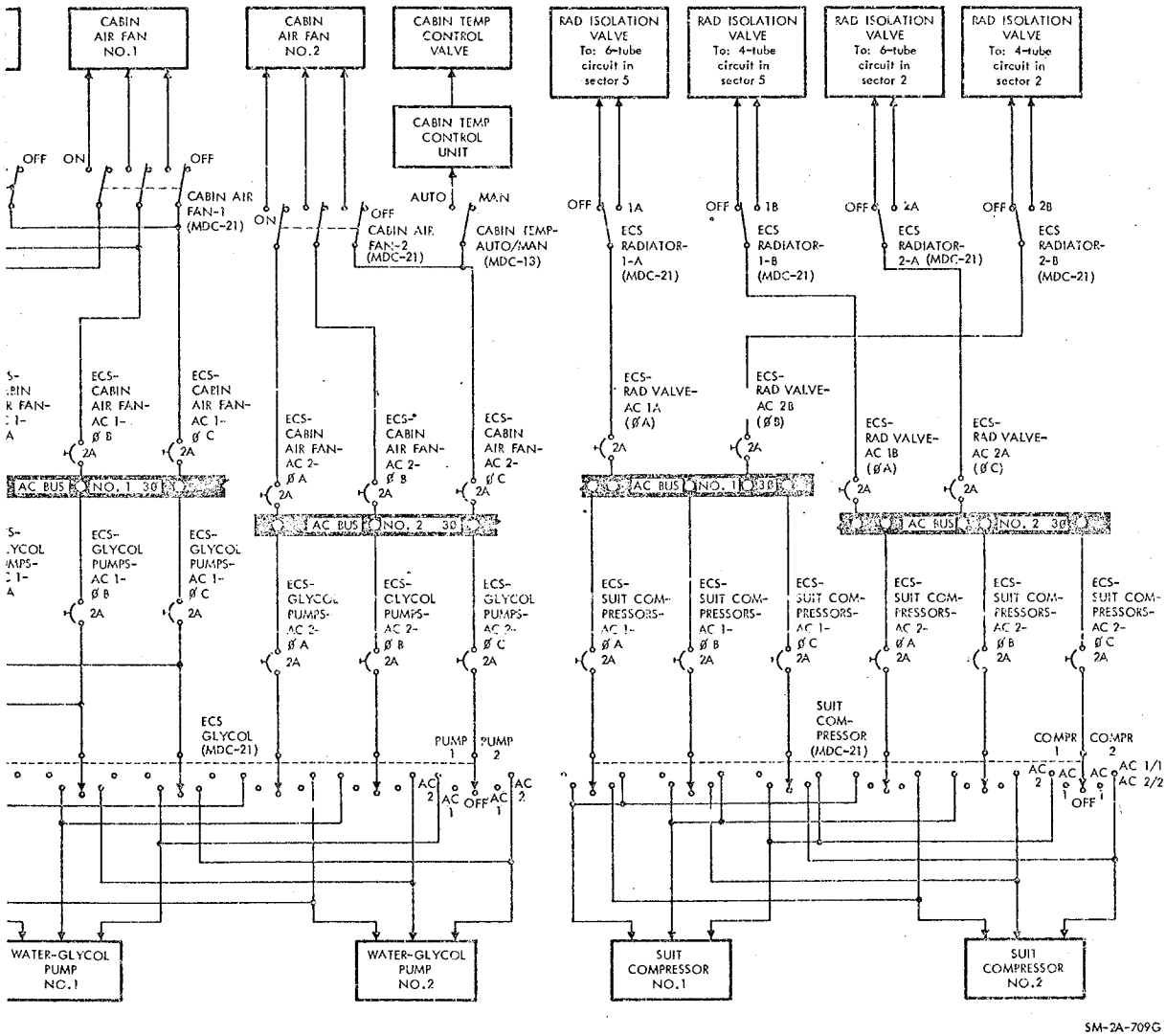
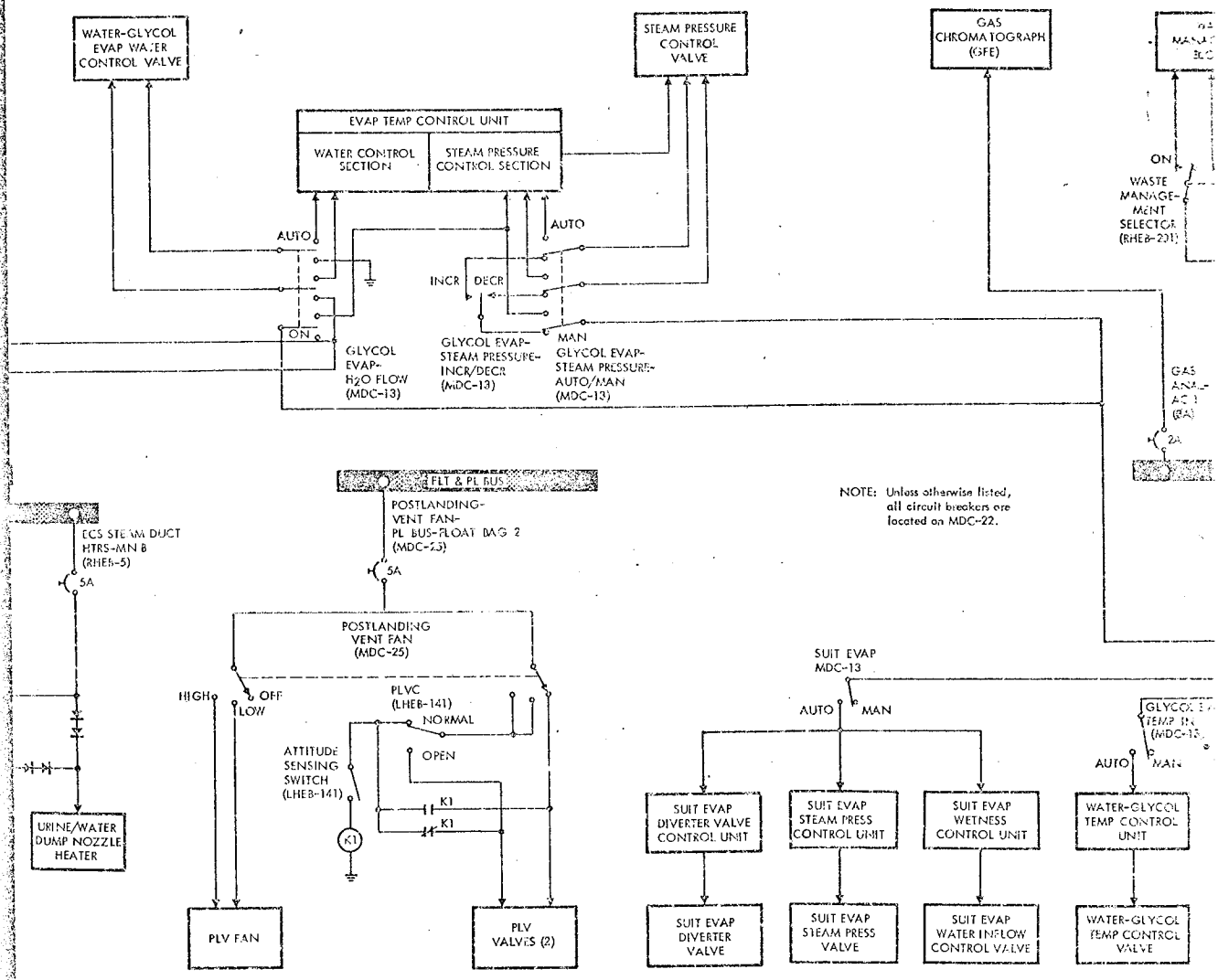
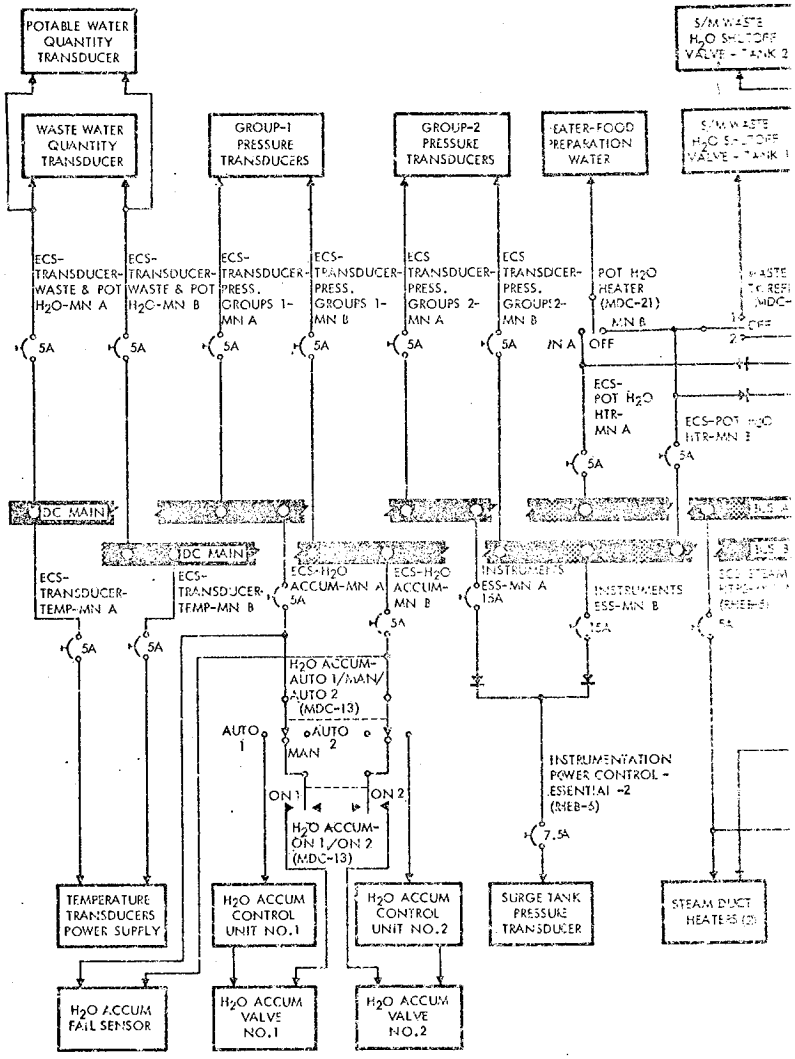


Figure 2.7-10. ECS Power Distribution Diagram


WATER-GLYCOL EVAP WATER CONTROL VALVE
STEAM PRESSURE CONTROL VALVE
GAS CHROMATOGRAPH (GFE)
EVAP TEMP CONTROL UNIT
WATER CONTROL SECTION
STEAM PRESSURE CONTROL SECTION
AUTO
AUTO
INCR
DECR
ON
ON
WASTE MANAGE-MENT SELECTOR (RHEB-231)
GLYCOL EVAP-H2O FLOW (MDC-13)
GLYCOL EVAP-STEAM PRESSURE-INCR/DECR (MDC-13)
MAN
GLYCOL EVAP-STEAM PRESSURE-AUTO/MAN (MDC-13)
GAS ANALYZER (BA)
2A
FLT & PL BUS
POSTLANDING-VENT FAN-PL BUS-FLOAT BAG 2 (MDC-23)
5A
ECS STEAM DUCT HTRS-MN B (RHEB-5)
5A
POSTLANDING VENT FAN (MDC-25)
HIGH
OFF
LOW
PLVC (LHEB-141)
NORMAL
OPEN
ATTITUDE SENSING SWITCH (LHEB-141)
K1
K1
K1
URINE/WATER DUMP NOZZLE HEATER
PLV FAN
PLV VALVES (2)
NOTE: Unless otherwise listed, all circuit breakers are located on MDC-22.
SUIT EVAP MDC-13
AUTO
MAN
AUTO
MAN
SUIT EVAP DIVERTER VALVE CONTROL UNIT
SUIT EVAP STEAM PRESS CONTROL UNIT
SUIT EVAP WETNESS CONTROL UNIT
WATER-GLYCOL TEMP CONTROL UNIT
SUIT EVAP DIVERTER VALVE
SUIT EVAP STEAM PRESS VALVE
SUIT EVAP WATER INFLOW CONTROL VALVE
WATER-GLYCOL TEMP CONTROL VALVE


POTABLE WATER QUANTITY TRANSDUCER
WASTE WATER QUANTITY TRANSDUCER
GROUP-1 PRESSURE TRANSDUCERS
GROUP-2 PRESSURE TRANSDUCERS
ECS-TRANSDUCER-WASTE & POT H2O-MN A
ECS-TRANSDUCER-WASTE & POT H2O-MN B
ECS-TRANSDUCER-PRESS. GROUPS 1-MN A
ECS-TRANSDUCER-PRESS. GROUPS 1-MN B
ECS TRANSDUCER-PRESS. GROUP 2-MN A
ECS TRANSDUCER-PRESS. GROUP2-MN B
POT H2O HEATER (MDC-21)
ECS-POT H2O HTR-MN A
5A
OFF
DC MAIN
ECS-TRANSDUCER-TEMP-MN A
ECS-TRANSDUCER-TEMP-MN B
ECS-H2O ACCUM-MN A
ECS-H2O ACCUM-MN B
INSTRUMENTS ESS-MN A
INSTRUMENTS ESS-MN B
15A
H2O ACCUM-AUTO 1/MAN/AUTO 2 (MDC-13)
AUTO 1
AUTO 2
MAN
ON 1
ON 2
H2O ACCUM-ON 1/ON 2 (MDC-13)
INSTRUMENTATION POWER CONTROL - ESSENTIAL -2 (RNEB-6)
7.5A
TEMPERATURE TRANSDUCERS POWER SUPPLY
H2O ACCUM CONTROL UNIT NO.1
H2O ACCUM CONTROL UNIT NO.2
SURGE TANK PRESSURE TRANSDUCER
H2O ACCUM FAIL SENSOR
H2O ACCUM VALVE NO.1
H2O ACCUM VALVE NO.2

2.7.4 PERFORMANCE AND DESIGN DATA.

2.7.4.1 Metabolic Data.

The following table contains the average metabolic rates, thermal balance, and water requirements for S/C crewmembers.

Parameter	Pressurized Cabin (Normal)	Depressurized Cabin (Emergency)
Total metabolic load BTU per man/day	11,200	12,000
Water production lb per man/day	4.0	9.8
CO_2 production lb per man/day	2.12	2.27
O_2 consumption lb per man/day	1.84	1.97
Water consumption lb per man/day	6.6	12.4
Urine production lb per man/day	2.6	2.6

2.7.4.2 Oxygen Supply Subsystem.

Performance and design data for the oxygen supply subsystem are as follows:

- Maximum oxygen flow rate to ECS from cryogenic storage tanks: 9.0 lb per hr
- Surge tank quantity: 3.7 lb (approx)
  Surge tank nominal pressure: 900±35 psig
  Surge tank pressure relief setting: 1045±25 psig
- Entry tank quantity: 1 lb (approx)
  Entry tank nominal pressure: 900±35 psig
  Entry tank pressure relief setting: None
- Regulated working oxygen pressure: 100±10 psig
  Pressure relief setting: 130±10 psig
  Flow rate: 0.7 lb per min max
- Regulated tank pressurization oxygen pressure: 20±2 psig
  Pressure relief setting: 25±2 psig
  Flow rate: 0.075 lb per min (one regulator) and 0.15 lb per min (two regulators)

2.7.4.3 Pressure Suit Circuit Subsystem.

Performance and design data for the pressure suit circuit subsystem are as follows:

- Heat exchanger cooling capacity: 2100 BTU per hr max (Gly or evap)
- Water evaporation rate: 1.97 lb per hr max
- Regulated demand pressure
  Normal: 2.5 to 3.5 in. H_2O below cabin pressure
  Emergency: 3.75 ±0.25 psia
  Flow rate: 0.67 lb per min max
- Suit compressor volumetric flow
  Normal flight: 35 cfm
  Emergency flight: 33.6 cfm
- Automatic temperature control: 45° to 55°F
- Max O_2 flow into suit circuit: 0.66 lb per min (regulator or manual valve)

2.7.4.4 Cabin Pressure and Temperature Control Subsystem.

Performance and design data for the cabin pressure and temperature control subsystem are as follows:

- Heat exchanger cooling capacity: 1250 BTU per hr max
- Regulated cabin pressure: 5.0±0.2 psig
  Flow rate: 0.65 lb per hr (one regulator) and 1.3 lb per hr (two regulators)
- Emergency inflow pressure (maximum of 0.5 in. diameter total leakage area): 3.5 psia for 5 minutes
  Flow rate: 0.67 lb per min max
- Cabin pressure relief
  Positive relief: 6.0 (+0.2, -0.4) psig
  Negative relief: 10 to 25 in. H_2O
- Differential pressure (C/M cabin-to-aft section)
  Normal ascent: 7.0 psig max.
  Abort ascent: 8.6 psig max.
- Automatic temperature control (flight): 70° to 80°F
- O_2 required for cabin repressurization, 0 to 5 psig at 70°F: 9.1 lb

2.7.4.5 Water-Glycol Coolant Subsystem.

Performance and design data for the water-glycol coolant subsystem are as follows:

- Reservoir quantity: 9 lb (approx)
- Total system quantity (less reservoir): 18 lb (approx)
- Evaporator cooling capacity: 7620 BTU per hr max

- Water evaporation rate: 7.5 lb per hr max
- Accumulator quantity: 1.36 lb (approx)
- Pump flow: 200 lb per hr
- Pump pressure
  Inlet: 7.5±1.5 psig
  Outlet (flight): 38(+8, -12) psia
- Automatic temperature control: 40° to 50.5°F

2.7.4.6 Water Supply Subsystem.

Performance and design data for the water supply subsystem are as follows:

- Potable tank quantity: 36 lb
- Waste tank quantity: 56 lb
- S/M water tank quantity: 112 lb (2 tanks)
- S/M nitrogen tank quantity (pressurant): capacity of 3.7 lb, filled to 1.5 lb (approx)
- Nitrogen tank fill pressure: 900 psig
- Nitrogen tank pressure relief setting: 1045±25 psig
- Nitrogen system regulated pressure: 40±2 psig
- Nitrogen system pressure relief setting: 44 to 48 psig
- Overboard dump pressure: approx 32 psi above outside ambient
  Flow rate: 2.5 lb per min max
- Food preparation water supply unit
  Capacity: 1.9 lb
  Hot water: 154°±4°F
  Cold water: 50°F (at water chiller)

2.7.4.7 Waste Management System.

Performance and design data for the waste management system is as follows:

- Urine/water dump nozzle orifice: 0.055 in.

2.7.4.8 ECS Power Consumption Data.

The following list contains the latest available data on electrical power consumed by components of the ECS. The wattage figures are for the earth orbit phase only, and apply to operations during the normal mode (pressurized cabin).

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
OXYGEN SUPPLY						
O_2 flow transducer	ECS-TRANSDUCER-PRESS GROUPS-2 cb (2)	1		2.4		2.4
O_2 press transducer	ECS-TRANSDUCER-PRESS GROUPS-2 cb (2)	1		0.8		0.8
PRESSURE SUIT CIRCUIT						
Suit compressor	SUIT COMPRESSORS sw	2	85.0		†85.0 170.0	
ΔP sensor	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1		1.28		1.28
CO_2 sensor	ECS-TRANSDUCER-PRESS GROUPS-2 cb (2)	1		1.0		1.0
Diverter valve control unit	SUIT EVAP sw	1	2.5		2.5	
Diverter control valve	SUIT EVAP sw	1	*7.2		*7.2	
Steam press control unit	SUIT EVAP sw	1	2.5		2.5	
Steam press cont valve	SUIT EVAP sw	1	*7.2		*7.2	
Steam duct abs press sensor	SUIT EVAP sw	1		1.28		1.28
Wetness control unit	SUIT EVAP sw	1	5.0		5.0	
Water inflow control valve	SUIT EVAP sw	1		*3.0		*3.0
Wetness sensor	SUIT EVAP sw	1		0.2		0.2
Water-gly temp sensor	SUIT EVAP sw	1		0.001		0.001
Evap outlet air temp sensor	SUIT EVAP sw	1		0.001		0.001

*Intermittent operating components
†Only one component operates at a time

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Suit press transducer	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1		0.8		0.8
Suit temp sensor	ECS-TRANSDUCER-TEMP GROUP cb (2)	1	0.04		0.04	
CABIN PRESSURE & TEMP CONTROL						
Cabin air fan	CABIN AIR FAN-1&2 sw (2)	2	19.0		38.0	
Cabin temp control unit	CABIN TEMP-AUTO/MAN sw	1	2.5		2.5	
Cabin temp cont valve	CABIN TEMP-AUTO/MAN sw	1	*7.2		*7.2	
Cabin temp sensor	ECS-TRANSDUCER-TEMP GROUP cb (2)	1		0.001		0.001
Cabin temp anticipator	ECS-TRANSDUCER-TEMP GROUP cb (2)	1		0.001		0.001
Cabin press transducer	ECS-TRANSDUCER-PRESS GROUPS-2 cb (2)	1		0.8		0.8
WATER-GLYCOL COOLANT						
Water-glycol pump	ECS GLYCOL sw	2	36.0		†36.0	
Pump outlet press transducer	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1		0.8		0.8
Water-gly accum qty sensor	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1		0.8		0.8

*Intermittent operating components
†Only one component operates at a time

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Water-gly temp control unit	GLYCOL EVAP-TEMP IN sw	1	2.5		2.5	
Water-gly temp control valve	GLYCOL EVAP-TEMP IN sw	1	*7.2		*7.2	
Water-gly temp sensor	GLYCOL EVAP-TEMP IN sw; GLY EVAP-STEAM PRESS-AUTO/MAN sw; GLYCOL EVAP-H_2O FLOW sw	5		0.001		0.005
Steam press control unit	GLY EVAP-STEAM PRESS-AUTO/MAN sw	1	2.5		2.5	
Steam press cont valve	GLY EVAP-STEAM PRESS-INCR/DECR sw	1	*7.2		*7.2	
Steam duct press switch	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1	TBD	TBD	TBD	TBD
Water control unit	GLYCOL EVAP-H_2O FLOW sw	1	5.0		5.0	
Water control valve	GLYCOL EVAP-H_2O FLOW sw	1		*3.0		*3.0
Wick temp sensor	GLYCOL EVAP-H_2O FLOW sw	1		0.28		0.28
Rad outlet temp sensor	ECS-TRANSDUCER-TEMP GROUP cb (2)	1	0.04		0.04	
Rad isolation valve	ECS RADIATOR sw (4)	4	*14.4		*57.6	

*Intermittent operating components

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
WATER SUPPLY						
Pot water qty transducer	ECS-TRANSDUCER-WASTE & POT H_2O-MN A&B cb (2)	1		1.28		1.28
Waste water qty transducer	ECS-TRANSDUCER-WASTE & POT H_2O MN A&B cb (2)	1		1.28		1.28
Food prep water supply unit	POT H_2O HEATER sw	1		*45.0		*45.0
H_2O accum control unit	H_2O ACCUM-AUTO/MAN sw	1		3.0		3.0
H_2O accum valve	H_2O ACCUM-ON/OFF sw	2		*3.0		*3.0
H_2O accum fail sensor	ECS-H_2O ACCUM-MN A&B cb (2)	1		1.5		1.5
S/M water tank shut-off valve	WASTE H_2O TK REFILL sw	2		*160.0		*160.0
MISCELLANEOUS						
WMS blower	WASTE MANAGE-MENT SELECTOR valve	1	*20.0			*20.0
Urine/water dump nozzle heater	ECS-STEAM DUCT HTR-MN A&B cb (2)	1		5.7		5.7
Steam duct heater	ECS-STEAM DUCT HTR-MN A&B cb (2)	2		3.0		6.0
Temp xducer pwr supply	ECS-TRANSDUCER-TEMP GROUP cb (2)	1		10.5		10.5

*Intermittent operating components

SYSTEMS DATA

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Temp sensor amplifier	ECS-TRANSDUCER-TEMP GROUP cb (2)	5	0.04		0.2	
Steam duct temp sensor signal conditioner	ECS-TRANSDUCER-TEMP GROUP cb (2)	1		1.5		1.5
Gas chromatograph	GAS ANAL—AC 1 cb	1	9		9	

*Intermittent operating components

2.7.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS

2.7.5.1 ECS Caution Placards.

Caution notes bordered by yellow and black stripes appear adjacent to the postlanding vent valves in the forward tunnel area. The notes read, "POST LANDING VENT VALVE—PULL PIN BEFORE OPERATING VENT FAN." If the pins were not in place during flight, inadvertent opening of the cabin vent valves would immediately dump all cabin pressure, with possible catastrophic results.

A placard on each CO_2-odor absorber canister cover cautions the crewman to "PUSH BUTTON BEFORE OPENING," and includes an arrow to indicate direction button should be pushed. This instruction must be followed any time a canister cover is to be opened. By pressing the push-button, the differential pressure is equalized and the cover may then be removed.

The caution note on LHEB-314 pertains to filling the PLSS oxygen tanks and, therefore, is not applicable to earth orbital (Block 1) missions. It reads, "CAUTION 900 PSI CLOSE VALVE BEFORE REMOVING CAP."

2.7.5.2 ECS Caution Notes.

Design restrictions require that certain procedures be followed when positioning the inlet and outlet selector valves of the tank pressure regulator and relief valve assembly. If the inlet selector valve is placed to position 1 (or 2), the outlet selector valve must also be placed to position 1 (or 2) or to NORMAL position. This prevents shutting off the supply of oxygen for pressurizing the potable and waste water tanks and the water-glycol reservoir. Conversely, if the outlet selector valve is placed to position 1 (or 2), the inlet selector valve must be placed to position 1 (or 2) or to NORMAL position.

2.7.5.3 ECS General Data.

Several ECS controls are inaccessible during the mission. Those affected are located behind the two removable Y-axis attenuator panels in the LHEB. They include all controls mounted on LHEB-311, the suit circuit return air manual valve, and the diverter valve handle for the CO_2-odor absorber canisters. The attenuator panels are in place during the entire mission, but are removed to gain access to these ECS controls, and then immediately reinstalled. They provide an adequate bearing surface for the Y-axis attenuator shock strut pad for the landing impact.

The circuit breaker for the postlanding ventilation system is not engaged until after landing impact. This precaution, in conjunction with the lockpins previously inserted in the postlanding vent valves, assures that the cabin pressure will not be inadvertently dumped during flight.

High-oxygen flow during cabin repressurization, or when filling an empty (150 psia min) surge tank, may cause water-glycol freezing. This will occur when there is less than full flow through the warm water-glycol line upon which the flow restrictors are wound. Full coolant flow at this location, therefore, may be assured in the following manner. Between 15 and 30 minutes prior to anticipated high oxygen flow, set the GLYCOL EVAP-TEMP IN switch (MDC-13) to MAN, and override the GLYCOL EVAP TEMP IN valve (LHEB-311) to the full cool position.

Radiator heat rejection (as freezing) is a function of radiator inlet temperature and radiator orientation. Thus, if the radiator inlet temperature decreases to 75°F, the S/C must be placed in a 2 to 5 RPH (0.2 to 0.5 degree per second) roll rate. During this time radiator inlet temperature must not decrease below 70°F, or the individual radiator outlet temperature below 30°F.

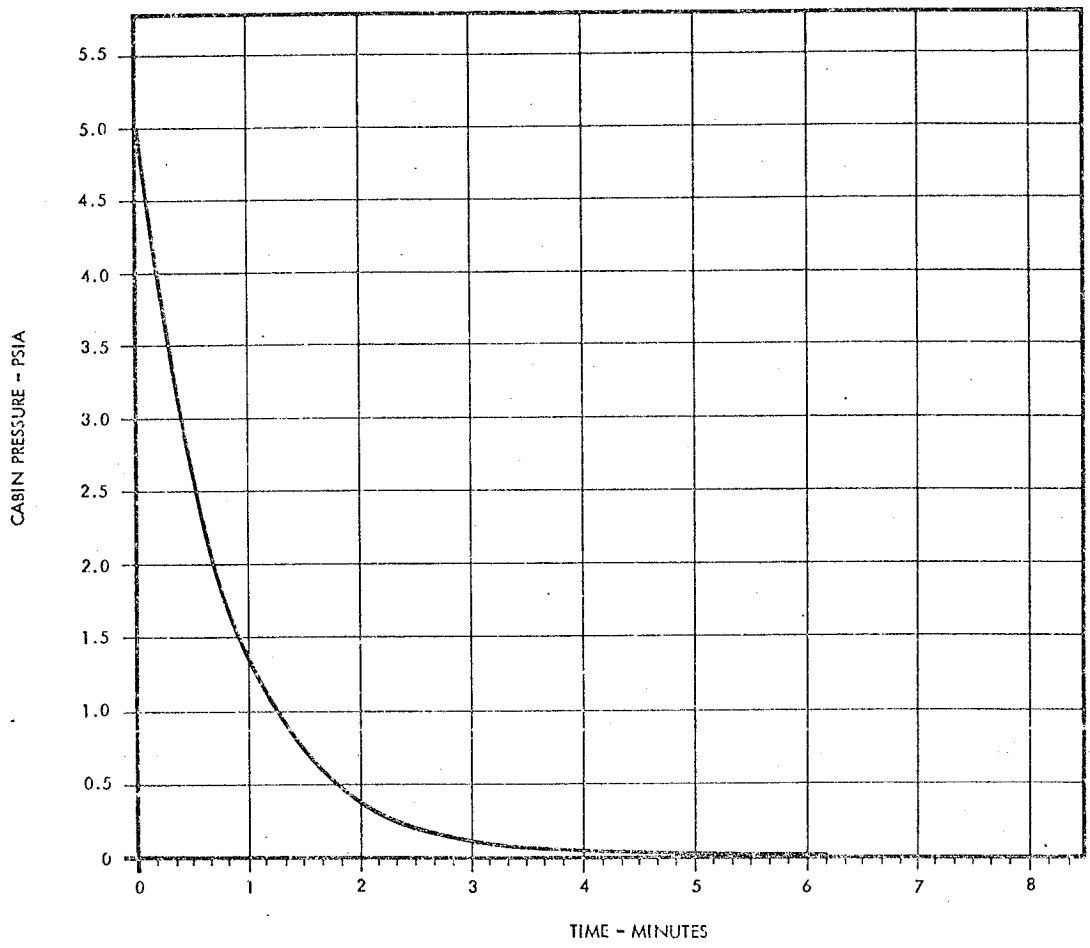
2.7.5.4 Cabin Depressurization Rates.

The time required for the C/M cabin to become depressurized is contingent upon how pressure is released. If the cabin is intentionally dumped, the time it takes to reach zero pressure will be as shown in figure 2.7-11, sheet 1 of 2. However, if the pressure is lost as the result of meteoroid punctures, the time will vary according to the size and number of holes. Figure 2.7-11, sheet 2 of 2, only reflects flow rate data for meteoroid holes that do not exceed a total equivalent area of 0.5 in. in diameter. The same chart also applies to the flow rate of one cabin pressure relief valve that has failed open while in the NORMAL position.

2.7.5.5 Cabin Repressurization Rates.

The C/M cabin may be repressurized by using either of two flow rates. To return the cabin pressure to normal in the shortest possible time, the conditions as set forth in figure 2.7-12, sheet 1 of 2, must be complied with. The flow rate, however, is dependent upon a full supply of oxygen in the

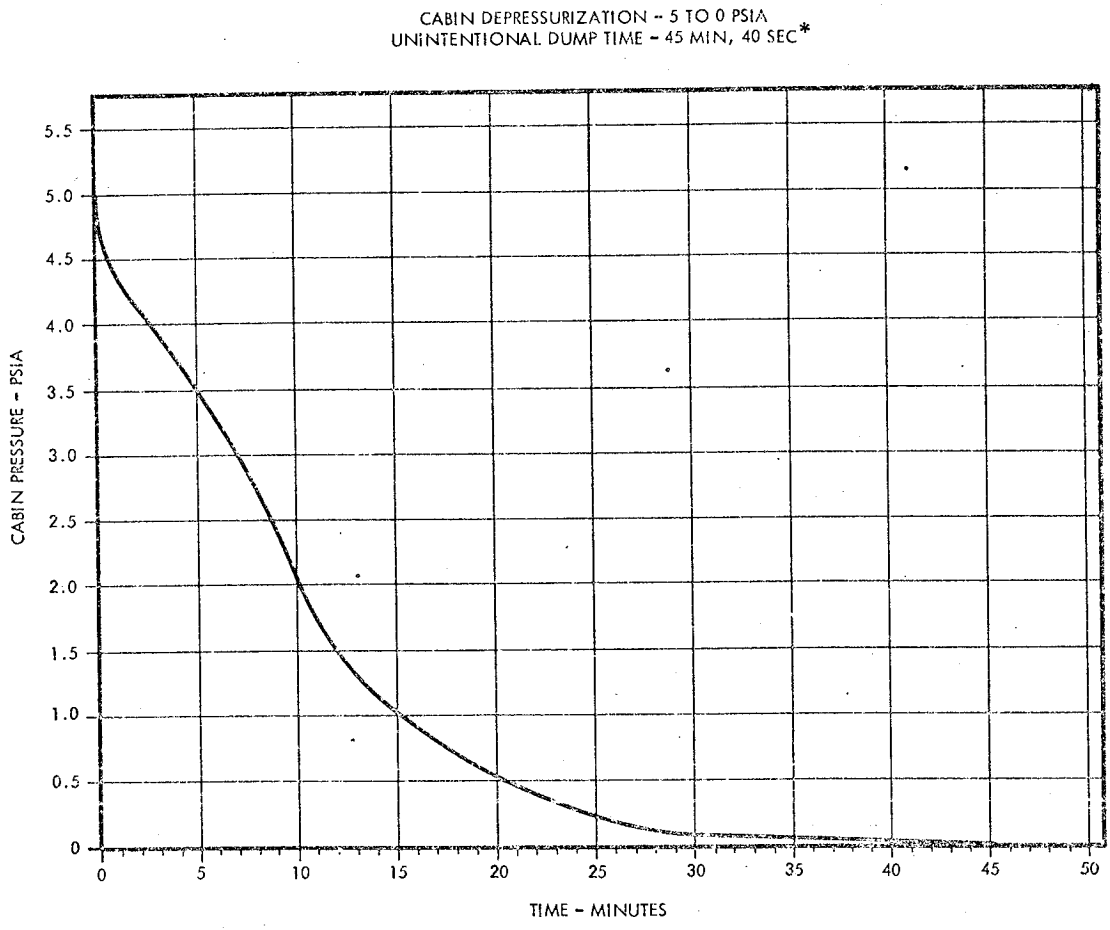
CABIN DEPRESSURIZATION - 5 TO 0 PSIA
INTENTIONAL DUMP TIME - 6 MIN, 11 SEC



CONDITIONS:
1. EMERGENCY CABIN PRESSURE selector valve set to OFF.
2. CABIN REPRESS manual valve set to close.
3. CABIN PRESSURE RELIEF valve set to DUMP.
4. Normal cabin pressure regulators automatically close at 3.5 psia.

SM-2A-890

Figure 2.7-11. Cabin Depressurization Rates (Sheet 1 of 2)



CONDITIONS:
1. EMERGENCY CABIN PRESSURE selector valve set to NORMAL.
2. CABIN REPRESS manual valve set to close.
3. CABIN PRESSURE RELIEF valves set to NORMAL.
4. Normal cabin pressure regulators automatically closed at 3.5 psia.
5. EMERGENCY CABIN PRESSURE selector valve set to OFF position when pressure reaches 3.5 psia (5 minutes).

*Depressurization is through a 0.5-inch-diameter (or equivalent) meteoroid puncture, or the maximum flow through one CABIN PRESSURE RELIEF valve that fails open while in the NORMAL position.

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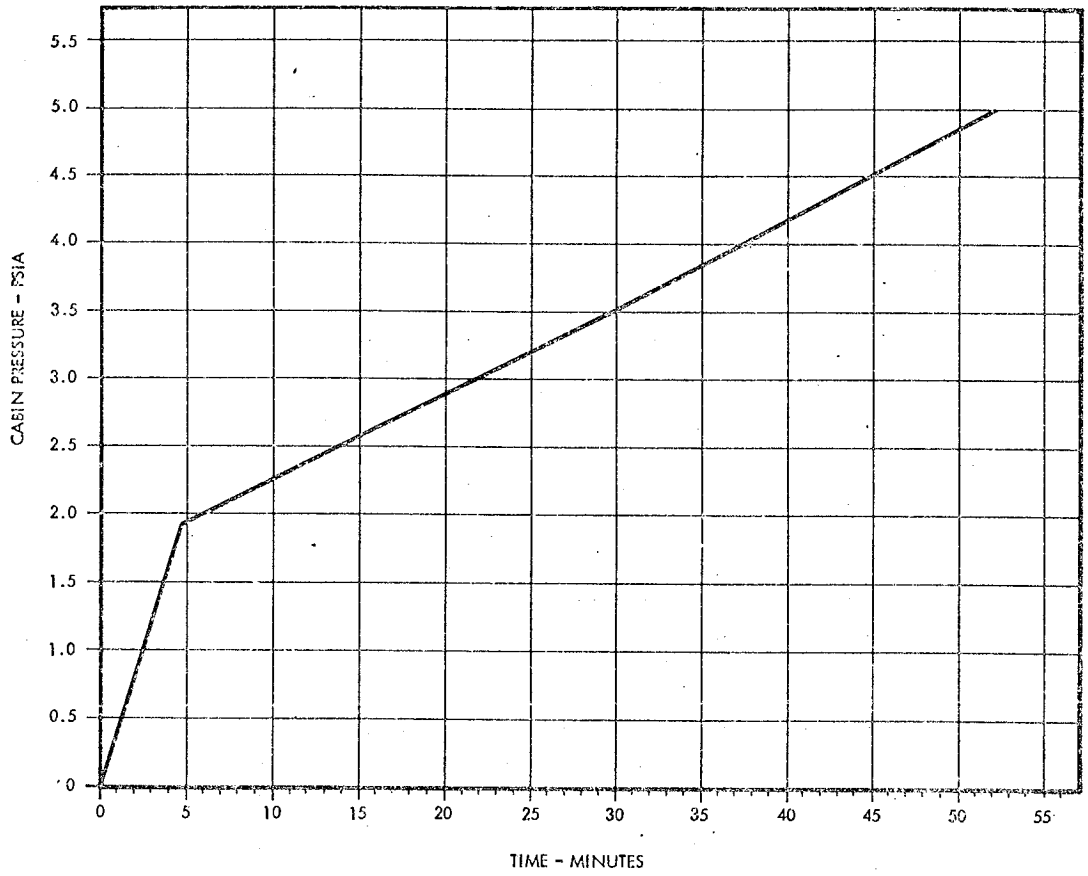
Figure 2.7-11. Cabin Depressurization Rates (Sheet 2 of 2)

CABIN REPRESSURIZATION - 0 TO 5 PSIA *
MINIMUM TIME - 52 MIN, 22 SEC

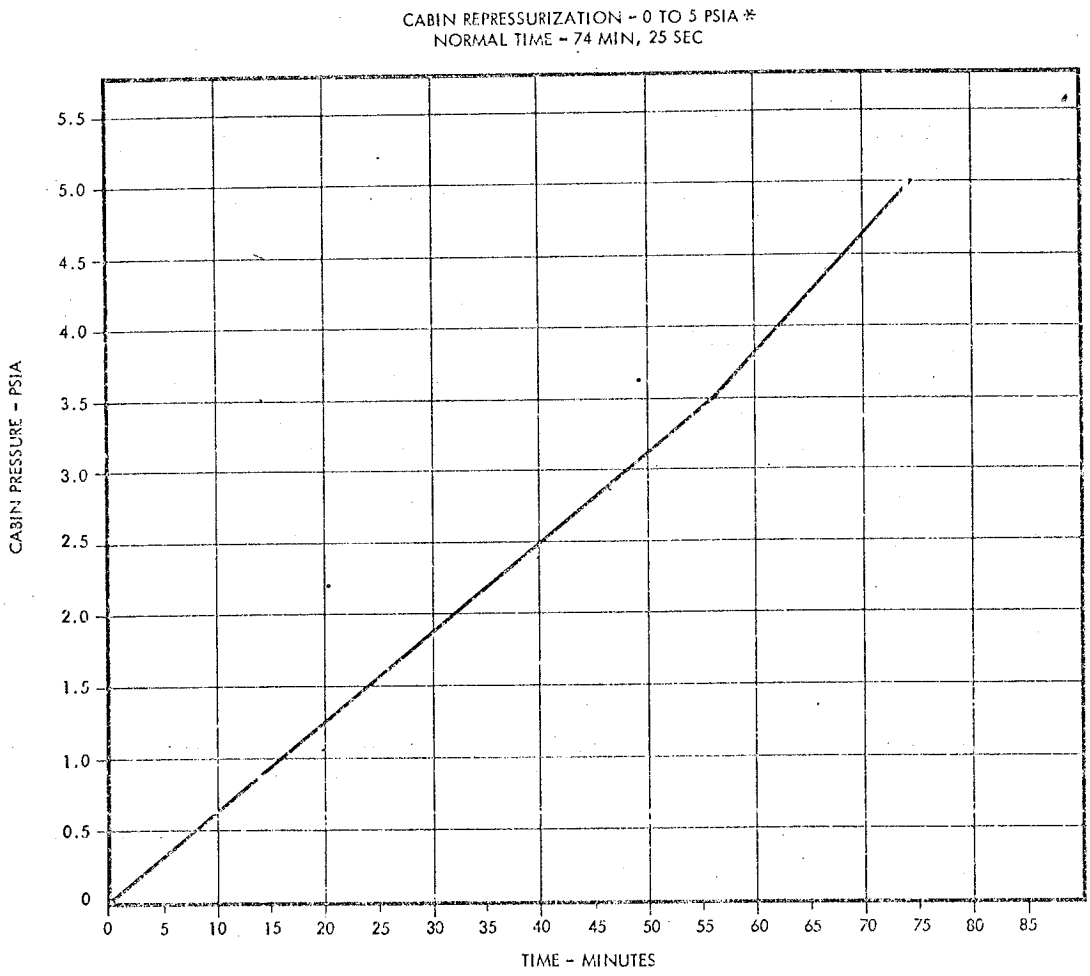


CONDITIONS:
1. EMERGENCY CABIN PRESSURE selector valve set to NORMAL.
2. CABIN REPRESS manual valve set to OPEN.
3. When surge tank pressure indicator decreases to 150 psia, EMERGENCY CABIN PRESSURE selector valve set to OFF; surge tank minimum pressure (150 psia) maintained by regulating CABIN REPRESS manual valve until valve is full open and surge tank pressure starts to increase.
4. Normal cabin pressure regulators automatically open at 3.5 psia.
5. When surge tank pressure again decreases to 150 psia, CABIN REPRESS manual valve regulated to maintain this minimum surge tank pressure.
6. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close.

* Requires 9.1lb oxygen at 70°F cabin temperature

SM-2A-889A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 1 of 2)



CONDITIONS:
1. EMERGENCY CABIN PRESSURE selector valve set to OFF.
2. CABIN REPRESS manual valve set to OPEN.
3. Normal cabin pressure regulators automatically open at 3.5 psia.
4. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close.

* Requires 9.1lb oxygen at 70°F cabin temperature

SM-2A-887A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 2 of 2)

surge tank. When the surge tank is not full, or the repressurization time is not critical, the conditions for the flow rate as shown in figure 2.7-12, sheet 2 of 2, are used.

2.7.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all ECS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low-bit rate operation.

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
CF 0001 P	Pressure cabin	0/17 psia	5.0±0.2 psia	PRESS - CABIN indicator
CF 0002 T	Temp cabin	40/125°F	70° to 80°F	TEMP - CABIN indicator
CF 0005 P	Press CO_2 partial	0/30 mm Hg	<7.6 mm Hg	PART PRESS CO_2 indicator and CO_2 PP HI C&W light
*CF 0006 P	Press surge tank	50/1050 psia	900±35 psia	TANK PRESS - 1 - O_2 indicator
*CF 0008 T	Temp suit supply manf	20/95°F	55°F	TEMP - SUIT indicator
CF 0009 Q	Quantity waste water tank	0/100%	Variable	WATER - QUANTITY indicator
CF 0010 Q	Quantity potable H_2O tank	0/100%	Variable	WATER - QUANTITY indicator
CF 0012 P	Press suit demand reg sense	0/17 psia	3.75±0.25 psia	PRESS - SUIT indicator
CF 0015 P	Press suit compressor diff	0/1 psid	Min 0.3 to 0.4 psid	ΔP SUIT COMPR indicator
CF 0016 P	Press glycol pump outlet	0/60 psia	37 to 45 psia	PRESS GLY DISCH indicator

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CF 0017 T	Temp glycol evap outlet steam	20/95°F	>45°F	None
CF 0018 T	Temp glycol evap outlet liquid	25/75°F	40° to 50.5°F	GLY EVAP - OUTLET TEMP indicator
CF 0019 Q	Quantity glycol accum	0/100%	40 to 60%	GLY ACCUM - QUANTITY indicator
CF 0020 T	Temp space radiator outlet	-50/+100°F	Variable	ECS RAD - OUTLET TEMP indicator and GLYCOL TEMP LOW C&W light
*CF 0025 P	Press pump package inlet	0/60 psia	7 psi min	None
CF 0034 P	Back press glycol evaporator	0.05/0.25 psia	0.098 to 0.154 psia	GLY EVAP STEAM PRESS indicator
CF 0035 R	Flow rate ECS O_2	0.2/1.0 lb/hr	0.425 lb/hr	FLOW O_2 indicator
*CF 0036 P	Press outlet O_2 reg supply	0/150 psia	100±10 psia	None
*CF 0120 P	Press H_2O and glycol tanks	0/50 psia	18 to 35 psid	None
*CF 0135 R	Flow rate manifold inlet to suit 1	0/0.2 lb/hr	TBD	None
*CF 0136 R	Flow rate manifold inlet to suit 2	0/0.2 lb/hr	TBD	None
*CF 0137 R	Flow rate manifold inlet to suit 3	0/0.2 lb/hr	TBD	None
*CF 0148 P	DP supply and return manifold	0/0.8 psid	0.25 to 0.5 psid	None
*CF 0153 T	Temp compressor inlet	50/125°F	TBD	None
*CF 0184 T	Temp CO_2 absorber outlet	90/200°F	TBD	None

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CF 0245 T	Temp O_2 reg inlet	-50/+150°F	TBD	None
*CF 0326 P	Press potable H_2O tank drain	0/50 psia	18 to 35 psid	None
*CF 0327 P	Press waste H_2O tank drain	0/50 psia	18 to 35 psid	None
*CF 0481 T	Temp CP branch 1 inlet	40/150°F	TBD	None
*CF 0482 T	Temp CP branch 1 outlet	40/150°F	TBD	None
*CF 0483 T	Temp CP branch 2 inlet	40/150°F	TBD	None
*CF 0484 T	Temp CP branch 2 outlet	40/150°F	TBD	None
*CF 0549 P	Diff press coldplate branch 1	0/2.0 psid	TBD	None
*CF 0550 P	Diff press coldplate branch 2	0/10 psid	TBD	None
CT 0108 K	Gas analysis - suit and cabin	N/A	N/A	None
SF 0665 T	Temp space radiator inlet	60/150°F	Variable	None
SF 0671 T	Temp ECS radiator outlet 1	0/50°F	Variable	ECS RAD OUT TEMP-1 indicator
SF 0672 T	Temp ECS radiator outlet 2	0/50°F	Variable	ECS RAD OUT TEMP-2 indicator

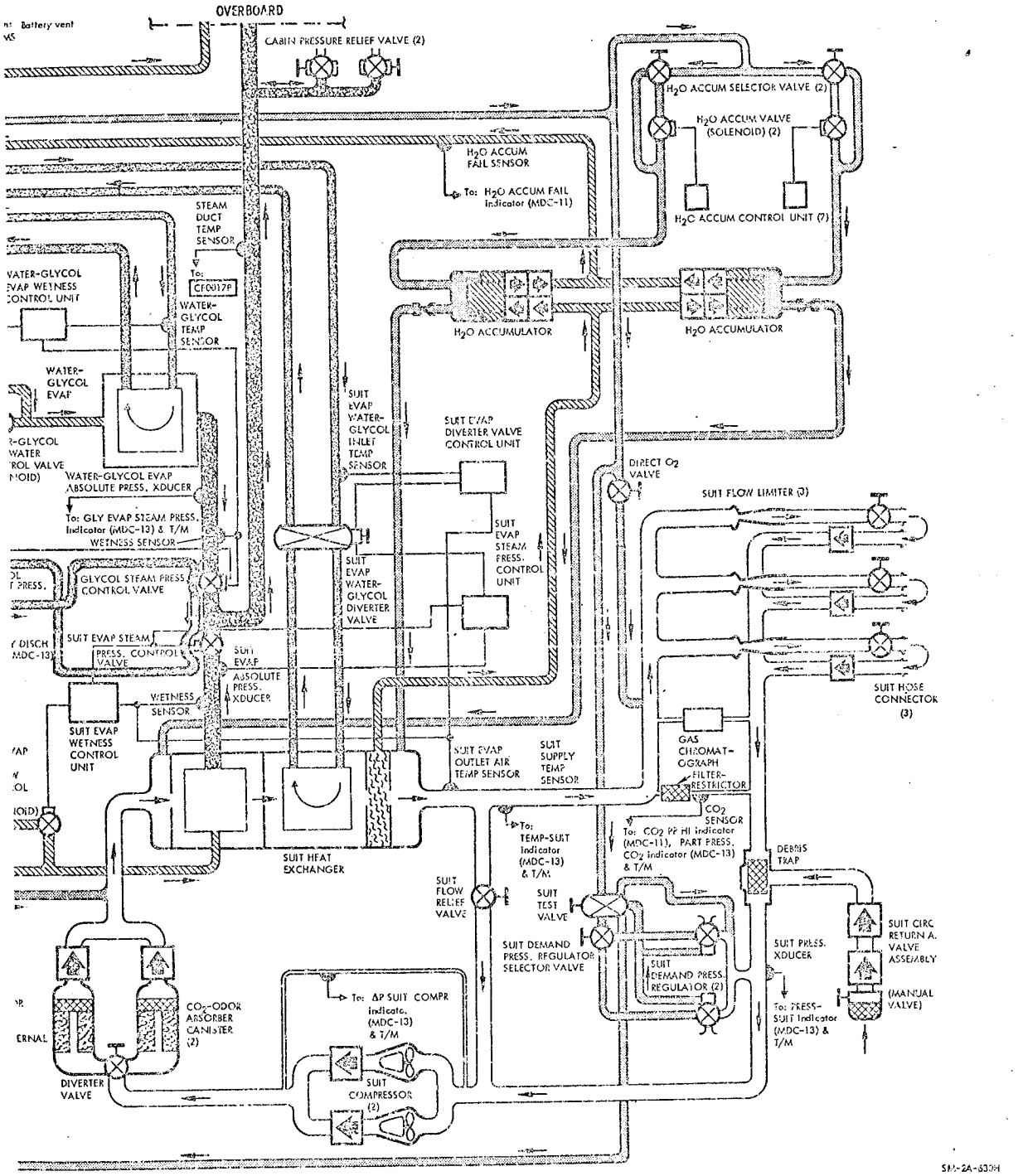
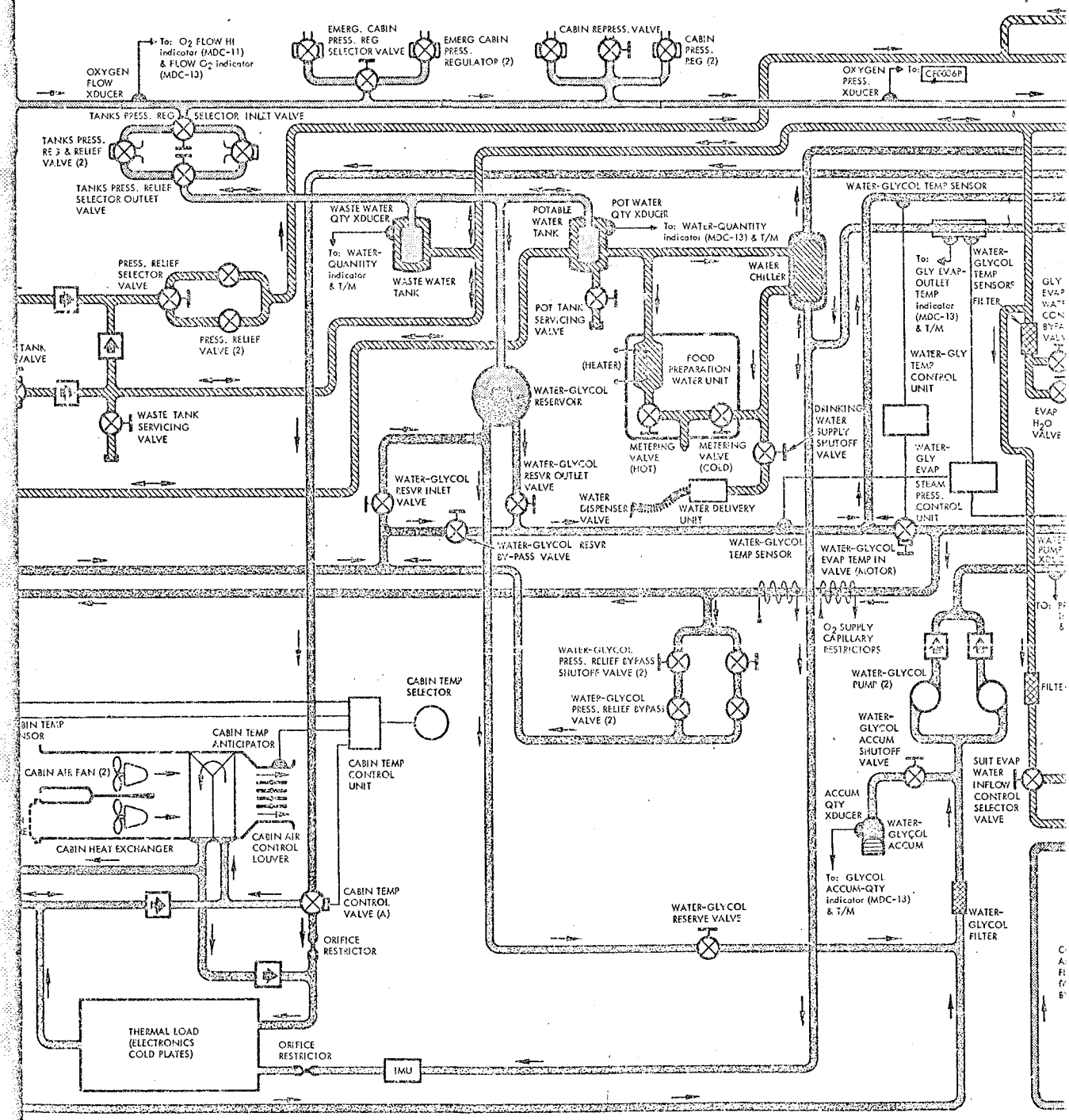
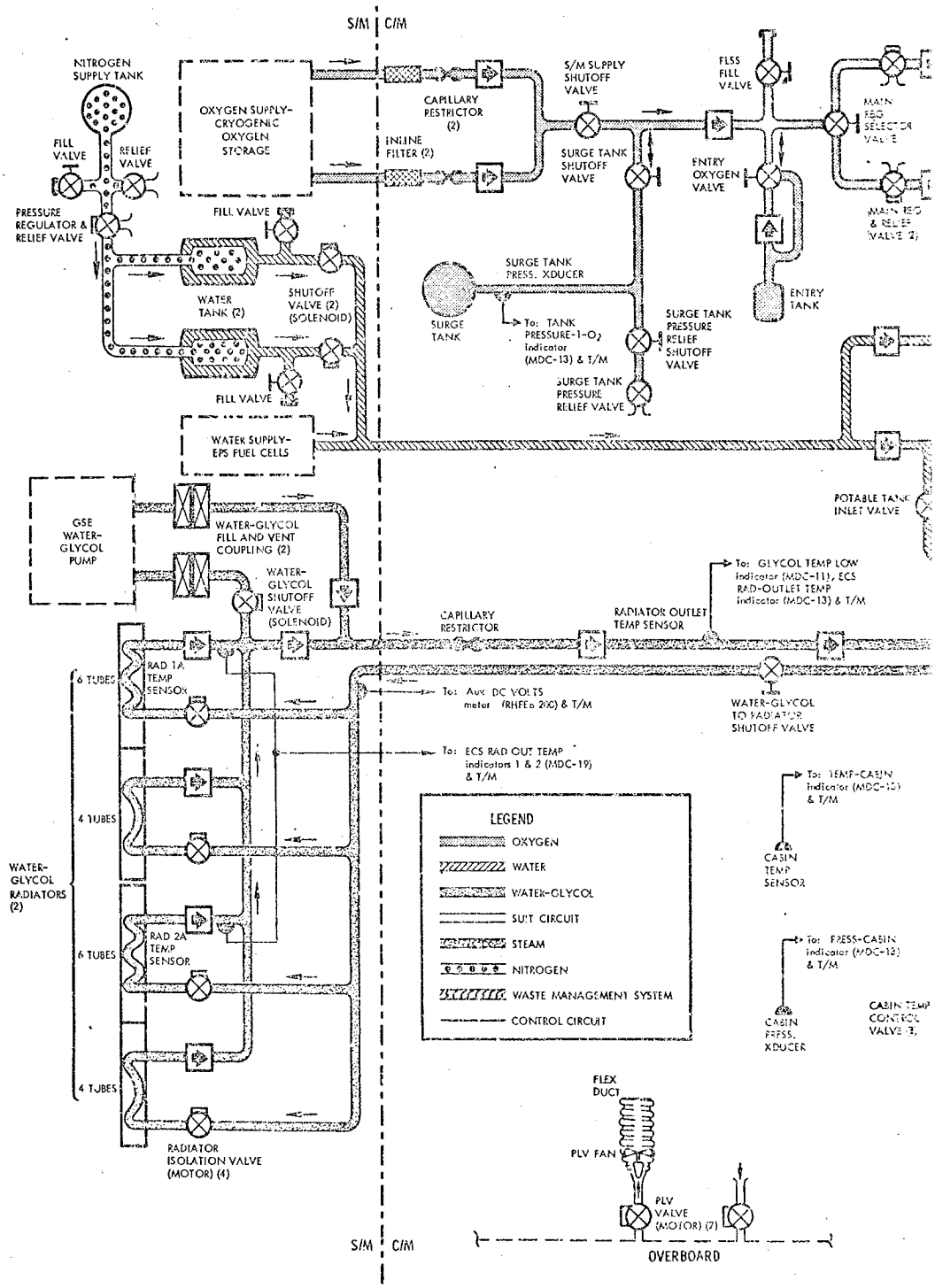


Figure 2.7-13. ECS Schematic Diagram


OXYGEN FLOW XDUCER
To: O_2 FLOW HI indicator (MDC-11) & FLOW O_2 indicator (MDC-13)
EMERG. CABIN PRESS. REG SELECTOR VALVE
EMERG CABIN PRESS. REGULATOR (2)
CABIN REPRESS. VALVE
CABIN PRESS. REG (2)
OXYGEN PRESS. XDUCER
To: C2C036P
TANKS PRESS. REG & SELECTOR INLET VALVE
TANKS PRESS. REG & RELIEF VALVE (2)
TANKS PRESS. RELIEF SELECTOR OUTLET VALVE
WASTE WATER QTY XDUCER
To: WATER-QUANTITY indicator & T/M
WASTE WATER TANK
POTABLE WATER TANK
POT WATER QTY XDUCER
To: WATER-QUANTITY indicator (MDC-13) & T/M
WATER-GLYCOL TEMP SENSOR
WATER CHILLER
PRESS. RELIEF SELECTOR VALVE
PRESS. RELIEF VALVE (2)
POT TANK SERVICING VALVE
To: GLY EVAP-OUTLET TEMP indicator (MDC-13) & T/M
WATER-GLYCOL TEMP SENSORS
FILTER
WATER-GLY TEMP CONTROL UNIT
TANK VALVE
WASTE TANK SERVICING VALVE
(HEATER)
FOOD PREPARATION WATER UNIT
WATER-GLYCOL RESERVOIR
DRINKING WATER SUPPLY SHUTOFF VALVE
EVAP H_2O VALVE
METERING VALVE (HOT)
METERING VALVE (COLD)
WATER-GLY EVAP STEAM PRESS. CONTROL UNIT
WATER-GLYCOL RESVR INLET VALVE
WATER-GLYCOL RESVR OUTLET VALVE
WATER DISPENSER VALVE
WATER DELIVERY UNIT
WATER-GLYCOL RESVR BY-PASS VALVE
WATER-GLYCOL TEMP SENSOR
WATER-GLYCOL EVAP TEMP IN VALVE (MOTOR)
O_2 SUPPLY CAPILLARY RESTRICTORS
WATER-GLYCOL PRESS. RELIEF BYPASS SHUTOFF VALVE (2)
WATER-GLYCOL PRESS. RELIEF BYPASS VALVE (2)
WATER-GLYCOL PUMP (2)
CABIN TEMP SELECTOR
CABIN TEMP ANTICIPATOR
CABIN TEMP CONTROL UNIT
CABIN AIR FAN (2)
WATER-GLYCOL ACCUM SHUTOFF VALVE
SUIT EVAP WATER INFLOW CONTROL SELECTOR VALVE
ACCUM QTY XDUCER
WATER-GLYCOL ACCUM
To: GLYCOL ACCUM-QTY indicator (MDC-13) & T/M
CABIN HEAT EXCHANGER
CABIN AIR CONTROL LOUVER
CABIN TEMP CONTROL VALVE (A)
WATER-GLYCOL RESERVE VALVE
WATER-GLYCOL FILTER
ORIFICE RESTRICTOR
THERMAL LOAD (ELECTRONICS COLD PLATES)
ORIFICE RESTRICTOR
IMU


S/M
C/M
NITROGEN SUPPLY TANK
FILL VALVE
RELIEF VALVE
PRESSURE REGULATOR & RELIEF VALVE
OXYGEN SUPPLY-CRYOGENIC OXYGEN STORAGE
CAPILLARY RESTRICTOR (2)
INLINE FILTER (2)
S/M SUPPLY SHUTOFF VALVE
SURGE TANK SHUTOFF VALVE
FLSS FILL VALVE
ENTRY OXYGEN VALVE
MAIN REG SELECTOR VALVE
MAIN REG & RELIEF VALVE (2)
ENTRY TANK
FILL VALVE
WATER TANK (2)
SHUTOFF VALVE (2) (SOLENOID)
FILL VALVE
SURGE TANK PRESS. XDUCER
SURGE TANK
To: TANK PRESSURE-1-O2 Indicator (MDC-13) & T/M
SURGE TANK PRESSURE RELIEF SHUTOFF VALVE
SURGE TANK PRESSURE RELIEF VALVE
WATER SUPPLY-EPS FUEL CELLS
POTABLE TANK INLET VALVE
GSE WATER-GLYCOL PUMP
WATER-GLYCOL FILL AND VENT COUPLING (2)
WATER-GLYCOL SHUTOFF VALVE (SOLENOID)
CAPILLARY RESTRICTOR
RADIATOR OUTLET TEMP SENSOR
To: GLYCOL TEMP LOW Indicator (MDC-11), ECS RAD-OUTLET TEMP Indicator (MDC-13) & T/M
WATER-GLYCOL TO RADIATOR SHUTOFF VALVE
To: Aux DC VOLTS meter (RHFEB 20C) & T/M
To: ECS RAD OUT TEMP Indicators 1 & 2 (MDC-19) & T/M
6 TUBES
RAD 1A TEMP SENSOR
4 TUBES
WATER-GLYCOL RADIATORS (2)
RAD 2A TEMP SENSOR
6 TUBES
4 TUBES
RADIATOR ISOLATION VALVE (MOTOR) (4)
LEGEND
OXYGEN
WATER
WATER-GLYCOL
SUIT CIRCUIT
STEAM
NITROGEN
WASTE MANAGEMENT SYSTEM
CONTROL CIRCUIT
To: TEMP-CABIN Indicator (MDC-10) & T/M
CABIN TEMP SENSOR
To: PRESS-CABIN Indicator (MDC-13) & T/M
CABIN PRESS. XDUCER
CABIN TEMP CONTROL VALVE (3)
FLEX DUCT
PLV FAN
PLV VALVE (MOTOR) (2)
OVERBOARD
S/M
C/M

SECTION 2

SUBSECTION 2.8

TELECOMMUNICATION SYSTEM

2.8.1 INTRODUCTION.

The telecommunication (T/C) system includes the spacecraft (S/C) communications and data equipment required for voice communications; acquisition, processing, storage and transmission of operational and flight qualification telemetry (TLM), television (TV), and biomedical data; reception of up-data; and transmission of appropriate tracking and ranging signals. At least part of the T/C system will be in operation during all phases of the mission—from prelaunch through recovery. The following list summarizes T/C capabilities as utilized on SC-012.

- S/C intercommunications between crewman
- Hardline voice communications and transmission of TV and TLM data to the Launch Control Center (LCC) via the service module umbilical (USM) during prelaunch
- In-flight voice communications with the manned spaceflight network (MSFN)
- Voice tape recording of comments, observations, opinions, etc., with time correlation
- Acquisition and processing of TLM, TV, and operational biomedical data from the S/C structure and systems, TV camera, and crewman biomedical sensors, respectively
- TLM data storage
- Transmission of real-time or stored TLM data
- Reception of up-data (guidance and navigation, and timing data and real-time commands) from the MSFN
- Transmission of C-band tracking pulses in response to received radar signals
- Limited capabilities for S-band operation, including transmission of voice and TLM data plus TV, stored analog, or pseudo-random noise (PRN), ranging codes, and reception of voice and up-data
- Postlanding recovery aids including voice communications and recovery beacon transmission

- Generation of timing signals for synchronization of the T/C and other S/C systems.

2.8.2 FUNCTIONAL DESCRIPTION.

The functional description of the T/C system is divided into four parts: voice communications, data operations, tracking and ranging, and S-band operations. The unified S-band subsystem (USBS), used for all S-band operations, provides back-up voice, data, tracking and ranging capabilities, and the sole means for transmission of TV or analog data.

2.8.2.1 Voice Communications.

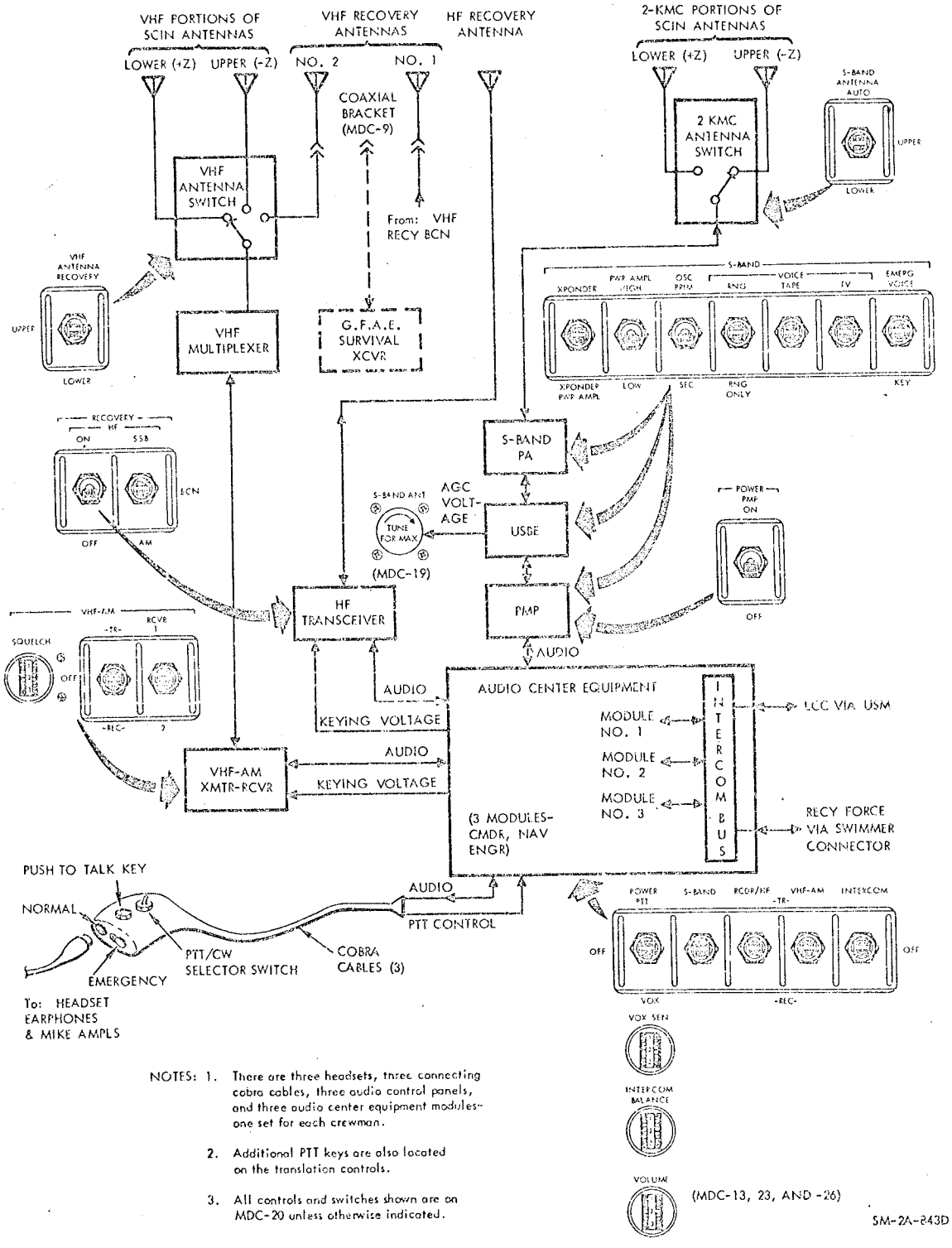
2.8.2.1.1 General.

All S/C voice communications (figure 2.8-1) originate and terminate in the crewmen's personal communication assemblies (headsets). Each crewman has two headsets; one is located in the "bump-hat" for use while wearing the constant-wear garment; the other is located in the spacesuit helmet. Each headset is comprised of two independently operating earphones and two microphones with self-contained preamplifiers. The headsets are used for all voice transmission and reception.

Each crewman's headset is connected to the audio center (A/C) equipment by a separate electrical umbilical assembly, commonly referred to as a "cobra cable." In addition to the audio circuits, each of the three cobra cables contains wiring for the operational biomedical sensors in the constant wear garments and the push-to-talk (PTT) control circuitry. The PTT control circuitry consists of a pushbutton-type PTT key and a PTT/CW selector switch. With the PTT/CW selector switch in the PTT position, the PTT key permits manual control of voice transmission by the appropriate transmitter and mike amplifier circuit in the audio center module.

The PTT mode was designed to be used during the launch phase of the mission when high noise levels would preclude usage of the VOX circuitry. In this mode, the PTT key will enable the microphone amplifier, voice recorder, VHF-AM and S-Band transmitters if the latter three have their attendant control switches configured properly. The audio center power switch and the cobra cable mode switch would be in PTT position during this mode.

The CW mode was also designed to be used during the high-noise levels of the launch phase. In this mode, however, the VHF and S-band downvoice communications links are not enabled. This gives us a PTT controlled intercommunications. The voice recorder could also be enabled in this mode if needed. The audio center power switch would also be in the PTT position, but the mode switch on the cobra cable must be in the CW position. It should be noted that on older cobra cables, the CW position was used only for emergency key. Now, this position will be used for both



NOTES: 1. There are three headsets, three connecting cobra cables, three audio control panels, and three audio center equipment modules-one set for each crewman.

2. Additional PTT keys are also located on the translation controls.

3. All controls and switches shown are on MDC-20 unless otherwise indicated.

Figure 2.8-1. Voice Communications

emergency key and the PTT intercommunications functions. PTT keys are also located on the translation controls. Their function duplicates that of the PTT key with the PTT/CW selector in the PTT position on the cobra cable.

The head of each cobra cable has two electrical connectors, marked NORM and EMER. Normally, the connector marked NORM will be used; however, in the event of failure in one of the A/C modules, the affected crewman may connect the cable from his spacesuit to the connector marked EMER. This will connect his audio circuits to another A/C module and allow the same module to be shared by two crewmen.

A strap has been added to the cobra cable so the PTT button can be held in the ON position if desired. This would allow a continuous intercom if the Audio center POWER switch, (MDC 13, 23, 26) is in the PTT position.

The A/C equipment contains three separate but identical modules, one for each crewman, and a commonly connected intercom bus. This equipment serves as a control and distribution center for all S/C audio signals. Each of the three modules has a separate but identical set of controls located on MDC-26, -13, and -23 for the command pilot, senior pilot, and pilot, respectively. Thus each crewman is provided with independent control of all audio inputs and outputs to and from his own headset. A POWER switch on each panel controls application of power to its respective A/C module and selects the PTT or voice-operated relay (VOX mode) of operation. The PTT mode permits monitoring of incoming audio signals plus PTT activation of the microphone amplifier, voice recorder, and the enabling of any communications transmitters if their attendant control switches are properly configured.

The VOX mode permits the microphone amplifier to be activated by the voice-operated switching circuitry within the audio center. The audio output of the amplifier is then applied to isolation and switching diodes controlled in part by the audio center controls located on panels MDC-26, -13, and -23.

Voice transmission over, the activated unified S-band equipment is allowed by placing the S-BAND switch to REC (MDC-26, -13, -23), setting the cobra cable PTT/CW switch at PTT and closing the PTT pushbutton on either the cobra cable or the translation controls.

Voice transmission over, the HF transceiver is limited to the post-landing phase of the mission; however, the RCDR/HF switch (MDC-26, -13, -23) in the T/R position provides a ground for the power control relay in the voice recorder. The intercom switch (MDC-26, -13, -23) would also have to be in the T/R position so the audio signal would be available for recording.

Voice transmission over, the activated VHF-AM transmitter is allowed by placing the VHF-AM switch to T/R (MDC-26, -13, -23), setting the cobra cable PTT/CW switch to PTT, and closing the PTT pushbutton on either the cobra cable or the translation controls. Monitoring the VHF-AM is provided by placing the VHF-AM T/R/OFF/REC switch to REC.

Each audio control panel has three thumbwheel-type potentiometer controls: a VOX SENS control for adjusting the sensitivity of the VOX circuit, an INTERCOM BALANCE control for decreasing the level of the audio signals received from the RF equipment relative to that received from the intercom bus, and a VOLUME control for changing the overall level of all audio signals to the earphones. Each channel, in the A/C modules, also contains sidetone circuitry which enables a crewman to monitor his own transmission.

2.8.2.1.2 S/C Intercommunications.

S/C intercommunications and hardline voice communications are conducted via the intercom bus, which is commonly connected to each of the three A/C modules, to the LCC during prelaunch via the USM, and to recovery forces via the swimmer electrical connector during recovery operations. To communicate, a crewman must activate his A/C module by placing the POWER switch to VOX or PTT and setting the INTERCOM switch to T/R.

An A/C intercom transmission can only be initiated with the PTT key, if the PTT position of the power switch is selected. In the VOX position, either the VOX circuit or the PTT key will indicate an intercom transmission. If only an intercom transmission is desired, the PTT/CW switch on the cobra cable should be in the CW position. Normally, the A/C modules will remain activated throughout the entire mission.

2.8.2.1.3 In-Flight Voice Communications.

In-flight voice communications with the MSFN will be conducted over the USBS and the VHF-AM transmitter-receiver equipment. Controls for the S-band and the VHF-AM groups are located on MDC-20, and MDC-26, -13, and -23. The VHF-AM controls on MDC-20 consist of a T/R/OFF/REC switch that controls application of power, a RCVR switch to control which of two receiver modes 1 simplex, 2 duplex, are operational, a SQUELCH control to establish the level of RF signal required to pass audio signals to the audio center, and a VHF ANTENNA switch to manually select the upper (+Z), or lower (-Z), antenna. Voice transmission via VHF-AM is controlled by the placement of the VHF-AM switch (MDC-26, -13, or -23) to T/R, the cobra cable MODE switch to PTT, and depressing the PTT pushbutton on the cobra cable. Either T/R or REC permits voice reception from the MSFN.

Voice communication is possible in all operational modes of the USBS, with the exception of the emergency key mode, providing the S-BAND switch (MDC-26, -13, or -23) is placed at REC. Transmission is controlled by the PTT pushbutton on the cobra cable, providing the cobra cable MODE switch is in the PTT position. (Refer to paragraph 2.8.3.3.4 for additional information on the unified S-band operations.)

2.8.2.1.4 Recovery Voice Communications.

After touchdown, the HF transceiver equipment will be utilized for voice communications. It is controlled by the RECOVERY-HF switches on

MDC-20 which include an ON-OFF switch and a SSB/BCN/AM switch for selecting mode. Either the single sideband (SSB) or amplitude modulation (AM) modes may be used for voice communications. The beacon (BCN) mode is used to transmit a continuous wave beacon for tracking purposes.

Voice transmission in either the SSB or AM mode can be VOX- or PTT-controlled when the RCDR/HF switch (MDC-26, -13, -23) is placed to T/R.

The HF transceiver utilizes the HF recovery antenna. This antenna must be deployed after touchdown by setting the POSTLANDING—ANTENNA DEPLOY switches on MDC-25 to their upper positions, A and B, while the MASTER EVENT SEQ CONT switches 1 and 2 (MDC-24) are at arm and MASTER EVENT SEQ CONT ARM A and B circuit breakers (MDC-22) are closed.

The VHF/AM transmitter-receiver equipment can be used as backup by utilizing VHF recovery antenna No. 2 which can be selected by setting the VHF ANTENNA switch (MDC-20) to RECOVERY. Also, the GFAE survival transceiver can be used inside the S/C by connecting its coaxial cable to VHF recovery antenna No. 1 or No. 2 at the coaxial bracket, MDC-9. These coaxial connectors may be utilized, during the interval preceding the arrival of the recovery forces, in the most advantageous manner. Any combination of VHF recovery beacon, GFAE survival transceiver, and VHF-AM transmitter-receiver may be employed as warranted by the serviceability of the communications equipment.

2.8.2.2 Data Operations.

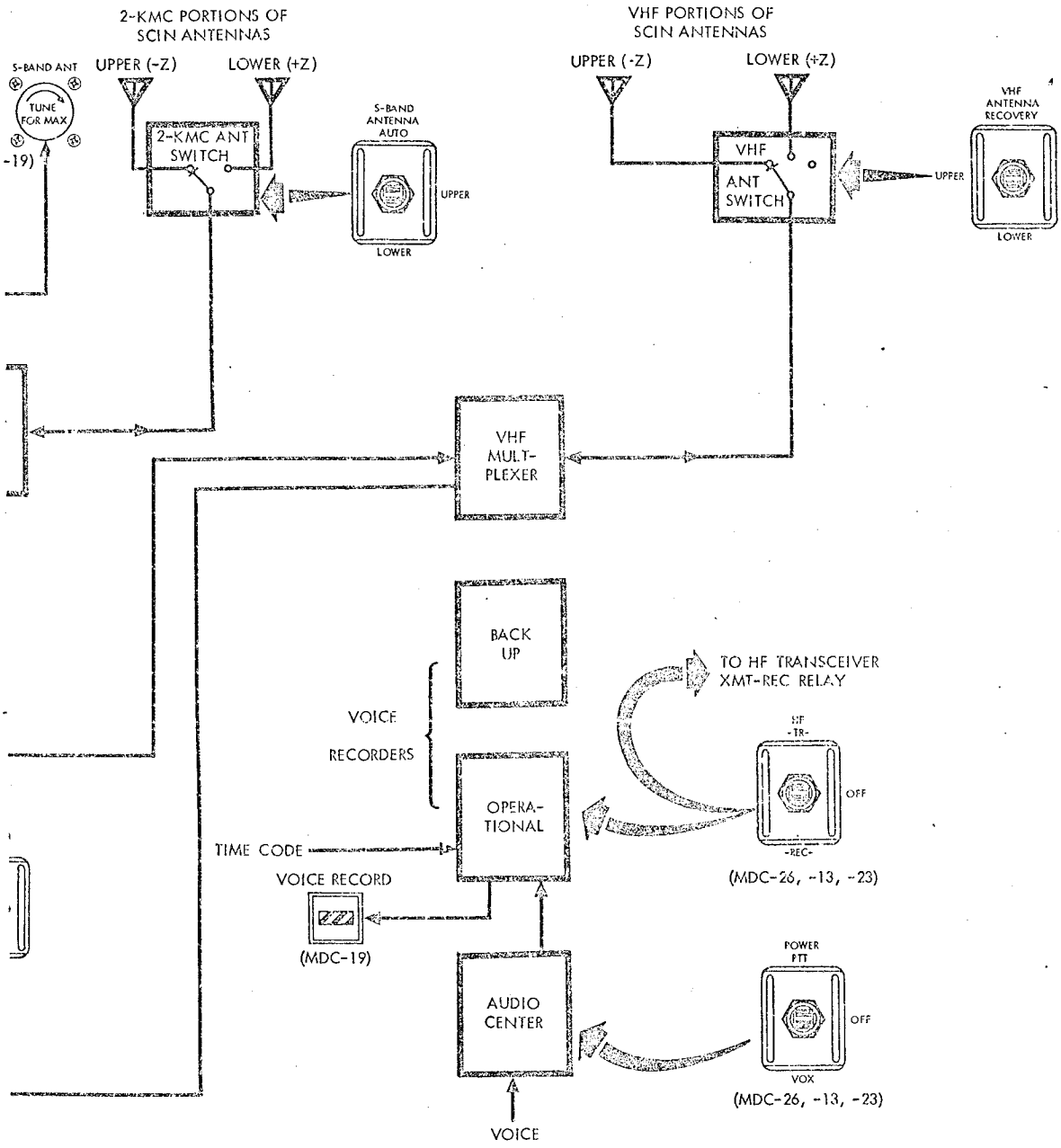
2.8.2.2.1 General.

T/C system data capabilities include the processing, storage, and transmission of TLM data to the MSFN; the reception and processing of up-telemetry data (up-data) received from the MSFN; and during USBE testing, the transmission of TV from the TV camera. In addition to transmitted data, verbal comments may be recorded on the voice recorder. (See figure 2.8-2.)

2.8.2.2.2 TLM Transmission and Storage.

TLM data may simultaneously be transmitted via VHF-FM and/or S-band and recorded in the DSE for delayed time transmission when requested by MSFN. The system configuration prohibits transmission or recording of real time data while transmitting stored data.

TLM data for transmission to the MSFN consists of analog and digital signals obtained from the guidance and navigation system, central timing equipment, instrumentation sensors and transducers located throughout the S/C structure and operational systems, and biomedical sensors worn by

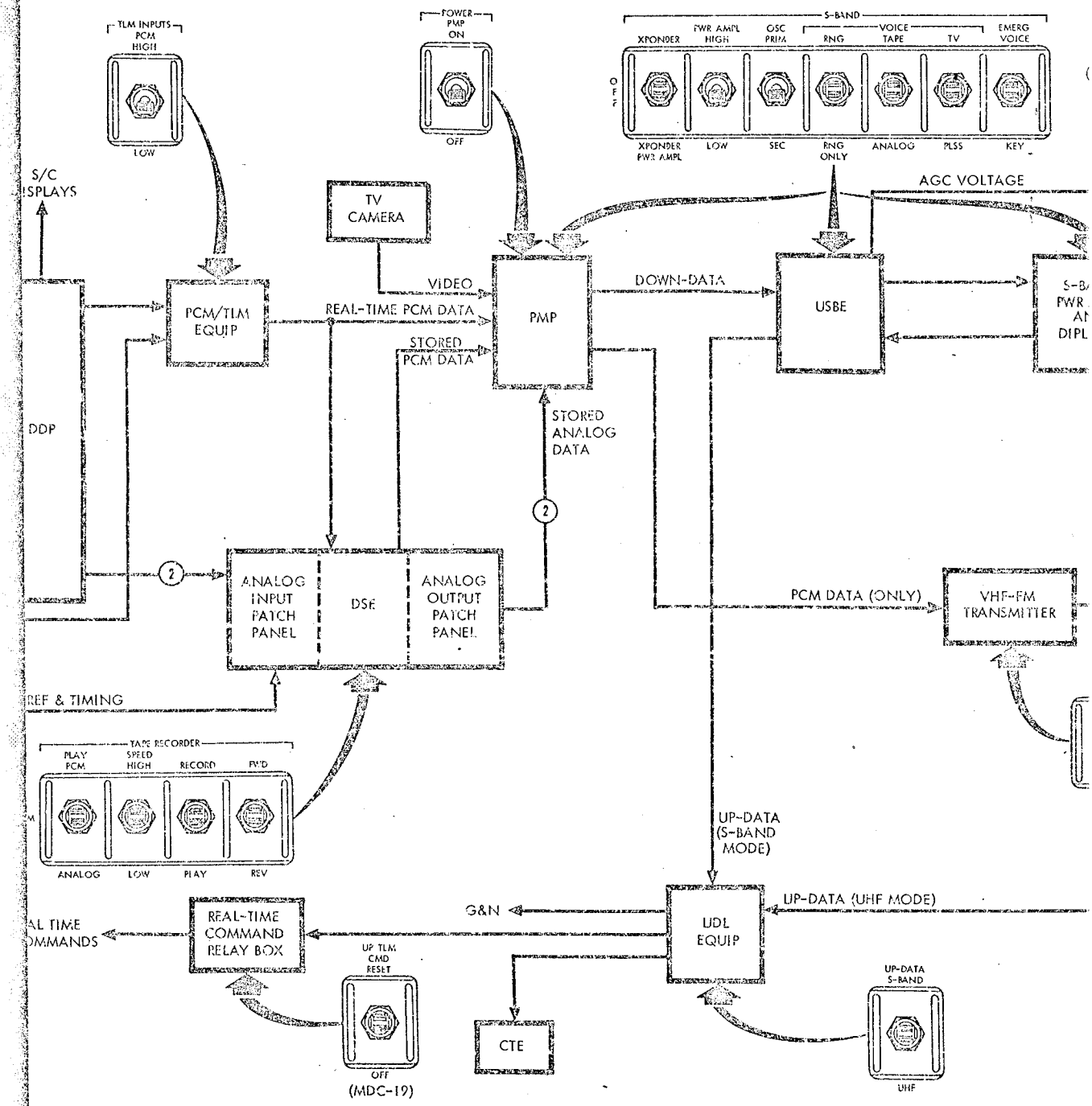


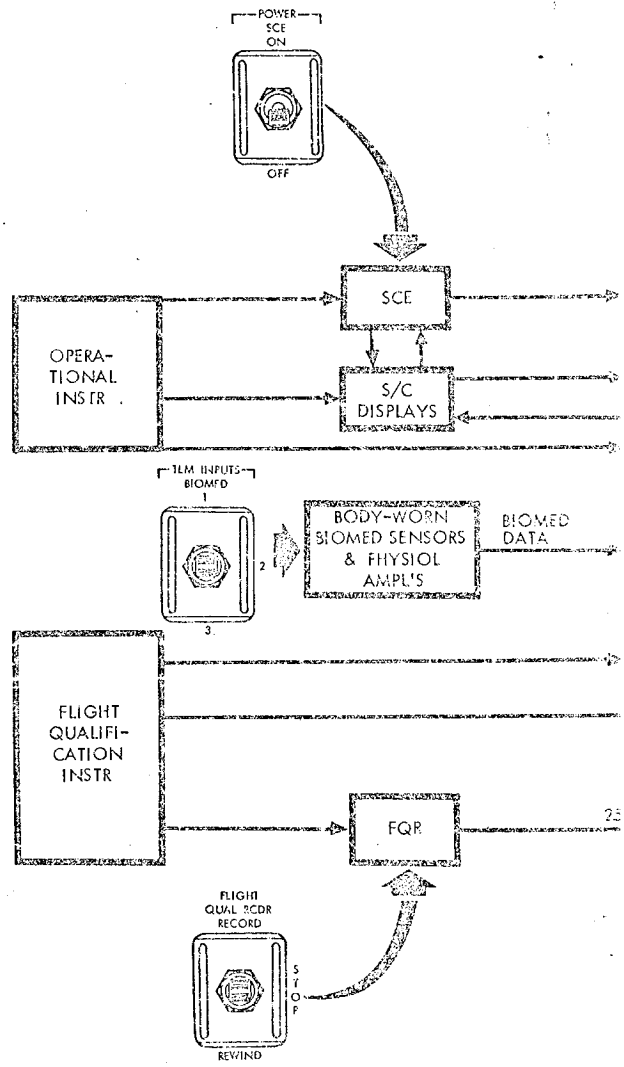
NOTES: 1. All switches shown are on MDC-20 unless otherwise indicated.

2. Not scheduled for use on SC 012 and SC 014.

SM-2A-844B

Figure 2.8-2. Data Operations


TLM INPUTS PCM HIGH
LOW
POWER PMP ON
OFF
S-BAND
XPONDER
PWR AMPL HIGH
OSC PRIM
VOICE RNG
VOICE TAPE
TV
EMERG VOICE
OFF
XPONDER PWR AMPL
LOW
SEC
RNG ONLY
ANALOG
PLSS
KEY
AGC VOLTAGE
S/C
ISPLAYS
TV CAMERA
VIDEO
REAL-TIME PCM DATA
STORED PCM DATA
PCM/TLM EQUIP
PMP
DOWN-DATA
USBE
S-B
PWR
AN
DIPL
DDP
STORED ANALOG DATA
2
2
ANALOG INPUT PATCH PANEL
DSE
ANALOG OUTPUT PATCH PANEL
PCM DATA (ONLY)
VHF-FM TRANSMITTER
REF & TIMING
TAPE RECORDER
PLAY PCM
SPEED HIGH
RECORD
FWD
ANALOG
LOW
PLAY
REV
UP-DATA (S-BAND MODE)
UP-DATA (UHF MODE)
G&N
UDL EQUIP
AL TIME
OMMANDS
REAL-TIME COMMAND RELAY BOX
UP TLM CMD RESET
OFF
(MDC-19)
CTE
UP-DATA S-BAND
UHF


POWER
SCE
ON
OFF
SCE
OPERA-
TIONAL
INSTR .
S/C
DISPLAYS
TLM INPUTS
BIOMED
1
2
3
BODY-WORN
BIOMED SENSORS
& PHYSIOL
AMPL'S
BIOMED
DATA
FLIGHT
QUALIFI-
CATION
INSTR
FQR
FLIGHT
QUAL RCDR
RECORD
STOP
REWIND

(MDC-19)

the crewman. Some of the instrumentation signals require conditioning before they can be utilized. This is accomplished by the signal conditioning equipment (SCE) activated by the POWER-SCE switch on MDC-20. The remaining TLM signals are either conditioned at their source by local signal conditioners, which requires no action on the part of crewmen, or do not need conditioning. The operational instrumentation signals are used for S/C displays and real time or delayed TLM transmission via VHF-FM and/or S-band. Those to be telemetered are routed to the pulse-code modulation-telemetry (PCM TLM) equipment. Most of the flight qualification signals are routed to the PCM TLM equipment along with the operational TLM signals. A few, however, are recorded as analog signals in the flight qualification recorder (FQR) for postflight analysis only. The FQR will be activated at brief intervals only during critical phases of the mission by the FLIGHT QUAL RCDR switch on MDC-19.

The PCM TLM equipment combines the signals to be telemetered and converts them to a single, digital, pulse train which is then fed to the pre-modulation processor equipment (PMP) and the data storage equipment (DSE). The PCM TLM equipment is activated at all times. Its only control is the TLM INPUTS – PCM switch on MDC-20. This switch is used to select the PCM bit-rate. In the HIGH (51.2 KBPS) position, all TLM inputs to the PCM TLM equipment are processed and combined into the output signal. The LOW (1.6 KBPS) position eliminates the less essential parameters and is used only when a PCM pulse train of reduced bandwidth is required. The reduced bandwidth allows PCM data to be recorded at a reduced (3.75 ips) speed when long periods of data recording are required.

The PCM signal is fed to the PMP and DSE simultaneously for real-time (R/T) transmission and/or storage. For R/T transmission, the signal is processed through the PMP to the VHF/FM and/or S-BAND transmitters. The PMP is controlled by the POWER – PMP switch, the S-BAND group of switches, and the TAPE RECORDER – PLAY switch. When R/T transmission is not possible, the PCM data can be stored in the DSE, which is controlled by the TAPE RECORDER group of switches and the TLM INPUTS – PCM switch discussed in the previous paragraph. When played back later, the stored PCM data is also processed through the PMP to the VHF/FM and/or S-BAND transmitters for transmission. The sole function of the VHF/FM transmitter is the transmission of R/T or stored PCM data. Its only control is the VHF-FM – ON/OFF switch on MDC-20. It utilizes the same antennas as the VHF/AM transmitter-receiver, namely, the upper or lower SCIN antenna as selected by the VHF antenna switch.

Backup capability for the transmission of PCM TLM data is provided by the USBS. (Refer to a subsequent discussion of unified S-band operations.)

2.8.2.2.3 Up-Data Reception.

Up-data which can be transmitted to the S/C by the MSFN consists of three types: G&N data for up-dating the Apollo guidance computer,

timing data for up-dating the central timing equipment (CTE), and realtime commands (RTCs) for providing the MSFN with limited control of certain on-board functions.

During normal operations, up-data is received by the UHF/FM receiver contained in the up-data link (UDL) equipment. Once received, the signal is processed and decoded, and the information is routed to the G&N system, the CTE, or UDL-RTC relay box. For backup, up-data can also be transmitted by MSFN stations to the S/C via the S-band carrier. When this occurs, the up-data is received by the USBE receiver which extracts the up-data subcarrier and routes it to the PMP where the intelligence is removed from the signal and sent to UDL equipment for processing, decoding, and distribution. In this S-band mode, the UHF/FM receiver is bypassed. Selection of the UHF or S-BAND mode is made with the UP-DATA switch on MDC-20. The UP TLM CMD – RESET/OFF switch (MDC-19) enables the crew to nullify previous RTCs and return control to the S/C. An UP TLM – ACCEPT/BLOCK switch (MDC-14) is also provided so that G&N up-data can be prevented from effecting the computer and the attendant validity signal being sent to the PCM format.

2.8.2.3 Tracking and Ranging.

2.8.2.3.1 In-Flight Tracking and Ranging.

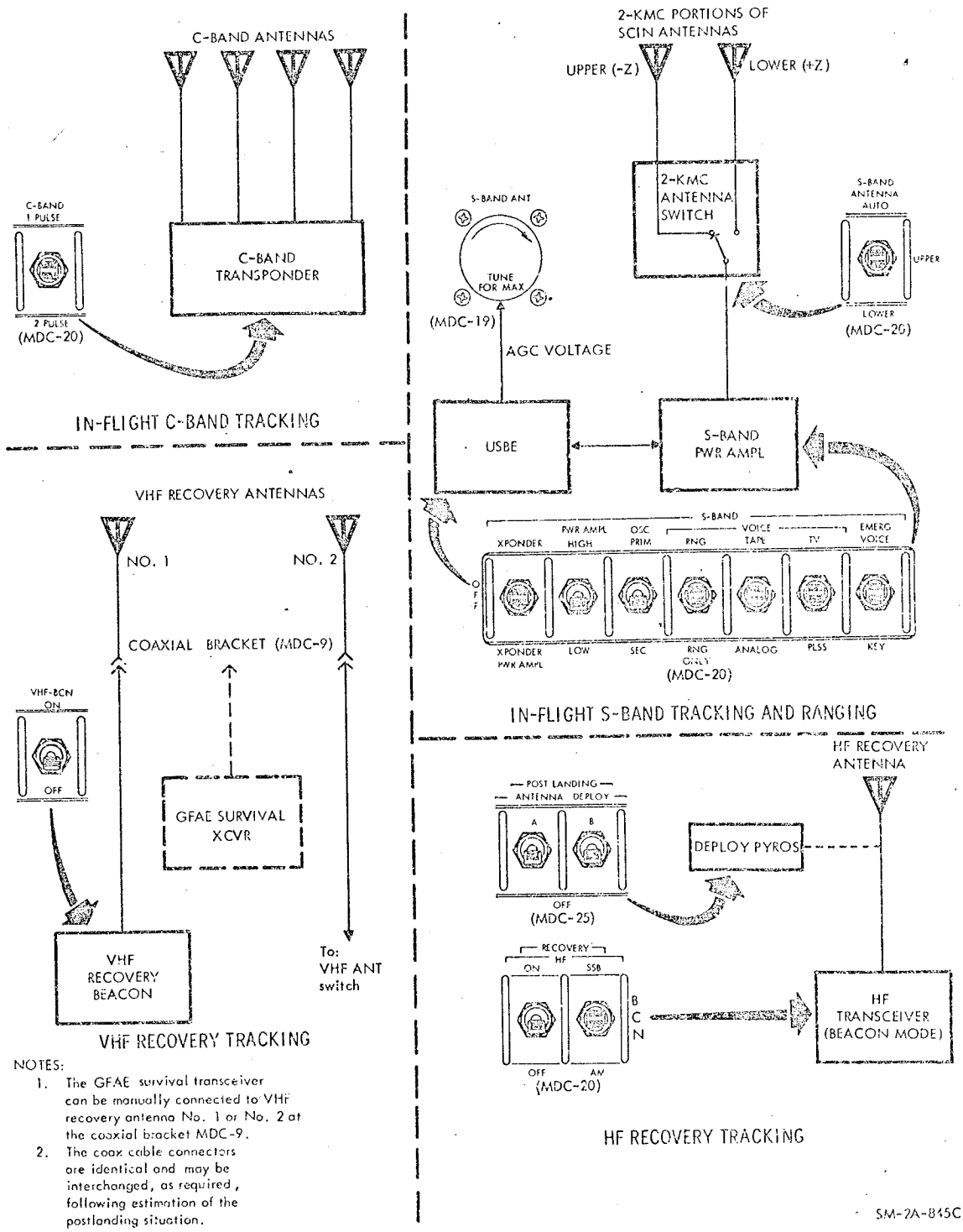
The function of the in-flight tracking and ranging equipment (figure 2.8-3) is to assist the MSFN in determining S/C position and velocity. The primary method employed is C-band tracking. The C-band transponder on-board the S/C is used for this purpose. It operates in conjunction with conventional, earth-based, radar equipment by transmitting response pulses to the MSFN when radar pulses from the earth are received. It operates in a "1-pulse" or a "2-pulse" mode, depending on the type of radar equipment being used at the nearest MSFN station. A single control, the C-BAND switch on MDC-20, is used to activate the C-band transponder in either mode.

Backup tracking and ranging capabilities are provided by the USBS.

2.8.2.3.2 Recovery Tracking.

Line-of-sight and beyond-line-of-sight beacon transmission capabilities are provided to assist recovery personnel in locating the S/C during parachute descent and after touchdown. Line-of-sight beacon transmission is accomplished using the VHF recovery beacon equipment. The beyond-line-of-sight capability is furnished by operating the HF transceiver in a beacon mode.

During parachute descent the VHF recovery beacon is activated by setting the RECOVERY – VHF-BCN switch (MDC-20) to ON. This causes a 2-second, modulated VHF pulse to be transmitted every 5 seconds from VHF recovery antenna No. 1, which is deployed automatically with VHF recovery antenna No. 2 when the main parachutes are deployed.



NOTES:
1. The GFAE survival transceiver can be manually connected to VHF recovery antenna No. 1 or No. 2 at the coaxial bracket MDC-9.
2. The coax cable connectors are identical and may be interchanged, as required, following estimation of the postlanding situation.

Figure 2.8-3. Tracking and Ranging

After touchdown, the HF recovery antenna must be deployed by setting the POSTLANDING – ANTENNA switches (MDC-25) to DEPLOY A and B while the MASTER EVENT SEQ CONT switches (MDC-24) are at PYRO ARM 1 and 2. HF beacon transmission at a preassigned frequency of 10.006 mc is accomplished by placing the RECOVERY – HF switch (MDC-20) to ON and the RECOVERY – HF-SSB/BCN/AM switch to BCN.

The GFAE survival transceiver (part of the crew's personal equipment) can also be operated in a beacon mode. If used inside the S/C, one of the VHF recovery antennas (No. 1 or No. 2) can be used by manually connecting it to the applicable coax connector on MDC-9.

The VHF antennas and communications equipment condition, as determined by the crew during the postlanding pre-recovery period, will decide the utilization of the coaxial cable connectors located on MDC-9. The connectors are identical and the recovery equipment coaxial cables may be interchanged to provide the most beneficial tracking configuration.

2.8.2.4 Unified S-Band Operations.

2.8.2.4.1 General.

The USBS is primarily designed to be used as a deep-space communications link between the S/C and the MSFN. Nevertheless, on mission 205 some of its capabilities will be tested and it may be called upon for use as backup equipment for voice communications, PCM data transmission, up-data reception, or S/C tracking and ranging when the S/C is within range of a MSFN station equipped for S-band operations. In addition, only the USBS is capable of transmitting TV.

The USBS consists of the S-band transmitter and receiver combined in a single electronic package called the unified S-band equipment (USBE) and the S-band power amplifier (PA). The function of the S-band PA is to provide additional power amplification of the USBE transmitter output. Two levels of amplification (high and low) are possible. A bypass mode is also possible wherein the S-band PA is turned off and the output of the USBE transmitter is sent to the S-band antenna equipment "as is." The 2-kmc portions of the upper and lower SCIN antennas are used for transmission and reception of S-band signals. Antenna selection is made by placing the S-BAND ANTENNA switch (MDC-20) to UPPER, LOWER, or AUTO. In the AUTO position, the antenna will be automatically switched if the signal falls below a minimum threshold.

The PMP is controlled in conjunction with the USBE by the S-BAND switches to provide the proper voice and data inputs to the USBE in accordance with the S-band mode selected.

When operating in a ranging mode, the MSFN can transmit a "coded" pseudo-random noise (PRN) pulse to the S/C via the S-band carrier. The S/C USBE will respond by transmitting an identical pulse to the MSFN. By

measuring the time lapse between transmission of the signal and reception of the response signal the MSFN can accurately determine the S/C range. Once established, this value can then be continually updated by measuring the doppler shift in the S-band carrier. A ranging mode can be selected again at later times, to verify or up-date the doppler data.

2.8.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

To facilitate this presentation, the equipment comprising the T/C system (figure 2.8-4) has been divided into four groups designated as instrumentation equipment, voice and data equipment, RF electronics equipment, and antenna equipment. Specifically, these equipment groups contain the following:

Instrumentation equipment group

- Operational instrumentation
- Flight qualification instrumentation

Voice and data equipment group

- Audio center (A/C) equipment
- Signal conditioning equipment (SCE)
- Pulse-code modulation-telemetry (PCM TLM) equipment
- Television (TV) equipment
- Premodulation processor (PMP) equipment
- Data storage equipment (DSE)
- Flight qualification recorder (FQR) equipment
- Up-data link (UDL) equipment
- Central timing equipment (CTE)
- Voice recorder

RF electronics equipment group

- VHF/AM transmitter-receiver equipment
- HF transceiver equipment
- VHF/FM transmitter equipment
- Unified S-band equipment (USBE)
- S-band power amplifier equipment
- C-band transponder equipment
- VHF recovery beacon equipment

Antenna equipment group

- VHF/2-KMC omni-antenna equipment
- HF antenna equipment
- VHF recovery antenna equipment
- C-band beacon antenna equipment

2.8.3.1 Instrumentation Equipment Group.

The S/C instrumentation equipment consists of various types of sensors and transducers for providing environmental, operational status, and performance measurements of the S/C structure, operational systems, and experimental equipment. The outputs from these sensors and transducers are conditioned to signals suitable for utilization by the S/C displays, presentation to the PCM TLM equipment, or both. In addition, various digital signals are presented to the PCM TLM equipment, including event information, guidance and navigation data, and a time signal from the CTE.

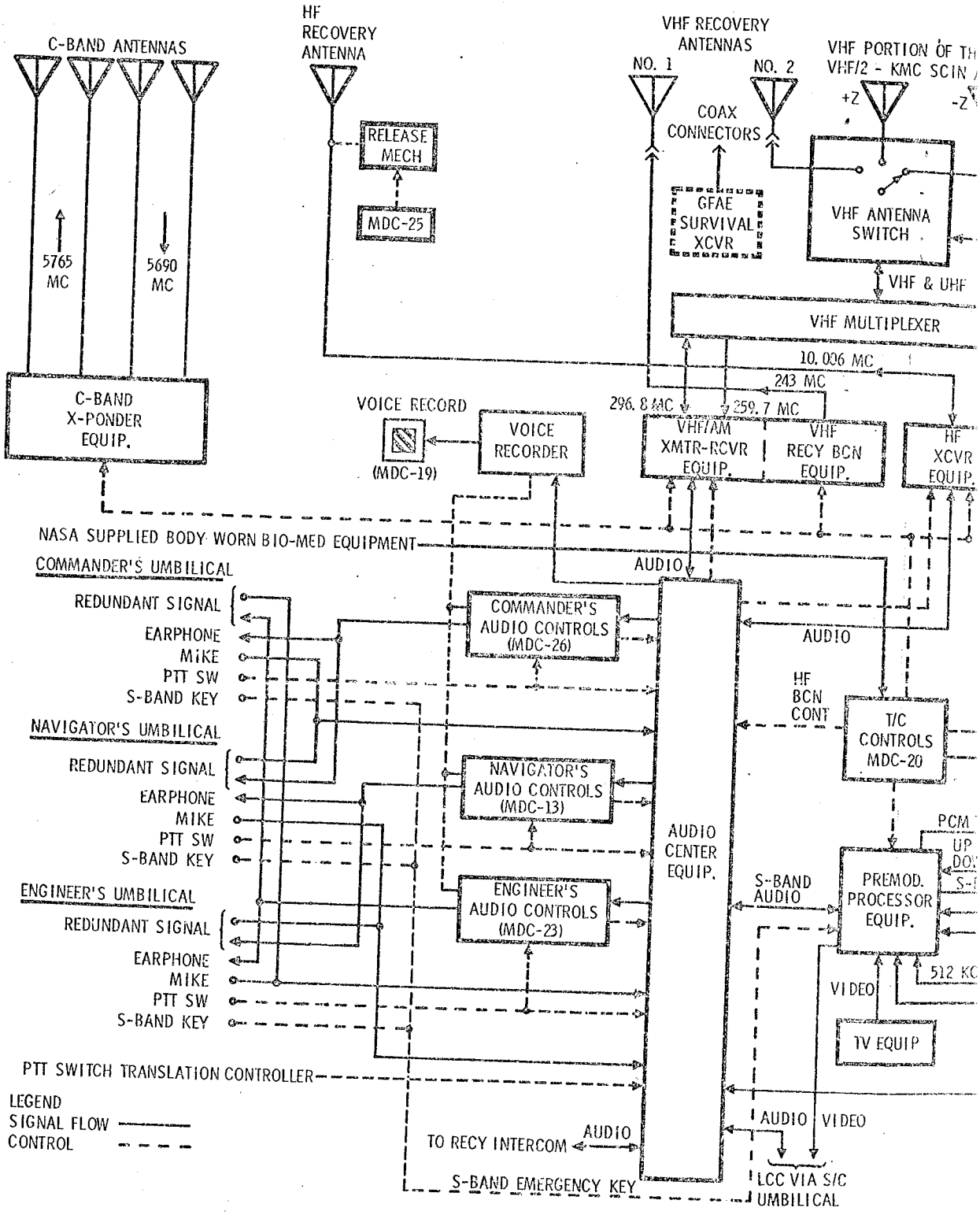
Many of the signals emanating from the instrumentation sensors are of forms or levels which are unsuitable for use by the S/C displays or PCM TLM equipment. Signal conditioners are used to convert these signals to forms and levels which can be utilized. Some signals are conditioned at or near the sensor by individual conditioners located throughout the S/C. Other signals are fed to the signal conditioning equipment (SCE), a single electronics package located in the lower equipment bay. (Refer to signal conditioning equipment in the Voice and Data Equipment Group.) In addition to conditioning many of the signals, the SCE also supplies 5-vdc excitation power to some sensors. The SCE can be turned on or off with the POWER-SCE switch on MDC-20. This is the only control that the crew can exercise over instrumentation equipment for operational and flight qualification measurements. These two instrumentation groups are discussed in the following two paragraphs. Information on scientific and special instrumentation can be found in section 4 of this manual, Experiments and Scientific Equipment.

2.8.3.1.1 Operational Instrumentation.

Operational measurements are those which are normally required for a routine mission and include three categories: in-flight management of the S/C, mission evaluation and system performance, and preflight checkout of the S/C. The operational instrumentation sensors and transducers are capable of making the following types of measurements: pressure, temperature, flow attitude, rate, quantity, angular position, current, voltage, frequency, RF power, and "on-off" type events.

2.8.3.1.2 Flight Qualification Instrumentation.

Flight qualification measurements are those which will vary on different S/C, depending on mission objectives and state of hardware development. Most of them will be pulse-code modulated along with the operational measurements and transmitted to the MSFN. Other flight qualification measurements will be stored in the FQR for postflight analysis only.


C-BAND ANTENNAS
5765 MC
5690 MC
C-BAND X-PONDER EQUIP.
HF RECOVERY ANTENNA
RELEASE MECH
MDC-25
VHF RECOVERY ANTENNAS
NO. 1
NO. 2
COAX CONNECTORS
GFAE SURVIVAL XCVR
VHF PORTION OF TH
VHF/2 - KMC SCIN
+Z
-Z
VHF ANTENNA SWITCH
VHF & UHF
VHF MULTIPLEXER
10.036 MC
243 MC
296.8 MC
259.7 MC
VOICE RECORD
(MDC-19)
VOICE RECORDER
VHF/AM XMTR-RCVR EQUIP.
VHF RECY BCN EQUIP.
HF XCVR EQUIP.
NASA SUPPLIED BODY WORN BIO-MED EQUIPMENT
AUDIO
COMMANDER'S UMBILICAL
REDUNDANT SIGNAL
EARPHONE
MIKE
PTT SW
S-BAND KEY
COMMANDER'S AUDIO CONTROLS (MDC-26)
AUDIO
HF BCN CONT
T/C CONTROLS MDC-20
NAVIGATOR'S UMBILICAL
REDUNDANT SIGNAL
EARPHONE
MIKE
PTT SW
S-BAND KEY
NAVIGATOR'S AUDIO CONTROLS (MDC-13)
AUDIO CENTER EQUIP.
PCM
ENGINEER'S UMBILICAL
REDUNDANT SIGNAL
EARPHONE
MIKE
PTT SW
S-BAND KEY
ENGINEER'S AUDIO CONTROLS (MDC-23)
S-BAND AUDIO
PREMOD. PROCESSOR EQUIP.
512 KC
VIDEO
TV EQUIP
PTT SWITCH TRANSLATION CONTROLLER
LEGEND
SIGNAL FLOW
CONTROL
TO RECY INTERCOM
AUDIO
AUDIO
VIDEO
S-BAND EMERGENCY KEY
LCC VIA S/C UMBILICAL

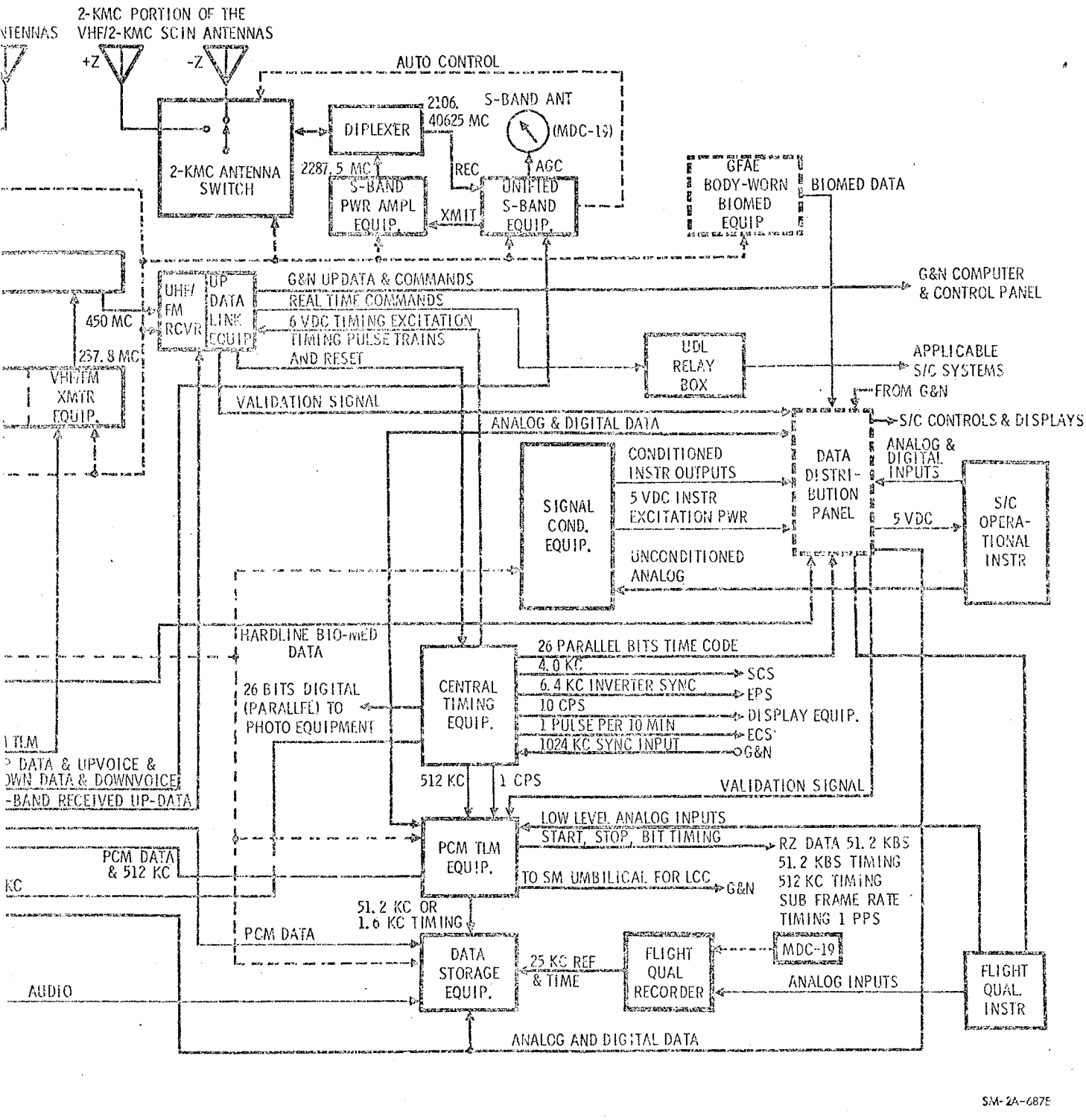


Figure 2.8-4. Telecommunications System

2.8.3.2 Voice and Data Equipment Group.

2.8.3.2.1 Audio Center (A/C) Equipment.

The A/C equipment (figure 2.8-5) consists of three separate identical modules located in a single electronics package in the lower equipment bay. Each module is controlled independently by its own control panel and supplied with 28-vdc power through separate circuit breakers. The three control panels, MDC-26, -13, and -23, are located in stations 1, 2, and 3, respectively. Each of the astronaut's headsets, containing two microphones and two microphone amplifiers, and two independently operating earphones, is connected to one of the A/C modules by a cobra cable. Thus each astronaut has a separate headset, audio center module, and audio control panel to provide him with individual control of voice transmission and reception.

Each A/C module contains a microphone amplifier, VOX circuitry, an earphone amplifier, and various signal attenuation, switching, and isolation circuits. The earphone and microphone amplifiers amplify the voice signals to and from the headset. The VOX circuitry is a voice-operated keying circuit that supplies a ground return path necessary for activating the microphone amplifier and the transmitter keying relays in the HF transceiver, intercommunication system, and the power control relay in the operating voice recorder.

Audio signals are provided to and from the HF transceiver equipment, VHF/AM transmitter-receiver equipment, USBE (via the PMP), and the intercom bus. The intercom bus is common to all three modules and provides for the hardline communications between crewmen and with the LCC and recovery forces.

Inputs and outputs are controlled by the RCDR/HF, VHF/AM, S-BAND, and INTERCOM switches on the audio control panels. Each of these switches has three positions: T/R, OFF, and REC. Setting any of the switches to T/R (except S-BAND) permits transmission and reception of voice signals over its respective equipment. REC permits reception only, and OFF disables the input and the output. The operation of the microphone amplifier in each module is controlled by the VOX keying circuit or the PTT pushbutton on the cobra cable or the translation controller. The VOX circuit is energized by the position of the POWER – PTT/OFF/VOX switch on each audio control panel. The PTT position permits monitoring and activation of the microphone amplifier, voice recorder HF, VHF/AM and S-band voice transmission circuits by the PTT key. The VOX position permits all the functions of the PTT position plus VOX activation of the microphone amplifier, voice recorder and HF transmitter.

Three potentiometer controls are also provided on each audio control panel: VOX SENS, INTERCOM BALANCE, and VOLUME. The VOX SENS control is used to adjust the sensitivity of the VOX circuitry, determining the amplitude of the voice signal necessary to trigger the VOX keying

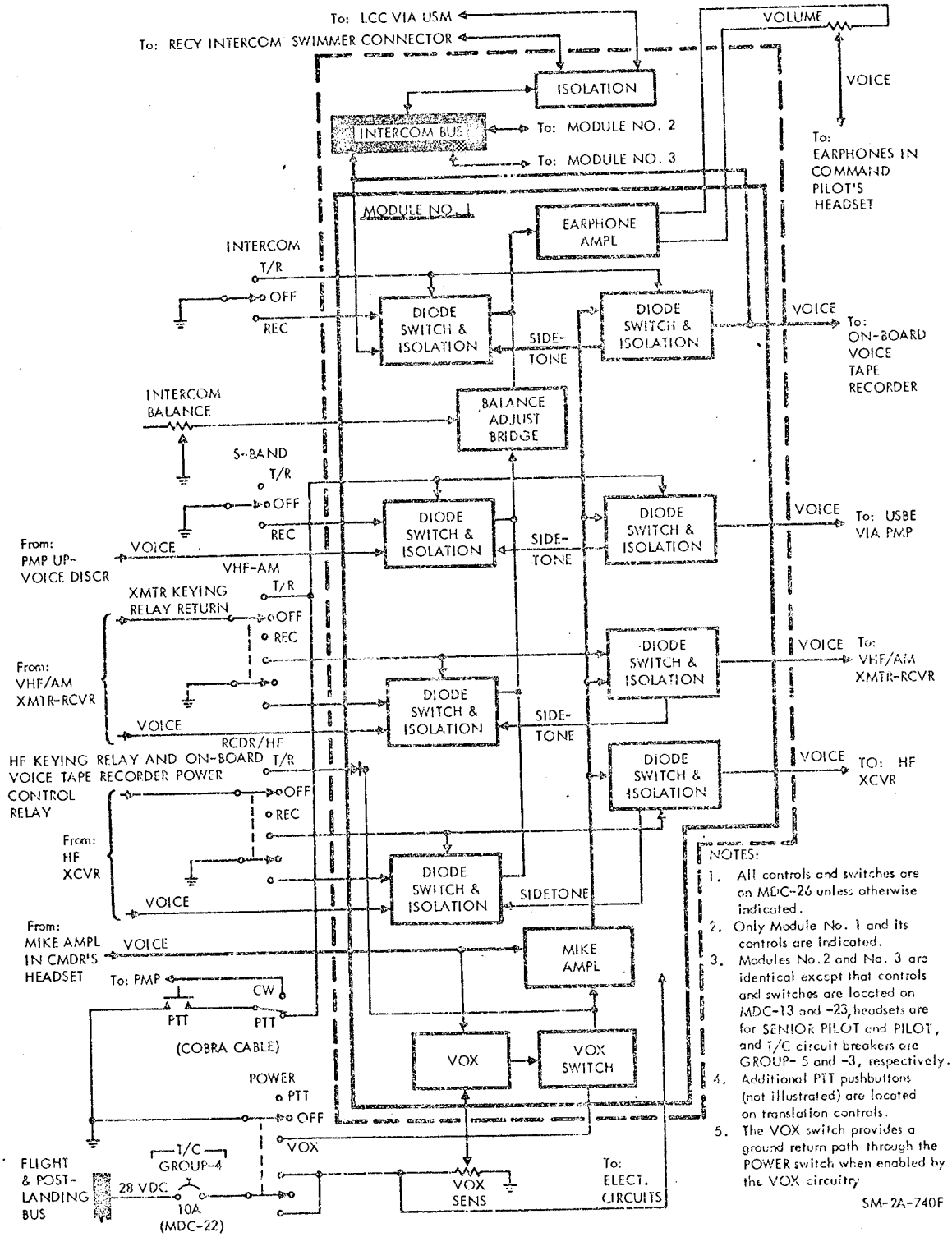


Figure 2.8-5. Audio Center Equipment

circuit. The INTERCOM BALANCE control adjusts the level of voice signal inputs from the RF equipment relative to the level of voice signal inputs from the intercom bus. The VOLUME control adjusts the output of the earphone amplifier.

2.8.3.2.2 Signal-Conditioning Equipment (SCE).

The signal-conditioning equipment (SCE) is contained in a single electronics package located in the LEB. (See figure 2.8-6.) Its functions are to convert various kinds of unconditioned signals from the instrumentation equipment into compatible, 0- to 5-volt d-c analog signals, and to provide excitation voltages to some of the instrumentation sensors and transducers.

The SCE uses the following module types: The active attenuator, to attenuate high-signal voltages; the ac-(am)to-dc converter, to detect the amplitude variations of an a-c signal; the dc differential amplifier, to amplify small signals; the dc differential bridge amplifier, to detect resistance changes; the bi-phase demodulator, to convert S/C position resolver outputs; the frequency demodulator, to detect frequency changes in an a-c signal; and the power supply, to provide +20 volts and -20 volts to the SCE circuitry, 10 volts as bridge excitation, and 5 volts to excite other S/C sensors.

The conditioned output signals from the SCE are routed to the data distribution panel (DDP). The DDP provides parallel outputs, where necessary, and routes the signals to the PCM telemetry equipment, S/C displays, and GSE connections.

The only external control for the SCE is the two-position POWER—SCE toggle switch on MDC-20. Placing this switch to ON applies 28 volts dc to the latch winding of the latching relay, which closes contacts applying 3-phase a-c power to the power supply module. In the OFF position, the relay is unlatched, removing a-c power from the power supply.

2.8.3.2.3 Pulse-Code Modulation Telemetry (PCM TLM) Equipment.

The function of the PCM TLM equipment (figure 2.8-7) is to convert TLM data inputs from various sources into one serial digital output signal. This single output signal is routed to the PMP for transmission to the MSFN or to the DSE for storage. The PCM TLM equipment is contained in two separate units located in the lower equipment bay: PCM unit 1 and PCM unit 2.

Input signals to the PCM TLM equipment are of four general types: low-level analog, high-level analog, parallel digital, and serial digital. Some of the low-level analog inputs are supplied directly from the instrumentation sensors; other data inputs are routed through the data distribution panel (DDP).

Two modes of operation are possible: the high- (normal) bit-rate mode of 51.2 kilobits per second (KBS) and the low- (reduced) bit-rate mode of 1.6 KBS. Operational mode is selected by placing the TLM INPUTS—PCM switch on MDC-20 to HIGH or LOW, as applicable. When the switch is in the LOW position, the high PCM bit-rate can be commanded by the MSFN via the UDL equipment.

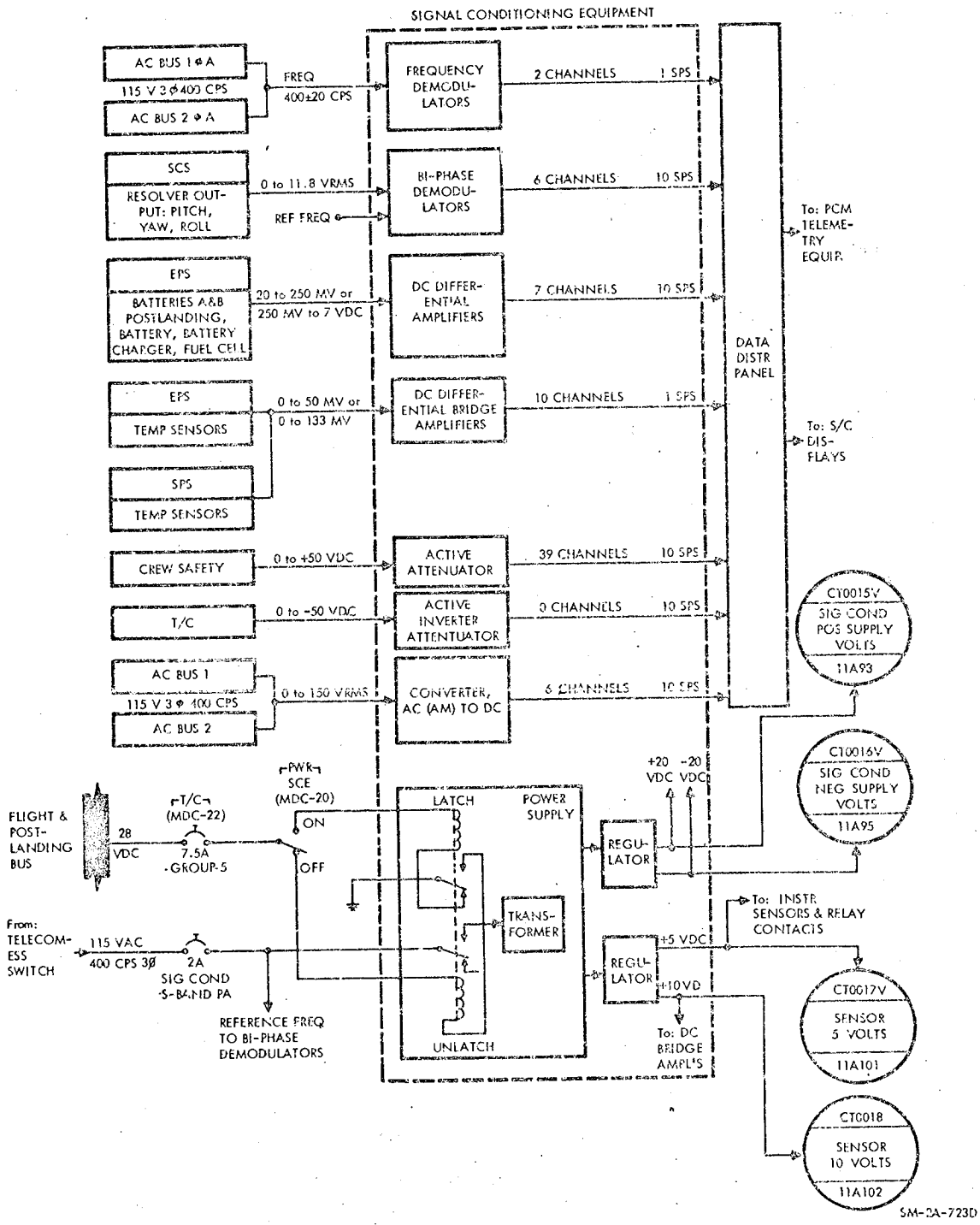


Figure 2.8-6. Signal Conditioning Equipment

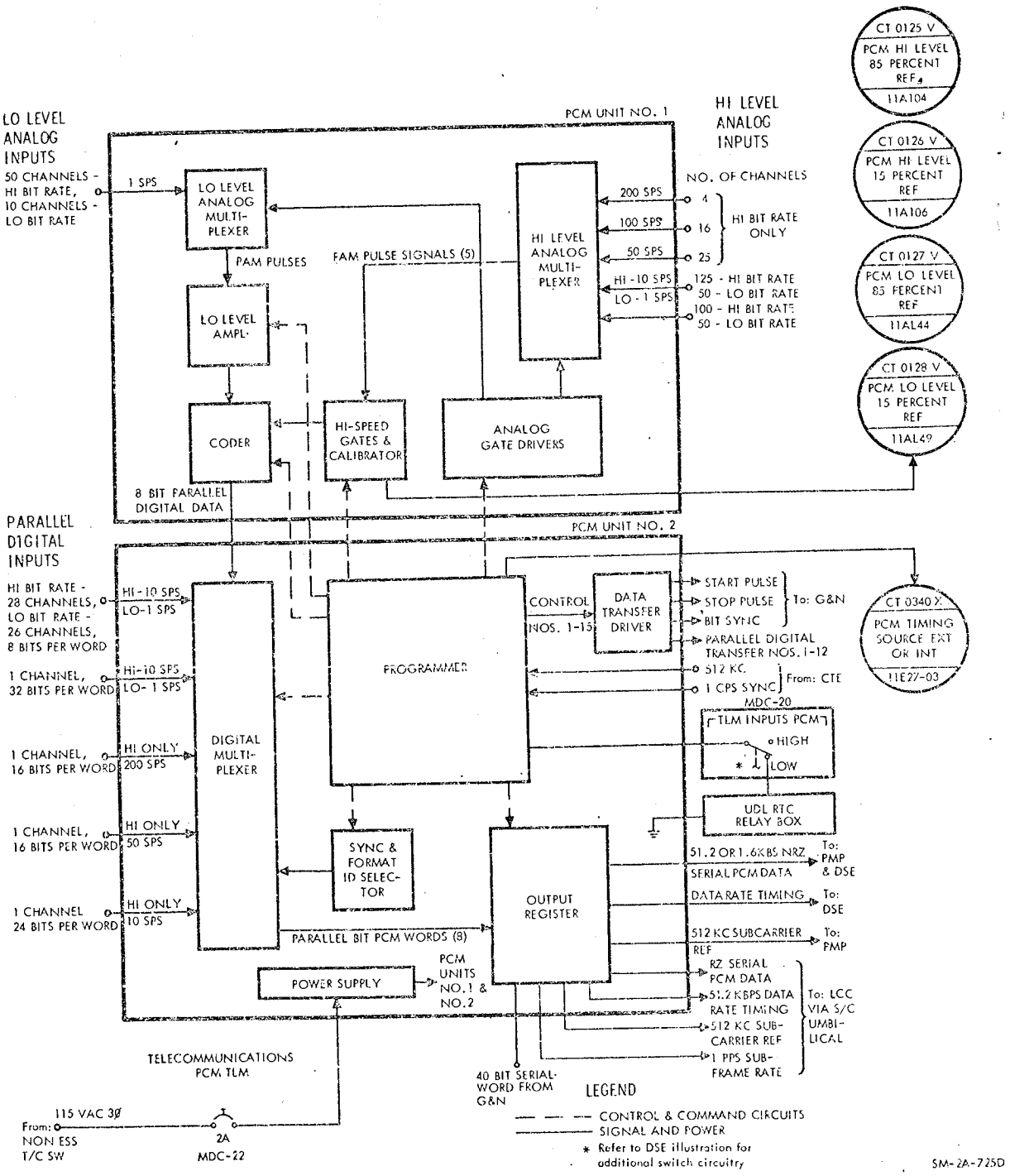


Figure 2.8-7. Pulse Code Modulation Telemetry

2.8.3.2.4 Television (TV) Equipment.

The TV equipment consists of a small, portable, TV camera (figure 2.8-8) that can be hand-held or mounted in one of four locations in the command module. Its function is to acquire real-time video information for transmission to the MSFN during S-band testing.

The first camera mounting position is located below the main display console, and will permit a front view of the crew lying in their couches. The second position is located behind the head of the center seat, and will permit viewing of crew activities in the middle of the command module. The second position is also provided with a five-foot stretch cable to permit hand-held use of the camera for coverage of any desirable target inside or outside the S/C. The third position is located in the right-hand equipment bay, and permits viewing of astronauts at work in that area. The final position utilizes a special bracket which allows the TV camera to look out the right-hand docking window.

The TV camera is connected directly to the PWR cable at the first mounting position. If the TV camera is to be used in the mounting position behind the center couch, the PWR cable must be connected to the connector marked "TV Cam to Hatch J107," and the camera, in turn, should be connected to the connector at that position (J191), by the stretch cable. If the TV camera is to be mounted by the right-hand equipment bay, the PWR cable must be connected to the connector marked "TV Cam to RHEB," and the TV camera connected to the connector at that location (J195) by the stretch cable.

The TV camera is constructed with a pistol-grip type of handle on the bottom, which can be extended to facilitate portable use. The TV camera is fitted with a fixed-focus wide-angle lens for picture taking within the command module. For taking pictures of the earth or moon through the C/M window, an interchangeable zoom lens is provided. The zoom lens has a look angle of from 9 degrees through 30 degrees. It is fitted with a through-the-lens type viewer that will enable the operator to see the change in field of view and relative size of the scene while the lens is adjusted. The electronic circuitry in the camera is equipped with an automatic gain control to allow for differences in target illumination.

The TV camera is activated by a slide switch in the pistol-grip handle, which applies 28 volts dc to the camera power supply when set to on. This energizes the entire camera and results in a video output signal that is fed to the PMP. In the PMP, the video signal is frequency multiplexed with the telemetry data and voice, which is transmitted to earth via the USBE. The USBE must be operating in a TV mode to permit this transmission. An AUTO LIGHT CONTROL switch has been added to the camera, permitting it to compensate for either peak or average scene illuminations from 0.1 to 30 foot candles.

2.8.3.2.5 Premodulation Processor (PMP) Equipment.

The PMP equipment (figure 2.8-9) functions as a data processing and distribution center providing necessary interface, where required, between the voice, data, and RF equipment. The PMP consists of ten modules mounted in a single electronics package located in the lower equipment bay. These modules contain filters, oscillators, modulators, demodulators, detectors, switching circuits, discriminators, mixing and keying networks, and a power supply.

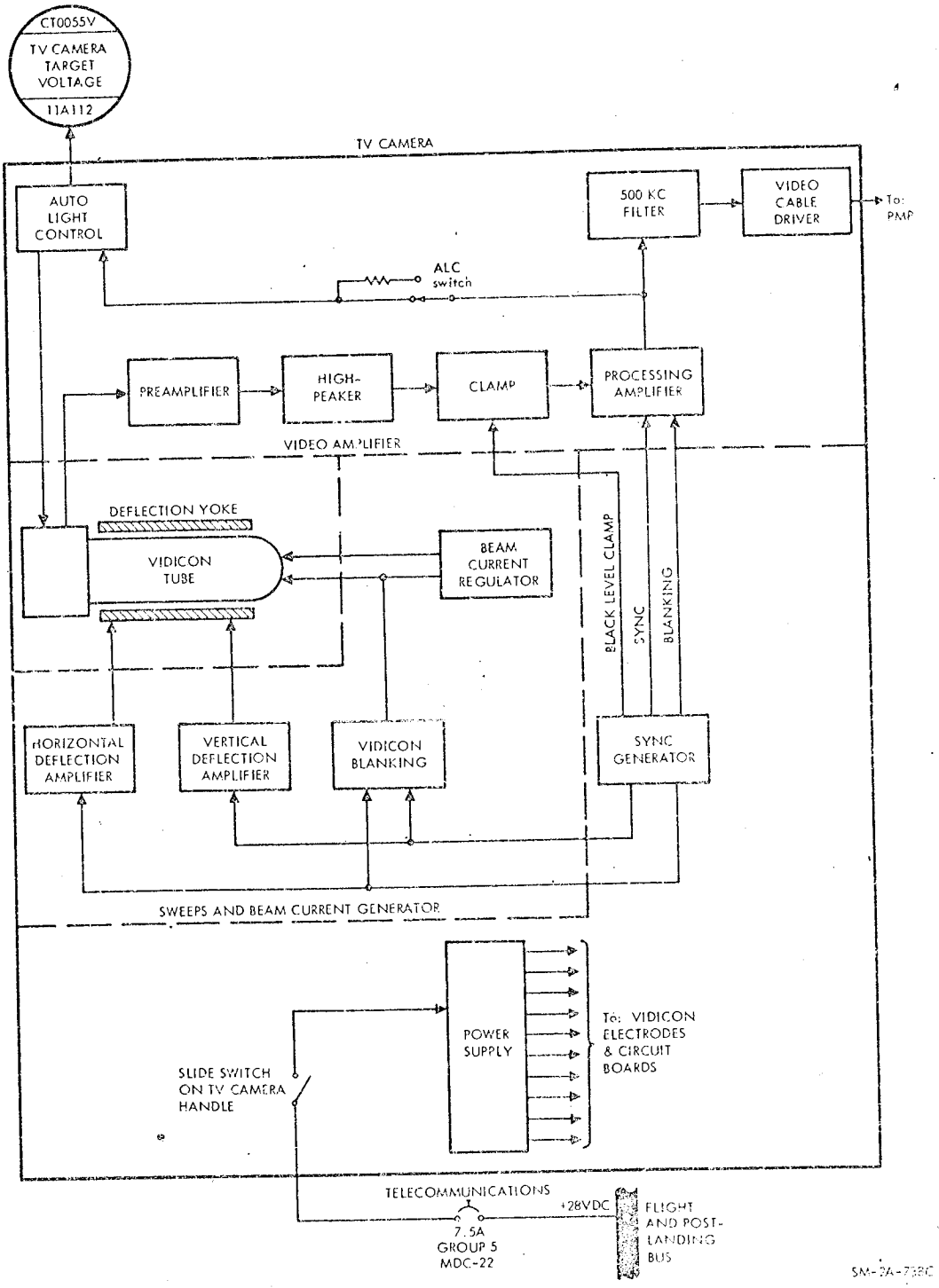


Figure 2.8-8. Television Equipment

The PMP can operate in many possible modes. All of the external controls for the PMP are switches located on MDC-20. The switches which affect the PMP consist of the POWER – PMP switch, the S-BAND – VOICE group of switches, the S-BAND – EMERG switch, and the TAPE RECORDER – PLAY and – RECORD/PLAY switches. Also, during emergency key operation, the PTT keys on the cobra cables and translation controls, control the PMP emergency key network. All of the signal inputs available to the PMP are listed in the PMP INPUTS table at the end of this paragraph. PMP outputs are dependent upon switch configuration. The PMP OUTPUTS table, also at the end of this paragraph, shows the various composite output signal possibilities along with their destinations and the switch positions required for any mode of operation. It should be noted that the S-BAND and TAPE RECORDER switches also affect the operational mode of the USBE and DSE.

One function of the PMP is to process the PCM TLM signal obtained from the PCM TLM equipment or DSE and route it to the VHF/FM transmitter equipment for transmission to the MSFN. This output will be provided whenever a PCM input is available, regardless of mode and simultaneously with other PMP outputs.

All remaining PMP functions involve interface with the USBE. Inputs to the PMP from the USBE are the 70-kc up-data and 30-kc up-voice subcarriers. These are fed into the up-data and up-voice discriminator circuits. These two circuits (as well as circuitry needed for emergency S-band modes) do not require the PWR-PMP switch to be on. They are supplied with power independently whenever the USBE is in operation. Outputs from the up-data and up-voice discriminators are fed to the UDL and A/C equipment, respectively.

The PMP supplies an output to one of the three USBE inputs, depending on S-band mode as selected by the S-BAND – VOICE group of switches and the S-BAND – EMERG switch. The USBE inputs are designated PM, FM-1, and FM-2. During normal S-band modes, the PMP supplies either a PM or FM-1 output to the USBE. The PM output supplies real-time PCM TLM and voice to the USBE when the USBE is operating in a normal voice or a ranging mode. If the USBE ranging only mode is selected, the PCM TLM portion of the output is eliminated, leaving only voice signals in the PM-1 output. When recorded data or TV data is to be transmitted along with PCM TLM and voice data, the FM-1 output is supplied to the USBE. This mode permits the greater bandwidth which is required for transmission of this data.

There are two emergency modes; emergency voice and emergency key, selected by the S-BAND – EMERG switch and used to permit emergency transmission of voice or code over the USBE with the PMP shutdown. With the S-BAND – EMERG switch in the center (OFF) position, the PWR – PMP switch controls the application of power to the PMP. However, with the S-BAND – EMERG switch set to either VOICE or KEY, a-c power is removed from the PMP. In the KEY position, a separate 28-volt d-c

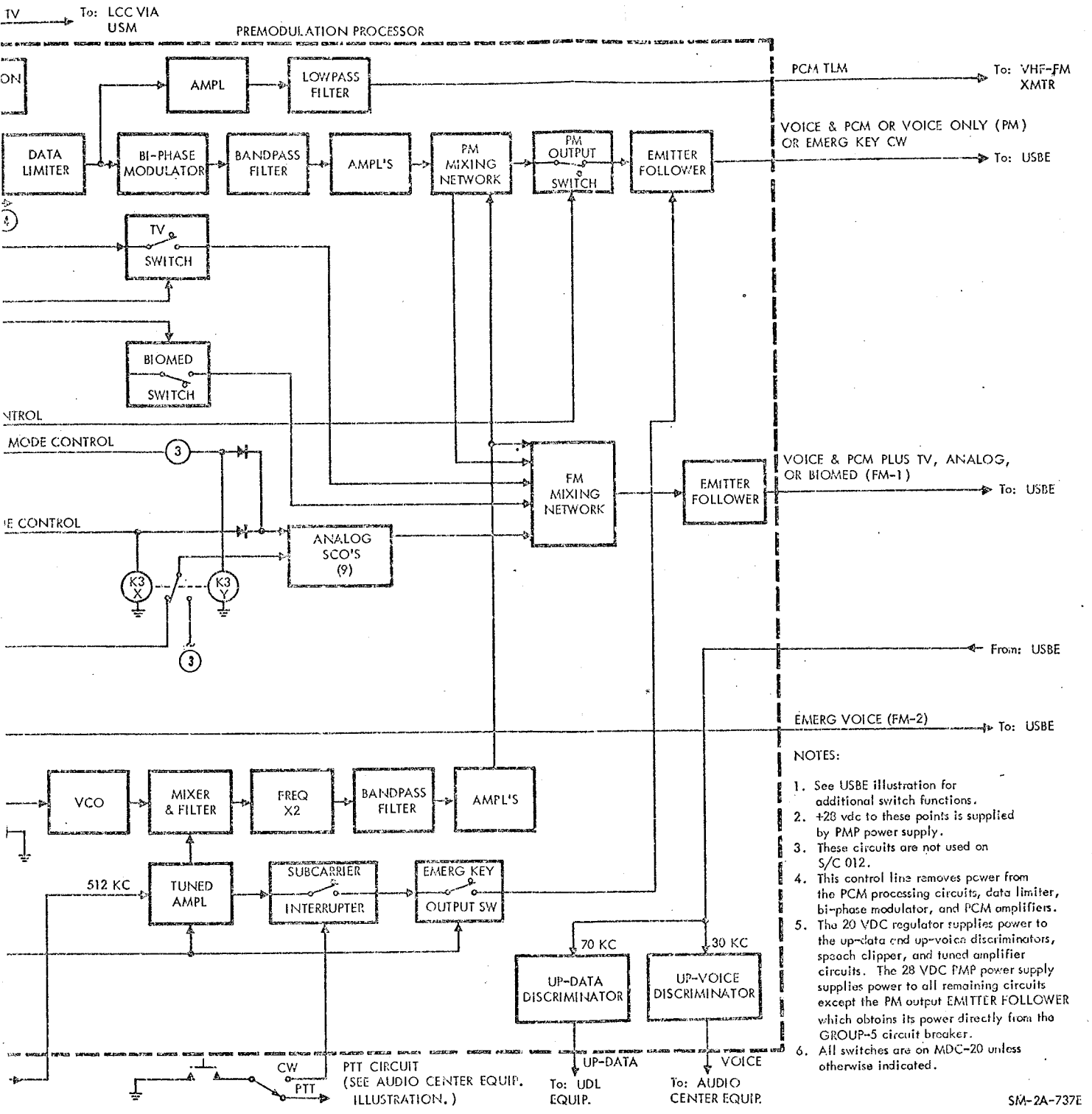
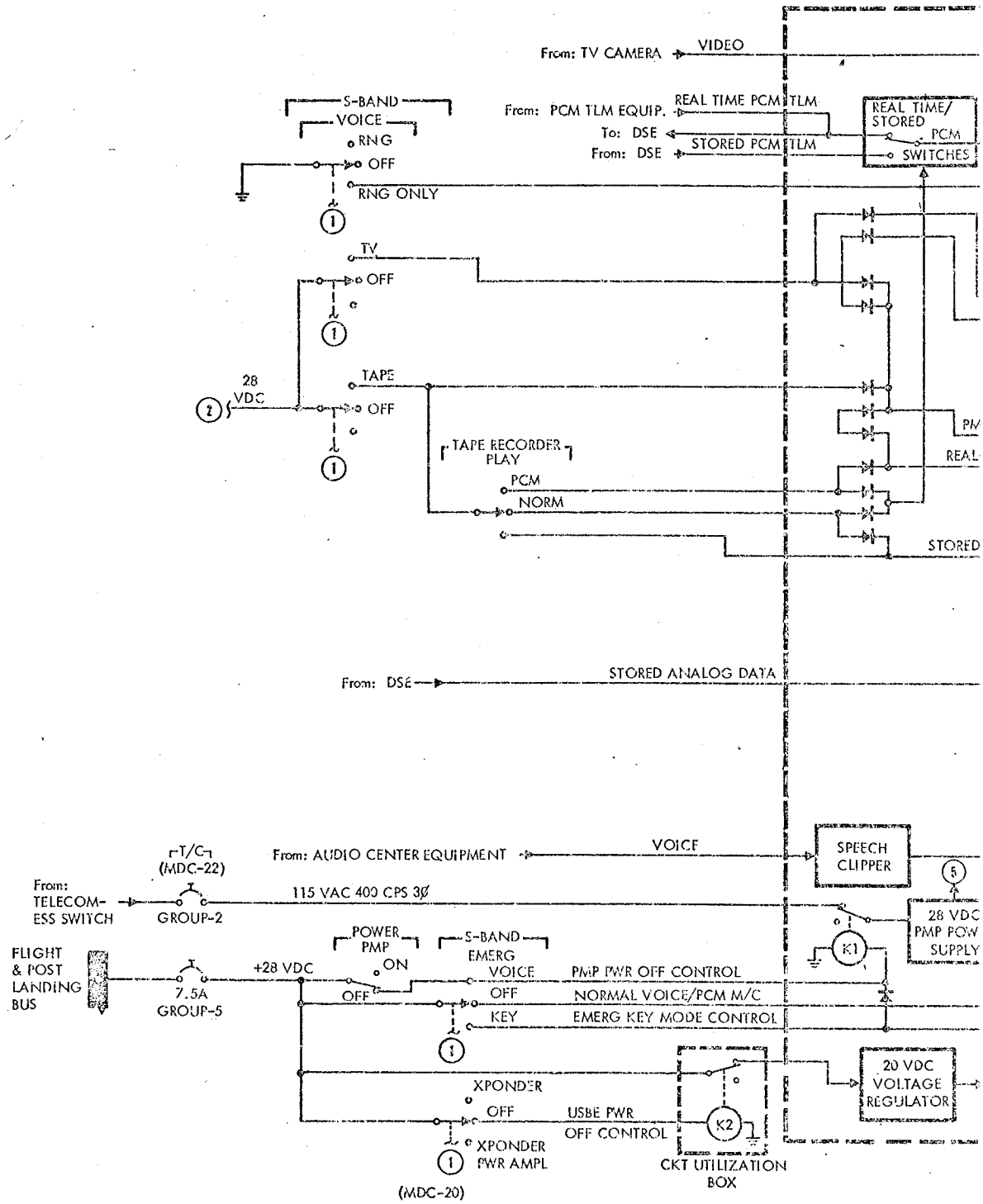


Figure 2.8-9. Premodulation Processor Equipment


From: TV CAMERA
VIDEO
S-BAND
VOICE
RNG
OFF
From: PCM TLM EQUIP.
REAL TIME PCM TLM
To: DSE
From: DSE
STORED PCM TLM
REAL TIME/ STORED
PCM
SWITCHES
RNG ONLY
TV
OFF
28 VDC
TAPE
OFF
TAPE RECORDER PLAY
PCM
NORM
STORED
From: DSE
STORED ANALOG DATA
T/C (MDC-22)
From: AUDIO CENTER EQUIPMENT
VOICE
SPEECH CLIPPER
From: TELECOM-ESS SWITCH
GROUP-2
115 VAC 400 CPS 3Ø
28 VDC PMP POW SUPPLY
K1
FLIGHT & POST LANDING BUS
7.5A
GROUP-5
+28 VDC
POWER PMP
ON
OFF
S-BAND EMERG VOICE
OFF
KEY
PMP PWR OFF CONTROL
NORMAL VOICE/PCM M/C
EMERG KEY MODE CONTROL
XPONDER
OFF
USBE PWR OFF CONTROL
K2
20 VDC VOLTAGE REGULATOR
XPONDER PWR AMPL
(MDC-20)
CKT UTILIZATION BOX

source is used to enable the emergency key network only, which permits a 512-kc signal from the CTE to be keyed by the PTT key in the cobra cable. This signal is applied to the PM input of the USBE. In the VOICE position, voice signals from the audio center equipment are routed directly through the PMP and supplied to the FM-2 (emergency voice) input of the USBE.

The following matrix shows the switching configurations of the S-band system in several operational modes.

PMP Inputs

Signal Type	Source	Application
Real-time PCM TLM	PCM TLM equipment	Transmission to MSFN via USBE or VHF/FM transmitter
Video	TV equipment	Transmission to MSFN via USBE
Voice	Audio center equipment	Transmission to MSFN via USBE
Recorded PCM TLM	DSE	Transmission to MSFN via USBE or VHF/FM transmitter
512-kc square wave	CTE	CW transmission to MSFN during emergency key mode
512-kc square wave	PCM TLM equipment	Subcarrier for transmission of PCM TLM to MSFN via USBE
70-kc up-data subcarrier	USBE	Detection of up-data received from MSFN via USBE
30-kc up-voice subcarrier	USBE	Detection of up-voice received from MSFN via USBE

PMP Outputs

Output		Switch Positions (MDC-20)						
		PWR	S-BAND – VOICE Group			S-BAND	TAPE RECORDER	
Types of Data	Destination	PMP	RNG-Off-RNG ONLY	TAPE-Off	TV-Off	EMERG	PLAY	RECORD-Off-PLAY
Real-time voice	USBE (FM-2)	*	*	*	*	VOICE	*	*
Interrupted 512-kc carrier (keyed by PTT switch)	USBE (PM)					KEY		
Real-time PCM TLM	VHF/FM Transmitter	ON		Off (center)		Off (center)		
Recorded PCM TLM				TAPE			PCM or NORM	PLAY
Real-time PCM TLM and voice	USBE (PM)		RING or Off (center)	Off (center)	Off (center)		*	RECORD or OFF (center)
Real-time voice			RNG ONLY					
Recorded PCM and real-time voice	USBE (FM-1)		*	TAPE			NORM	PLAY

*This switch does not affect this output mode.

PMP Outputs								
Output		Switch Positions (MDC-20)						
		PWR	S-BAND – VOICE Group			S-BAND	TAPE RECORDER	
Types of Data	Destination	PMP	RNG-Off-RNG ONLY	TAPE-Off	TV-Off	EMERG	PLAY	RECORD-Off-PLAY
Recorded PCM TLM and real-time voice	USBE (FM-1)	ON	*	TAPE	Off (center)	Off (center)	PCM	Play
Real-time PCM TLM and voice								
Real-time PCM TLM, voice, and TV				Off (center)	TV		*	*
Real-time PCM TLM and voice								
Up-data commands	UDL			*	*			
Up-voice	Audio Center Equipment							

*This switch does affect this output mode.

2.8.3.2.6 Data Storage Equipment (DSE).

The DSE (figure 2.8-10)is a three-speed, 14-track magnetic tape recorder and reproducer located in the LEB. It is used to store data during phases of the mission which inhibit or prevent the successful transmission of this data to the MSFN. Data can be recorded in parallel on five digital channels, and played back during a later phase of the mission for transmission to the MSFN. Each reel contains 2250 feet of one-inch-wide, magnetic, Mylar tape.

The PCM TLM data is obtained from the PCM TLM equipment as a single serial pulse train at a high bit-rate of 51.2 KBPS or a low bit-rate of 1.6 KBPS, depending on the PCM TLM mode. In the DSE, a serial-to-parallel converter circuit converts this signal into four parallel digital channels, each of which as a resulting pulse repetition rate (PRR) of only 12.8 KBPS or 0.4 KBPS (one-fourth of the original PRR). The PCM TLM equipment also furnishes a 51.2-kc or 1.6-kc square wave timing signal to the DSE, which is also divided by four. These five signals, the four channels of PCM TLM and the clock signal, are amplified by the five digital record amplifiers and fed to the digital record heads. Only one analog channel, the 25-kc reference and timing signal from the FQR, is scheduled for use on SC012.

During playback, the playback heads pick up the recorded data and present it to the digital playback amplifiers. The four parallel channels of recorded digital data and the clock signal divided by four are picked up by the five digital playback heads and presented to the five digital playback amplifiers. The amplified signals are then routed to the parallel-to-serial converter and the reproduce module. The four digital signals are converted back to a single serial pulse train which is fed to the PMP equipment. The bit-rate of this output will always be 51.2 KBPS, even if the recorded data was originally 1.6 KBPS. This is due to different speeds used in recording and reproducing. The 51.2 KBPS high bit-rate PCM signal is recorded at 15 inches per second (ips) and played back at the same speed. The low bit-rate signal of 1.6 KBPS is recorded at 3.75 ips, however, and played back at 120 ips, an increase of 32 times. This increases the 1.6 KBPS PRR to 51.2 KBPS.

The DSE is a bidirectional machine with a tape transport mechanism capable of forward or reverse operation at any of three speeds: 3.75 ips (low speed), 15 ips (normal speed), and 120 ips (high speed). The low speed of 3.75 ips is used only to record low bit-rate PCM TLM data. The DSE playback electronics is automatically disabled whenever this speed is selected. The normal speed of 15 ips is used to record and play back high bit-rate PCM TLM data. The high speed of 120 ips is used for fast dump of the low bit-rate PCM TLM data which was recorded at 3.75 ips. The high speed is also used for fast forward or reverse rewinding. Maximum operating times, to record or play back the entire 2250 feet of tape, are as follows: 2 hours at the low speed of 3.75 ips, 30 minutes at the normal speed of 15 ips, and 3.75 minutes at the high speed of 120 ips.

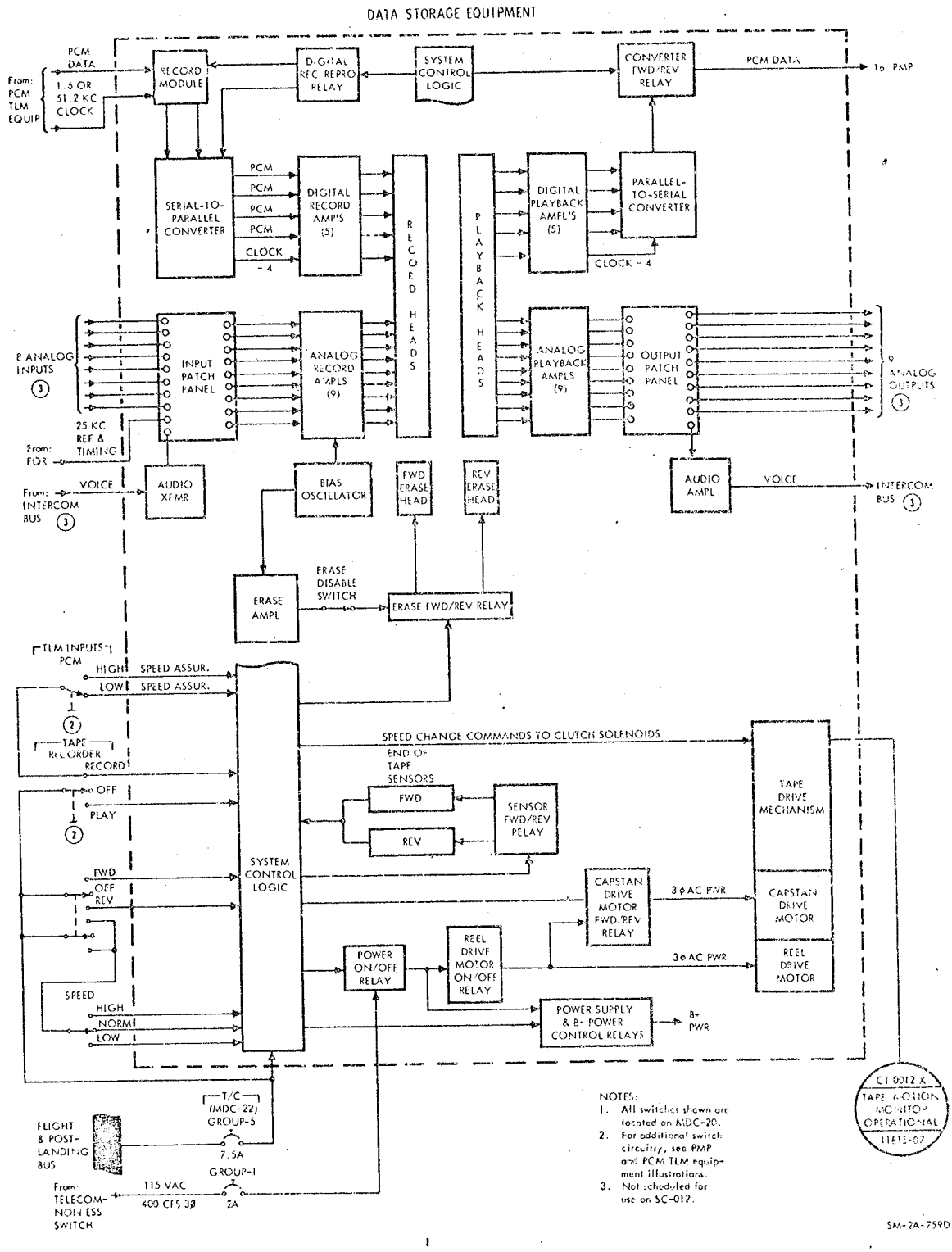


Figure 2.8-10. Data Storage Equipment

Tape speed and direction are controlled by the TAPE RECORDER – SPEED and – FWD/OFF/REV switches on MDC-20. Other TAPE RECORDER switches are the RECORD/PLAY switch which selects the record or playback mode, and the PLAY switch which selects the type of data to be reproduced. The PLAY switch has two positions: PCM and NORM. In either position, only PCM TLM data is reproduced and routed to the PMP equipment. The S-BAND – VOICE – TAPE switch must be set to TAPE before the TAPE RECORDER – PLAY switch becomes effective. The TLM INPUTS – PCM switch also affects tape recorder operation when recording. The interlock circuit in the DSE system control logic, which prevents selection of conflicting operational modes, locks the tape speed at 15 ips (normal) when the TLM INPUTS – PCM switch is set to HIGH. When set to LOW, the tape speed is locked at 3.75 ips. The proper control switch configuration for all DSE modes is shown in the table at the end of this paragraph.

An end-of-tape sensing circuit in the DSE automatically removes power from the tape drive mechanism and electronic circuits when the end of the tape is reached.

DSE Functions	Switch Positions					
	S-BAND–VOICE	TAPE RECORDER				TLM INPUTS
	TAPE-Off-ANALOG	PLAY PCM-NORM-ANALOG	SPEED HIGH-NORM-LOW	RECORD-Off-PLAY	FWD Off-REV	PCM HIGH-LOW
Record high bit rate	OFF	Any	NORM	RECORD	FWD* or REV	HIGH
Record low bit rate	OFF	Any	LOW	RECORD	FWD* or REV	LOW
Playback recorded high bit rate	TAPE	PCM or NORM	NORM	PLAY	FWD or REV	Any
Playback recorded low bit rate	TAPE	PCM or NORM	HIGH	PLAY	FWD or REV	Any
Playback recorded** mixed bit rate	TAPE	PCM or NORM	NORM	PLAY	FWD or REV	Any
Reposition tape to end of reel (rewind)	OFF	Any	HIGH	PLAY	FWD or REV	Any

*Since the DSE is a bidirectional machine, it can record, play back, or rewind in either direction.
**Under present mission procedures, this mode should not be necessary.

Illegal Modes:

1. High bit rate must be recorded at normal speed or tape motion will stop.
2. Low bit rate must be recorded at low speed or tape motion will stop.
3. If tape is played back at low speed, the tape will move, but there will be no play back data available to the transmitters.
4. If tape is played back at high speed and contained high bit rate data, the play back data will be garbled.
5. If a FWD or REV command only is given to initiate a rewind, there will be no tape motion. A mode must also be selected (preferably PLAY) before tape will move.

2.8.3.2.7 Flight Qualification Recorder (FQR).

The FQR is a 14-track magnetic tape recorder which is used to record certain flight qualification measurements during critical phases of the mission. (See figure 2.8-11.) This data will be used for postflight analysis only; the FQR has no in-flight playback or transmission capability. It will be activated in a record mode during the ascent and entry phases of the mission and during SPS burns.

Flight qualification data is recorded in analog form. (Digital data cannot be recorded on the FQR.) Two recording tracks (one record head in each of two record-head stacks) are used for reference and time code recording. To accomplish this, an elapsed time code generator is used to modulate a narrow-band VCO. The output of the VCO is then mixed with the output of a 50 kc reference oscillator. This composite signal is presented to each of the two record heads through two direct record amplifiers.

The FQR operates at a record speed of 15 ips and a rewind speed of 120 ips. The 15 ips record speed allows a total of 30 minutes recording time per reel of tape. Because there are no provisions for crewmembers to change tape reels during the mission, the FQR must be used conservatively. Normally, the rewind function will not be used unless it is required to back the tape up to the beginning during prelaunch activities. End-of-tape sensing is provided, which will automatically halt the tape motion and remove power from the electronic circuits when the end of the tape is reached in either direction.

Crewman control of the FQR is provided by the FLIGHT QUAL RCDR, 3-position toggle switch on MDC-19. In the STOP position, all a-c and d-c power is removed. Placing the switch to RECORD activates all electronic circuitry and the tape transport mechanism, which moves the tape forward at 15 ips. The REWIND position activates the tape transport mechanism to move the tape backward at 120 ips.

The measurement numbers and names of the parameters stored in the FQR are presented in the following list. This does not include the two FQR channels utilized for storage of reference and timing code storage.

Measurement Number	Identity
CG 2010 V	X PIPA output, in phase
CG 2030 V	Y PIPA output, in phase
CG 2050 V	Z PIPA output, in phase
CK 0004 A	Linear acceleration structure X axis A
CK 0005 A	Linear acceleration structure Y axis A

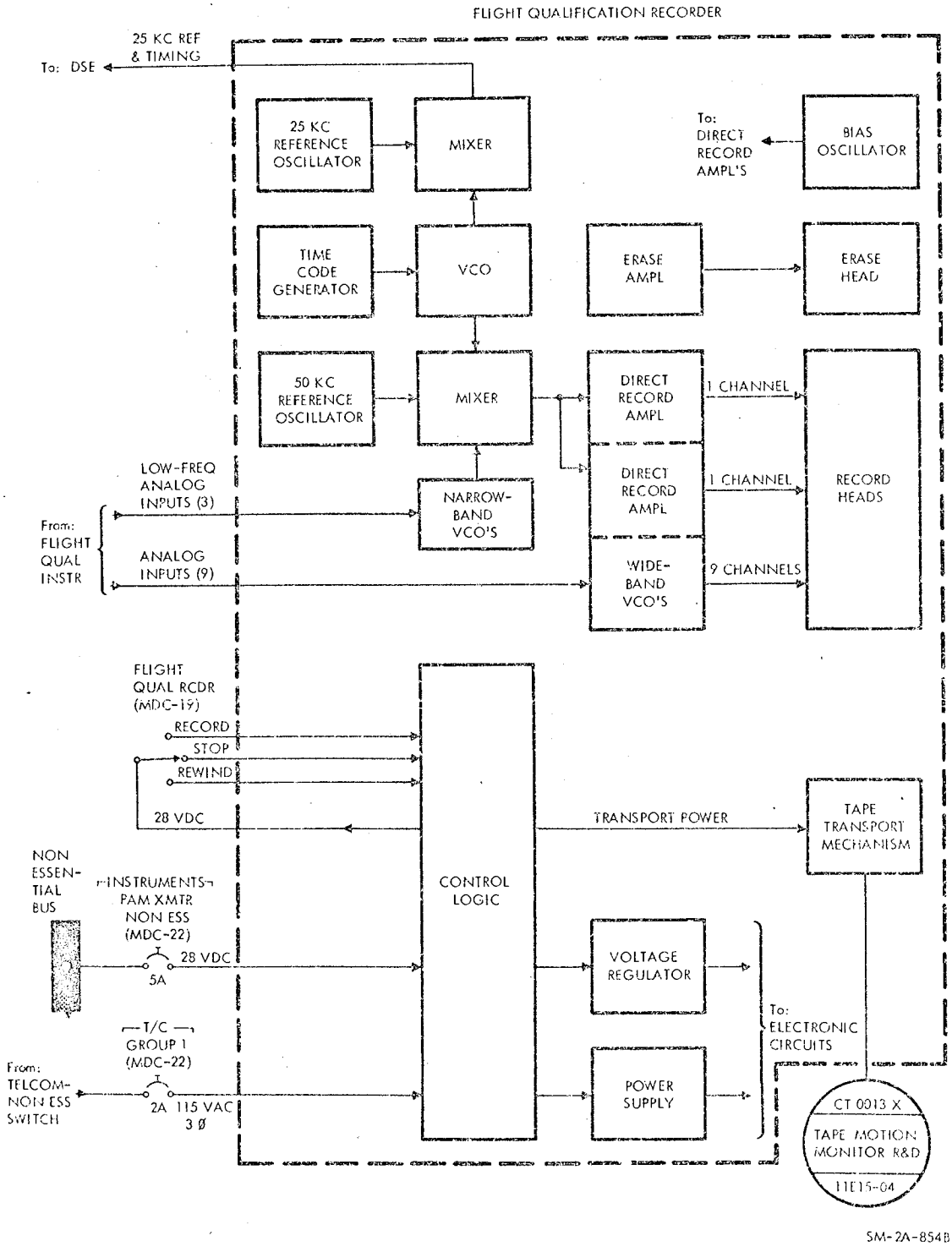


Figure 2.8-11. Flight Qualification Recorder Equipment

Measurement Number	Identity
CK 0006 A	Linear acceleration structure Z axis A
CR 0514 P	CCW roll engine pressure, system A
CR 0520 P	CCW roll engine pressure, system B
CR 0623 P	Fuel line pressure, system A
CR 0624 P	Fuel line pressure, system B
CR 0625 P	Oxidizer line pressure, system A
CR 0626 P	Oxidizer line pressure, system B

2.8.3.2.8 Up-Data Link (UDL) Equipment.

The function of the UDL equipment is to receive, verify, and distribute digital up-dating information sent to the S/C by the MSFN at various times throughout the mission to up-date or change the status of operational systems. The UDL (figure 2.8-12) consists of a UHF-FM receiver, a transistor mode switch, detecting and decoding circuitry, a buffer storage unit, output relay drivers, and a power supply. The UDL provides the means for MSFN to update the AGC, the CTE, and to select certain vehicle functions.

Two operational modes are possible: UHF and S-band. The mode normally used is UHF. In this mode, the incoming 450-mc up-data carrier is received by the VHF omni-antenna equipment and fed to the UHF receiver in the UDL. The intelligence is detected from the carrier and routed through the mode switch to the sub-bit detector, which converts it to a serial digital signal. The digital output from the sub-bit detector is fed to the remaining UDL circuitry, which stores and checks the digital data, determines the proper destination of the data, and processes it to the appropriate S/C system or equipment.

Real-time commands from the real-time command (RTC) drivers are supplied to the UDL RTC relay box which contains four, RTC, 2-position, latching relays. Thus eight real-time commands are possible: four "set" commands and four "reset" commands. The chart on the following page lists the eight commands by number and function.

The S-band up-data mode can be selected when the USBE is in operation. In this mode, the UHF receiver in the UDL is deactivated and its function is replaced by the USBE receiver and the PMP. Up-data information can be transmitted to the S/C within the 2-kmc S-band signal. When this signal is received by the USBE receiver, the 70-kc subcarrier containing the up-data information is extracted and sent to the up-data discriminator in the PMP. The resulting composite audio frequency signal is routed to the sub-bit detector in the UDL.

There are three external controls for the UDL equipment. One is the three-position, center-off, UP-DATA switch on MDC-20. When set to the

UDL Real-Time Commands				
Command	Action	UDL Relay	MDC-20 SW Position	Results
00	Deactivates system A abort request light	K1 (RESET)		MDC-3
01	Activates system A abort request light	K1 (SET)		MDC-3 turns on abort light.
02	Effect on C-band equipment operation determined by position of C-band switch on MDC-20	K3 (RESET)	C-BAND 1 PULSE	C-band equipment continues to operate in 1-pulse mode.
			OFF	C-band equipment remains off.
			2 PULSE	C-band equipment continues to operate in 2-pulse mode.
03	Turns C-band equipment on in 2-pulse mode	K3 (SET)	C-BAND 1 PULSE	C-band equipment continues to operate but switches to 2-pulse mode.
			OFF	Energizes C-band equipment which operates in 2-pulse mode.
			2 PULSE	No effect on C-band operation.
04	Effect on VHF-FM transmission of PCM data determined by position of VHF-FM-ON/OFF and TLM INPUTS-HIGH/LOW switches on MDC-20	K4 (RESET)	VHF-FM ON	No effect on VHF-FM transmitter.
			OFF	No effect on VHF-FM transmitter.
			TLM INPUTS PCM HIGH	PCM TLM remains in 51.2 KBS.
			LOW	PCM TLM output is 1.6 KBS.
05	Turns VHF-FM transmitter on and changes bit rate from low to high	K4 (SET)	VHF-FM ON	No effect on VHF-FM transmitter.
			OFF	Energizes VHF-FM transmitter.
			TLM INPUTS PCM HIGH	No effect on bit rate.
			LOW	Switches from 1.6 KBS to 51.2 KBS. NOTE: If data is being recorded, DSE will automatically stop if TAPE RECORD-SPEED switch is not positioned to HIGH.
06	Deactivates system B abort request light	K2 (RESET)		MDC-3
	Activates system B abort request light	K2 (SET)		MDC-3 turns on abort light.

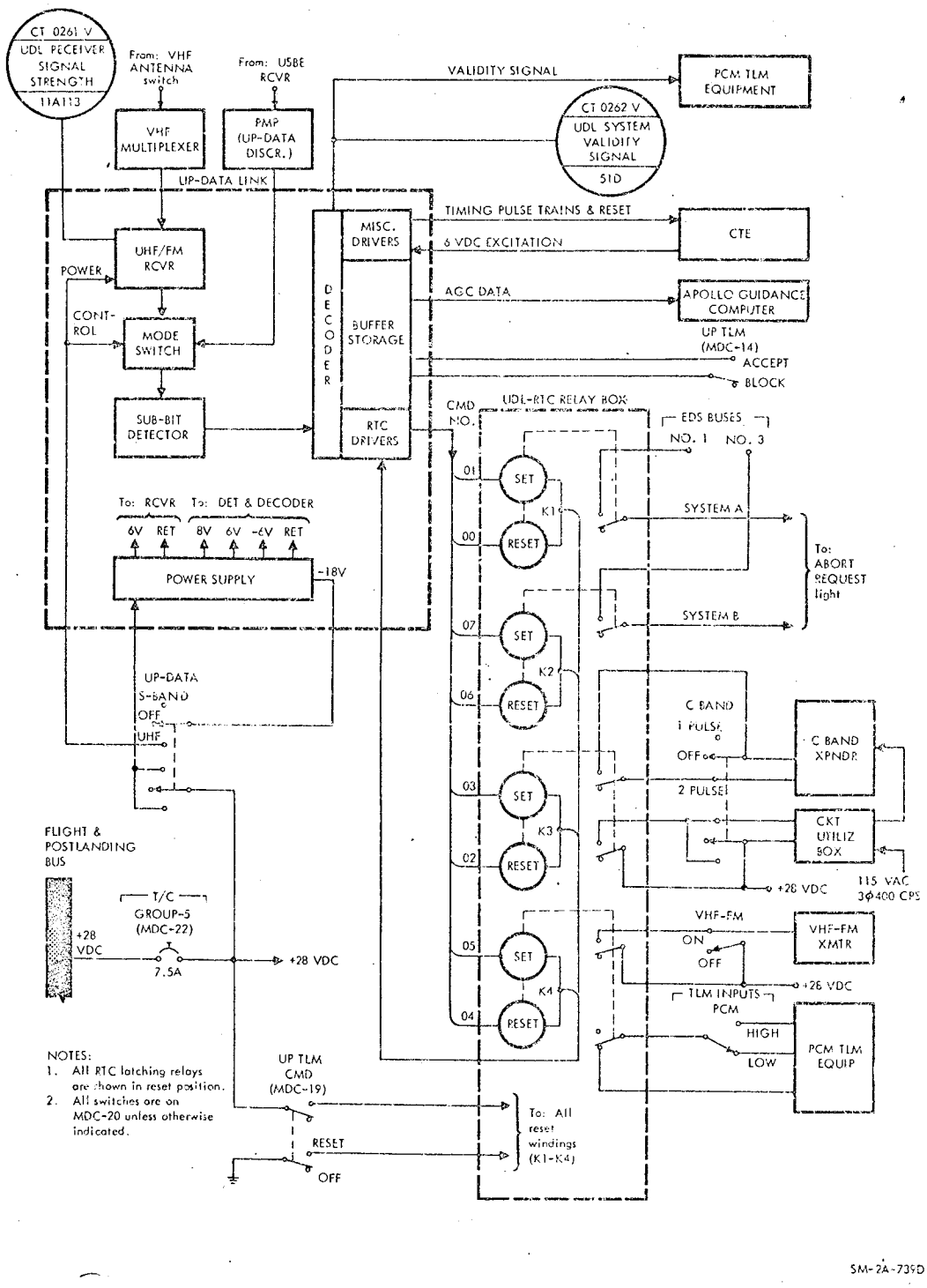


Figure 2.8-12. Up-Data Link Equipment

UHF position, the UHF up-data mode is selected and 28-volt d-c power is applied to the UDL power supply. The S-BAND position also applies 28-volt d-c power, but selects the S-band up-data mode and deactivates the UHF/FM receiver. Another control, located on MDC-19, is the two-position spring-loaded UP TLM CMD switch. When set momentarily to the RESET position, all "reset" commands listed in the UDL real time commands chart are commanded. This nullifies all "set" commands which have been received from the MSFN. An UP TLM – ACCEPT/BLOCK switch (MDC-14) is also provided which enables the crew to permit or prevent G&N up-data from affecting the guidance computer.

2.8.3.2.9 Central Timing Equipment (CTE).

The CTE provides precision square wave timing pulses of several frequencies to time-correlate all S/C time-sensitive functions. It also generates and stores the real-time day, hour, minute, and second time-from-launch (TFL) in binary-coded decimal (BCD) format for display and transmission to the MSFN. (See figure 2.8-13.)

In the primary or normal mode of operation, the Apollo guidance computer (AGC) provides a 1024-kc sync pulse to the CTE. This automatically synchronizes the CTE with the AGC and provides a stability of $\pm 2 \times 10^{-6}$ parts in 14 days. In the event of sync pulse failure, the CTE automatically switches to the secondary mode of operation with no time lapse and operates using its own crystal oscillator at a stability reduced to $\pm 2.2 \times 10^{-6}$ parts in 5 days.

The CTE contains two power supplies for redundancy. Each one is supplied from a different power source and through separate circuit breakers. These circuit breakers, CENTRAL TIMING SYS – MN A and – MN B on MDC-22, provide the only external means of control for the CTE. The two power supplies provide parallel 6-volt d-c outputs, either one of which is sufficient to power the CTE.

The timing signals generated by the CTE, and their applications, are listed in the CTE Outputs chart.

CTE Outputs

Signal	Destination	Purpose
512-kc square wave	PCM TLM equipment	Synchronization of internal clock
	PMP equipment	Modulating signal for S-band emergency key transmission
6.4-kc square wave	EPS inverters (three)	Synchronization of 400-cycle a-c power

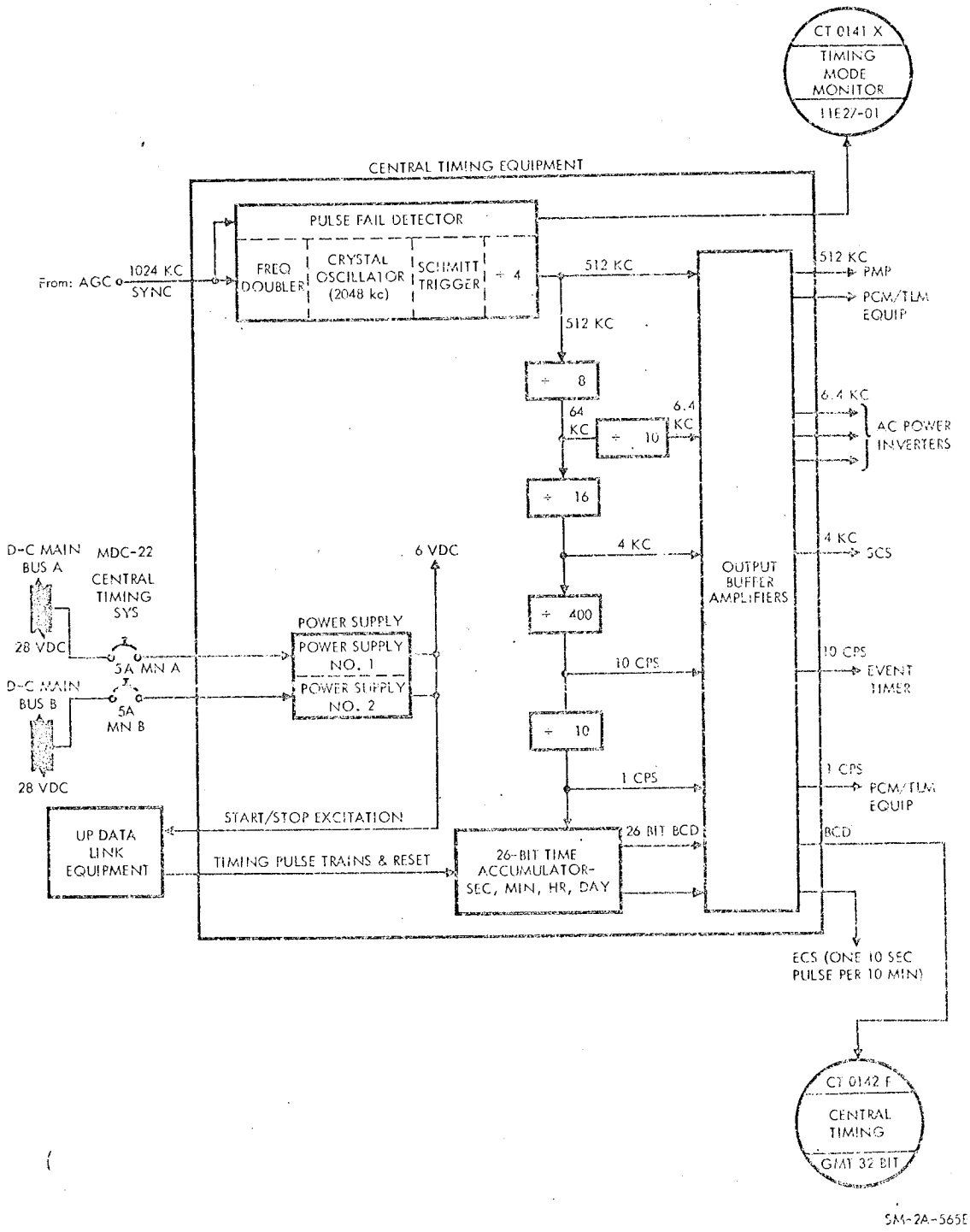


Figure 2.8-13. Central Timing Equipment

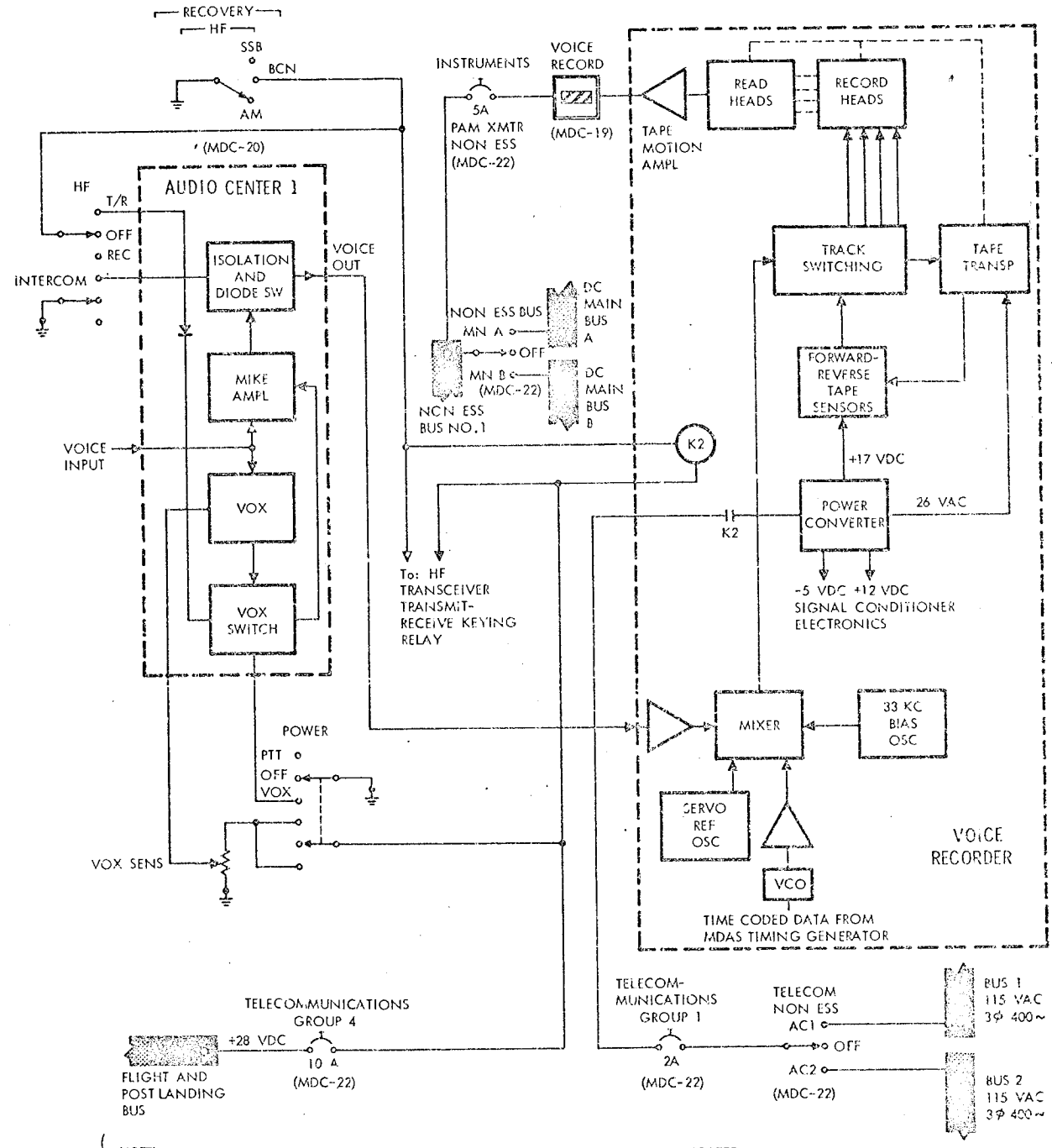
Signal	Destination	Purpose
4-kc square wave	SCS	Synchronization of X-axis accelerometer integrator
10-cps square wave	Displays	Digital event timer
1 cps	PCM TLM equipment	Synchronization of subframe of PCM data, Displays, and T-Timer
DC	PCM TLM equipment	Pulse-fail detection and indication. (Sampling rate equals 10 samples/sec, 5μ sec pulse duration.)
Binary coded decimal time code	PCM TLM equipment	Provides time code data to TLM in BCD format (TLM measurement No. CT0142F, C T-GM5 32 bit).
1 pulse per 10 minutes	ECS	Supplies pulse every 10 minutes to ECS circuitry which opens a solenoid for 10 seconds in every 10 minutes to remove water from space suits.

2.8.3.2.10 Voice Recorders

Two voice recorders have been provided to enable the crewmembers to keep a voice log of mission activites. Both units are mounted in the right-hand equipment bay, one in an operating condition and the other stowed. Changeover to the inoperative recorder is made by changing the electrical power connector.

Each tape recorder provides 450 feet of 1/4-inch tape which operates at a speed of 0.6 inches per second. The use of tape reversal, automatic head switching, and four individual recording heads provide ten hours of usable recording time per tape recorder. The information contained on the tape cannot be dumped during flight but must be played back utilizing suitable GSE.

To ready the connected voice recorder for operation, the following switch positions must be selected: the RCDR/HF switch to T/R (MDC-13, -23, -26), the intercom switch to T/R, the HF power switch to OFF (MDC-20), and the mode selector to SSB or AM. (See figure 2.8-14.) Actual activation of the voice recorder is possible three ways: two correct; one wrong. The first correct activation path has the POWER switch at PTT (MDC-13, -23, -26) and the PTT pushbutton on the cobra cable depressed. The other correct method of activation requires the POWER switch to be at VOX and the VOX circuit enabled or the PTT pushbutton



NOTE: ONLY COMMAND PILOT AUDIO CENTER MODULE AND CONTROLS ARE INDICATED.

SM-2A-955C

Figure 2.8-14. Voice Tape Recorder

depressed. The connected voice tape recorder can be inadvertently activated by positioning the HF mode switch to BCN (MDC-20). This would continuously run the connected voice tape recorder until it used up its tape. A VOICE RECORD flag indicator (MDC-19) will display the striped area when recording is in progress. The indicator grey area will be displayed when voice recording is not in progress or the tape supply has been exhausted during recording.

The stowed voice recorder may be placed in operating condition by moving the RCDR/HF switch to OFF (MDC-13, -23, and -26), removing the electrical connector from the exhausted recorder, and installing it to the connector on the stowed recorder. Operation is resumed by moving the RCDR/HF switch to T/R (MDC-13, -23, or -26).

NOTE To include the timing reference while recording on the voice tape recorder, the MDAS MAIN POWER switch must be ON (LEB compartment C) and the TIMER switch must be at "NORMAL."

2.8.3.3 RF Electronics Equipment Group.

The RF electronics equipment group includes all T/C equipment which functions as RF transmitters or receivers. The antenna used by this equipment are mentioned only briefly in this paragraph. More information on the antennas can be found in the paragraph on antenna equipment.

2.8.3.3.1 VHF/AM Transmitter-Receiver Equipment.

The VHF/AM transmitter-receiver equipment (figure 2.8-15) provides the primary means for in-flight voice communications with the MSFN. It is contained in the same electronics package as the VHF recovery beacon equipment, in the LEB.

Two modes of operation are possible: simplex and duplex. The simplex mode will normally be utilized. The duplex mode will be used on future missions for EVA and LEM communications. During recovery, the transmitter can be utilized as a backup VHF recovery beacon by holding down the PTT key.

The transmitter operates at 296.8 mc in both operational modes. The receiver contains two "front ends." The receive 1 front end operates at 296.8 mc and is used for simplex operations. For duplex operations, the receive 2 front end, which operates at 259.7 mc, is selected.

The VHF/AM transmitter-receiver is controlled by the VHF-AM controls on MDC-20. The T/R/OFF/REC switch activates the transmitter and receiver when in the T/R position; the REC position activates the receiver alone; the OFF position removes power from both. Simplex or duplex operation is selected by placing the RCVR switch to 1 or 2, respectively. The remaining, thumbwheel-type SQUELCH control can be rotated up or down to increase or decrease the sensitivity of the squelch gate.

Audio to and from the VHF-AM is controlled by the VHF-AM-T/R/OFF/REC switch on MDC-13, -23, -26. Voice transmission is possible when this switch is at T/R, the POWER switch is at PTT, the cobra cable PTT/CW switch is at PTT and the PTT key is pressed.

NOTE The POWER switch can also be at VOX, but actual keying of the VHF/AM must be via the PTT circuit.

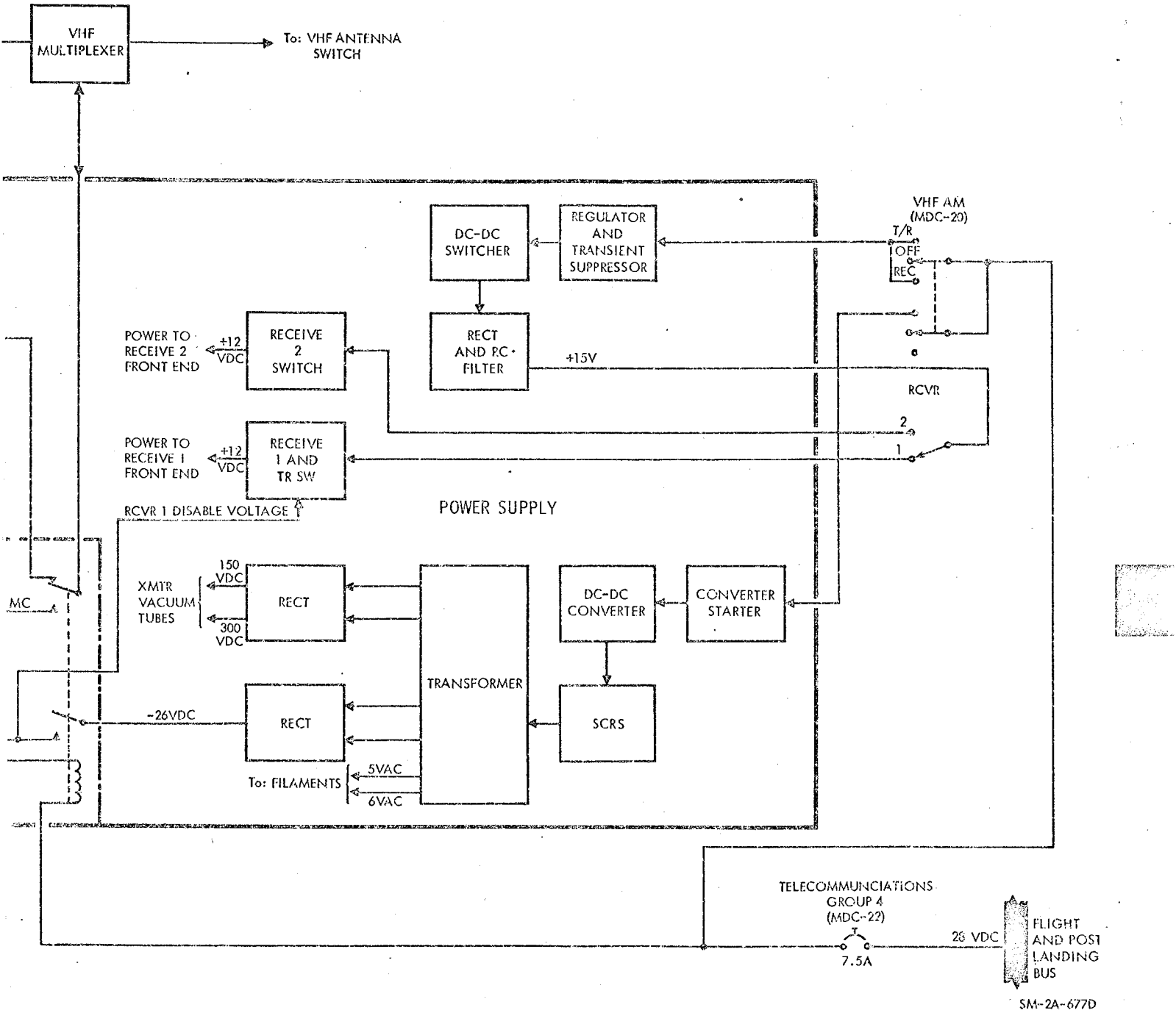
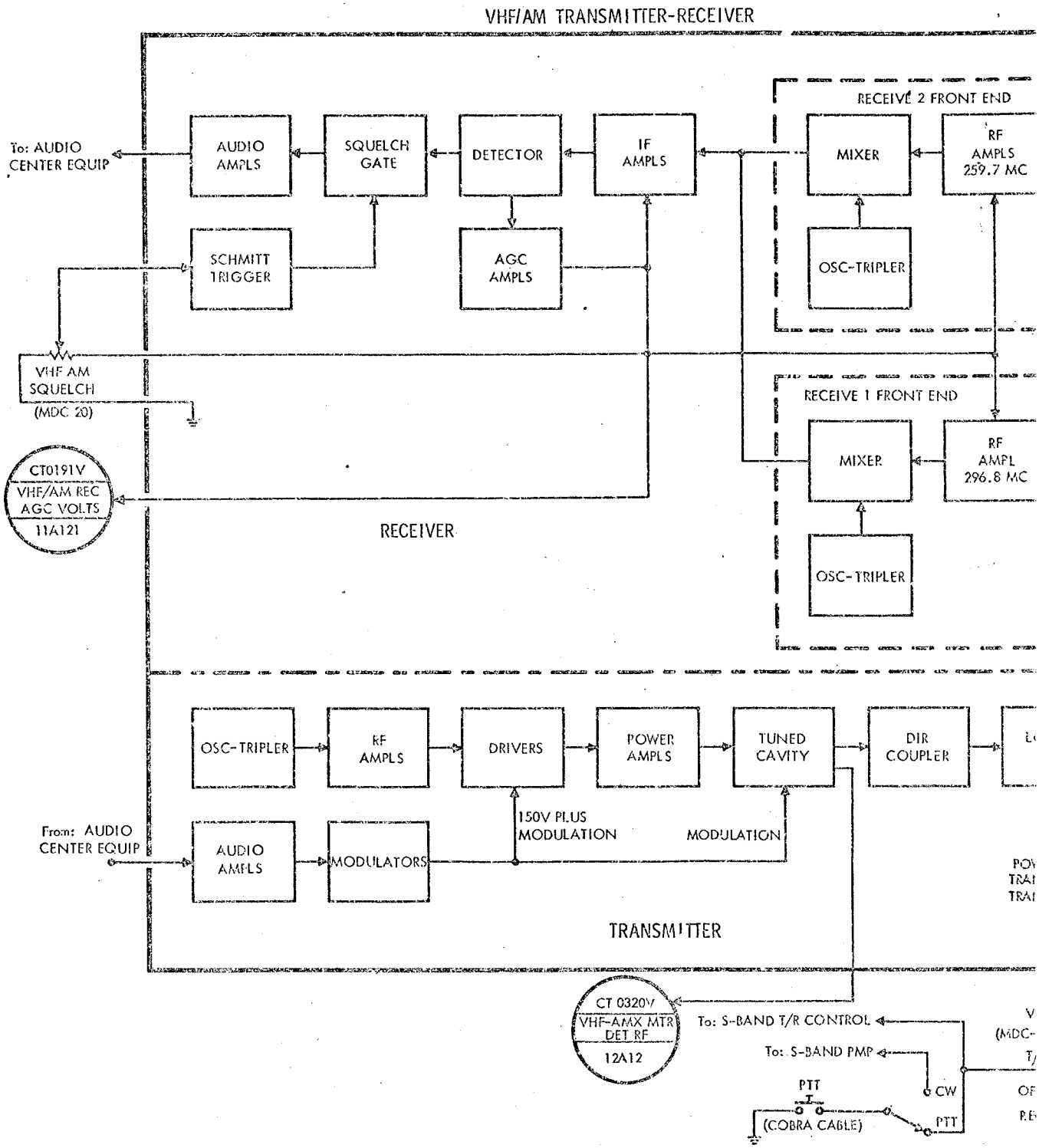


Figure 2.8-15. VHF/AM Transmitter-Receiver Equipment


VHF/AM TRANSMITTER-RECEIVER
RECEIVE 2 FRONT END
To: AUDIO CENTER EQUIP
AUDIO AMPLS
SQUELCH GATE
DETECTOR
IF AMPLS
MIXER
RF AMPLS 259.7 MC
SCHMITT TRIGGER
AGC AMPLS
OSC-TRIPLER
VHF AM SQUELCH
(MDC 20)
RECEIVE 1 FRONT END
MIXER
RF AMPL 296.8 MC
CT0191V
VHF/AM REC AGC VOLTS
11A121
RECEIVER
OSC-TRIPLER
OSC-TRIPLER
RF AMPLS
DRIVERS
POWER AMPLS
TUNED CAVITY
DIR COUPLER
150V PLUS MODULATION
MODULATION
From: AUDIO CENTER EQUIP
AUDIO AMPLS
MODULATORS
TRANSMITTER
CT 0320V
VHF-AMX MTR DET RF
12A12
To: S-BAND T/R CONTROL
To: S-BAND PMP
PTT
CW
(COBRA CABLE)
PTT

The VHF portion of the upper or lower SCIN antenna is used during flight. VHF recovery antenna No. 2 is used during recovery. Antenna selection is made with the VHF ANTENNA switch on MDC-20.

2.8.3.3.2 HF Transceiver Equipment.

The HF transceiver equipment (figure 2.8-16) is the primary means to aid recovery operations during the postlanding phase of the mission by providing long-range, simplex, voice communications and beyond line-of-sight direction finding capabilities. It is contained in the same electronics package as the VHF-FM transmitter equipment in the LEB.

The HF transceiver equipment is controlled by the RECOVERY-HF switches on MDC-20. The ON/OFF switch, when placed to ON, connects d-c power to the transceiver. The SSB/BCN/AM switch is used to select the operational mode. Three modes of operation are available; single sideband (SSB), beacon (BCN), and amplitude modulation (AM). The BCN mode is used to transmit an unmodulated, continuous wave, direction finding beacon. The SSB and AM modes are used for long-range, simplex, voice communications. The operating frequency is 10.006 mc for the transmitter and receiver in all modes.

The audio center equipment supplies the audio input to the modulator in the translator module and accepts the detected audio signal from the receiver module of the transceiver. The HF transmitter is keyed by VOX or PTT.

The HF recovery antenna is used for transmission and reception and will be deployed after touchdown as part of the postlanding sequence of operations. The transceiver must not be operated prior to antenna deployment or damage may occur.

2.8.3.3.3 VHF/FM Transmitter Equipment.

The sole function of the VHF/FM transmitter equipment (figure 2.8-17) is to transmit PCM TLM data to the MSFN. These data are supplied to the VHF/FM transmitter by the PMP in the form of a 3-volt p-p pulsating d-c, modulating signal at a rate of 51,200 bits per second (bps) or 1600 bps. The bit rate depends on the PCM rate selected.

The nominal (center) frequency of the emitted RF carrier is 237.8 mc. Because the transmitter is frequency modulated, the 3-volt p-p modulating signal causes a frequency deviation of ±125 kc. The resulting 10-watt RF output is fed to the VHF portion of the VHF/2-KMC SCIN antennas.

The only external control for the VHF/FM transmitter equipment is the VHF-FM — ON/OFF switch on MDC-20 which energizes a relay in the transmitter, applying a-c power to the equipment. If the switch is set to OFF, the VHF/FM transmitter can be activated from the MSFN by a real-time command via the UDL equipment.

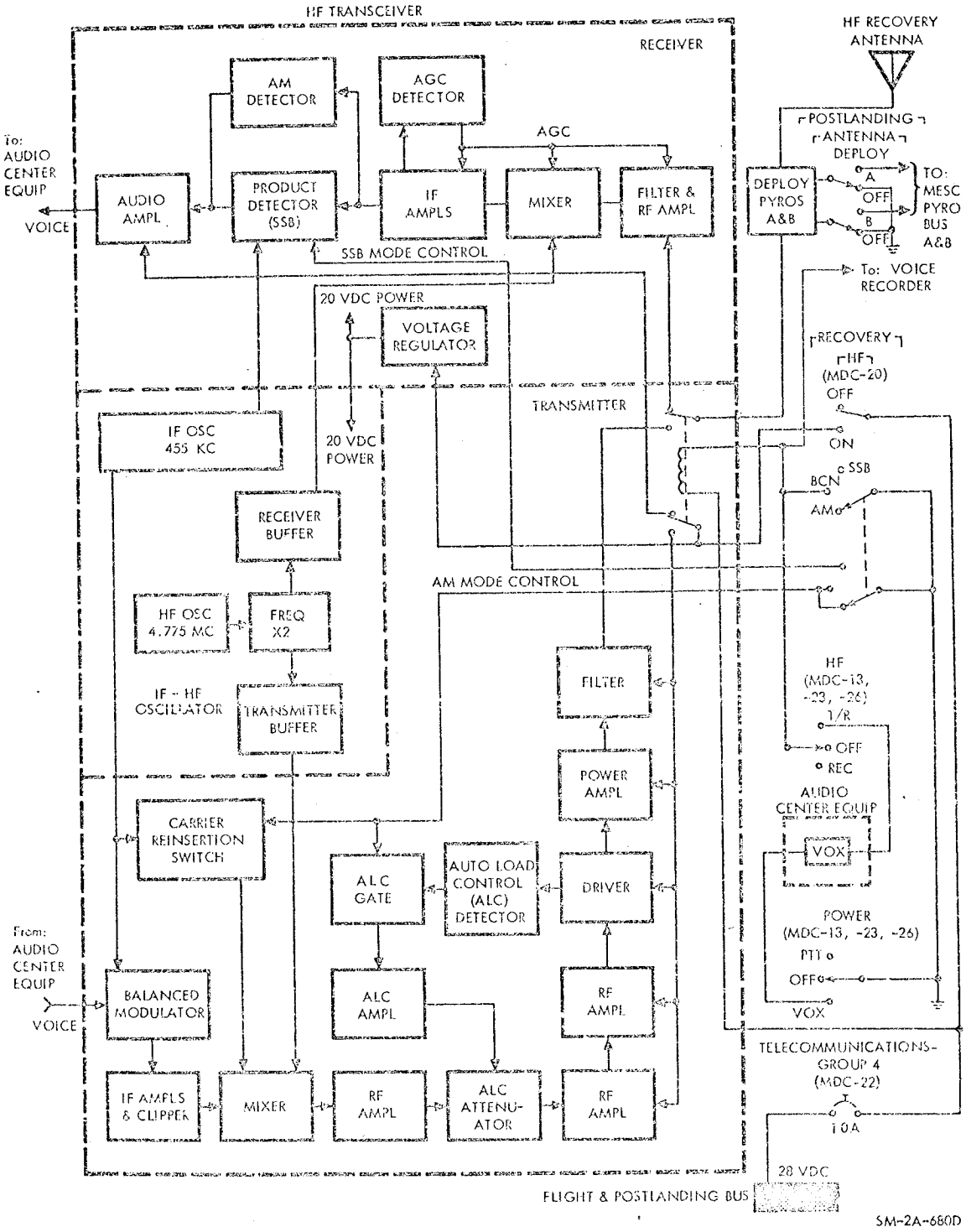


Figure 2.8-16. HF Transceiver Equipment

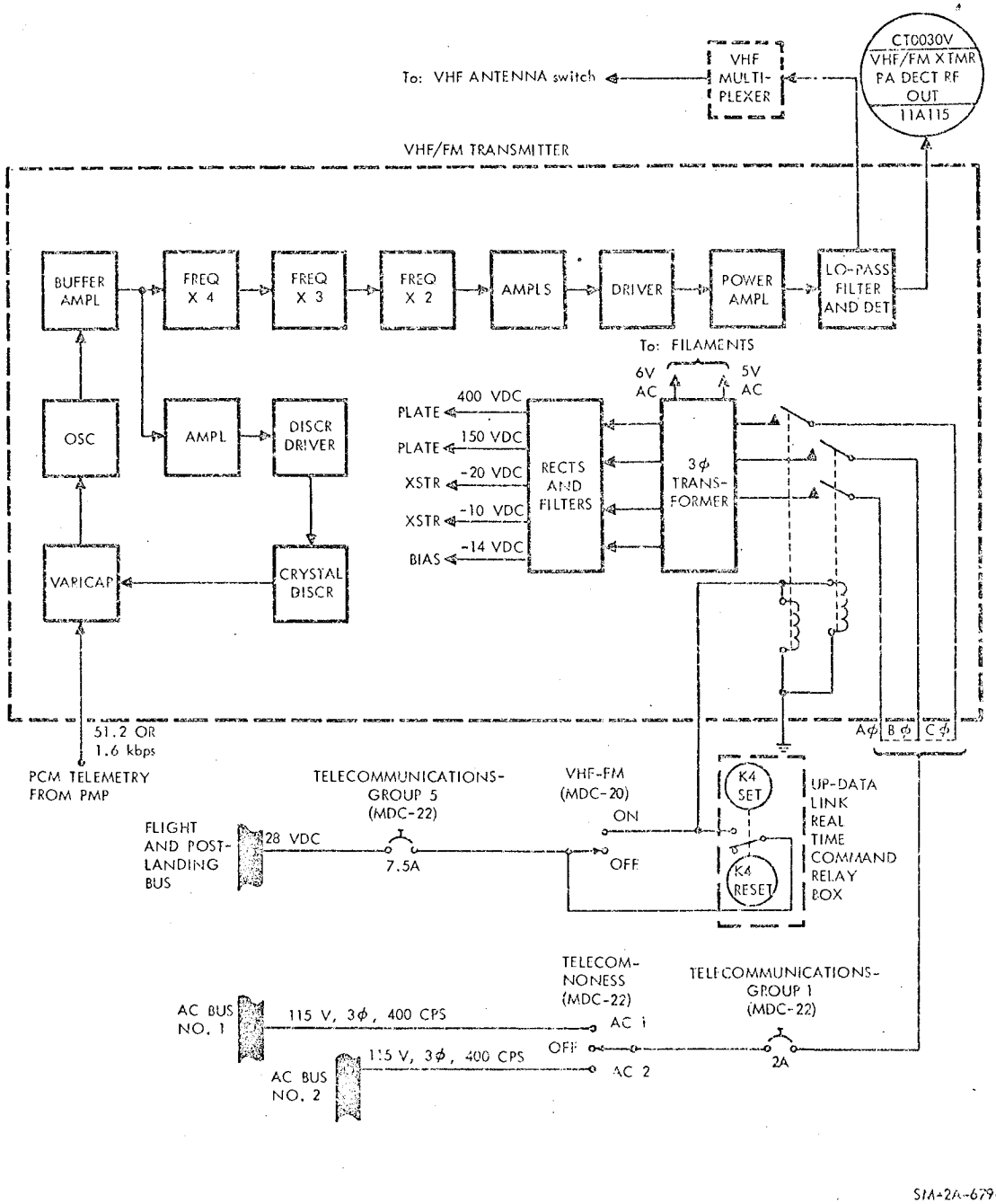


Figure 2.8-17. VHF/FM Transmitter Equipment

2.8.3.3.4 Unified S-Band Equipment (USBE).

The USBE (figure 2.8-18) consists of a receiver, transmitter, and power supply contained in a single electronics package in the lower equipment bay. Although primarily designed for deep-space communications, the USBE will be tested on this mission and used as backup for in-flight voice communications, tracking and ranging, transmission of PCM data, and reception of up-data. The USBE also provides the sole means for transmission of TV

The USBE tracking method employed is the two-way or double-doppler method. In this technique, a stable carrier of known frequency is transmitted to the S/C where it is received by the phase-locked receiver, multiplied by a known ratio, and then retransmitted to the MSFN for comparison. Because of this capability, the USBE is also referred to as the S-band transponder. From the double-doppler tracking method, S/C velocity, acceleration, and range can be determined.

For determining S/C range, the MSFN phase-modulates the transmitted carrier with a pseudo-random noise (PRN) binary ranging code. This code is detected by the S/C USBE receiver and used to phase-modulate the carrier transmitted to the MSFN. The MSFN receives the carrier and measures the amount of time dealy between transmission of the code and reception of the same code, thereby obtaining an accurate measurement of range. Once established, this range can be continually up-dated by the double-doppler measurements discussed earlier. The MSFN can also transmit up-data commands and voice signals to the S/C USBE by means of two subcarriers: 70 kc for up-data and 30 kc for up-voice.

The USBE receiver is a phase-tracking receiver that accepts a 2106.4-mc, phase-modulated RF signal containing the up-data and up-voice subcarriers and a pseudo-random noice (PRN) code when ranging is desired. This signal is supplied to the receiver via the diplexer in the S-band power amplifier equipment and presented to two separate detectors: the loop phase detector and the ranging phase detector. In the ranging phase detector, the 9.531-mc IF is detected; and the 70-kc up-data and 30-kc up-voice subcarriers are extracted, amplified, and routed to the up-data and up-voice discriminators in the PMP equipment. Also, when operating in a ranging mode, the PRN ranging signal is derived, filtered, and routed to the USBE transmitter as a modulating signal input to the phase modulator. In the loop phase detector, the 9.531-mc IF signal is detected by comparing it with the loop reference frequency. The resulting d-c output is used to control the frequency of the 19.0625-mc voltage-controlled oscillator (VCO). The output of the VCO is used as the reference frequency for receiver circuits as well as for the transmitter. The receiver is also provided with automatic gain control (AGC) and antenna selector circuitry which automatically selects the proper SCIN antenna when the S-BAND ANTENNA switch is in the AUTO position. The AGC circuitry also supplies a signal to the S-BAND ANT S-meter located on MDC-19. By observing this meter and rotating the S/C, the optimum S/C attitude for S-band communications can be attained.

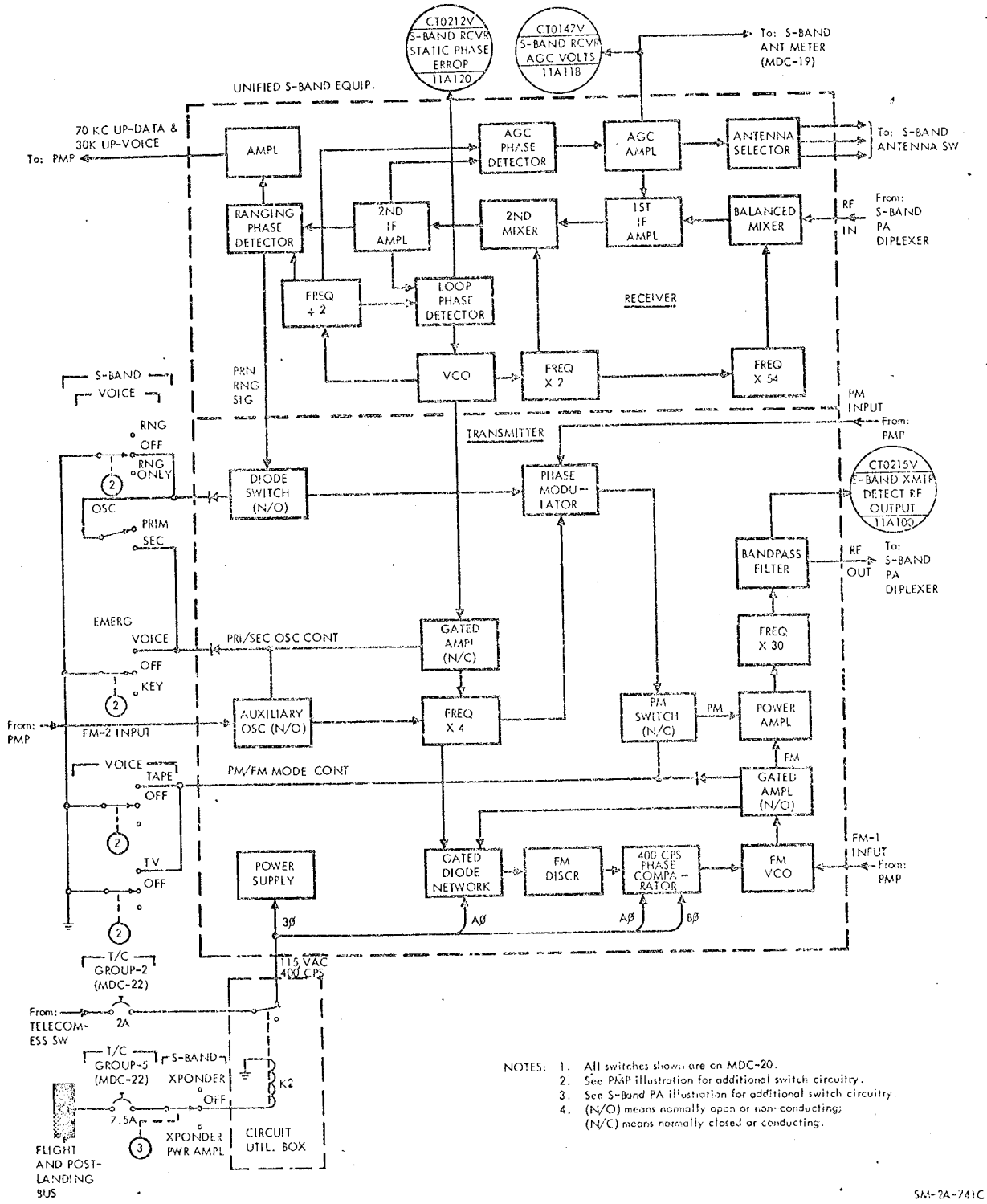


Figure 2.8-18. Unified S-Band Equipment

The USBE transmitter is capable of transmitting a 2287.5-mc signal, either phase-modulated or frequency-modulated. In the PM mode, the initial transmitter frequency is obtained from one of two sources: the VCO in the phase-locked USBE receiver or the auxiliary oscillator in the transmitter. When operating in the FM mode, the VCO or auxiliary oscillator initial frequency is not multiplied and used directly, but is used to control the frequency of a third oscillator, the FM VCO. The FM VCO is the source for the frequency-modulated 2287.5-mc signal.

Output mode and frequency source are controlled by the S-BAND group of switches on MDC-20. The VOICE and EMERG switches, contained in this group, also have an effect on PMP operation, thus ensuring compatibility between USBE and PMP modes. All data to be transmitted by the USBE is supplied by the PMP. Normally, the initial transmitter frequency is obtained from the receiver VCO. In case of failure of the VCO or S-band PA equipment, the auxiliary oscillator can be selected. This is done by moving the OSC switch from PRIM to SEC (with the RNG/RNG ONLY switch at the normal, center position) or by placing the EMERG switch to VOICE. If the latter is done, the PMP will provide a voice modulating signal directly to the auxiliary oscillator.

With all three S-BAND – VOICE switches and the S-BAND – EMERG switch set at their center positions, the USBE transmits a phase-modulated signal containing PCM TLM and voice data from the PMP. Setting the RNG/RNG ONLY switch to RNG, enables the PRN ranging code to be transmitted also. Setting this switch to RNG ONLY, adds the PRN ranging code but eliminates the PCM TLM portion of the PM input from the PMP. This mode is used to increase the strength of the PRN ranging code received by the MSFN. The other two S-BAND – VOICE switches are the TAPE and the TV switches. For PM operation, both of these switches must be at their center, off position. Setting either of them to any other position changes the USBE mode to FM for increased band-width and selects the FM-1 output of the PMP. Thus, these four switches (the three VOICE switches and the EMERG switch) are used to establish the operational mode. Only one switch at a time may be placed to any position other than center for proper operation of the USBE and PMP. For further description of PMP outputs, refer to the discussion of the PMP equipment.

The USBE is activated by the S-BAND – XPONDER/XPONDER PWR AMPL switch. Setting this switch to XPONDER or XPONDER PWR AMPL energizes a relay that applies 115 volts ac to the USBE power supply, which provides +15 volts dc and -15 volts dc outputs to the USBE transmitter and receiver. The RF output of the USBE transmitter is fed to the S-band power amplifier equipment. Here, the signal is either bypassed directly to the S-BAND ANTENNA switch or amplified and then fed to the S-BAND ANTENNA switch.

2.8.3.3.5 S-Band Power Amplifier Equipment.

The S-band power amplifier (PA) equipment (figure 2.8-19) is used to amplify the RF output from the USBE transmitter when additional signal

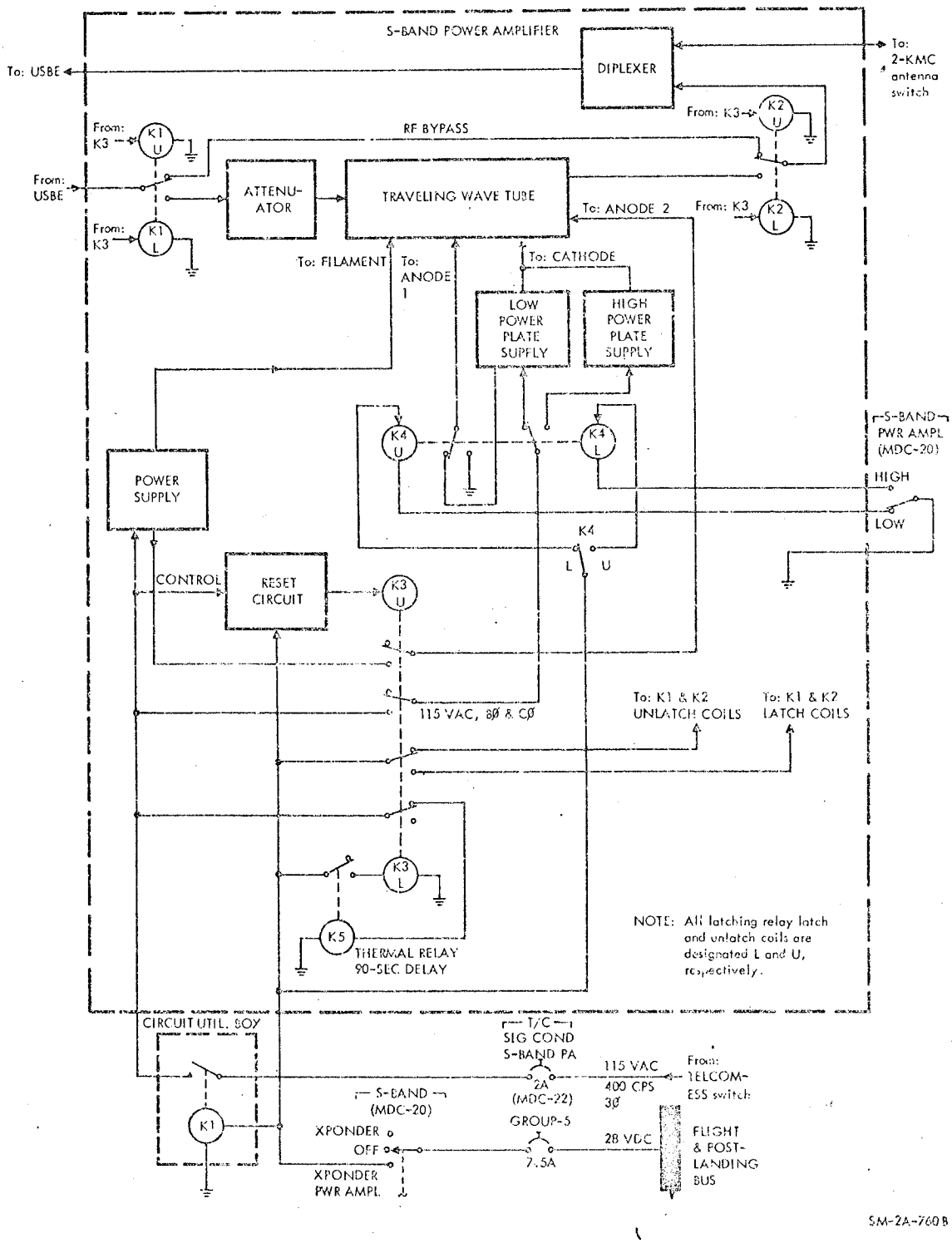


Figure 2.8-19. S-Band Power Amplifier Equipment

strength is required for adequate reception of the S-band signal by the MSFN. It consists of a diplexer, a traveling-wave tube for amplification, power supplies, and the necessary switching relays and control circuitry. The S-band PA is contained in a single electronics package located in the lower equipment bay.

All received and transmitted S-band signals pass through the S-band PA diplexer. The 2106.4-mc S-band carrier received by the S/C enters the S-band PA diplexer from the S-band antenna equipment. The diplexer passes the signal straight through to the USBE receiver. The 2287.5-mc output signal from the USBE transmitter enters the S-band PA where it is either bypassed directly to the diplexer and out to the S-band antenna equipment, or amplified first and then fed to the diplexer. There are three power amplifier modes of operation: bypass, low power, and high power.

Two of the S-BAND switches on MDC-20 are used to control the S-band power amplifier. Setting the XPONDER/XPONDER PWR AMPL switch to the XPONDER PWR AMPL position energizes the USBE power supply and applies 3-phase 115-volt a-c power to the S-band PA through relay K1 in the circuit utilization box. This also activates the 90-second time-delay relay in the S-band PA. Upon initial application of power, only the low-voltage power supply is energized, which applies power to the traveling wave tube heater. After 90 seconds, the RF signal from the USBE transmitter is switched from the bypass circuit to the amplifier circuit and 3-phase 115-volt a-c power is applied to either the low power or high power section of the high-voltage power supply, which supplies the correct operating voltages to the remaining elements of the traveling-wave tube. Selection of the low power (LOW) or high power (HIGH) mode is controlled by the S-BAND – PWR AMPL – HIGH/LOW switch.

2.8.3.3.6 C-Band Transponder Equipment

An earth-based C-band tracking and ranging system is used to provide S/C position data to the MSFN during the launch, near-earth, and entry phases of the mission. The function of the S/C C-band transponder equipment (figure 2.8-20) is to effectively extend the range of the system beyond that which would be possible using skin-tracking techniques only. Upon reception of a properly coded pulsed interrogation from the earth-based equipment at 5690 mc, the C-band transponder transmits a response pulse to the earth after a 3-microsecond delay at 5765 mc.

The C-band transponder contains four receivers, a transmitter, a power supply, and associated circuitry for comparing and decoding received signals and switching antennas. There are four C-band antennas, one for each receiver, located around the perimeter of the command module. The interrogation may be received by any one or more of the four antennas and routed through circulators to the associated receivers. If the pulses are properly coded the comparator determines which antenna received the strongest signal and activates the switch driver, which drives the RF

Function \ Switch Name	S-Band Power	Pwr Ampl	OSC	Ranging	Tape	TV	Emergency UP Data S-Band Ant			Remarks
	XPONDER-OFF-XPONDER PWR AMPL	HIGH LOW	PRIM SEC	RNG-Off-RNG ONLY	TAPE-Off	TV-Off	Voice-Off-Key	S-Band-Off-UHF	AUTO-UPPER-LOWER	
S-band PM mode real time voice, telemetering and ranging	XPONDER PWR AMPL	LOW	PRIM	RNG	Off	Off	Off	As reqd	UPPER or LOWER as reqd	
S-band PM mode real time voice and data	XPONDER PWR AMPL	LOW	PRIM or SEC	Off	Off	Off	Off	As reqd	UPPER or LOWER as reqd	
S-band FM mode real time voice, data and TV	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	TV	Off	As reqd	UPPER or LOWER as reqd	TV camera power switch must be on.
S-band FM mode real time voice, play back data	XPONDER PWR AMPL	LOW	PRIM or SEC	Off	TAPE	Off	Off	As reqd	UPPER or LOWER	DSE switches must be properly configured for play back.
S-band emergency voice	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	Off	VOICE	As reqd	UPPER or LOWER	
S-band emergency key	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	Off	KEY	As reqd	UPPER or LOWER	Cobra cable mode switch at CW and PTT button used as key.
S-band reception of up-data	XPONDER or XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	RNG Off RNG ONLY	Off	Off	Off	S-band	UPPER or LOWER	

Notes: 1. TAPE and TV switches are 3-position switches with the down position no longer performing a valid function. The down position of these switches should not be selected.

2. The TAPE and TV switches should never be in the UP position together.

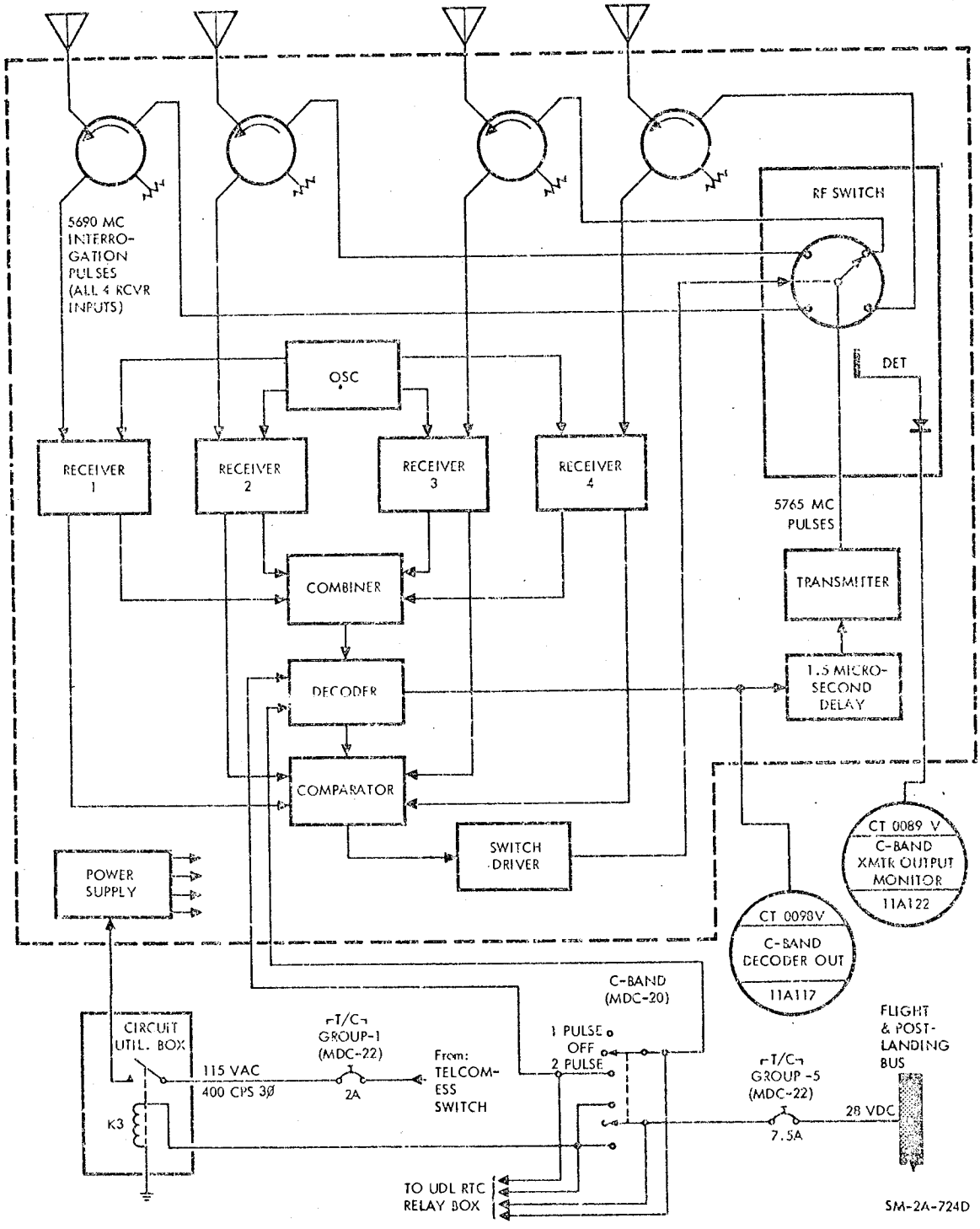


Figure 2.8-20. C-Band Transponder Equipment

switch to the proper antenna position. Three microseconds after interrogation, the transmitter sends a response pulse to the selected antenna. This 3-microsecond delay gives the RF switch time to operate. It also enables MSFN personnel to simultaneously observe the transponder reply and the skin track reply on the same visual display device (cathode ray tube), for comparison.

Two modes of operation can be selected: 1 pulse or 2 pulse. Mode selection will depend on the type of earth-based radar equipment that is being used at a particular area in the orbital path. During the launch and ascent phases of the mission, the 2-pulse mode will be used.

The only external control for the C-band transponder equipment is the C-BAND three-position toggle switch on MDC-20. The OFF position removes a-c power from the equipment; the 1 PULSE and 2 PULSE positions apply a-c power to the equipment and select the mode of operation. Activation and mode selection can also be commanded from the MSFN by a real-time command via the UDL equipment.

2.8.3.3.7 VHF Recovery Beacon Equipment.

The VHF recovery beacon equipment (figure 2.8-21) provides a line-of-sight direction finding capabilities to aid in locating the S/C during the recovery phase of the mission. It is located in the same electronics package as the VHF/AM transmitter-receiver equipment in the LEB. The beacon signal emitted is an interrupted 243-mc carrier, modulated by a 1000-cps square wave. The signal is transmitted for 2 seconds, then interrupted for 3 seconds.

Manual control of the equipment is provided by the RECOVERY — VHF-BCN, two-position ON/OFF switch on MDC-20.

The output of the VHF recovery beacon equipment is fed to VHF recovery antenna No. 1, which is deployed automatically when the main chutes are deployed.

2.8.3.3.8 GFE VHF Survival Beacon/Transceiver.

The VHF beacon/transceiver is a hand-held GFE item to be used in the recovery phase of the Apollo mission. The unit, plus an extra battery, is stored with the survival equipment.

Figure 2.8-22 shows the three major parts of the unit, the transmitter-receiver assembly, the battery pack assembly, and the quarter wave antenna.

The receiver-transmitter assembly and battery pack assembly mate to form a water-tight unit measuring 8 by 4-1/2 by 3 inches. The antenna is an 11-1/2-inch-long tapered flexible steel tape, terminated in a coaxial RF connector, and is normally stored in a retaining spool and clip on top of the radio unit.

The radio is capable of line-of-sight operation in either of two modes (beacon or voice) through use of either its own antenna or a suitable connected remote antenna. The transmitter output is protected against damage while operating due to accidental shorting of the antenna or submergence of the unit in salt water. In the beacon mode, the transmitter operates unattended, for periods up to 24 hours, to transmit an interrupted 1000-cps tone, amplitude modulated 25 percent on the 243-mc RF carrier. In the

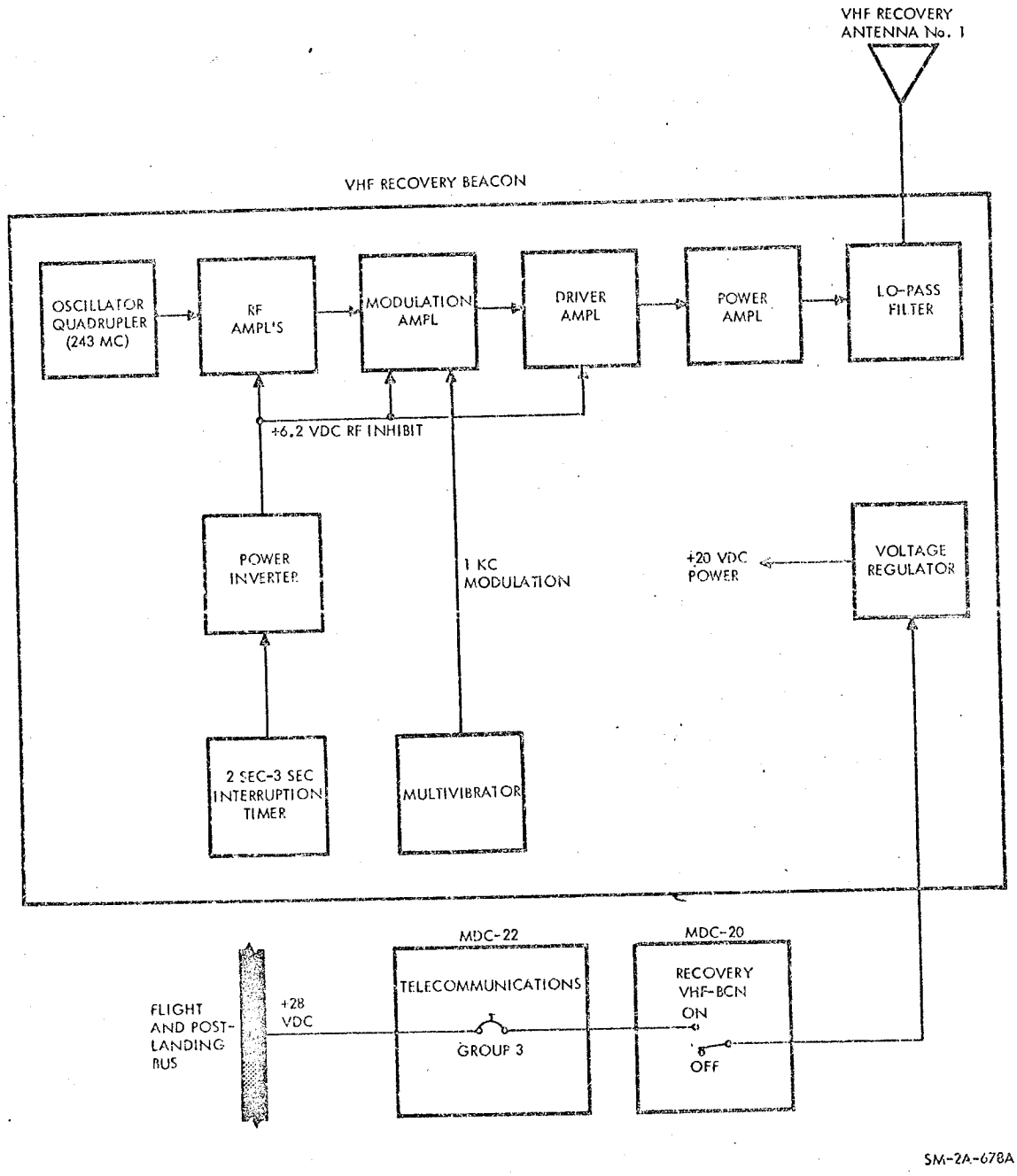


Figure 2.8-21. VHF Recovery Beacon Equipment

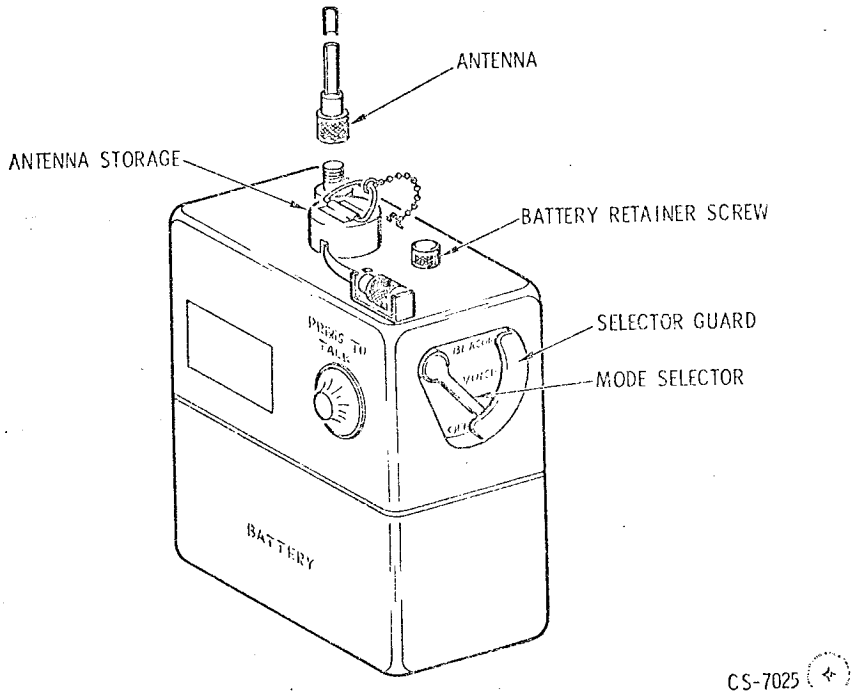


Figure 2.8-22. Survival Beacon/Transceiver Radio

voice mode, the radio provides two-way AM voice communication through use of an integral speaker-microphone and PUSH-TO-TALK switch.

2.8.3.4 Antenna Equipment Group.

The antenna equipment group contains all of the S/C antennas and ancillary equipment used in the T/C system. (See figures 2.8-23 and 2.8-24.)

2.8.3.4.1 VHF/2-KMC Omni-Antenna Equipment.

The VHF/2-kmc omni-antennas and corresponding ancillary equipment consists of two VHF/2-kmc SCIN antennas, a VHF multiplexer, a VHF antenna switch, a 2-kmc antenna switch, and the necessary signal and control circuits. The function of this equipment is to provide capabilities for radiation and pickup of RF signals in the VHF and S-band spectrums. The VHF portion of this equipment is used in conjunction with the up-data link (UDL) receiver, the VHF/FM transmitter, and the VHF/AM transmitter-receiver on two frequencies. The 2-kmc portion of this equipment is used with the USBE.

The VHF multiplexer is a passive, six-channel, filtering device which enables six items of VHF transmitting or receiving equipment to utilize one VHF antenna simultaneously. The six channel filters are composed of two or three tuned cavities, each of which function as bandpass filters. No power is required by the device and there are no external controls.

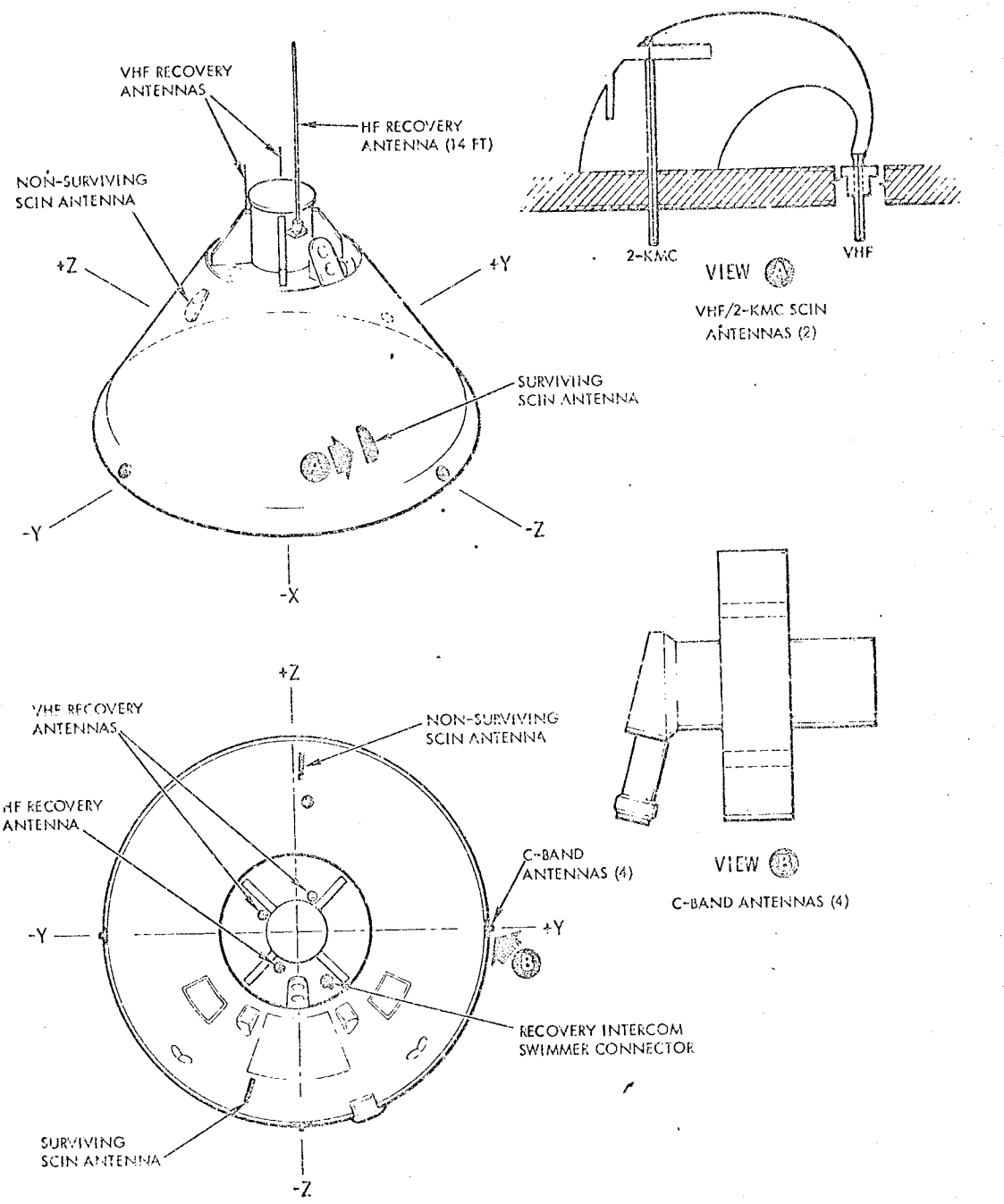


Figure 2.8-23. Antenna Locations

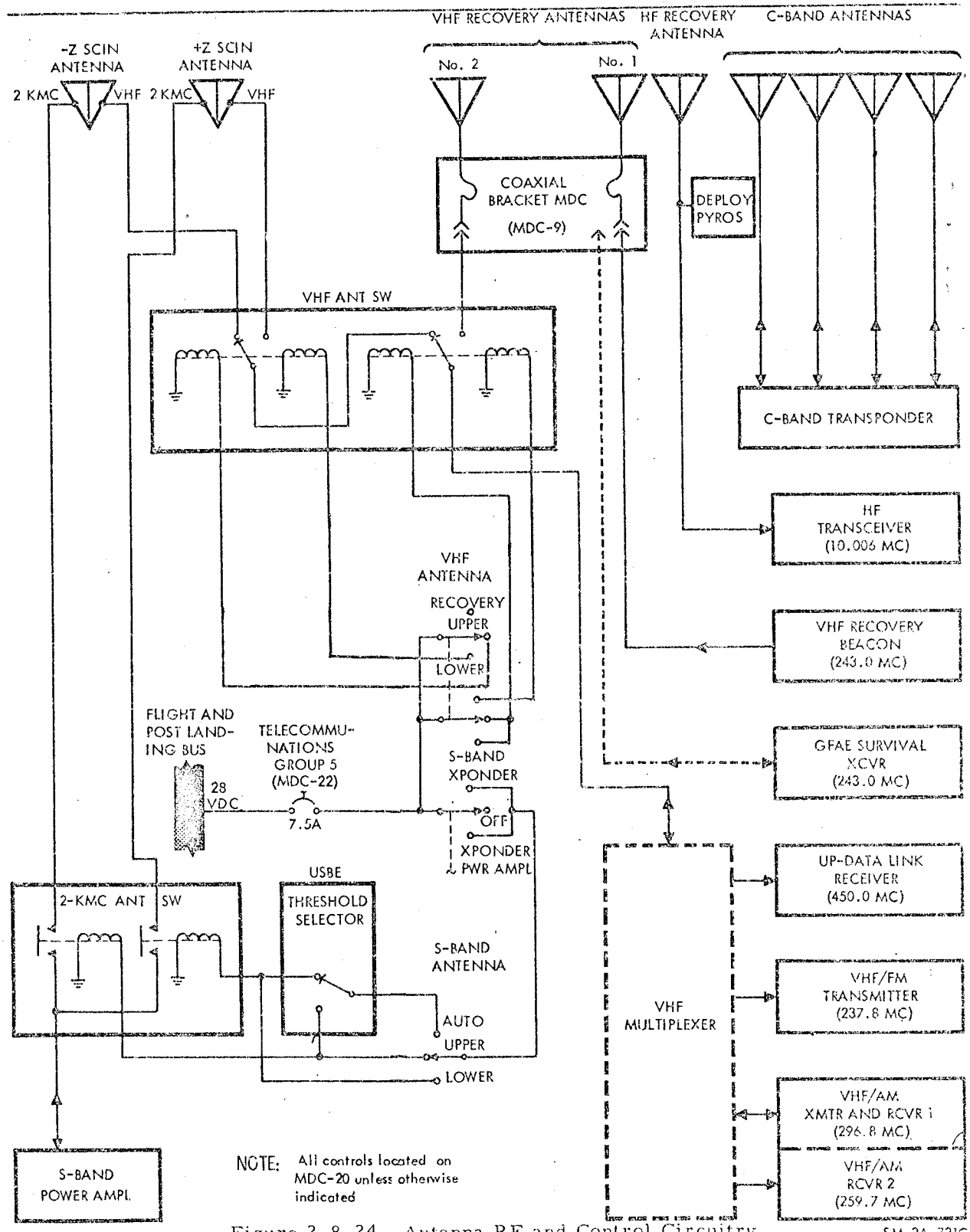


Figure 2.8-24. Antenna RF and Control Circuitry SM-2A-721C

The VHF/2-kmc SCIN antennas are dual-purpose antennas with approximately hemispherical radiation patterns. Figures 2.8-25 and 2.8-26 show the propagation patterns of the VHF-UHF and S-band portions of the antenna, respectively. The word "SCIN" is an acronym for "SCImitar" and "Notch." Because of its characteristic shape, that portion of the antenna used for VHF is called a scimitar. In the broad end of the scimitar is a notch which functions independently and is used for S-band frequencies.

There are two VHF/2-kmc SCIN antennas; they are located on opposite sides of the S/C. One is located near the +Z axis and is called the +Z or lower SCIN antenna; the other is located near the -Z axis and is called the -Z or upper SCIN antenna. Because of their approximate hemispherical radiation patterns, fully omnidirectional capabilities can be obtained only by switching from one antenna to the other. This is accomplished with the VHF ANTENNA remote control switch on MDC-20 for VHF communications, or with the S-BAND ANTENNA remote control switch, also on MDC-20, for S-band communications.

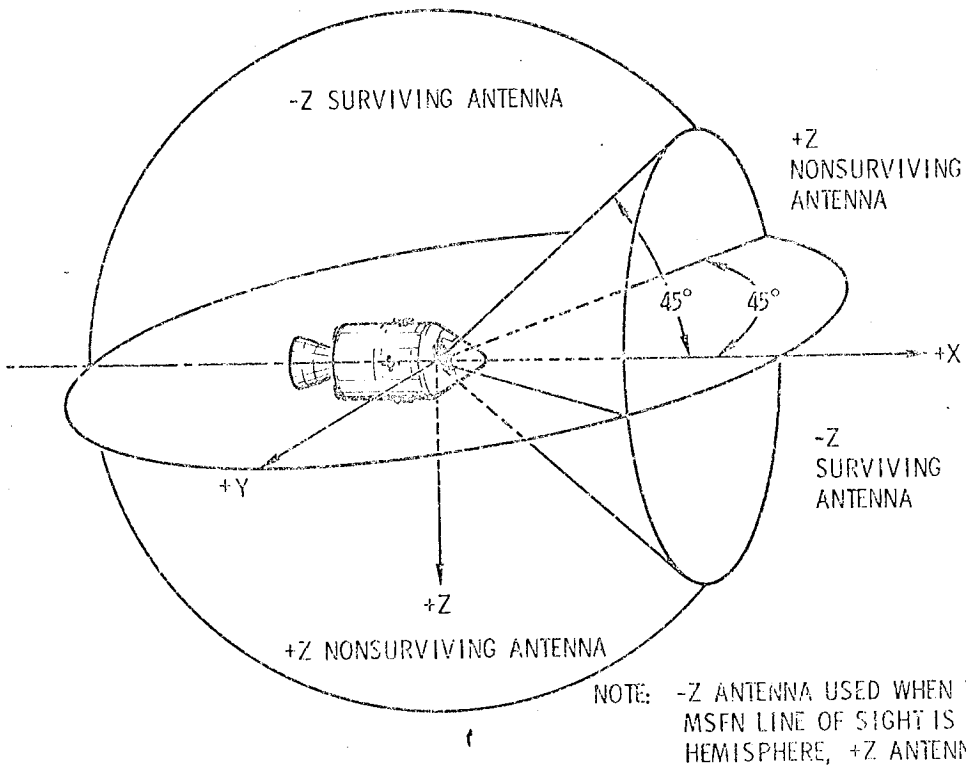


Figure 2.8-25. Antenna Switching Regions, VHF-UHF

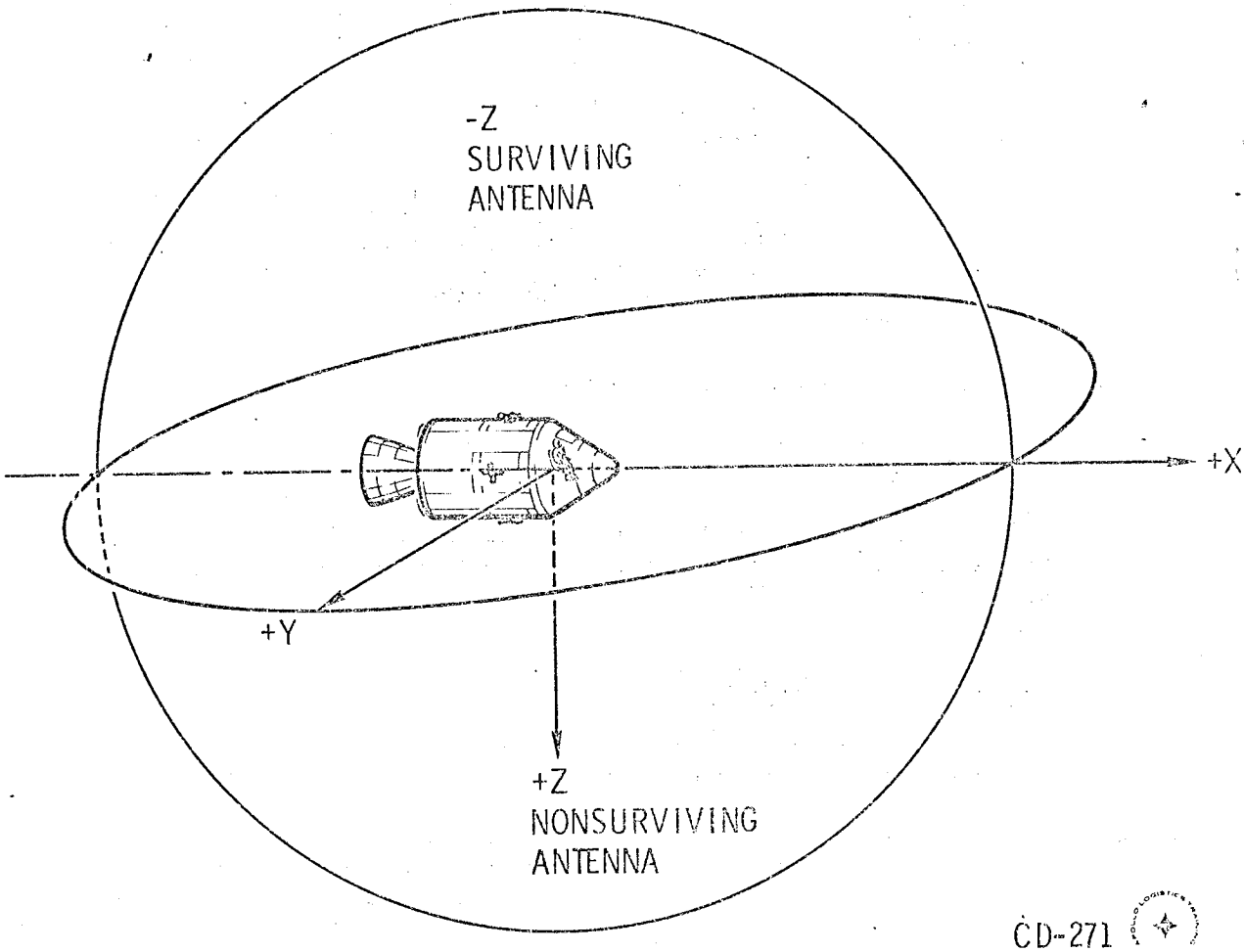


Figure 2.8-26. Antenna Switching Regions, S-Band

The lower (+Z) SCIN antenna may be burned off during entry. The upper (-Z) SCIN antenna is located at a minimum heat point and is covered with ablative material to provide thermal protection for entry survival.

2.8.3.4.2 HF Recovery Antenna Equipment

The HF recovery antenna is provided solely for use with the HF transceiver to provide for voice communication with recovery forces after touchdown. It is stowed inside a canister, located in the forward compartment of the S/C, until deployed by manual activation of a pyrotechnic device. The pyrotechnic device is activated by setting the POST LANDING -- ANTENNA DEPLOY switches to their upper positions (A and B), while the MASTER EVENT SEQ CONT switches (2) are at PYRO ARM (MDC-24) position.

2.8.3.4.3 VHF Recovery Antenna Equipment.

There are two VHF recovery antennas, No. 1 and No. 2, stowed in the forward compartment of the S/C. Each antenna consists of a quarterwave

stub, 11 inches long, and a ground plane. They are automatically deployed 8 seconds after main parachute deployment during the descent phase of the mission.

VHF recovery antenna No. 1 is connected to the VHF recover beacon equipment through a coaxial connector on the coaxial bracket, MDC-9. VHF recovery antenna No. 2 is to be used with the VHF/AM transmitter-receiver equipment, thus it is connected to the VHF antenna switch, also through a connector on the coaxial bracket. The purpose of the coaxial bracket is to allow either of the VHF recovery antennas to be used with the GFAE survival transceiver. This requires that the coaxial cable from one of the antennas be manually disconnected at the coaxial bracket and reconnected to the survival transceiver.

2.8.3.4.4 C-Band Beacon Antenna Equipment.

There are four, flush-mounted, C-band beacon antennas located around the perimeter of the S/C near the four S/C axes: +Z, -Z, +Y, and -Y. All four antennas are connected at all times to the C-band transponder equipment with reception by all four antennas. Circuitry in the C-band transponder equipment determines which antenna received the strongest signal and automatically selects that antenna for transmission of response pulses.

2.8.3.5 Electrical Power Distribution.

Electrical power distribution for the voice and data, and the RF equipment groups is shown on sheet 1 of figure 2.8-27. Instrumentation equipment power distribution is shown on sheet 2. Electrical power to most of the equipment on sheet 1 is controlled by the T/C switches on MDC-20. These switches and control circuits can be found on the illustrations for the individual components in paragraphs 2.8.3.3 and 2.8.3.4.

2.8.4 PERFORMANCE AND DESIGN DATA

The following chart contains the a-c and d-c power consumption values for the T/C voice, data, and RF equipment.

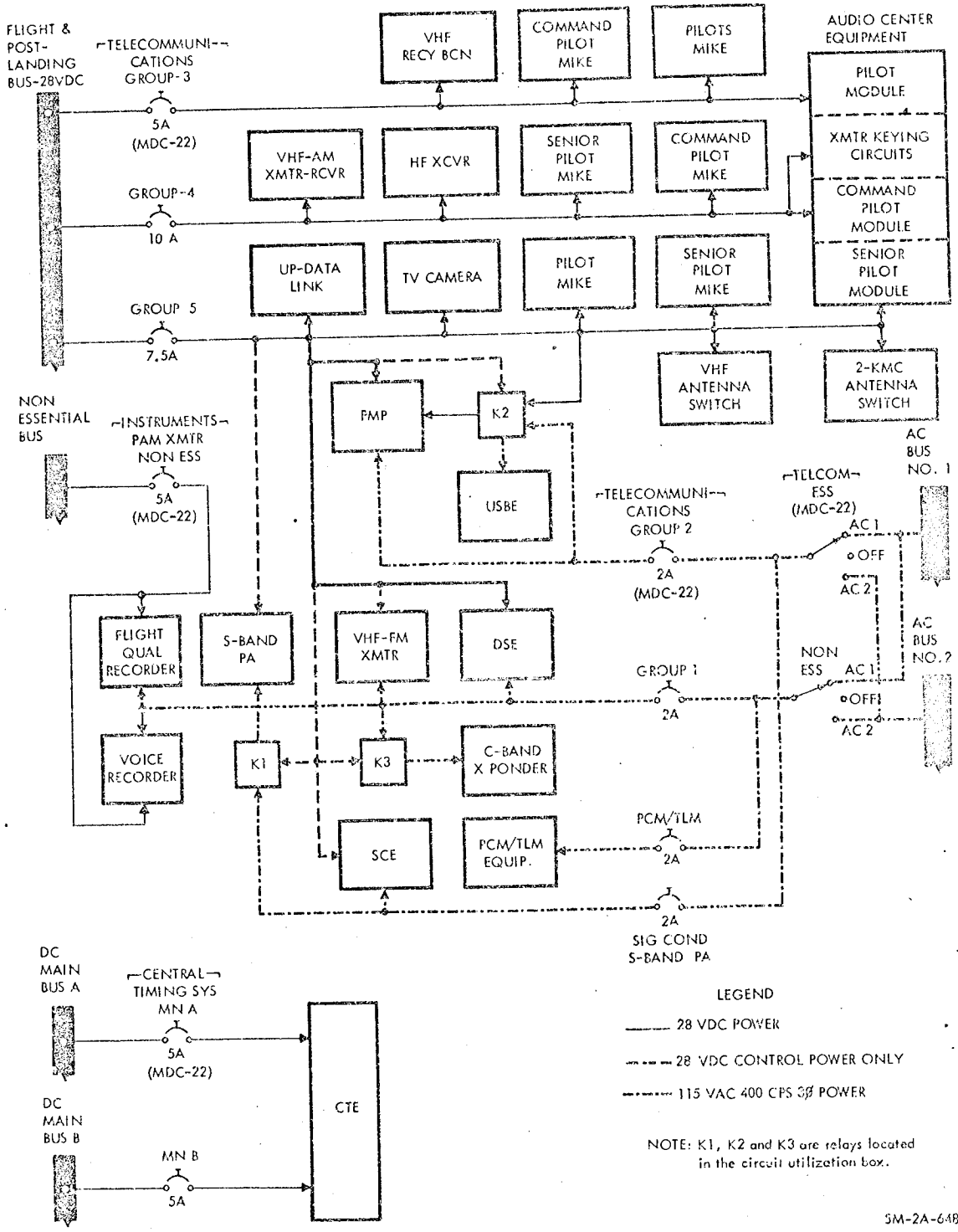


Figure 2.8-27. Telecommunications Power Distribution (Sheet 1 of 2)

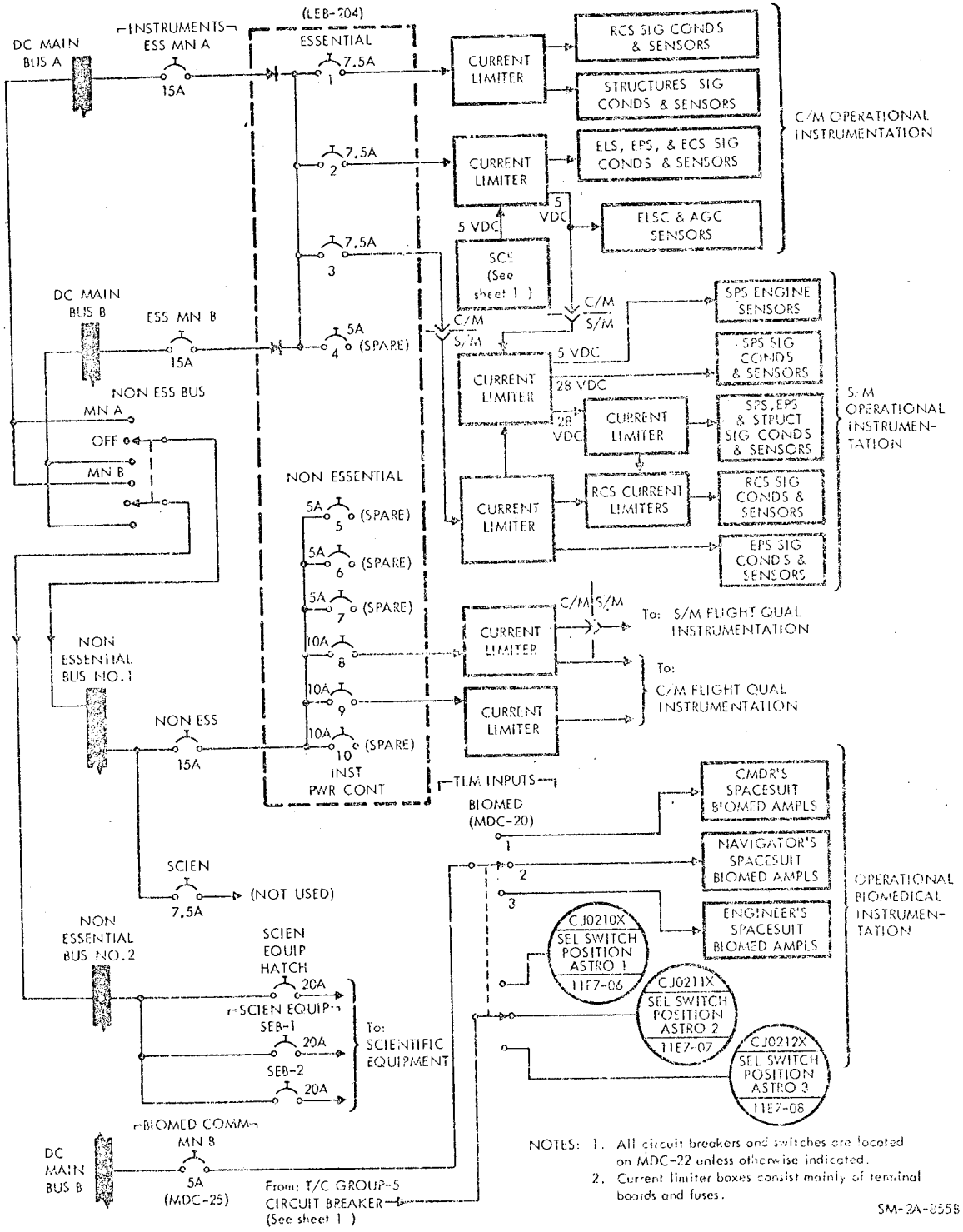


Figure 2.8-27. Telecommunication Power Distribution (Sheet 2 of 2)

T/C Equipment Power Consumption

Equipment	Quantity	Control	D-C Watts	A-C Watts	Total D-C Watts	Total A-C Watts
A-C equipment	3	PWR switch to VOX, MDC (13, 23, 26)	4.3		12.8	
SCE	1	SCE PWR switch ON, MDC 20		45.0		45.0
PCM TLM equipment	1	PCM control button ON, MDC 22		10.5		10.5
TV camera	1	PWR switch ON, TV camera handle	6.0		6.0	
PMP	1	PMP PWR switch ON, MDC 20	2.6	4.0	2.6	6.4
		+ TAPE SWITCH ON, MDC 20	2.6	6.4	2.6	6.4
		EMER VOICE switch ON, MDC 20	3.2		3.2	
		EMER KEY ON, MDC 20	3.6		3.6	
DSE	1	RECORD/PLAYBACK switch other than OFF, MDC 20	0.5	32.5	0.5	32.5
FQR	1	RECORD switch to RECORD MDC 19	34.0	15.0	34.0	15.0
UDL	1	UDL switch to VHF, MDC 20	9.6		9.6	
CTE	1	2-CTE control buttons ON, MDC 22	21.0		21.0	
VHF/AM transmitter-receiver		VHF/AM switch to REC, MDC 20	1.5		1.5	
		VHF/AM switch to T/R, MDC 20	15.5		15.5	
		VHF/AM switch to T/R, PTT button ON, cobra cable MODE switch to PTT	61.5		61.5	
HF transceiver	1	HF POWER switch ON, MDC 20	0.6		0.6	
		HF PWR switch ON, MODE switch to BCN or AM, MDC 20, cobra cable PTT button ON	29.0		29.0	
		HF PWR switch ON, MODE switch to SSB, PTT button on cobra cable ON	40.0		40.0	
VHF/FM transmitter	1	VHF FM switch ON, MDC 20	1.5	50.0	1.5	50.0

SYSTEMS DATA

Equipment	Quantity	Control	D-C Watts	A-C Watts	Total D-C Watts	Total A-C Watts
USBE	1	S-BAND XPONDER switch to XPONDER MDC 20		13.5		13.5
S-band PA	1	S-BAND XPONDER switch to XPONDER PWR AMP, PWR AMP switch LOW, MDC 20	3.0	27.4	3.0	27.4
		S-BAND XPONDER switch to XPONDER PWR AMP, PWR AMP switch HIGH	3.0	80.0	3.0	80.0
C-band transponder	1	C-BAND PWR switch 1 pulse or 2 pulse, MDC 20	3.0	75.0	3.0	75.0
VHF recovery beacon	1	VHF BCN switch ON, MDC 20	8.0		8.0	
2-KMC antenna switch	1	S-BAND XPONDER switch ON S-BAND switch changed, MDC 20	15.0		15.0	
Voice recorder	1	HF switch and INTER-COM switch to TR, MDC 20; PTT button ON on cobra cable	0.025	1.99	.025	1.99

2.8.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.8.5.1 Antennas.

For S-band transmission and reception, the SCIN antenna on the side of the S/C nearest to the MSFN station must be utilized. For VHF transmission and reception, the SCIN antenna indicated in figure 2.8-25 should be utilized. This may require switching between the upper (-Z) and lower (+Z) SCIN antennas while making a single station pass. For VHF operations this must be done manually with the VHF ANTENNA switch. For S-band operations, this can be accomplished either manually or automatically with the S-BAND ANTENNA switch.

At greater slant ranges, null points may exist in the SCIN and C-band beacon overall antenna patterns along the centerline of the S/C, forward and aft of the C/M. Pointing either of these null points at the MSFN station may cause communications to be interrupted.

The lower (+Z) SCIN antenna will be burned off during entry. Thus after entry, the upper (-Z) SCIN antenna or VHF recovery antenna No. 2 must be utilized for communications via the VHF/AM transmitter-receiver.

2.8.5.2 Data Storage Equipment.

a. Maximum DSE running times for the entire reel of tape at the three operating speeds are as follows: 3.75 ips (LOW – 120 minutes, 15 ips (NORM) – 30 minutes, 120 ips (HIGH, for rewind and LBR PCM dump only) – 3.75 minutes.

b. Stored HBR and LBR PCM data, if intermixed on the tape, cannot be dumped within one station pass, due to the different playback speeds required. LBR PCM must be recorded at 3.75 ips and may be played back at 15 ips or 120 ips; HBR PCM must be recorded at 15 ips and played back at 15 ips.

c. Stored PCM TLM need not be played back in the same direction in which it was recorded. Playback in the direction of recording requires rewinding of the tape between recording and dumping.

d. There is no provision for recording TV data.

e. High-bit rate PCM must be recorded at normal speed or tape motion will stop.

f. Low-bit rate PCM must be recorded at low speed or tape motion will stop.

g. If tape is played back at low speed, the tape will move but there will be no playback data available to the transmitters.

h. If high-bit rate data is played back at high speed, the transmitter data will be garbled.

i. If only a FWD or REV command is given to initiate a rewind, there will be no tape motion. A mode (preferably PLAY), must also be selected before tape will move.

j. Refer to paragraph 2.8.3.2.6 for proper DSE operating functions.

2.8.5.3 Unified S-Band System.

a. S-band operations will be limited due to the limited number of MSFN stations that will have operational S-band capabilities.

b. If one of the S-band mode switches (TAPE - OFF - ANALOG or TV - OFF - PLSS) is moved from the OFF position, the FM selection of the S-band transmitter will be selected, reducing the circuit margins and disabling the S-band tracking.

c. TV can only be transmitted via the USBE.

d. The secondary oscillator can only be selected in normal operation with the RNG-RNG only switch in the off position and the OSC switch is SEC.

e. The TAPE and TV switches are 3-position switches with the down position no longer performing valid functions. The down position of these switches should not be selected.

f. The TAPE and TV switches should never be positioned up simultaneously.

g. Refer to paragraph 2.8.3.2.5 for valid unified S-band equipment operational modes and their attendant switching configuration.

2.8.5.4 General.

a. The maximum slant range for reliable VHF-FM TLM communications should not exceed 1500 nautical miles. Also, the maximum elevation angle from the earth to the S/C should not be less than 5 degrees.

b. Real-time and recorded PCM TLM cannot be transmitted simultaneously. One or the other, however, can be transmitted via the VHF/FM transmitter and the USBS at the same time, and real-time PCM data may be recorded while it is being transmitted.

c. The FQR has a maximum recording time of approximately 30 minutes. To maintain sufficient time for all scheduled recordings of flight qualification analog data, the FQR must be used conservatively.

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX C

SECTION 2

RECEIVED
NASA STI FACILITY
ACCESS DEPT.

SECTION 2

SUBSECTION 2.9

SEQUENTIAL SYSTEMS

2.9.1 INTRODUCTION.

The sequential systems consist of control and detection systems which function during ascent and entry portions of a mission or in pre-orbital aborts. The control functions are sensing L/V status, displaying L/V status to the crew, automatically initiating LES aborts in an emergency during early ascent, and automatically sequencing the ELS during descent. Backup controls are provided for critical functions and normal events. The systems are the sequential events control system (SECS), emergency detection system (EDS), launch escape system (LES), and earth landing system (ELS). The systems interface with the reaction control system (RCS), guidance and navigation (G&N), service propulsion system (SPS), stabilization and control system (SCS), electrical power system (EPS), telecommunications (T/C), and controls and displays (C&D).

2.9.2 FUNCTIONAL DESCRIPTION.

The purpose of the sequential systems is to provide safety for the crew during the ascent and descent phases of a mission, and to perform normal separation functions. The EDS monitors operation of the L/V and will initiate an automatic abort in an emergency. The LES is provided for use during an emergency arising from malfunction of the L/V or other systems affecting crew safety. The LES will be utilized to abort the mission in an emergency by separating the C/M from the L/V and S/M. The LES can be operational from the launch pad until the launch escape tower is jettisoned. Following second stage booster ignition, the LES tower is jettisoned from the CSM-L/V combination. The ELS is provided to stabilize and decelerate the C/M following an entry into the earth atmosphere or following an abort. The ELS parachutes will lower the C/M at a suitable velocity and attitude until time of touchdown. A functional description of the sequential systems is contained in the following paragraphs.

SEQ

2.9.2.1 Sequential Events Control System (SECS).

The SECS consists of controllers (figure 2.9-1) that provide automatic, semiautomatic, and manual control for initiation or termination of functional events during various phases of the Apollo mission. The controllers are the master events sequence controller (MESC), earth landing sequence controller (ELSC), C/M reaction control system controller (C/M RCSC), service module jettison controller (SMJC). Each

controller consists of redundant relays, timers, and other devices to control systems operation and automatic timing of events. Two controllers are provided in all cases for dual redundancy. The SECS will control the automatically sequenced events during a mission abort, normal CSM-SLA separation, normal C/M-S/M separation, and events during the earth landing phase. The SECS provides conditioned signals to telemetry equipment through the data distribution box so that vital information may be telemetered to MSFN.

The SECS will control the launch escape system (LES) during an abort up to the time of normal launch escape tower jettison. The SPS engine is utilized during an abort after LES tower jettison to propel the CSM away from the L/V. Normal separation of the SLA is performed by the SECS following manual initiation after earth orbit is attained. Emergency separation of the SLA is performed automatically 1.7 seconds after an SPS abort is manually initiated. C/M-S/M separation is performed by the SECS, and is manually initiated during the entry phase or subsequent to an SPS abort. During a LES abort, the C/M-S/M separation is performed automatically by the SECS. Events performed by the earth landing system are automatically controlled by the SECS during normal descent. Switches are provided for manual backup of critical events.

The basic functions performed by the SECS are as follows:

Event	Originates	Function/Input	Manual Control
Auto abort enable	MESC	Lift-off signal	EDS AUTO switch (MDC-16)
LE and PC motors fire	MESC	C/M-S/M separation relays	LES MOTOR FIRE switch (MDC-5)
Pitch motor inhibit	C/M RCSC	Lift-off + 61 seconds	ABORT SYSTEM-OX DUMP switch (MDC-16)
Auto RCS oxidizer dump inhibit	C/M RCSC	Lift-off + 61 seconds	ABORT SYSTEM-OX DUMP switch (MDC-16)
LES tower jettison	MESC	ELS armed and 24K ft baroswitch closure on LES aborts, manual 3 minutes after lift-off	ABORT SYSTEM-MODE switches A and B (MDC-16)
CSM-SLA separation	MESC	Translation control + 1.7 seconds	ADAP SEP switch (MDC-5)

SYSTEMS DATA

Event	Originates	Function/Input	Manual Control
RCS/SCS enable	MESC	Adapter separation + 2.5 seconds or C/M-S/M deadface +1 second	REACTION CONTROL SYSTEM-CMD switch (MDC-16)
LES abort initiation	MESC	EDS abort signal from L/V-IU	Translation control
C/M-S/M separation	MESC	C/M-S/M deadface relays +0.1 second	C/M-S/M SEP switches A and B (MDC-15)
Canard deploy	MESC	LES abort lockup relays +11 seconds	CANARD DEPLOY switch (MDC-5)
SPS abort initiation	MESC	Manual	Translation control
RCS/SCS disable	MESC	ELS armed and 24K ft baroswitch closure	REACTION CONTROL SYS-CMD switch (MDC-16)
Apex cover jettison	MESC	ELS armed and 24K ft baroswitch closure +0.4 second	APEX COVER JETT switch (MDC-5)
Drogue parachutes deploy	ELSC	ELS armed and 24K ft baroswitch closure +2 seconds	DROGUE DEPLOY switch (MDC-5)
Drogue parachutes release and main parachutes deploy	ELSC	ELS armed and 24K ft baroswitch closure + 14 seconds + 10K ft baroswitch closure	MAIN DEPLOY switch (MDC-5)
RCS propellants burn	C/M RCSC	Manual	C/M PROP JETT DUMP switch (MDC-8)
RCS purge	C/M RCSC	Manual	C/M PROP JETT PURGE switch (MDC-8)

SEQ

Event	Originates	Function/Input	Manual Control
Main parachutes release	ELSC	Manual	MAIN CHUTE release switch (MDC-16)
Postlanding antenna deploy	MESC	Manual	POST LANDING-ANTENNA-DEPLOY switches A and B (MDC-25)

2.9.2.2 Emergency Detection System.

The EDS is designed to detect and display status and emergency conditions of the launch vehicle-spacecraft combination to the astronaut. The EDS also provides automatic abort initiation, under certain conditions, after lift-off up to the normal time of LES tower jettison.

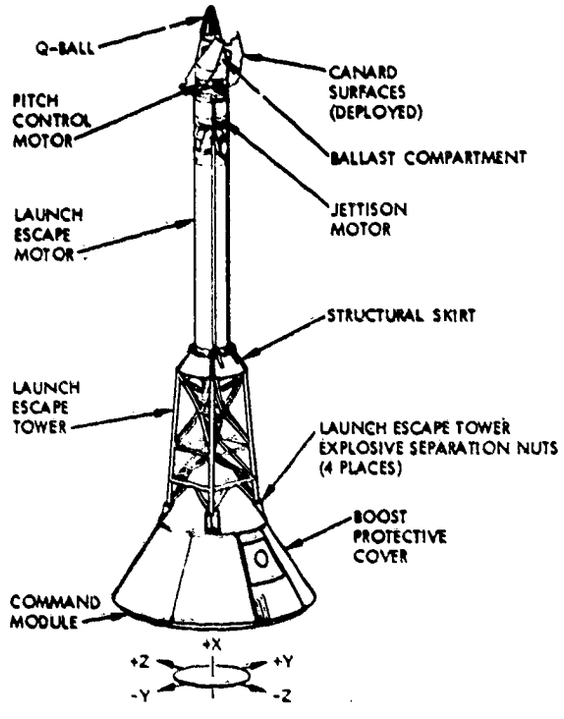
The EDS display circuitry is enabled when the EDS POWER switch (MDC-24) is in the ON position and will illuminate lights on MDC-5 to indicate L/V status. The red L/V RATE light will illuminate when L/V rates are in excess of 20 degrees per second in roll and 5 degrees per second in pitch and yaw. The rates are sensed by three rate gyros mounted on each L/V axis in the instrumentation unit (IU). The red L/V GUID light (MDC-5) illuminates to indicate failure of the guidance unit which is also located in the instrumentation unit. The yellow L/V ENGINES lights (MDC-5) illuminate when a respective S-I booster engine is developing less than 90 percent of total thrust output. The L/V ENGINES lights are monitored for engine status during thrusting periods. During staging, the L/V ENGINES lights are monitored for illumination to indicate BECO and extinguish to indicate stage separation. After staging, the number 1 L/V ENGINE light indicates the status of the S-IVB Stage engine, it will be extinguished when the engine is producing 65 percent rated thrust. The ABORT light (MDC-3) is a red lamp assembly containing 4 bulbs. Two bulbs are in system A and two bulbs are in system B for redundancy. The ABORT light is illuminated if an abort is requested by launch control center for a pad abort or an abort during lift-off via radio. The ABORT light can be illuminated after lift-off by the Range Safety Officer transmitting a destruct arm command. The destruct arm command will also initiate BECO. An abort may also be requested via radio from the MSFN after lift-off +10 seconds.

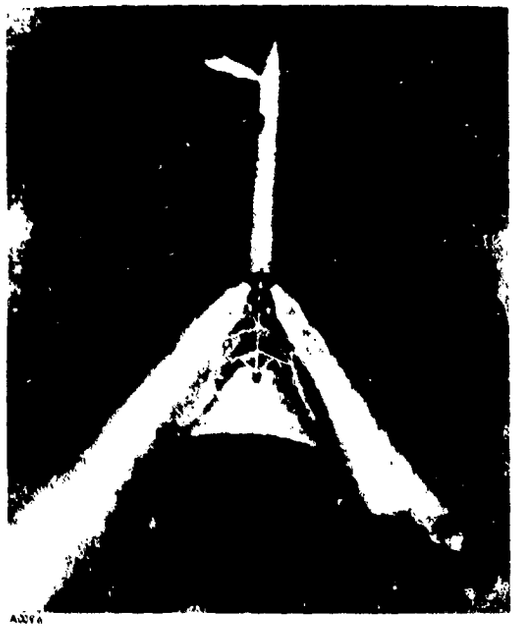
The EDS automatic abort circuitry is enabled at lift-off providing the EDS AUTO switch (MDC-16) is in the AUTO position. (See figure 2.9-2.) A circuit is completed through the lift-off enable and first motion relays at lift off. The lift-off enable relays are latching

type and are latched closed by GSE just prior to lift-off. The normally closed first motion relays remain energized by GSE until actual lift-off occurs. A circuit is completed through the relays and the EDS AUTO switch upon lift-off. The white LIFT-OFF light (MDC-5) illuminates and the red NO AUTO ABORT light (MDC-5) should remain extinguished. The astronaut presses the NO AUTO ABORT switch-light if it illuminates. The NO AUTO ABORT switch-light should also be pressed if the LIFT OFF light does not illuminate at lift-off. This would indicate that the circuit was not completed for illuminating the LIFT OFF light and energizing the auto abort enabling relays. Pressing the NO AUTO ABORT switch-light will energize the auto abort enabling relays through circuitry in the MESC. The EDS AUTO switch must be at AUTO to complete the circuit. The LIFT OFF light would not illuminate in this case. (Refer to Malfunction Procedures in section 9.) The LIFT OFF light is extinguished by circuitry in the L/V IU at approximately 5 seconds after illumination at lift-off. The EDS will automatically initiate an abort when two L/V engines fail or L/V excessive rates are sensed if these two functions are enabled. The two functions are enabled with the ABORT SYSTEM - 2 ENG OUT switch (MDC-16) and ABORT SYSTEM - RATES switch (MDC-16). The two switches are set to off to inhibit the two functions prior to S-IB staging. L/V guidance failure will not initiate an automatic abort. The crew will contact MSFN and a decision made on the action to be taken. If a destruct arm command is transmitted prior to inhibiting the two-engine out auto abort capability, the EDS will detect BECO and initiate an automatic abort. If a destruct arm command is transmitted after the two-engine out auto abort capability is inhibited, a manual abort must be initiated immediately when the ABORT light illuminates. Structural breakup or separation of the structure between the IU and C/M will also be detected by the EDS and an automatic abort initiated. During ascent on a normal mission, the EDS AUTO switch must be set to OFF prior to launch escape tower jettison. Inhibiting of the auto abort capability ensures that an automatic abort can not be initiated at the same time that the launch escape tower is being jettisoned. An abort may be initiated manually by rotating the commander's translation control to the counterclockwise detent position (20 degrees).

The parameters being sensed by the EDS are extremely time-critical at various periods during the boost phase. When these parameters are exceeded, an LES abort is automatically initiated to propel the escaping vehicle (C/M and LES) safely away from the launch vehicle prior to a catastrophic condition. Concurrently with abort initiation, either automatically or manually, logic circuitry will shut down engines in the L/V activate stage. The engine shutdown signal is inhibited by circuitry in the IU for the first 40 seconds of launch because of range safety restrictions.

A Q-ball (figure 2.9-3) mounted above the LES motors, provides an electrical signal input to the L/V AOA/SPS P_c indicator on MDC-3 and an electrical signal input to ground control via telemetry.





SM-2A-74

Figure 2.9-3. Launch Escape System

The Q-ball has four static ports for measuring ΔP which is a function of angle of attack. The ΔP is related to pitch and yaw, and is electronically analyzed and displayed on the L/V AOA SPS P_c indicator on MDC-3. The indicator is graduated to 150 percent because of start transients of the SPS. The indicator is monitored for the L/V AOA function from 40 seconds after litt-off until approximately one minute and 40 seconds.

Position of the red line is based on vehicle structural limits and launch vehicle capabilities. A decision for manual abort initiation will be made when the indicator pointer reaches the red line and a moveout is also observed on the FDAI.

2.9.2.3 Launch Escape System.

Purpose of the LES (figure 2.9-3) is to provide immediate abort capabilities from the launch pad to the normal time of LES tower jettison. The ABORT SYSTEM - MODE switches 1 and 2 (MDC-16) are in the LES MODE position prior to LES tower jettison, and an abort will be accomplished by utilizing the launch escape system. A manual or

automatic initiated abort signal will activate a master event sequence controller (MESC). The MESC will initiate C/M-S/M separation, and ignite the launch escape and pitch control motors. Firing of the pitch control motor is automatically inhibited 61 seconds after lift-off by a time-delay relay. The LES motors provide sufficient thrust for the lift and lateral translation of the C/M away from the launch pad, or trajectory of the launch vehicle. Two canard surfaces (figure 2.9-3) are deployed 11 seconds after abort initiation to orient the C/M to a blunt-end-forward attitude. (Refer to Abort Procedures in section 9.)

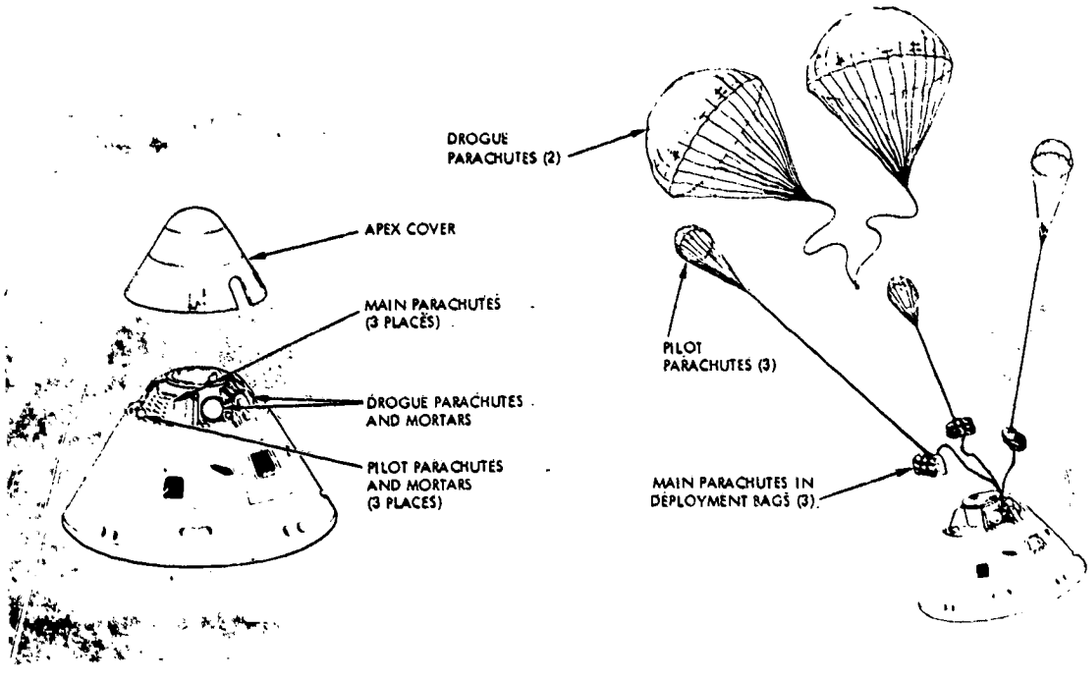
During a normal mission, the LES tower is jettisoned shortly after second stage booster (S-IVB) engine ignition. LES tower jettison is manually initiated approximately 3 minutes after lift-off by setting the ABORT SYSTEM MODE switches 1 and 2 (MDC-16) to the TWR JETT SPS MODE position. Either switch will enable systems A and B of the redundant circuitry. Both switches should be set at the same time. Any abort, after LES tower jettison, must be accomplished in the SPS mode by utilizing the SPS engine. (Refer to Abort Procedures in section 9.)

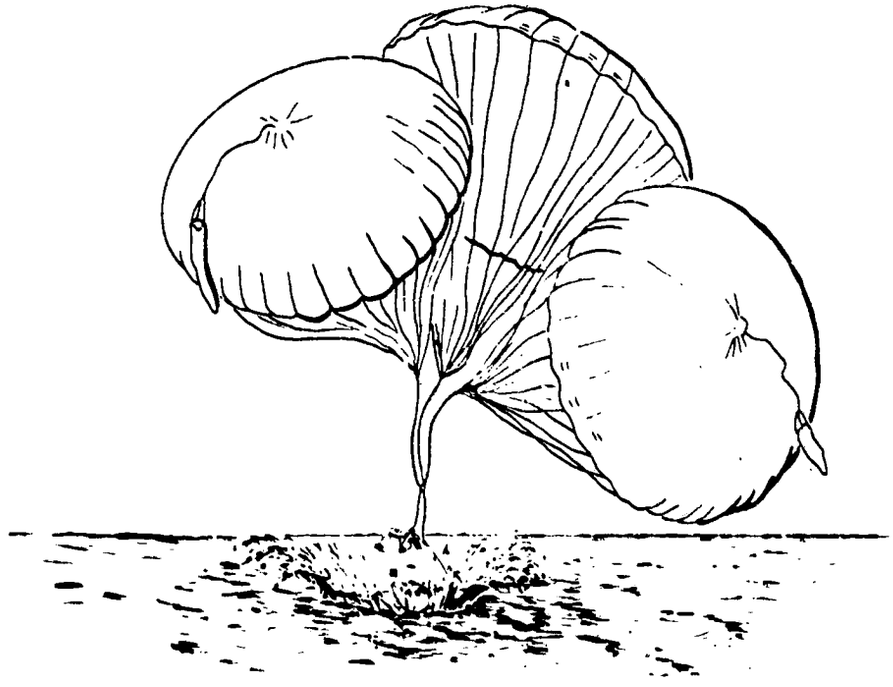
A boost protective cover (BPC) completely covers the conical section of the command module. The cover protects the command module and windows from heating during the ascent phase, and soot at launch escape tower jettison in the event of an abort. The cover is attached to and is jettisoned with the LES tower. A removable section allows access to the C/M crew compartment. The cover has one window fabricated of fused silica glass and is located over the forward viewing window.

2.9.2.4 Earth Landing System.

The ELS provides for safe return of the command module and crew following an earth orbital mission, a lunar mission, or mission abort. The ELS consists of two earth landing system controllers (ELSC) and parachutes. The ELS logic circuitry is armed automatically during an abort in the LES mode, and is armed manually with the ELS LOGIC switch on MDC-8 during a SPS abort or normal entry. The ELSC contains baro switches and time-delay relays. After the logic circuitry is armed, the ELSC automatically senses altitude and initiates deployment of the parachutes at the proper time. The time-delay relays control initiation of automatic events after the 24,000 feet baro switch closes. The parachutes (figure 2.9-4) are located in the forward compartment of the C/M, under the apex cover. During a normal entry or descent from an abort initiated above 30,000 feet, the 24,000 feet baro switch closes and completes a circuit to the MESC which jettisons the launch escape tower. The MESC initiates apex cover jettison 0.4 seconds after launch escape tower jettison. Closing of the 24,000 feet baro switch completes a circuit to a 2-second time delay and a 14-second time delay to jettison the drogue parachutes in 2 seconds. The 14-second time delay completes a circuit to the 10,000 feet baro switch.

SEQ





SM-2A-[illegible]

Figure 2.9-4. ELS Parachute Equipment

The drogue parachutes are held in a reefed condition for 8 seconds by two reefing lines. Each reefing line has two reefing line cutters. A pyrotechnic time-delay train in each reefing line cutter is ignited at the time of drogue parachute line stretch, causing automatic disreefing after 8 seconds. The drogue parachutes remain attached to the command module until descent to approximately 10,000 feet where the 10,000 feet baro switch closes to initiate drogue parachute disconnect. Simultaneously with drogue parachute disconnect, three pilot parachutes are independently mortar deployed, which removes the main parachute packs from the C/M and extracts the main parachutes from their deployment bags. The main parachutes are reefed for 8 seconds. Disreefing then occurs, and the parachutes fully inflate to lower the C/M safely to landing. Three reefing line cutters are employed on each of the two reefing lines for the main parachutes.

A 27-1/2-degree hang-angle of the C/M is maintained by means of the main parachutes attachment. The hang-angle contributes to the crew tolerance impact by ensuring that impact occurs at the specifically designed C/M structural attenuation point. This attenuation point is on the +Z-axis.

Special note should be made that the apex cover jettison and deployment of the drogue parachutes may be manually initiated at 45,000 feet during a normal entry if the flight characteristics of the command module become unstable. (Refer to operational limitations and restrictions.)

An ELS - AUTO/MAN switch (MDC-16) is provided for the crew to inhibit automatic deployment of the main parachutes during a low-altitude abort initiated prior to 61 seconds after lift-off. The switch is set to the AUTO position prior to launch. In the event of an abort prior to 61 seconds after lift-off, the crew will set the switch to MAN after drogue parachute deployment if the C/M is above an altitude of 3300 feet. Deployment of the main parachutes will be manually initiated by pressing the MAIN DEPLOY switch on MDC-5, when the altimeter pointer reaches the adjustable marker setting (3300 feet) on the altimeter face. This action will preclude the possibility of the command module drifting back on a land area. The ELS switch should be returned to AUTO after the main parachutes are deployed. This will allow a 14-second time delay to time out and permit release of the main parachutes when the MAIN CHUTE RELEASE switch is actuated after touchdown.

SEQ

The postlanding recovery aids consist of a sea dye marker, swimmers umbilical, C/M vent fan, C/M uprighting system, HF recovery antenna, and a flashing beacon light. The sea dye marker and swimmers umbilical are deployed automatically when the recovery antenna is deployed. The marker and swimmers umbilical are tethered to the C/M forward compartment deck. The sea dye marker will last approximately 12 hours. The C/M vent fan (part of the ECS) is turned on after landing to vent the C/M to the outside atmosphere. The C/M uprighting system is activated only if the C/M is in a stable inverted attitude. (Refer to Command Module Uprighting System in section 2.)

The flashing beacon light and two VHF antennas located on the forward compartment deck on the C/M are automatically deployed to an upright position after main parachute deployment. The risers of the main parachutes actuate reefing line cutters, which cut retention ties and allows the beacon light and VHF antennas to be extended in 8 seconds. The beacon light has a self-contained power supply capable of operating the light for three 8-hour duty cycles. The flash rate is 15 per minute at an intensity of 1.2 candle-seconds per flash.

The postlanding control switches are located on MDC-25. A recovery pickup cable is provided on the command module for retrieval by recovery forces.

2.9.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

Each of the sequential systems employ redundant circuits for reliability. Seven batteries are provided in the spacecraft to furnish electrical power for the spacecraft portion of the systems during operation. Entry batteries A, B, and C, and two pyro batteries are located in the command module, and two S/M jettison batteries are located in the service module. Entry batteries A, B, and C are the only batteries that are rechargeable during the mission.

Entry batteries A and B furnish power for the EDS displays and MESC logic circuitry. The pyro batteries furnish power for detonation of pyrotechnic devices during aborts, separation functions, and parachute operation during the normal landing sequence. (See figure 2.9-5 for a C/M battery bus tie-in schematic.) A description of each of the sequential systems is contained in the following paragraphs.

2.9.3.1 Sequential Events Control System.

The SECS consists of two master events sequence controllers (MESC), two earth landing sequence controllers (ELSC), two command

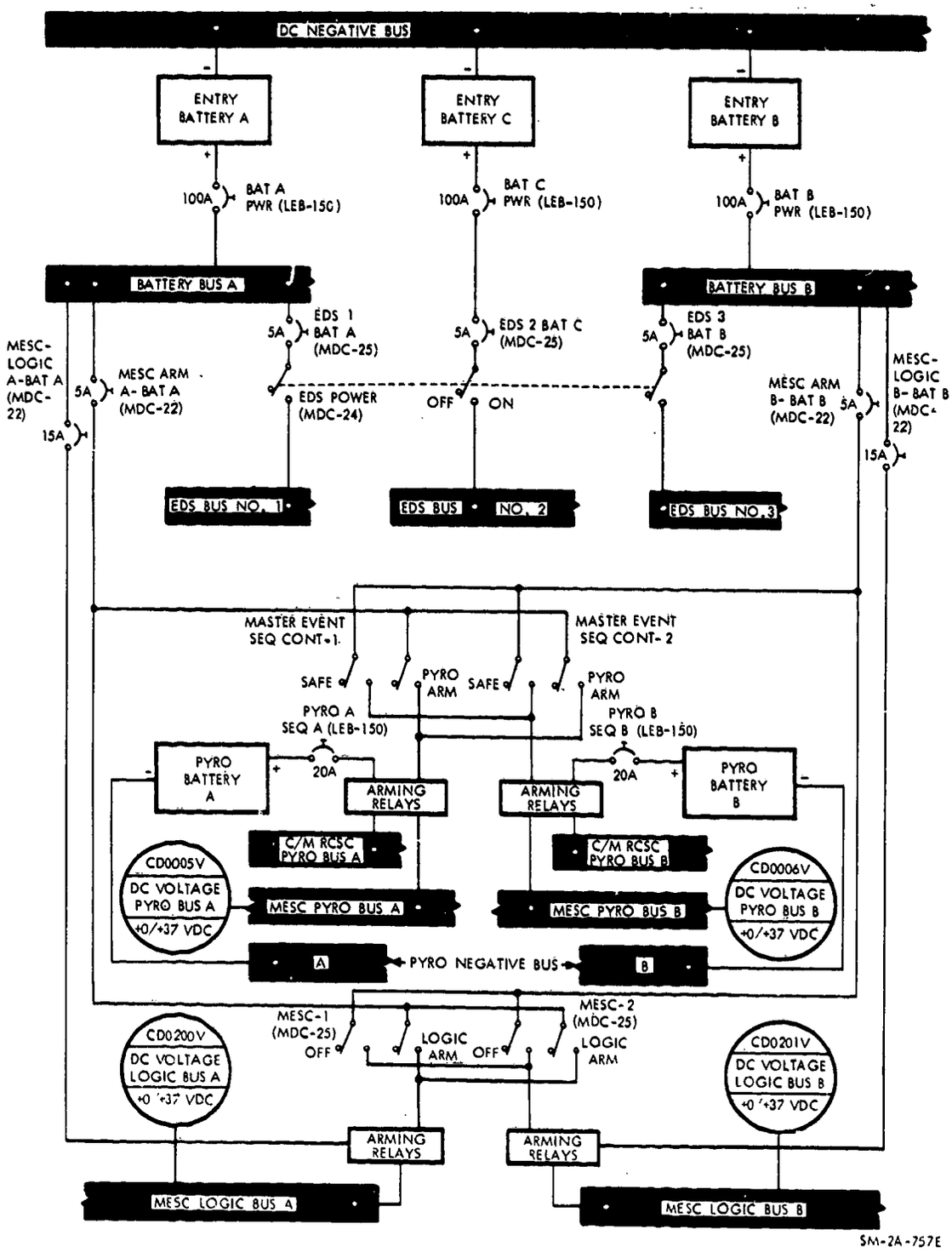


Figure 2.9-5. C/M Battery Bus Tie-In Schematic

SEQ

module reaction control system controllers (C/M RCSC), and two service module jettison controllers (SMJC). The SMJC is located in the service module. All other controllers are located in the command module. Each controller consists of relays, timers, and other devices to provide automatic and semiautomatic control of the systems.

Many operations in the SECS are accomplished by pyrotechnic devices of various types. Apollo standard initiators (ASI) are used throughout the spacecraft to initiate firing of the pyrotechnic devices. The initiator acts as a primer, in most applications, for the main pyrotechnic device. Pins in the initiators are electrically connected with a one-ohm-resistance wire. When a current of at least 3.5 amperes at 28 volts is applied, the one-ohm-resistance wire ignites a primary explosive. The primary explosive, in turn, ignites a secondary explosive to fire a detonator, igniter, or gas cartridge assembly. The detonator assemblies are used to transfer detonation from the ASI/detonator combination to explosive components to perform a specific function. The other high explosive devices are flexible, linear-shaped charges (FLSC) and mild detonating fuzes (MDF) that are employed during module separation functions. The igniter assemblies are used to ignite the LES motors. The gas cartridges are used to actuate the apex cover thruster assemblies, canard thrusters, SLA thrusters, circuit interrupters, and parachute deployment mortars. A control relay maintains a shunt across each pyrotechnic device prior to firing and simultaneously removes the shunt upon receiving a firing command. The Apollo standard initiator (ASI) acts as a pressure cartridge for RCS pyrotechnic valves.

The major pyrotechnic functions performed by the SECS are listed below.

Function and Pyro Device	Normal Actuating Control	Backup Control
Spacecraft LEM Adapter (SLA) separation	Automatic signal from MESC during SPS abort and manual control from ADAPT SEP switch	Command pilots translation control (left arm rest)
a. Umbilical disconnect		
b. Adapter separation (explosive train)		
c. Panel thrusters (8)		
Apex cover jettison	Automatic signal from MESC	APEX COVER JETT switch (MDC-5)
a. Thruster cartridges		
b. Apex cover pilot parachute mortar		

SYSTEMS DATA

Function and Pyro Device	Normal Actuating Control	Backup Control
RCS oxidizer dump a. He isolation valves b. He interconnect valve c. Oxidizer isolation valve d. Gas chromatograph	Automatic signal from RCSC during a LES abort initiated prior to 61 seconds after lift-off.	None for fast dump.
Oxidizer and fuel burnoff a. He interconnect valves b. Fuel interconnect valve c. Oxidizer interconnect valve	Manual actuation of the C/M PROP JETT-DUMP switch (MDC-8)	
RCS purge a. Oxidizer bypass valves b. Fuel bypass valves	C/M PROP JETT - PURGE switch (MDC-8)	C/M RCS - He DUMP/OFF switch (MDC-26), and also opposite commands from rotational controllers one and two for roll and yaw. One controller also commands minus pitch.
Drogue parachute mortars	Automatic signal from ELSC	DROGUE DEPLOY switch (MDC-5)
Pilot parachute mortars	Automatic signal from ELSC	MAIN DEPLOY switch (MDC-5)
Main parachute release mechanism	Manual actuation of MAIN CHUTE RELEASE switch (MDC-16)	None
C/M-S/M separation a. Tension-tie cutting charges	Automatic signal from MESC during a LES abort or C/M-S/M SEP switches 1 and 2 during normal mission	Command pilots translation control (left arm rest) for LES abort and C/M-S/M SEP switches 1 and 2 if translation control does not work.

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Function and Pyro Device	Normal Actuating Control	Backup Control
b. C/M-RCS pressurizing valves		
c. Circuit interrupters		
d. C/M-S/M umbilical guillotine		
e. LE and Pc motors igniter cartridges		
LE tower (TWR) jettison	Automatic signal from MESC or manual control from ABORT SYSTEM - MODE switches 1 and 2	ABORT SYSTEM - MODE switches 1 and 2 (MDC-16)
a. TWR to C/M attaching nuts (explosive)		
b. TWR jettison motor igniter cartridges		
Postlanding antenna deploy	Manual actuation of POSTLANDING - DEPLOY switches 1 and 2 (MDC-25)	

2.9.3.1.1 Master Events Sequence Controllers (MESC).

The MESC (figure 2.9-6) provides the logic and timing to initiate and terminate events associated with the ascent and abort modes. Controller A is in system A and controller B is in system B of the redundant systems. Crossover circuitry between controllers A and B ensures correct outputs for detonating pyrotechnic devices even if one redundant circuit is inoperative. The logic circuitry is armed with the two MESC-LOGIC ARM switches 1 and 2 on MDC-25. The pyro circuitry is armed with the two MASTER EVENT SEQ CONT-PYRO ARM switches 1 and 2 on MDC-24. Backup controls are provided for most of the events controlled by the MESC.

2.9.3.1.2 Earth Landing System Controllers (ELSC).

The ELSC (figure 2.9-7) provide automatic and manual control of drogue parachute deployment, drogue parachute release, and pilot parachute deployment. Two redundant controllers are provided for dual redundancy. Relays are energized in the ELSC and a pyro continuity verification box (PCVB) to control pyrotechnic devices and perform the events. The PCVB provides an access for checkout of pyro circuitry, and contains relays that work in conjunction with the ELSC. The ELSC contains baro switches that inhibit automatic operation of the ELS above

the baro switch setting. Other events are controlled by time-delay relays after the baro switches close. Refer to functional description of the ELS.

2.9.3.1.3 Command Module Reaction Control System Controllers (C/M RCSC).

The C/M RCSC (figure 2.9-8) provide automatic and manual control of events that occur in the reaction control system. Two redundant controllers are provided for dual redundancy. During an abort initiated prior to 61 seconds after lift-off, the C/M RCS oxidizer and helium are automatically dumped. When the abort signal is received, the following pyro valves are fired by initiators to pressurize and dump the RCS oxidizer:

a. Two helium isolation valves
b. Helium interconnect valve
c. Oxidizer interconnect valve
d. Two oxidizer overboard dump valves

The oxidizer overboard dump valves route the oxidizer to a blow-out plug in the aft heat shield of the C/M. Pressure buildup shears a pin which releases the blowout plug and dumps the oxidizer overboard.

The helium pressure is dumped into the aft compartment 18 seconds after abort initiation when the following pyro valves are fired by initiators:

a. Helium interconnect valve
b. Two oxidizer tanks bypass valves
c. Helium overboard dump valve

The three entry batteries are automatically connected to d-c main buses A and B during an LES abort or normal C/M-S/M separation, RCS control is transferred (S/M to C/M). (See figure 2.9-9 for RCS control schematic.) The controllers inhibit automatic oxidizer dump, helium dump, and LES pitch control motor firing automatically at 61 seconds after lift-off. RCS propellant burn and purge must be manually selected.

The pyro buses are armed when the MASTER EVENT SEQ CONT - PYRO ARM switches 1 and 2 are set to the PYRO ARM position. Backup controls are provided for most of the functions performed by the RCSC.

2.9.3.1.4 Service Module Jettison Controllers (SMJC).

The SMJC (figure 2.9-10) program the operation to impart a desired motion to the service module after C/M-S/M separation. The S/M reaction control system will be controlled by the SMJC and command continuous firing of the -X jets. It is possible that the resultant -X thrusting will be offset from the S/M X-axis; therefore, the S/M RCS + roll jets are activated for a 5.5-second interval, 2 seconds after separation. This ensures that a major component of the jettison thrusting will be in a direction that was parallel to the CSM (-X) axis at

severance. The dual controllers are powered by dual separation batteries located in the S/M. The batteries are not rechargeable during the mission.

2.9.3.1.5 C/M-S/M Separation Mechanism.

The C/M-S/M separation mechanism (figure 2.9-11) consists of electrical circuit interrupters, shear compression pads, tension ties, linear-shaped charges, and a dual-blade guillotine (umbilical severance device). Redundant systems (A and B) in the MESC provide dual redundant commands to fire dual initiators and charges to ensure sudden complete tension and umbilical severance with adequate reliability. Prior to umbilical severance, sensitive circuits in the umbilical are deadfaced by circuit interrupters. The shear compression pads are designed for interference-free separation after the tension ties are severed. A separation signal is sent to dual redundant service module jettison controllers which control the S/M after it separates from the C/M.

2.9.3.1.6 Spacecraft LEM Adapter (SLA) Separation Mechanism.

A command for CSM-SLA separation is automatically sent to the MESC when a SPS abort is manually initiated. An ADAPT SEP switch on MDC-5 may be used as a backup and for normal CSM-SLA separation during a normal mission. Separation of the adapter into four panels (figure 2.9-12) is accomplished by an explosive train. The explosive train consists of 28 charge holders, 2 initiators and shields, 8 panel thrusters, 8 initiator pressure cartridges, and an umbilical separation system. Redundant detonator assemblies fire dual lines of mild detonating fuse (MDF) installed between the adapter panels, top and bottom, and between each panel. Either line will sever the splice plates between the four panels and around both ends. Crossover boosters are used in the charge holder joints to ensure that both lines are firing simultaneously for complete reliability. The detonating lines are continuous lead sheaths surrounding an explosive core which is virgin RDX, class C. The mild detonating fuse separates the adapter panels and fires cartridges for the panel thrusters which open the four panels. Simultaneously with this operation, umbilical disconnect takes place. Four spring-loaded reels hold the panels in a 45-degree open position. The panels are stopped in the open position by eight attenuators that have honeycomb cores.

2.9.3.2 Emergency Detection System.

The EDS consists of sensors, logic circuitry and signal conditioners located in the launch vehicle, displays and controls located in the C/M, and Q-ball which is located on the forward tip of the LES tower above the canard. The displays and controls consist of L/V rates, L/V guidance, abort, and engines lights, along with an angle-of-attack

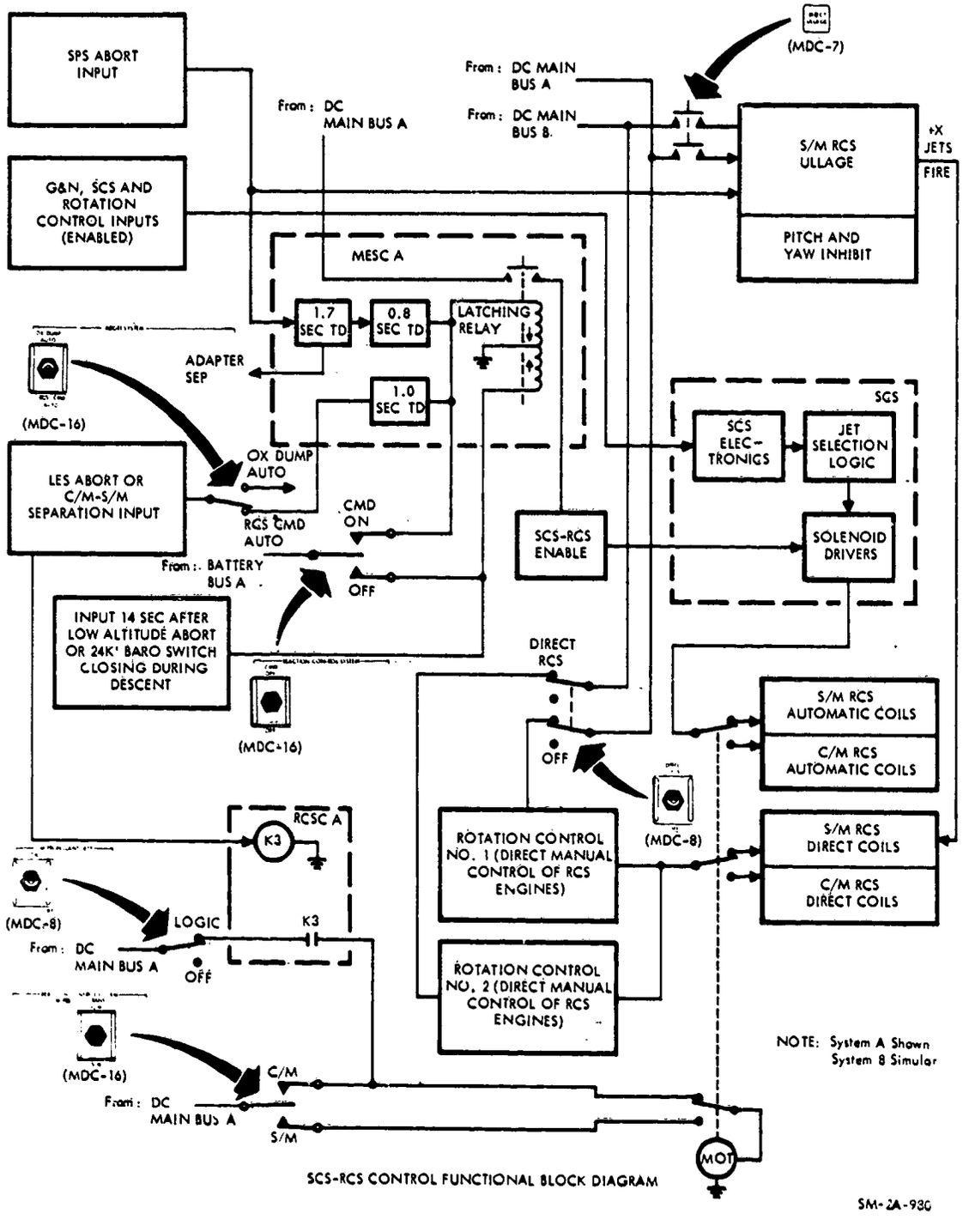


Figure 2.9-9. SCS-RCS Functional Block Diagram

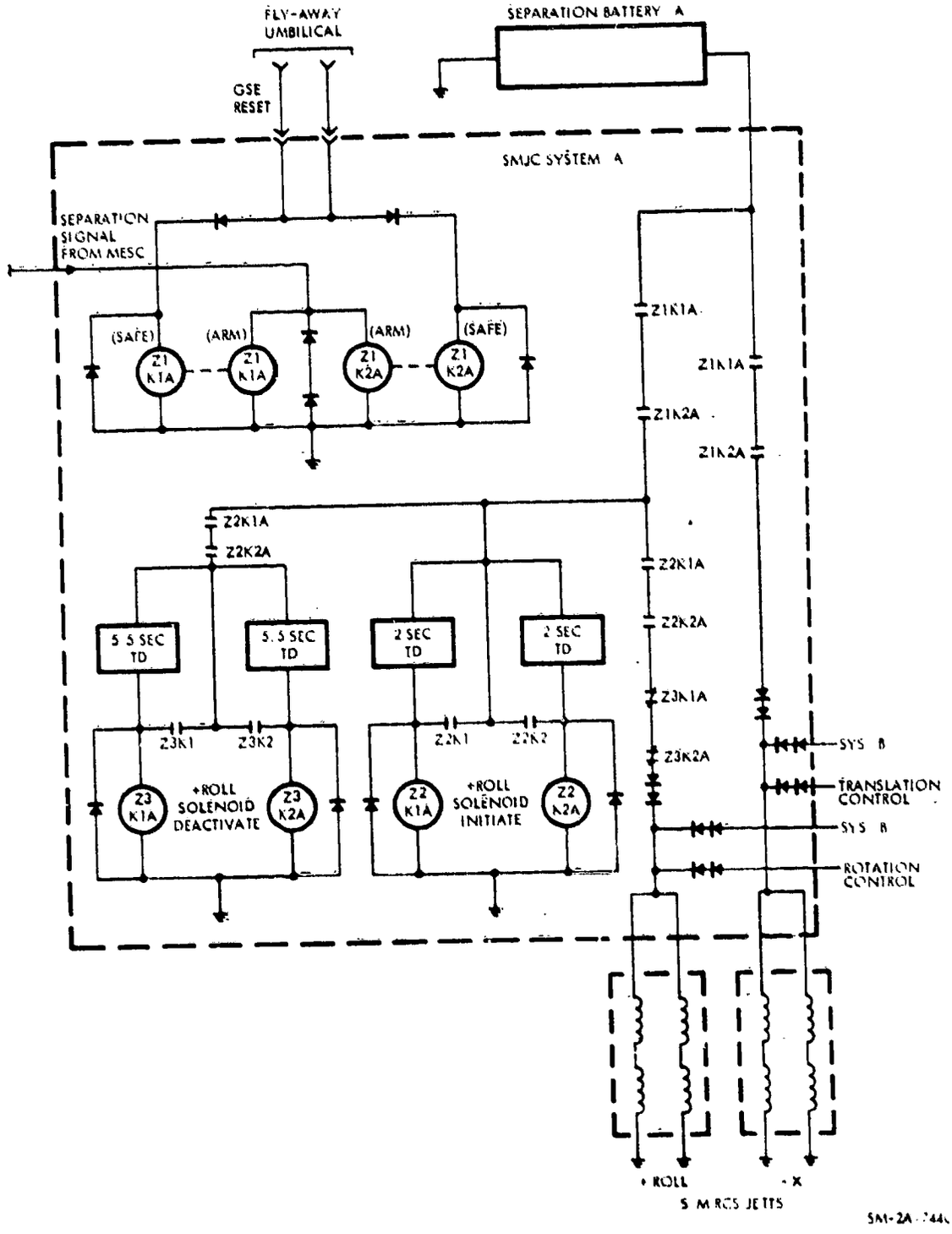


Figure 2.9-10. Service Module Jettison Controller Schematic

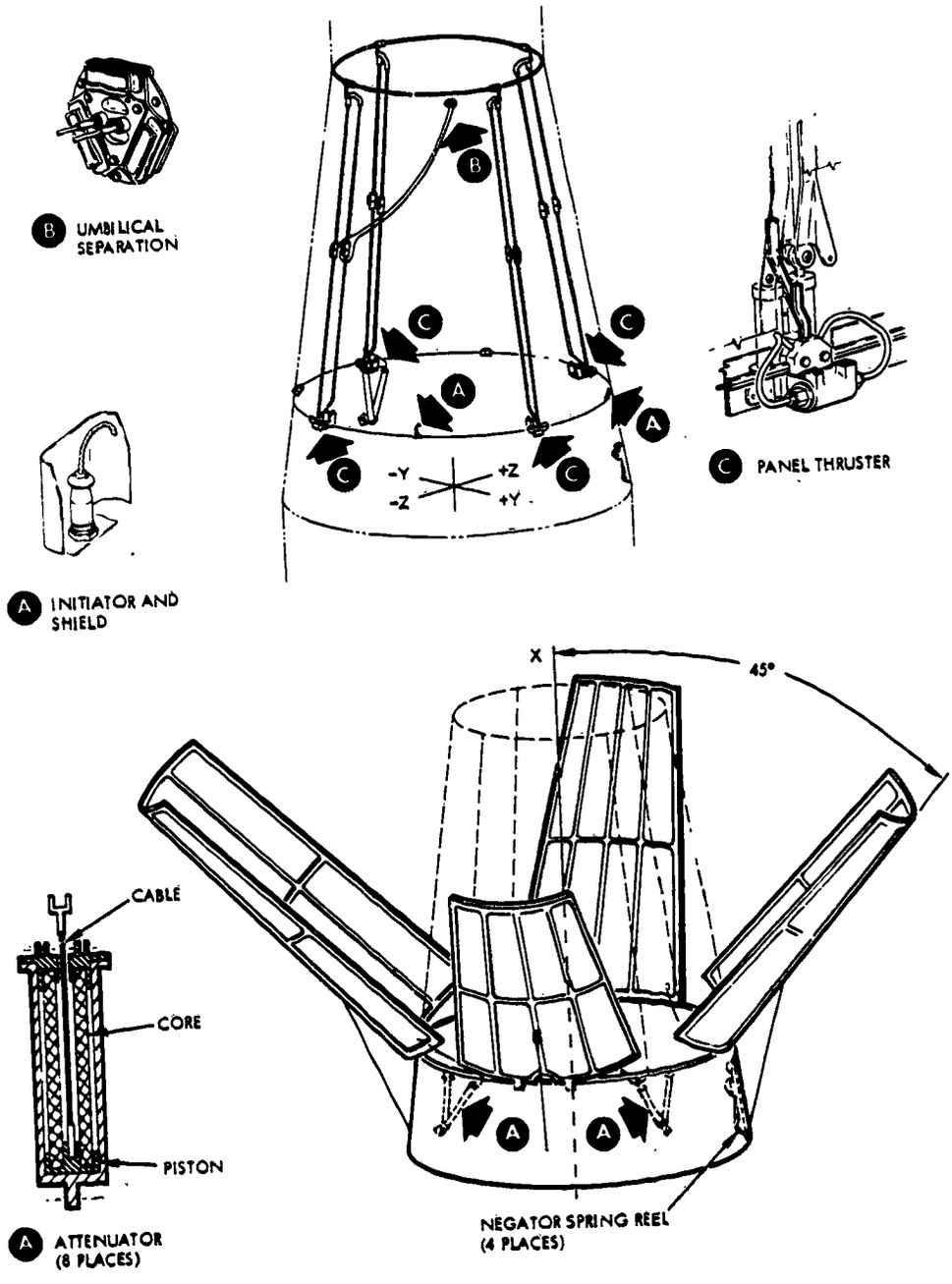


Figure 2.9-12. Adapter Separation Mechanism

indicator and control switches. The L/V portion of the EDS and the Q-ball are powered by eight L/V batteries. The displays are powered by two entry batteries A and B.

2.9.3.3 Launch Escape System.

The LES consists of two major assemblies (figure 2.9-3) that are installed on top of the command module prior to launch. The first structure is a four-legged, welded tubular titanium tower. The tower is attached to the command module with four frangible nuts on studs. Two detonator assemblies are installed in each nut to break it when LES tower jettison is commanded. The second structure is cylindrical in shape topped by the Q-ball, and houses the launch escape, tower jettison, and pitch control motors. A canard subsystem is installed near the forward end below the Q-ball.

2.9.3.3.1 LES Motors.

Each of the three motors in the LES (figure 2.9-3) are fired by two igniter assemblies. The three motors are the launch escape motor, tower jettison motor, and pitch control motor. The pitch control motor works in conjunction with the launch escape motor during a LES abort initiated prior to 61 seconds after lift-off. The pitch control motor has a fixed zero-degree, single-exhaust nozzle and is mounted below the ballast enclosure in a horizontal position. The motor produces approximately 2500 pounds of thrust for about 0.5 second to force the nose of the LES tower in the -Z direction. Firing of the piten control motor is inhibited 61 seconds after lift-off by a signal from the C/M RCSC. The launch escape motor has four nozzles that have a centerline cant angle of 35 degrees. The resultant thrust vector deflection is obtained by offsizing the nozzle throat diameters and producing a thrust vector in the -Y direction. Thrust output is approximately 150,000 pounds which starts dropping in approximately 4 seconds. Lateral translation of the escape vehicle is aided by the thrust vector alignment offset during an LES abort. The tower jettison motor has two nozzles in which the thrust vector alignment is offset approximately 4 degrees to produce a thrust component in the +Y direction. Thrust output is approximately 33,000 pounds.

2.9.3.3.2 Canard Subsystem.

The canard subsystem (figure 2.9-3) consists of two deployable surfaces faired into the outer skin of the LES below the Q-ball interface. Each surface is mounted on two hinges and is operated open by a pyrotechnic thruster with redundant gas cartridges. The surfaces are approximately 47 inches long, clam-shell shaped, and constructed of double-skin ribbed inconel. The canard surfaces are automatically opened during a LES abort and aerodynamic forces acting on the surfaces control a turnaround maneuver of the C/M. (Refer to Abort Procedures in section 9.)

2.9.3.4 Earth Landing Subsystem.

The ELS consists of the parachute subsystem (figure 2.9-4), two earth landing sequence controllers (figure 2.9-7), and the apex cover jettison mechanism.

The parachute subsystem is comprised of two fist-ribbon-type nylon drogue parachutes, 13.7 feet in diameter; three ring-slot-type nylon pilot parachutes, 7.2 feet in diameter; three ring-sail-type nylon main parachutes, 83.5 feet in diameter; deployment bags; bridles; suspension lines; mortars; and the necessary hardware for attachment to the C/M. The parachute subsystem is housed in the forward compartment under the apex cover of the C/M.

The earth landing sequence controllers are located in the right equipment bay of the C/M and controls automatic operation of the ELS. Crossover circuitry between the controllers ensures correct output signals. Backup emergency switches are provided on MDC-5 for apex cover jettison and parachute deployment. The apex cover is jettisoned by four gas-operated thrusters. Two gas-type cartridges are employed for redundancy and operate two thrusters each. Either pair of thrusters will jettison the apex cover. A pilot parachute and mortar are installed in the forward end of the apex cover. The mortar is fired at exactly the same time as the apex cover thrusters to deploy the parachute. The parachute will pull the apex cover from the negative pressure area following the C/M.

2.9.4 PERFORMANCE AND DESIGN DATA.

Entry descent velocities, altitude, and time are contained in the following tabulated data. The figures are based on a command module recovery weight of 11,000 pounds and a standard day barometric pressure.

The tabulated data states the automatic events that normally occur in the ELS during descent. Under certain entry conditions, the apex cover may be manually jettisoned, and the drogue parachutes manually deployed at 45,000 feet. Refer to operational limitations and restrictions that follow the tabulated data.

SEQ

SYSTEMS DATA

Occurrence	Altitude	Time on Parachutes	Descent Velocity
TWO DROGUE PARACHUTES			
24,000 feet baro switch closes	24,900 to 21,500 feet		
Apex cover jettison	24,000 feet baro switch closure + 0.4 seconds		425 ft/sec
Drogue parachutes (2) deploy	24,000 feet baro switch closure +2.0 seconds		410 ft/sec
10,000 feet baro switch closes	10,950 to 9,100 feet		
Drogue parachutes (2) release and main parachutes deploy	10,000 feet baro switch closure	45 to 46 seconds	225 ft/sec
Main parachutes open (reefed) after two drogue parachutes release			235 ft/sec
Main parachutes disreef	8400 ±500 feet	8 seconds after line stretch	110 ft/sec
ONE DROGUE PARACHUTE			
Drogue parachute (1) releases and main chutes deploy	10,000 feet baro switch closure	40 seconds	275 ft/sec
Main parachutes open (reefed) after one drogue parachute releases			290 ft/sec
Main parachutes disreef	8200 ±500 feet	8 seconds after line stretch	120 ft/sec
Touchdown (3 main parachutes)		5 minutes	28 ft/sec
Touchdown (2 main parachutes)		4.2 minutes	33.5 ft/sec

2.9.4.1 Power Requirements.

The SECS requires power only during the launch and ascent phase, for CSM-SLA separation in orbit, for C/M-S/M separation during the pre-entry phase, and during the parachute descent phase. Most all events performed by the SECS occur instantaneously, and not on a continuous duty cycle. In accordance with the Mission Modular Data Book (SID 66-1177), dated 1 September 1966, there are no power requirements for the SECS.

2.9.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Under certain entry conditions, the spacecraft may become unstable. Because of the erratic aerodynamic damping coefficients, wind gusts, and shears, the astronaut may not be able to damp the oscillations with single RCS. If this should occur, the apex cover and drogue parachutes may be manually deployed at 45,000 feet. This will stabilize and keep the C/M in a heat shield forward descending attitude. Figure 2.9-13 portrays the drogue development design envelope. The following precautions should be observed.

- Manual initiation of apex cover jettison and drogue parachute deployment should never be accomplished above 45,000 feet during entry.
- The C/M RCS must be turned off prior to apex cover jettison.
- The LES tower and apex cover should never be manually jettisoned above the automatic mode of 24,000 feet during LES aborts.

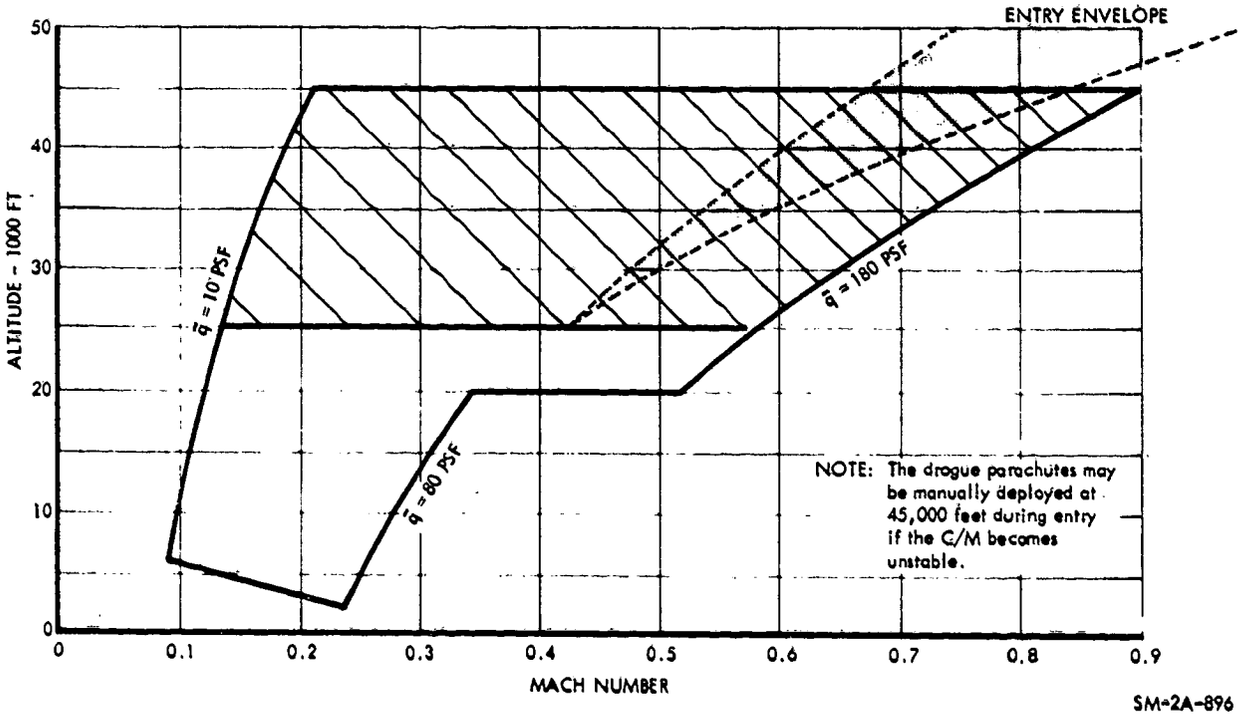


Figure 2.9-13. Drogue Parachute Deployment Design Envelope

2.9.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all sequential systems telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal sources as telemetry, unless a separate measurement number is included in the display column.

An asterisk (*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measurement Number	Description	Sensor Range	Crew Display
CD 0136 X	EDS abort logic out B	Event	None
CD 0140 X	Direct ullage on A	Event	None
CD 0141 X	Direct ullage on B	Event	None
CD 0170 X	RCS activate signal A	Event	None
CD 0171 X	RCS activate signal B	Event	None
CD 0173 X	CM-RCS pressurize signal A	Event	None
CD 0174 X	CM-RCS pressurize signal B	Event	None
*CD 0200 V	DC voltage logic bus A	+0, +37 vdc	None
*CD 0201 V	DC voltage logic bus B	+0/+37 vdc	None
CD 0230 X	Forward heat shield jettison A	Event	None
CD 0231 X	Forward heat shield jettison B	Event	None
CD 0315 X	EDS enable A	Event	None
CD 0316 X	EDS enable B	Event	None
CD 1006 X	LES motor fire initiate A	Event	None
CD 1007 X	LES motor fire initiate B	Event	None
CE 0001 X	Drogue deploy relay close A	Event	None
CE 0002 X	Drogue deploy relay close B	Event	None
CE 0003 X	Main parachute deploy-drogue release relay A	Event	None

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Crew Display
CE 0004 X	Main parachute deploy-drogue release relay B	Event	None
CE 0007 X	Baroswitch lock-in relay close A	Event	None
CE 0008 X	Baroswitch lock-in relay close B	Event	None
*CE 0035 P	Barometric pressure static reference	+0/+15 psia	Indicator
CE 0321 X	Main chute disconnect relay A	Event	None
CE 0322 X	Main chute disconnect relay B	Event	None
*LS 0001 V	Q-ball vector sum output	+0/+5 vdc	Indicator
BS 0016 X	Launch vehicle guidance fail A	Event	L/V GUID light
BS 0020 X	Launch vehicle rate excessive A	Event	L/V RATE light
BS 0030 X	Engine No. 1 out A	Event	ENGINES 1 light
BS 0032 X	Engine No. 2 out A	Event	ENGINES 2 light
BS 0034 X	Engine No. 3 out A	Event	ENGINES 3 light
BS 0036 X	Engine No. 4 out A	Event	ENGINES 4 light
BS 0038 X	Engine No. 5 out A	Event	ENGINES 5 light
BS 0040 X	Engine No. 6 out A	Event	ENGINES 6 light
BS 0042 X	Engine No. 7 out A	Event	ENGINES 7 light
BS 0044 X	Engine No. 8 out A	Event	ENGINES 8 light
BS 0061 X	Lift-off signal B	Event	LIFT OFF light

SEQ

SYSTEMS DATA

Measurement Number	Description	Sensor Range	Crew Display
CS [illegible]	EDS abort request A	Event	ABORT light
[illegible] X	Tower physical separation monitor A	Event	None
[illegible] X	Tower physical separation monitor B	Event	None
CS [illegible] X	CM-SM physical separation monitor A	Event	None
CS [illegible] X	CM-SM physical separation monitor B	Event	None
[illegible] X	SM/adapter physical separation monitor A	Event	None
[illegible] X	SM/adapter physical separation monitor B	Event	None

SECTION 2

SUBSECTION 2.10

CAUTION AND WARNING SYSTEM (C&WS)

2.10.1 INTRODUCTION.

The C&WS monitors critical parameters of most S/C systems in the C/M and S/M. When a malfunction or out-of-tolerance condition occurs in any of these systems, the crew is immediately alerted in order that corrective action may be taken.

2.10.2 FUNCTIONAL DESCRIPTION.

Upon receipt of malfunction or out-of-tolerance signals, the C&WS simultaneously identifies the abnormal condition and alerts the crew to its existence. Each signal will activate an appropriate systems status indicator and a master alarm circuit. The master alarm circuit visually and aurally attracts the crew's attention by alarm indicators on the MDC and an alarm tone in the headsets. Crew acknowledgement of an abnormal condition consists of resetting the master alarm circuit, but retaining the particular systems status malfunction indication. The capability exists for the crew to select several modes of observing systems status and master alarm indicators, and of monitoring C/M or S/M systems.

2.10.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The C&WS consists of one major component, the detection unit. It is located behind MDC-13 and, therefore, is neither visible nor accessible to the crew during the mission. The balance of the system is made up of visual indicators, aural alerting and associated circuits, and those switches required to control the various system functions. Visual indicators include the five upper-most electromechanical event devices on MDC-18, as well as all systems status and master alarm lights.

The detection unit circuits consist of comparators, logic, level detectors, lamp drivers, and a master alarm and tone generator. Also incorporated are two redundant power supplies that furnish regulated +12 and -12 d-c voltages for the electronics. Inputs to the detection unit consist of both analog and event-type signals.

The analog signals, totaling 51 inputs, are in the 0- to 5-volt d-c range. Alarm limits for these signals trigger voltage comparators, which, in turn, activate logic and lamp-driver circuits. This causes activation of the master alarm circuit and tone generator, illumination of application systems status lights on MDC-10 and -11, and/or activation of applicable electromechanical event indicators on MDC-18. A total of 25 event inputs are fed to the C&WS detection unit. These signals originate from solid state and mechanical switch closures in malfunction sensing devices. Of this number, 19 signals will directly illuminate applicable system status lights, and through logic circuitry, activate the master alarm circuit (and tone generator). Two other event signals directly illuminate the system

status lights, but require level detectors to activate the master alarm circuit. Each of the four remaining event signals to set to an OR gate, which is also fed by two analog signals. The resulting output will activate lamp drivers and the master alarm circuit. One other event signal, originating within the detection unit directly, illuminates the CAUT/WARN FAIL light, but activates only the MASTER ALARM lights of the MASTER ALARM circuit.

The master alarm circuit alerts crewmembers whenever abnormal conditions are detected. This is accomplished visually by the illumination of remote MASTER ALARM switch-lights on MDC-3 and -18, and the MASTER ALARM light on LEB-103. An audio alarm tone, sent to the three headsets, aurally alerts the crew, regardless of whether the telecom system is activated. The output signal of the tone generator is a square wave that is alternately 750 cps and 2000 cps, changing at a frequency of 2.5 cps. Although the tone is audible above the conversation level, it does not render normal conversation indistinct or garbled. When the crew has noted the abnormal condition, the three alarm lights and the tone generator are deactivated and reset by pressing either MASTER ALARM switch-light, both of which incorporate a push-switch. This action leaves the systems status lights illuminated, and resets the master alarm circuit for alerting the crew to the next abnormal condition. The individual system status lights will remain illuminated until the malfunction or out-of-tolerance condition is corrected.

The C&WS power supplies include sensing and switching circuitry that assure unit self-protection should high-input current, or high- or low-output voltage occur. Any of these conditions will cause the illumination of the master alarm lights and the CAUT-WARN FAIL systems status light. The tone generator, however, will not be activated due to requiring the 12-volt output from the malfunctioned power supply for its operation. The crew must then manually select the redundant power supply to return the C&WS to operation. In so doing, the CAUT/WARN FAIL status light is extinguished, but the master alarm circuit is activated, thus requiring it to be reset.

Incorporated into the C&WS is the capability to test the lamps of systems status and master alarm lights. Position 1 of the LAMP TEST switch (MDC-23) controls the illumination of status lights on MDC-10 and the MASTER ALARM switch-lights on MDC-3 and MDC-18. Position 2 tests only the status lights on MDC-11. The remaining MASTER ALARM light is on LEB-103, and is tested along with the nine G&N condition lights on that panel by pressing the CHECK CONDITION LAMPS push-switch on LEB-105. Although these nine lights are not part of the C&WS, all but three of them (PGNS, ZERO ENCODER, and IMU DISPLAY) are duplicated on MDC-10.

Switches on the MDC enable the crew to select C&WS operational modes. The position of the MODE switch (MDC-11) establishes the S/C systems to be monitored. Before separation and entry, systems in both the C/M and S/M are monitored for malfunction or out-of-tolerance conditions. After CSM separation, however, only those systems in the C/M are monitored. Repositioning the switch also prevents S/M systems status lights and event indicators from remaining activated after separation.

The C/W switch (MDC-13) permits three modes of status and alarm light illumination. For most of the mission the switch is set to the NORMAL position to give normal C&WS light operation; that is, upon receipt of abnormal condition signals, all systems status lights and master alarm

lights are capable of illumination. During the ascent phase the switch is set to the BOOST position, so that although all other C&WS lights operate normally, the MASTER ALARM switch-light on MDC-3 will not illuminate. This prevents possible confusion on MDC-3 between the red MASTER ALARM light and the adjacent red ABORT light. The ACK switch position is selected when the crew desires to adapt their eyes to orbital darkness, or if a continuously illuminated systems status light is undesirable. While in this mode, incoming signals will activate only the master alarm lights and the tone generator. To determine the abnormal condition, the crew must press either MASTER ALARM switch-light. This illuminates the applicable systems status light, and deactivates and resets the master alarm circuit. The systems status light will remain illuminated only as long as the switch-light is pressed. However, it may be recalled as long as the abnormal condition exists by again pressing either switch-light.

2.10.3.1 Electrical Power Distribution.

The C&WS only receives power from 28-volt d-c sources. (See figure 2.10-1.) Before CSM separation, the power source is from the fuel cells in the S/M, and following separation, from batteries located in the C/M.

2.10.4 PERFORMANCE AND DESIGN DATA.

2.10.4.1 C&WS Power Consumption Data.

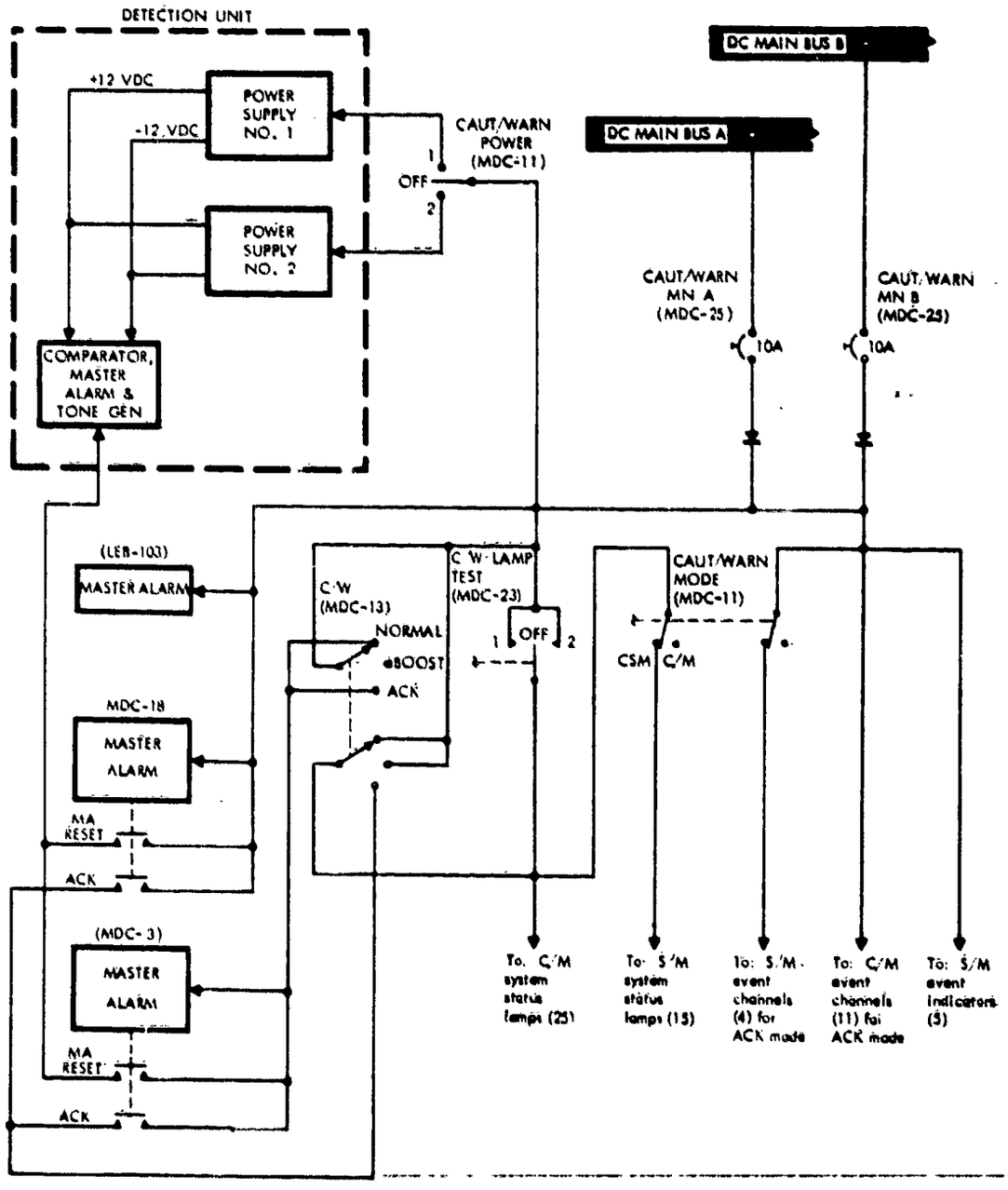
Total power consumed by the C&WS amounts to 7.5 watts, which is the maximum quiescent power for detection unit operation. Very small amounts of power are also required to illuminate several lamps whenever the C&WS is activated by malfunction input signals. These small amounts, however, are not considered in the overall C&WS power requirements.

2.10.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.10.5.1 C&WS General Data.

With the C/W switch in the BOOST position during ascent, the MASTER ALARM switch-light on MDC-3 will not illuminate should a malfunction occur. The master alarm circuit reset capability of the light is also disabled during this time. This requires the MASTER ALARM switch-light on MDC-18 to be used exclusively for monitoring and resetting functions.

Several peculiarities should be noted in regard to the CAUT. WARN-POWER switch. Whenever this switch is moved from, or through, the OFF position to either power supply position, the master alarm circuit is activated, which then requires it be reset. Also, switching from one power supply to another (when there is not power supply failure) will cause the CAUT/WARN FAIL status light to illuminate at the OFF position, and then be extinguished when the other power supply position is reached.



SM-2A-87JC

Figure 2.10-1. C&WS Power Distribution Diagram

Should the redundant power supply also fail, the C&WS is degraded to the following extent. Rendered inoperative is the complete master alarm circuit, as well as those status lights that illuminate as the result of analog-type input signals. This leaves only those status lights operative that require event-type input signals. Included are the following S/M and C/M lights: CDU FAIL, G&N ACCEL FAIL, IMU FAIL, G&N ERROR, IMU TEMP, GMBL LOCK, AGAP TEMP, SPS ROUGH ECO, H_2P ACCUM FAIL, PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNSR FAIL, O_2 FLOW HI, F/C BUS DISCONNECT, AC 1 BUS FAIL, AC BUS 1 OVERLOAD, AC 2 BUS FAIL, AC BUS 2 OVERLOAD, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, and CAUT/WARN FAIL.

The CAUT/WARN-MODE switch must be in the CSM position in order to conduct a lamp test of those status lights associated with S/M systems. The status lights of C/M systems may be tested with the MODE switch in either position. Circuit design also permits a complete lamp test to be conducted with the C/W switch in the ACK position.

Normally, each abnormal condition signal will activate the C&WS master alarm circuit and tone generator, and illuminate an applicable systems status light. The one exception to this concept is when the C&WS power supply fails. The visual indicators will function, but not the tone generator portion of the master alarm circuit. This is due to the tone generator requiring the +12 and -12 d-c voltage output of the failed power supply for its operation.

The MASTER ALARM light on LEB-103 is part of the master alarm circuit of the C&WS. As such, it is illuminated whenever the master alarm circuit is activated by an incoming abnormal condition signal. A lamp check of this light, however, it not accomplished by the C&WS. Instead, the light is checked by pressing the CHECK CONDITION LAMPS push-switch on LEB-105. The primary function of this switch is to check the lamps of the nine G&N condition lights on LEB-103, none of which are part of the C&WS.

2.10.x.2 System Status Light Data.

The following list provides the lamp trigger values and associated information for all system status lights on MDC 10 and -11.

C&W

SYSTEMS DATA

Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
CDU FAIL	1. Loss (-50%) 2.6 KC supply 2. Loss (-50%) motor excitation 3. ICDU error ≥1.2 mr for 5 seconds 4. MCDU error ≥1.2 mr for 5 seconds 5. OCDU error ≥1.2 mr for 5 seconds	CG5002X	PGNS light illuminated (LEB-103).	C/M	Light enabled in fine align mode only.
IMU FAIL	1. Loss (-50%) 3200 cps 2. Loss (-50%) 800 cps wheel power 3. IG servo air ≥2.9 mr for 2 seconds 4. MG servo air ≥2.9 mr for 2 seconds 5. OG servo air ≥2.9 mr for 2 seconds	CG5001X	PGNS light illuminated (LEB-103).	C/M	Inhibited (by AGC program) in coarse align mode.
IMU TEMP	1. IRIG temp ≤132°F 2. IRIG temp ≥138°F 3. PIPA temp ≤132°F 4. PIPA temp ≥138°F	CG5006X	None	C/M	IRIG temp (135°F) is internal and not end cap temp.
AGAP TEMP	1. Any BMAG ≤160°F 2. Any BMAG ≥171°F	CH2030V	None	C/M	
G&N ACCEL FAIL	1. X PIPA error ≥.27 mr for 5 seconds 2. Y PIPA error ≥.27 mr for 5 seconds 3. Z PIPA error ≥.27 mr for 5 seconds	CG5000X	PGNS light illuminated (LEB-103).	C/M	
G&N ERROR	1. Down TLM word rate too high or low 2. Up TLM bit rate too high 3. Up-link data in error	CG5008X	DSKY-TM FAIL (LEB-106) and PGNS lights (LEB-103) illuminated.	C/M	
GIMBL LOCK	MG angle ≥ 70°	CG5003X	FDAI attitude ball red zone under new axis indicator.	C/M	
H_2 PRESS	1. Tank 1 ≤220 psia 2. Tank 1 ≥270 psia 3. Tank 2 ≤220 psia 4. Tank 2 ≥270 psia	SF0039P SF0040P	TANK PRESSURE-H_2-1 indicator TANK PRESSURE H_2-1 indicator	S/M	
C/M RCS A	1. Fuel tk He press ≤765 psia 2. Fuel tk He press ≥825 psia 3. Ox tk He press ≤760 psia 4. Ox tk He press ≥820 psia	CR0008P CR0011P	C/M RCS PRESS-F indicator C/M RCS PRESS-OX indicator	C/M	Light functional only when CAUT/WARN-MODE switch in C/W
C/M RCS B	1. Fuel tk He press ≤760 psia 2. Fuel tk He press ≥820 psia 3. Ox tk He press ≤760 psia 4. Ox tk He press ≥820 psia	CR0006P CR0012P	C/M RCS PRESS-F indicator C/M RCS PRESS-OX indicator	C/M	Light functional only when CAUT/WARN-MODE switch in C/M
AGC PWR FAIL	1. Loss of +28 vdc supply 2. Loss of +14 vdc supply 3. Loss of -9 vdc supply	CG5030X	PGNS light illuminated (LEB-103).	C/M	

SYSTEMS DATA

Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
O_2 PRESS	1. Tank 1 ≤800 psia 2. Tank 1 >950 psia 3. Tank 2 ≤800 psia 4. Tank 2 >950 psia	SF0037P SF0038P	TANK PRESSURE-O_2-1 indicator TANK PRESSURE-O_2-2 indicator	S/M	
S M RCS A	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5065T SR5729P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S M RCS B	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5066T SR5776P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S M RCS C	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5067T SR5817P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S M RCS D	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5068T SR5830P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
SPS ROUGH ECO	1. 180G's for 70 m seconds 2. 360G's for 30 m seconds	None	Engine cuts off.	S/M	G-levels are peak-to-peak.
H_2O ACCUM FAIL	Three O_2 bubbles (min) in outlet water line	None	None	C/M	
F C BUS DISCONNECT	1. Fwd current at 75 amps for 15 min. or at 112 amps for 25 to 300 seconds 2. Reverse current at 4 amps for 10 sec. or 20 amps for 1 sec.	SC2120X SC2121X SC2122X SC2125X SC2126X SC2127X	MN BUS A event indicator (3) MN BUS B event indicator (3)	S/M	
F C 1	1. H_2 flow <0.018 lb/hr 2. H_2 flow >0.16 lb/hr 3. O_2 flow <0.14 lb/hr 4. O_2 flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <155°F 9. Cond exh >175°F 10. Rad out temperature-below -30°F 11. H_2 reg press >75 psia 12. O_2 reg press >75 psia 13. N_2 reg press >70 psia	SC2139R SC2142R SC2160X SC2084T SC2081T SC2087T SC2069P SC2066P SC2060P	FUEL CELL-FLOW-H_2 indicator FUEL CELL-FLOW-O_2 indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI -H_2 event ind REG OUT PRESS HI -O_2 event ind REG OUT PRESS HI -N_2 event ind	S/M	Event indicators pH, HI. F/C RAD TEMP LO, H_2 PRESS, O_2 PRESS, and N_2 PRESS are activated at lamp trigger values.
INV 1 TEMP HI	At 241°F	CC0175T	None	C/M	
GLYCOL TEMP LOW	At -30°F	CF0020T	GLY EVAP-OUTLET TEMP indicator	C/M	

SYSTEMS DATA

Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
SPS PRESS	1. Fuel tk He press <160 psia 2. Fuel tk He press >200 psia 3. Ox tk He press <160 psia 4. Ox tk He press >200 psia	SP0006P SP0003P	PRESSURE-FUEL indicator PRESSURE-OX indicator	S/M	
F C 2	1. H_2 flow <0.018 lb/hr 2. H_2 flow >0.16 lb/hr 3. O_2 flow <0.14 lb/hr 4. O_2 flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <155°F 9. Cond exh >175°F 10. Rad out temp below -30°F 11. H_2 reg press >75 psia 12. O_2 reg press >75 psia 13. N_2 reg press >70 psia	SC2140R SC2143R SC2161X SC2085T SC2082T SC2088T SC2070P SC2067P SC2061P	FUEL-CELL-FLOW-H_2 indicator FUEL CELL-FLOW-O_2 indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI-H_2 event indicator REG OUT PRESS HI-O_2 event indicator REG OUT PRESS HI-N_2 event indicator	S/M	Event indicator pH HI, F/C RAD TEMP LO, H_2 PRESS, O_2 PRESS, and N_2 PRESS are activated at lamp trigger values.
INV 2 TEMP HI	At 240°F	CC0176T	None	C/M	
PITCH GMBL DR FAIL	1. Under 6 amps 2. Over 40 amps	SP1000X	None	S/M	Overcurrent conditions dependent upon time and temp.
SPS WALL TEMP HI	At 378°F	SP0020T	None	S/M	
F/C 3	1. H_2 flow <0.018 lb/hr 2. H_2 flow >0.16 lb/hr 3. O_2 flow <0.14 lb/hr 4. O_2 flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <156°F 9. Cond exh >175°F 10. Rad out temp below -30°F 11. H_2 reg press >75 psia 12. O_2 reg press >75 psia 13. N_2 reg press >70 psia	SC2141R SC2144R SC2162X SC2086T SC2083T SC2089T SC2071P SC2068P SC2062P	FUEL CELL-FLOW-H_2 indicator FUEL CELL-FLOW-O_2 indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI-H_2 event indicator REG OUT PRESS HI-O_2 event indicator REG OUT PRESS HI-N_2 event indicator	S/M	Event indicators pH HI, F/C RAD TEMP LO, H_2 PRESS, O_2 PRESS, and N_2 PRESS are activated at lamp trigger values.
INV 3 TEMP HI	At 241°F	CC0177T	None	C/M	
YAW GMBL DR FAIL	1. Under 6 amps 2. Over 40 amps	SP1001X	None	S/M	Overcurrent condition dependent upon time and temp.
SPS PI SNSR FAIL	1. F/OX ratio unbalance over 300 lbs, or 90° of critical unbalance. 2. Primary and aux systems 1 to 4 disagreement.	None	UNBALANCE indicator (for over 300 lbs only)	S/M	Light functional only during SPS firing.

SYSTEMS DATA

Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
MN BUS A UNDERVOLT	At 26.25±0.1 vdc	CG0206V	DC VOLTS meter	C/M	
MN BUS B UNDERVOLT	At 26.25±0.1 vdc	CG0207V	DC VOLTS meter	C/M	
CO_2 PP HI	At 7.6 mm Hg	CF0005P	PART PRESS CO_2 indicator	C/M	
AC BUS 1 FAIL	1. At 95±3 vdc 2. At 130±2 vdc	CG0200V CG0201V CG0202V	AC VOLTS meter	C/M	
AC BUS 2 FAIL	1. At 95±3 vdc 2. At 130±2 vdc	CG0203V CG0204V CG0205V	AC VOLTS meter	C/M	
CAUT/WARN FAIL	1. At +11.7 vdc or -11.7 vdc 2. At +13.9 vdc or -13.9 vdc	None	MASTER ALARM lights (3)	C/M	Alarm tone inoperative.
O_2 FLOW HI	At 1.0 lb/hr	None	FLOW O_2 indicator	C/M	
AC BUS 1 OVERLOAD	1. 30 at 9 amp/0 for 15±5 sec 2. 10 at 11 amp for 5±1 sec	None	AC VOLTS meter	C/M	Overload disconnects inverter from bus.
AC BUS 2 OVERLOAD	1. 30 at 9 amp/0 for 15±5 sec 2. 10 at 11 amp for 5±1 sec	None	AC VOLTS meter	C/M	Overload disconnects inverter from bus.

2.10.6 TELEMETRY MEASUREMENTS

The following is a complete list of all C&WS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

Measurement Number	Description	Sensor Range	Crew Display
CS0150X	Master caution-warning on	Off/on event	MASTER ALARM lights

SECTION 2

SUBSECTION 2.11

MISCELLANEOUS SYSTEMS DATA

2.11.1 INTRODUCTION.

Miscellaneous systems data pertains to items that were not covered in a previous system. These items consist of clocks, timers, accelerometers (G-meter), interior lighting, etc.

2.11.2 CLOCKS.

Two clocks and two clock-like event timers, all mechanical, are provided for the crew in the command module. The 400-hour clock (MDC-12), used in monitoring mission elapsed time, is illuminated by floodlights. The GMT 24-hour clock and two 10-hour event timers are located on panel 306 in the LH forward equipment bay and lighted by integral bulbs controlled by the CLOCKS-BRT/OFF/DIM switch on LEB 100. For further information, refer to section 4.

2.11.3 DIGITAL EVENT TIMERS.

The digital event timers provide the crew with a means of monitoring and timing events. One event timer is located on MDC-5 the other is located on MDC-11. The event timers start automatically when lift-off occurs, and the timer located on MDC-5 will be reset if an abort is automatically or manually initiated. For further information, refer to section 3.

2.11.4 ACCELEROMETER (G-METER).

The accelerometer or G-meter (MDC-2), provides the crew with a visual indication of spacecraft positive and negative G-loads. This meter is illuminated by floodlights controlled by the LH area control panel (MDC-26). For detailed information on the accelerometer (G-meter), refer to section 4.

2.11.5 COMMAND MODULE INTERIOR LIGHTING.

The interior lighting provides light for the main display console and LEB panels in the command module.

MISC

2.11.5.1 Functional Description.

The interior lighting equipment consists of eight floodlight fixture assemblies and three control panels. Each fixture assembly contains two fluorescent lamps (one primary and one secondary) and a converter. The interior lighting is powered by 28 volts dc from main buses A and B for redundancy (figure 2.11-1). This assures a power source for lights in all areas in the event that either bus fails. The converter in each floodlight fixture converts 28 volts dc to a-c power to operate the fluorescent lamps. The floodlights are used to light three areas: the main display console (left and right areas) and the LEB area. Control panel (MDC-26) is located on the left and control panel (MDC-23) is located on the right of the main display console (figure 2.11-2). The third control panel is located in the lower equipment bay area on LEB-100. The floodlight fixtures are located around the interior of the command module. (See figure 2.11-2.)

Each control panel has a primary and secondary control for the floodlights in its respective area. The primary control is a rheostat that controls brightness of the primary floodlights. The secondary control is an ON-OFF switch for the secondary floodlights and is turned to ON when additional brightness is desired. The floodlight circuit breakers are on MDC-25. The operational use, or brightness level of the floodlights depends on two factors: the g-level and the task being performed. The floodlights should be turned up bright during ascent and entry. The floodlights will be adjusted as required while in earth orbit. The FDAI (MDC-4) is lighted by integral bulbs which are controlled by the FDAI LTG switch on MDC-25 and FDAI BRIGHTNESS rheostat on MDC-2. A switch is provided on the LEB floodlight control panel to control lighting for the clocks on LHFEB-306.

2.11.6 COMMAND MODULE UPRIGHTING SYSTEM.

The C/M uprighting system is manually controlled and operated after the C/M has assumed a stable inverted floating attitude. The system consists of three inflatable air bags, two relays, three solenoid control valves, two air compressors, control switches, and air lines. The inflatable bags are located in the C/M forward compartment and the air compressors are located in the aft compartment. The control switches and circuit breakers are located in the crew compartment. Switches 1 and 2 are powered by the postlanding bus switch 3 and the compressors are powered by battery buses A and B. (See figure 2.11-3.)

2.11.6.1 Functional Description.

POSTLANDING - FLOAT BAG switch 1 controls inflation of the air bag on +Y axis, switch 2 controls inflation of the air bag on the -Y axis, and switch 3 controls inflation of the air bag on the +Z axis of the C/M. (See figure 2.11-3.) Each bag is 43 inches in diameter and has a capacity of approximately 24 cubic feet when inflated. If the C/M becomes inverted

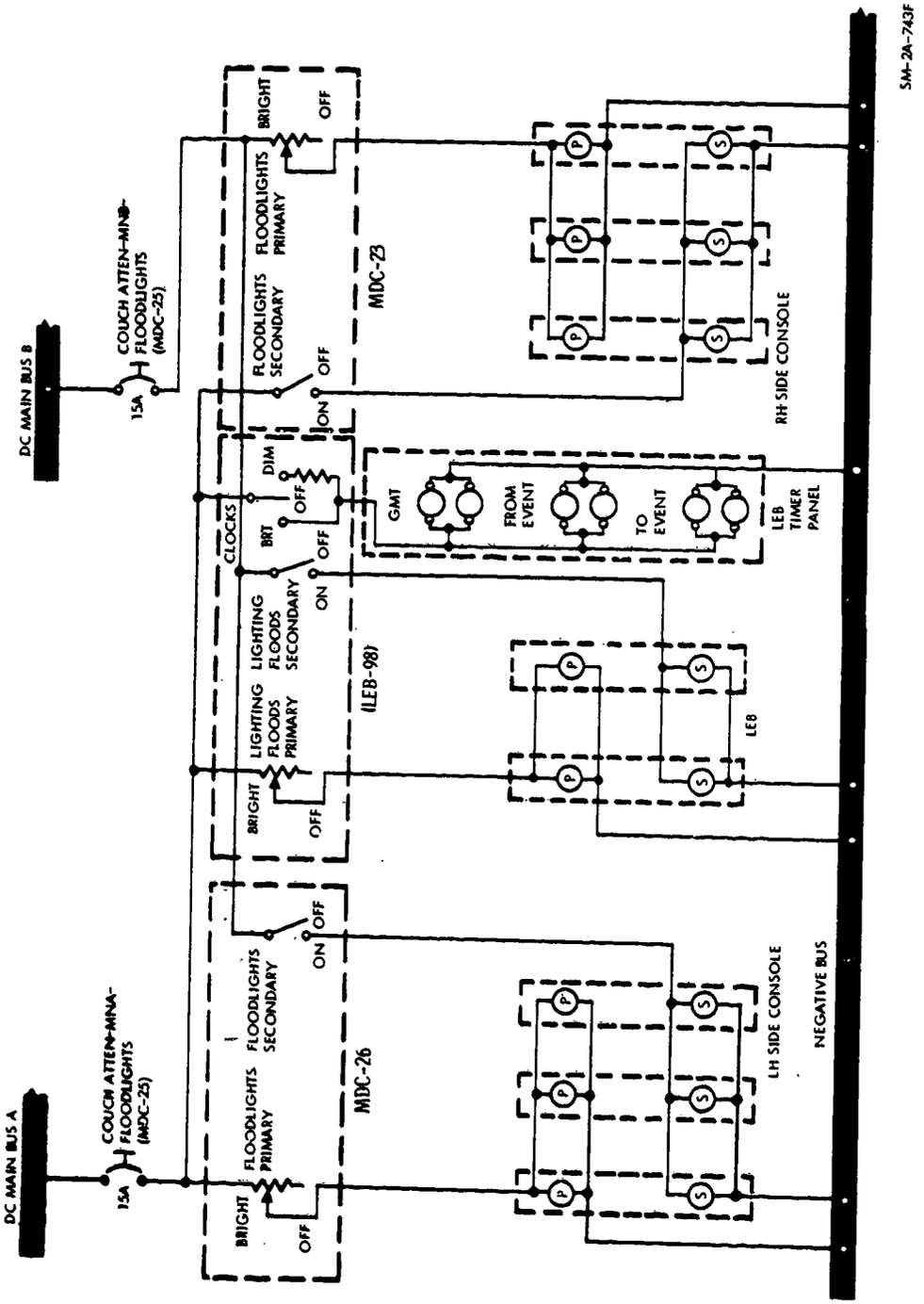


Figure 2.11-1. C/M Interior Lighting Schematic

MISC

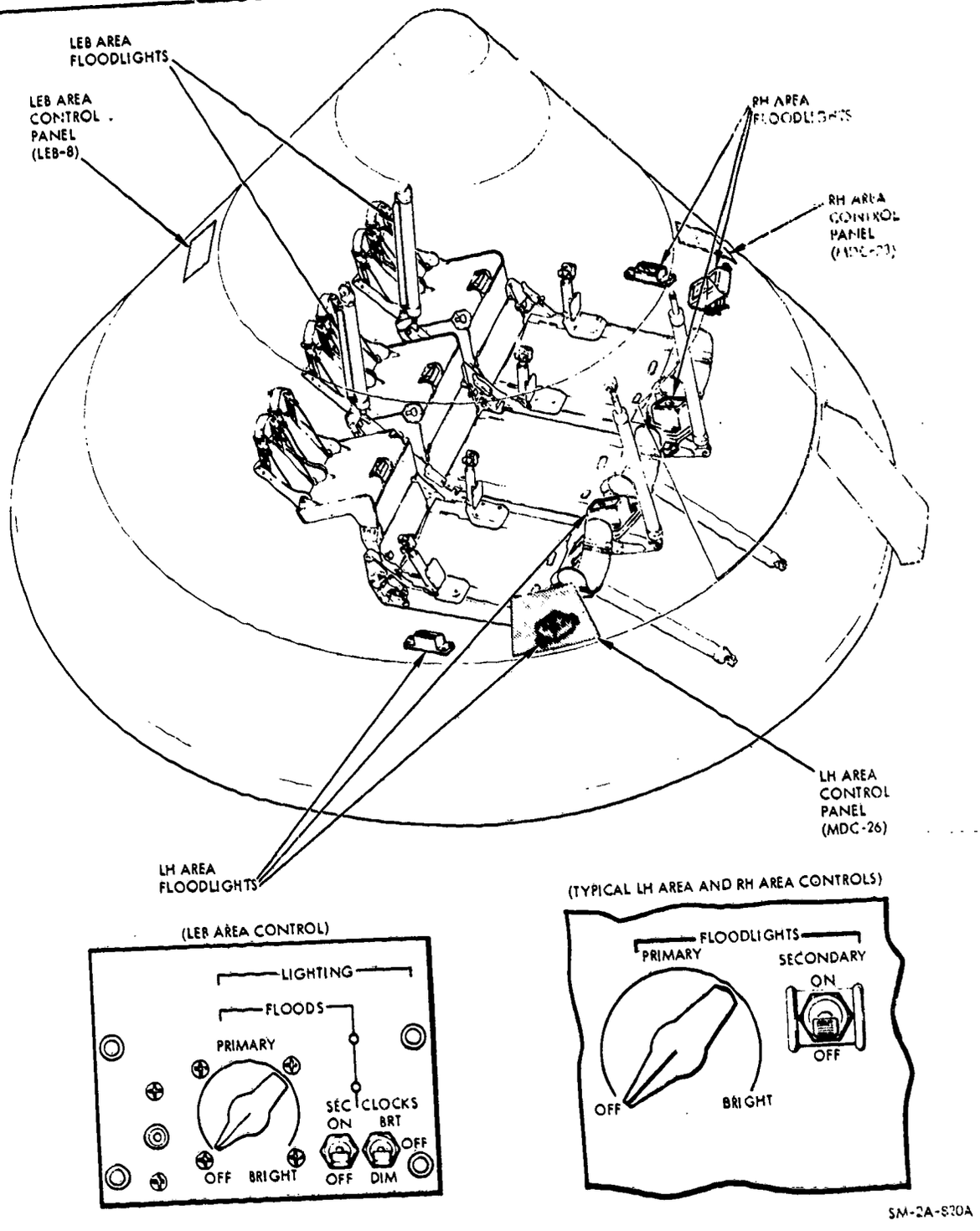


Figure 2.11-2. C/M Interior Lighting Configuration

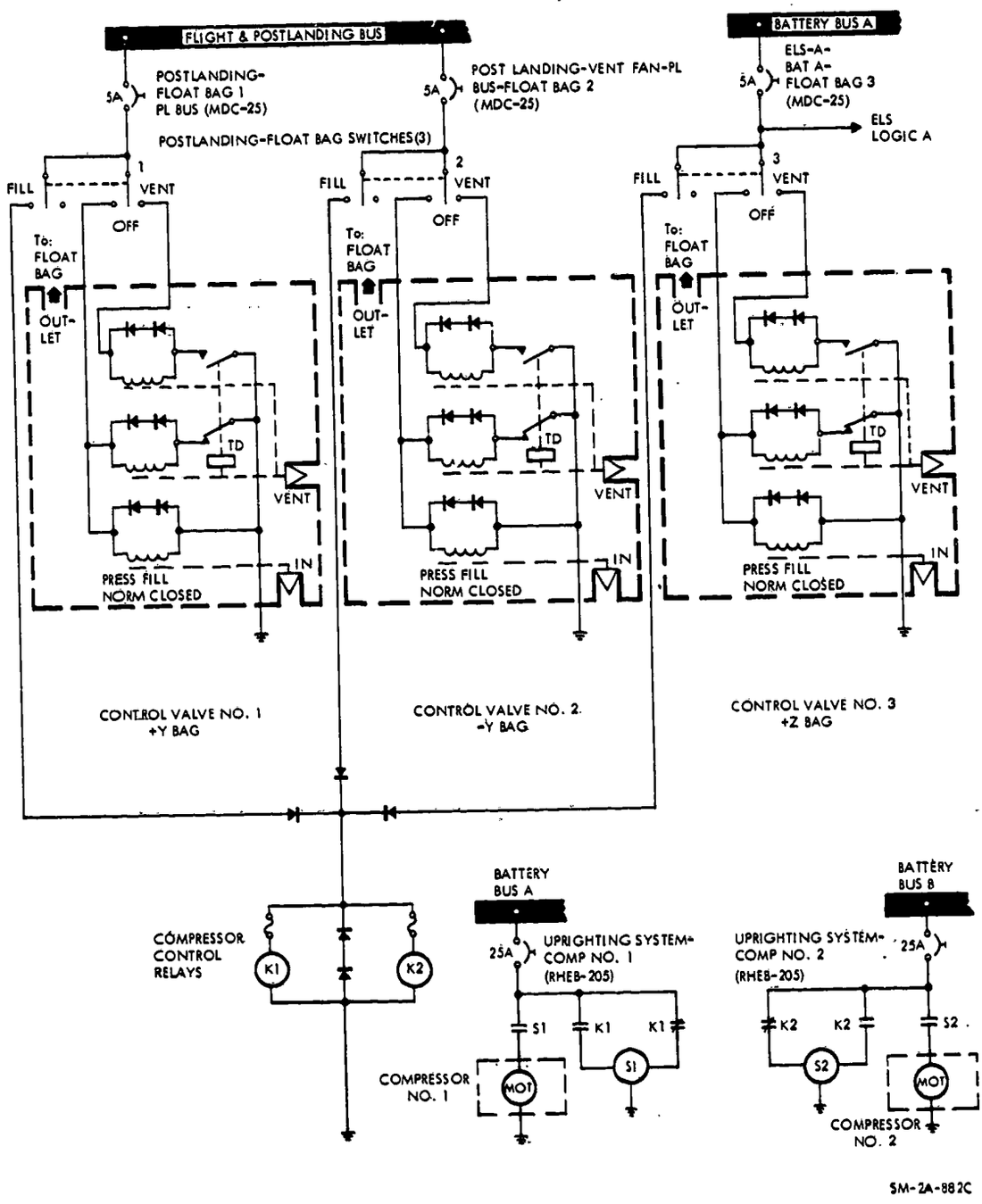


Figure 2.11-3. C/M Uprighting System Electrical Schematic

after landing, the crewmember at station 1 initiates filling of the three bags by setting the POSTLANDING - FLOAT BAG switches 1, 2, and 3 to FILL. When the C/M is uprighted, the three FLOAT BAG switches will be set to OFF. A 4.25±0.25 psi relief valve is located in the inlet of each bag. Backup relief valves set at 13.5 psi are located in the outlet of each compressor.

SECTION 3

CONTROLS AND DISPLAYS

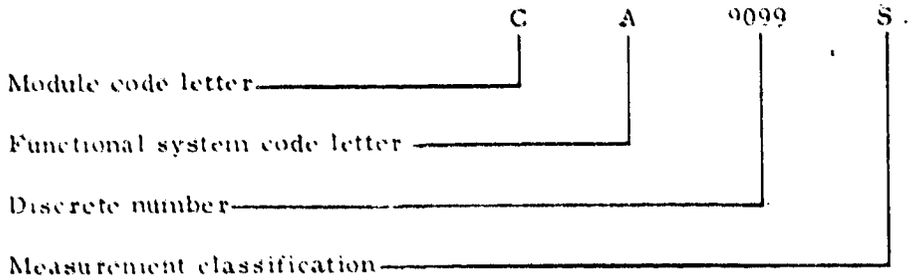
INTRODUCTION.

This section identifies each control and display in the command module and lists panel location, item nomenclature, positions and related functions, power source, telemetry measurement number, and associated explanatory data. Controls and displays are presented in a tabulated list in numerical order by panel number. Panel numbers are those appearing on the main display console drawing and the lower equipment bay drawing in figure 3-1. (The command module itself does not incorporate numbers on the panels.) The following is a detailed explanation of the columnar data presented in the tabulated list.

Location	Gives the location of a particular control or display by panel number or other descriptive information such as "LH couch armrest, etc."
Name and Position	Gives the exact nomenclature of a particular control or display and the control positions, as placarded on the panel. In the absence of a placard, a functional name is assigned and the positions are described physically ("up," "down," etc).
Function	Describes the function of each control in each position.
Circuit Breaker	Gives the name and location of the circuit breaker(s) controlling the electrical power to each control & display.
Power Source	Identifies and gives the rating of the immediate bus or source supplying power to a particular control or display.
Telemetry Code No. and Identity	Gives the measurement numbers for telemetry signals which are used to monitor the performance of components, systems, and subsystems, the status of consumable items, and the proper sequencing of critical

operations during all phases of the spacecraft mission. This information is monitored at MSFN stations for spacecraft management from the ground by use of voice or command links. Measurement numbers are entered only for displayed measurements. Those for undisplayed measurements are included in the telemetry measurements table for the appropriate system in section 2 of this handbook.

The number consists of seven characters: two letters followed by four numbers and one letter. An example is as follows:



a. The first letter designates the module in which the measurement originates. Module code letters are as follows:

A Adapter
B Booster
C Command module
L Launch escape tower
S Service module

b. The second letter denotes the system in which the measurement originates. Functional system code letters are as follows:

A Structures
C Electrical power
D Launch escape
E Earth landing
F Environmental control
G Guidance and navigation
H Stabilization and control
J Life systems
K Flight technology
P Propulsion
R Reaction control
S Crew safety
T Telecommunications and instrumentation

c. Characters three through six are numerals comprising a number which is assigned to a particular measurement point. These numbers are listed sequentially or are grouped for clarity within each system.

d. The seventh letter denotes measurement classification. Classification code letters are as follows:

A Acceleration	N Camera
B Phase	P Pressure
C Current	Q Quantity
D Vibration	R Rate
E Power	S Strain
F Frequency	T Temperature
G Force	V Voltage
H Position	W Time
J Biomedical	X Discrete event
K Radiation	Y Acoustical
L Velocity	Z pH - acidity
M Mass	

Remarks — Contains additional data and explanatory remarks.

3.1 CONTROLS/DISPLAYS LOCATOR INDEX.

To aid in finding data within this section, a locator index precedes the tabulated list. The index is sub-divided into spacecraft systems. Under each system is listed, in alphabetical order, all controls and displays associated with the particular system with cross reference to the panel on which the control or display is located. Where items, such as circuit breakers, are associated with more than one system, such items are repeated under each applicable system. Each panel number is preceded by an abbreviated descriptor to aid in quickly determining the general location of each item, as follows:

MDC	main display console (panels 1 thru 26)
LEB	lower equipment bay (panels 100 thru 107, 120, 150)
LHEB	left hand equipment bay (panels 307 thru 317 and 319)
LHFEB	left hand forward equipment bay (panels 300 thru 306 and 318)
RHEB	right hand equipment bay (panels 201 thru 206)
RHFEB	right hand forward equipment bay (panels 200 and 207)

The controls/displays locator index is sub-divided as follows:

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GUIDANCE AND NAVIGATION SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
ACCEL FAIL	Lt	LEB-103
ACTIVITY COMP	Lt	MDC14, LEB-106
AGC MODE	Sw	LEB-107
AGC PWR FAIL	Lt	MDC-10, LEB-103
ATT CONT MODE	Lt	LEB-101
ATTITUDE IMPULSE	Control	LEB-105
ATTITUDE IMPULSE ENABLE	Sw	LEB-105
BRIGHTNESS	Control	MDC-14, LEB-106
CDU FAIL	Lt	MDC-10, LEB-103
CDU MAN MODE	Lt	LEB-101
CHECK CONDITION LAMPS	Sw	LEB-105
CHECK COOLANT	Sw	LEB-105
CHECK COOLANT	Windows (2)	LEB-105
CHECK FAIL	Lt	LEB-106
CHECK MODE LAMPS	Sw	LEB-105
CLEAR	Sw	MDC-14, LEB-106
COARS ALIGN MODE	Lt	LEB-101
COMP FAIL	Lt	MDC-14
COMPUTER	CB (2)	MDC-22
CONDITION LAMP	Sw	LEB-105
COUNTER FAIL	Lt	LEB-106
DOOR LATCH	Control	LEB-105
DSKY	Keys	MDC-14, LEB-106
ENTER	Sw	MDC-14, LEB-106
ENTRY MODE	Lt	LEB-101
ERROR RESET	Sw	MDC-14, LEB-106
FINE ALIGN MODE	Lt	LEB-101
GMBL LOCK	Lt	MDC-10, LEB-103
G&N ACCEL FAIL	Lt	MDC-10
G&N ERROR	Lt	MDC-10
G&N VIEWER	Sw	MDC-22
IMU-CDU DIFFERENCE	Ind	LEB-101
IMU	CB (2)	MDC-22
IMU DELAY	Lt	LEB-103
IMU FAIL	Lt	MDC-10, LEB-103
IMU HTR	CB (2)	MDC-22
IMU TEMP	Lt	MDC-10, LEB-103
IMU TEMP MODE GAIN IRIG	Sw	LEB-105
IMU TEMP MODE GAIN PIPA	Sw	LEB-105
IMU TEMP MODE	Mode sw	LEB-105
IMU TEMP MODE ZERO	Sw	LEB-105
INNER GIMBAL (PITCH)	Ind	LEB-102
KEY RLSE	Lt	MDC-14, LEB-106
KEY RLSE	Sw	MDC-14, LEB-106
MANUAL ALIGN	Lt	LEB-101
MARK	Sw	LEB-105
MASTER ALARM	Lt	MDC-3, LEB-103

GUIDANCE AND NAVIGATION SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
MIDDLE GIMBAL (YAW)	Ind	LEB-102
-(minus sign switch)	Sw	MDC-14, LEB-106
NOUN	Sw	MDC-14, LEB-106
NOUN	End	MDC-14, LEB-106
OPTICS	CB (2)	MDC-22
OPTICS CONTROLLER MODE	Sw	LEB-105
OPTICS CONTROLLER SPEED	Sw	LEB-105
Optics hand controller (no placard)	Control	LEB-105
OPTICS HOLD	Sw	LEB-105
OPTICS	Mode sw	LEB-105
OPTICS SLAVE TELESCOPE	Sw	LEB-105
OUTER GIMBAL (ROLL)	Ind	LEB-102
PANEL BRIGHTNESS	Control	LEB-105
PARITY FAIL	Lt	LEB-106
PGNS	Lt	LEB-103
+ (plus sign switch)	Sw	MDC-14, LEB-106
PROG ALM	Lt	LEB-106
PROGRAM	Ind	MDC-14, LEB-106
REGISTER 1	Ind	MDC-14, LEB-106
REGISTER 2	Ind	MDC-14, LEB-106
REGISTER 3	Ind	MDC-14, LEB-106
RUPT LOCK	Lt	LEB-106
Sextant (not placarded)	SXT	LEB-104
SCALER FAIL	Lt	LEB-106
SHAFT ANGLE	Ind	LEB-102, LEB-104
SHAFT	Manual drive	LEB-104
Telescope (not placarded)	SCT	LEB-104
TC TRAP	Lt	LEB-106
TM FAIL	Lt	LEB-106
TRANSFER	Sw	LEB-101
TRUNNION ANGLE	Ind	LEB-104
TRUNNION	Manual drive	LEB-104
UPTEL ACCEPT BLOCK	Sw	MDC-14
VERB	Ind	MDC-14, LEB-106
VERB	Sw	MDC-14, LEB-106
VIEWER	CB (2)	MDC-22
ZERO ENCODE MODE	Lt	LEB-101
ZERO ENCODER	Lt	LEB-103
2X TRUNNION	Ind	LEB-102

STABILIZATION AND CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
AGAP TEMP	Warn lt	MDC-10
ATT DEADBAND	Sw	MDC-8
ATT SET	Sw	MDC-6
ATTITUDE IMPULSE-ENABLE	Sw	LEB-105
ATTITUDE/MONITOR/ENTRY	Sw	MDC-8
ATTITUDE SET-ROLL, PITCH, YAW	Thumbwheel (3)	MDC-6
ATTITUDE SET-ROLL, PITCH, YAW	Ind (3)	MDC-6
BMAG POWER	Sw	MDC-24
C/W-NORMAL/BOOST/ACK	Sw	MDC-13
CAUT/WARN-MNA, MNB	CB (2)	MDC-25
CAUTION/WARNING-MODE	Sw	MDC-11
DIRECT RCS	Sw	MDC-8
DIRECT ULLAGE	Sw	MDC-7
FCSM AUTO/OVERRIDE	Sw	MDC-2
FCSM ON/RESET	Sw	MDC-2
FDAI	Ind	MDC-4
FDAI ALIGN	Sw	MDC-6
FDAI BRIGHTNESS	Control	MDC-2
FDAI LTG	Sw	MDC-25
FDAI SELF TEST	Sw	MDC-2
.05G ENTRY	Sw	MDC-8
GIMBAL POSITION	Ind	MDC-6
G&N/SCS	Sw	MDC-8
G&N SYNC	Sw	MDC-25
LCL VERT	Sw	MDC-8
LIMIT CYCLE	Sw	MDC-8
MASTER EVENT SEQ CONT-A LOGIC B-BAT A, BAT B	CB (2)	MDC-22
NORMAL/OFF/DIRECT ON	Sw	MDC-7
PARTIAL SCS POWER	Sw	MDC-24
RATE GYRO POWER	Sw	MDC-24
RATE GYRO-ROLL, PITCH, YAW	Sw (3)	MDC-8
REACTION CONTROL SYS-TRANS	Sw	MDC-16
Rotational Controllers (not placarded)	Controls (2)	LH couch, RH armrest, RH couch, LH armrest
ROTATION CONTROL POWER	Sw	-24
SCS CHANNEL-A&C ROLL, B&D ROLL, PITCH, YAW	Sw (4)	MDC-8
STABILIZATION & CONTROL SYSTEM- A&C ROLL-MNA, MNB B&D ROLL-MNA, MNB DIRECT CONT-MNA, MNB GROUP 1-AC1, AC2 GROUP 1-MNA, MNB GROUP 2-AC1, AC2 GROUP 2-MNA, MNB	CB (18)	MDC-25

STABILIZATION AND CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
THRUST ON	Sw	MDC-7
Translational Controllers (not placarded)	Control (2)	LH couch, LH armrest
TVC 1 POWER	Sw	MDC-24
TVC 2 POWER	Sw	MDC-24
ΔV	Sw	MDC-8
ΔV REMAINING	Ind	MDC-7
ΔV SET	Sw	MDC-7
YAW, PITCH	Thumbwheel (2)	MDC-6

SERVICE PROPULSION SYSTEM – CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
ABORT SYSTEM-TWR JETT SPS MODE-A (B) two	Sw	MDC-16
CAUT/WARN-MNA (MNB)	CB (2)	MDC-25
ΔV	Sw	MDC-8
ΔV REMAINING	Sw	MDC-7
ΔV SET	Sw	MDC-7
DIRECT ULLAGE	Sw	MDC-7
FCSM-G&N	Sw	MDC-2
FCSM-SCS	Sw	MDC-2
G&N/SCS	Sw	MDC-8
GIMBAL POSITION-PITCH	Ind	MDC-6
GIMBAL POSITION-PITCH	Thumbwheel	MDC-6
GIMBAL POSITION-YAW	Ind	MDC-6
GIMBAL POSITION-YAW	Thumbwheel	MDC-6
H_e TANK-PRESS	Ind	MDC-20
H_e TANK-TEMP	Ind	MDC-20
INSTRUMENTS-ESS-MNA (MNB)	CB (2)	MDC-22
L/V AOA/SPS P_c	Ind	MDC-3
L/V AOA/SPS P_c	Sw	MDC-3
MASTER EVENT SEQ CONT-A LOGIC B-BAT A (BAT B)	CB (2)	MDC-22
NORMAL/OFF/DIRECT ON (Thrust)	Sw	MDC-7
OXID FLOW	Sw	MDC-20
OXID FLOW-DECREASE	Ind	MDC-20
OXID FLOW-INCREASE	Ind	MDC-20
PITCH GMBL DR FAIL	Status lts	MDC-11
PRESSURE-ENG INLET-FUEL	Ind	MDC-20
PRESSURE-ENG INLET-OX	Ind	MDC-20
PRESSURE-FUEL	Ind	MDC-20
PRESSURE-OX	Ind	MDC-20
QUANTITY-FUEL	Display	MDC-20
QUANTITY-OXID	Display	MDC-20
SENSOR	Sw	MDC-20
SERVICE PROPULSION SYSTEM-		
GAUGING-AC1 (AC2)	CB (2)	MDC-25
GAUGING-MNA (MNB)	CB (2)	MDC-25
GIMBAL MOTOR CONTROL -1 PITCH -BAT A (PITCH 2-BAT B)	CB (2)	MDC-25
GIMBAL MOTOR CONTROL -1 YAW -BAT A (YAW 2-BAT B)	CB (2)	MDC-25
H_e VALVE-MNA (MNB)	CB (2)	MDC-25
SPS ENGINE INJECT VALVE -1 (2, 3, 4)	Ind (4)	MDC-20
SPS GAUGING	Sw	MDC-25
SPS HELIUM (left hand and right hand)	Ind (2)	MDC-20
SPS HELIUM (left hand and right hand)	Sw (2)	MDC-20
SPS-INJECT PRE-VALVES-A (B)	Sw (2)	MDC-3
SPS-GIMBAL MOTORS -1 PITCH (PITCH 2)	Sw (2)	MDC-3

SERVICE PROPULSION SYSTEM–CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
SPS-GIMBAL MOTORS -1 YAW (YAW 2)	Sw (2)	MDC-3
SPS LINE HTR	Sw	MDC-19
SPS PRESS	Status lts	MDC-11
SPS PU SNSR FAIL	Status lts	MDC-11
SPS ROUGH ECO	Status lts	MDC-10
SPS TANK PRESS	Sw	MDC-20
STABILIZATION & CONTROL SYSTEM		
-DIRECT CONT-MNA (MNB)	CB (2)	MDC-25
-1 GROUP-AC 1 (GROUP 2-AC 2)	CB (2)	MDC-25
-1 GROUP-MNA (GROUP 2-MNB)	CB (2)	MDC-25
TELECOMMUNICATIONS–GROUP 5	CB	MDC-22
TEST/AUTO/TEST (propellant quantity)	Sw	MDC-20
THRUST ON	Switch-light	MDC-7
TK PRESS-N_2	Ind	MDC-20
UNBALANCE	Ind	MDC-20
VALVE	Sw	MDC-20

REACTION CONTROL SYSTEM – CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
ABORT SYSTEM-OX DUMP	Sw	MDC-16
CM PROP JETT-DUMP	Sw	MDC-8
CM PROP JETT-LOGIC	Sw	MDC-8
CM PROP JETT-PURGE	Sw	MDC-8
C/M RCS	Sw	MDC-26
C/M RCS A	Status lts	MDC-10
C/M RCS B	Status lts	MDC-10
C/M RCS HTRS	Sw	RHFEB-200
C/M RCS PRESS F	Ind	MDC-12
C/M RCS TEMP H_e	Ind	MDC-12
C/M RCS PRESS OX	Ind	MDC-12
C/M RCS PRPLNT-A	Sw	MDC-15
C/M RCS PRPLNT-A	Event ind	MDC-15
C/M RCS PRPLNT-B	Sw	MDC-15
C/M RCS PRPLNT-B	Event ind	MDC-15
C/M RCS TEMP H_e	Ind	MDC-12
C/M-S/M-SEP-A (B)	Sw (2)	MDC-15
DIRECT RCS	Sw	MDC-8
INSTRUMENTS-ESS-MNA (MNB)	CB (2)	MDC-22
MASTER EVENT SEQ CONT		
-A ARM B-BAT A (BAT B)	CB (2)	MDC-22
-A LOGIC B-BAT A (BAT B)	CB (2)	MDC-22
PROPELLANT QUANTITY-FUEL (bottom window)	Digital ind	MDC-12
PROPELLANT QUANTITY-OXIDIZER (top window)	Digital ind	MDC-12
PYRO A-RCS FUEL DUMP	CB	LEB-150
PYRO B-RCS FUEL DUMP	CB	LEB-150
RCS HEATERS-A MNB	CB	MDC-21
RCS HEATERS-B MNA	CB	MDC-21
RCS HEATERS-C MNB	CB	MDC-21
RCS HEATERS-D MNA	CB	MDC-21
RCS INDICATORS selector		
C/M section	Sw	MDC-12
S/M section	Sw	MDC-12
REACTION CONTROL SYS-CMD	Sw	MDC-16
REACTION CONTROL SYS-C/M PRESS	Sw	MDC-16
REACTION CONTROL SYS-TRANS	Sw	MDC-16
REACTION CONTROL SYSTEM		
-C/M-S/M TRANSFER-MNA (MNB)	CB (2)	MDC-25
-GAUGING-MNA (MNB)	CB (2)	MDC-25
-PROP ISOL-MNA (MNB)	CB (2)	MDC-25
S/M RCS-A (B, C, D)-HELIUM 1	Sw (4)	MDC-15
S/M RCS-A (B, C, D)-HELIUM 1	Event ind (4)	MDC-15
S/M RCS-A (B, C, D)-HELIUM 2	Sw (4)	MDC-15
S/M RCS-A (B, C, D)-HELIUM 2	Event ind (4)	MDC-15
S/M RCS PRESS H_e	Ind	MDC-12

REACTION CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
S/M RCS PRESS MANF	Ind	MDC-12
S/M RCS-A (B, C, D)-PROPELLANT	Event ind (4)	MDC-15
S/M RCS-A (B, C, D)-PROPELLANT	Sw (4)	MDC-15
S/M RCS TEMP PKG	Ind	MDC-12
S/M RCS A	Status lts	MDC-10
S/M RCS B	Status lts	MDC-10
S/M RCS C	Status lts	MDC-10
S/M RCS D	Status lts	MDC-10

ELECTRICAL POWER SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
AC BUS 1 FAIL	Lt	MDC-11
AC BUS 2 FAIL	Lt	MDC-11
AC BUS 1 OVERLOAD	Lt	MDC-11
AC BUS 2 OVERLOAD	Lt	MDC-11
AC INDICATORS	Sw	MDC-18
AC INVERTER—AC BUS 1-RESET	Sw	MDC-18
AC INVERTER—AC BUS 2-RESET	Sw	MDC-18
AC INVERTER—1	Sw	MDC-18
AC INVERTER—1-AC BUS 1	Sw	MDC-18
AC INVERTER—1-AC BUS 2	Sw	MDC-18
AC INVERTER—2	Sw	MDC-18
AC INVERTER—2-AC BUS 1	Sw	MDC-18
AC INVERTER—2-AC BUS 2	Sw	MDC-18
AC INVERTER—3	Sw	MDC-18
AC INVERTER—3-AC BUS 1	Sw	MDC-18
AC INVERTER—3-AC BUS 2	Sw	MDC-18
AC SNSR SIG-AC1	CB	MDC-25
AC SNSR SIG-AC2	CB	MDC-25
AC VOLTS	Meter	MDC-18
BAT A PWR-ENTRY	CB	LEB-150
BAT B PWR-ENTRY	CB	LEB-150
BAT CHGR	Sw	MDC-22
BAT CHGR-BAT C	CB	LEB-150
BAT C PWR-POSTLANDING ENTRY	CB	LEB-150
BAT RLY BUS-BAT A	CB	MDC-22
BAT RLY BUS-BAT B	CB	MDC-22
BATTERY CHARGER	Sw	MDC-18
BATTERY CHARGER-AC PWR	CB	MDC-22
BATTERY CHARGER-BAT A CHGE	CB	MDC-22
BATTERY CHARGER-BAT B CHGE	CB	MDC-22
BATTERY CHARGER-MNA	CB	MDC-22
BATTERY CHARGER-MNB	CB	MDC-22
CRYOGENIC SYSTEM-QTY AMPL-AC 1-ØC	CB	MDC-22
CRYOGENIC SYSTEM-QTY AMPL-AC 2-ØC	CB	MDC-22
CRYOGENIC SYSTEM-TANK HEATERS-H_2	CB	MDC-22
CRYOGENIC SYSTEM-TANK HEATERS-O_2	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-ØA	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-ØB	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-ØC	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-ØA	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-ØB	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-ØC	CB	MDC-22
DC AMPS	Meter	MDC-18
DC INDICATORS	Sw	MDC-18
DC SNSR SIG-MNA	CB	MDC-22
DC SNSR SIG-MNB	CB	MDC-22
DC VOLTS	Meter	MDC-18

ELECTRICAL POWER SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
DC VOLTS (auxiliary)	Meter	RHFEB-200
F/C-BUS DISCONNECT	Lt	MDC-11
F/C RAD TEMP LOW	Ind	MDC-18
F/C VALVES	Sw	MDC-19
F/C 1	Lt	MDC-11
F/C 2	Lt	MDC-11
F/C 3	Lt	MDC-11
FREQUENCY	Meter	MDC-18
FUEL CELL-FLOW-H_2	Ind	MDC-18
FUEL CELL-FLOW-O_2	Ind	MDC-18
FUEL CELL INDICATORS	Sw	MDC-18
FUEL CELL-MAIN BUS A-RESET	Sw	MDC-18
FUEL CELL-MAIN BUS B-RESET	Sw	MDC-18
FUEL CELL-MODULE TEMP-COND EXH	Ind	MDC-18
FUEL CELL-MODULE TEMP-SKIN	Ind	MDC-18
FUEL CELL 1-BUS CONT	CB	MDC-22
FUEL CELL 1-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 1-H_2&O_2 VALVE	CB	MDC-22
FUEL CELL 1-PURGE	CB	MDC-22
FUEL CELL-1-MAIN BUS A	Ind	MDC-18
FUEL CELL-1-MAIN BUS A	Sw	MDC-18
FUEL CELL-1-MAIN BUS B	Ind	MDC-18
FUEL CELL-1-MAIN BUS B	Sw	MDC-18
FUEL CELL-1 purge	Sw	MDC-18
FUEL CELL-1-REACTANTS	Ind	MDC-18
FUEL CELL-1-REACTANTS	Sw	MDC-18
FUEL CELL 2-BUS CONT	CB	MDC-22
FUEL CELL 2-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 2-H_2&O_2 VALVE	CB	MDC-22
FUEL CELL 2-PURGE	CB	MDC-22
FUEL CELL-2-MAIN BUS A	Ind	MDC-18
FUEL CELL-2-MAIN BUS A	Sw	MDC-18
FUEL CELL-2-MAIN BUS B	Ind	MDC-18
FUEL CELL-2-MAIN BUS B	Sw	MDC-18
FUEL CELL-2 purge	Sw	MDC-18
FUEL CELL-2-REACTANTS	Ind	MDC-18
FUEL CELL-2-REACTANTS	Sw	MDC-18
FUEL CELL 3-BUS CONT	CB	MDC-22
FUEL CELL 3-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 3-H_2&O_2 VALVE	CB	MDC-22
FUEL CELL 3-PURGE	CB	MDC-22
FUEL CELL-3-MAIN BUS A	Ind	MDC-18
FUEL CELL-3-MAIN BUS A	Sw	MDC-18
FUEL CELL-3-MAIN BUS B	Ind	MDC-18
FUEL CELL-3-MAIN BUS B	Sw	MDC-18
FUEL CELL-3 purge	Sw	MDC-18
FUEL CELL-3-REACTANTS	Ind	MDC-18
FUEL CELL-3-REACTANTS	Sw	MDC-18

ELECTRICAL POWER SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
FUEL CELL PUMP-1	Sw	MDC-22
FUEL CELL PUMP-2	Sw	MDC-22
FUEL CELL PUMP-3	Sw	MDC-22
FUNCTION SELECT	Sw	RHFEB-200
H_2 FANS-1	Sw	MDC-13
H_2 FANS-2	Sw	MDC-13
H_2 HEATERS-1	Sw	MDC-13
H_2 HEATERS-2	Sw	MDC-13
H_2 PRESS	Lt	MDC-10
INVERTER CONTROL-1	CB	MDC-22
INVERTER CONTROL-2	CB	MDC-22
INVERTER CONTROL-3	CB	MDC-22
INVERTER PWR-NO. 1 MNA	CB	RHEB-203
INVERTER PWR-NO. 2 MNB	CB	RHEB-203
INVERTER PWR-NO. 3 MNA	CB	RHEB-203
INVERTER PWR-NO. 3 MNB	CB	RHEB-203
INV 1 TEMP HI	Lt	MDC-11
INV 2 TEMP HI	Lt	MDC-11
INV 3 TEMP HI	LT	MDC-11
MAIN A-BAT BUS A	CB	RHEB-203
MAIN A-BAT C	CB	RHEB-203
MAIN B-BAT BUS B	CB	RHEB-203
MAIN B-BAT C	CB	RHEB-203
MAIN BUS TIE-BAT A&C	Sw	MDC-22
MAIN BUS TIE-BAT B&C	Sw	MDC-22
MN BUS A UNDERVOLT	Lt	MDC-11
MN BUS B UNDERVOLT	Lt	MDC-11
NON ESS BUS	Sw	MDC-22
O_2 FANS-1	Sw	MDC-13
O_2 FANS-2	Sw	MDC-13
O_2 HEATERS-1	Sw	MDC-13
O_2 HEATERS-2	Sw	MDC-13
O_2 PRESS	Lt	MDC-10
pH HI	Ind	MDC-18
POST LDG-BAT BUS A	CB	RHEB-203
POST LDG-BAT BUS B	CB	RHEB-203
POST LDG-BAT C	CB	RHEB-203
POST LDG-MAIN A	CB	RHEB-203
POST LDG-MAIN B	CB	RHEB-203
REG OUT PRESS HI-H_2	Ind	MDC-18
REG OUT PRESS HI-N_2	Ind	MDC-18
REG OUT PRESS HI-O_2	Ind	MDC-18
SNSR UNIT-AC BUS-1	CB	MDC-21
SNSR UNIT-AC BUS-2	CB	MDC-21
SNSR UNIT-DC BUS-A	CB	MDC-21
SNSR UNIT-DC BUS-B	CB	MDC-21

ELECTRICAL POWER SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
TANK PRESSURE-H_2-1	Ind	MDC-13
TANK PRESSURE-H_2-2	Ind	MDC-13
TANK PRESSURE-O_2-1	Ind	MDC-13
TANK PRESSURE-O_2-2	Ind	MDC-13
TANK QUANTITY-H_2-1	Ind	MDC-13
TANK QUANTITY-H_2-2	Ind	MDC-13
TANK QUANTITY-O_2-1	Ind	MDC-13
TANK QUANTITY-O_2-2	Ind	MDC-13
TEST SELECT	Sw	RHFEB-200
H_2 PURGE LINE HTR	Sw	MDC-15
INV. PHASE LOCK	Sw	RHEB 208

SEQUENTIAL SYSTEMS— CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
ABORT	Lt	MDC-3
ABORT SYSTEM-MODE	Sw (2)	MDC-16
ABORT SYSTEM-L/V RATES	Sw	MDC-16
ABORT SYSTEM-OX DUMP	Sw	MDC-16
ABORT SYSTEM-2 ENG OUT	Sw	MDC-16
ADAPT SEP	Sw	MDC-5
ALTIMETER	Indicator	MDC-1
APEX COVER JETT	Sw	MDC-5
CANARD DEPLOY	Sw	MDC-5
C/M-S/M SEP	Sw (2)	MDC-15
COUCH UNLOCK	Sw	MDC-8
Digital Event Timer Indicator (no placard)	Window	MDC-5
DIGITAL EVENT TIMER-MIN	Sw	MDC-8
DIGITAL EVENT TIMER-RESET	Sw	MDC-8
DIGITAL EVENT TIMER-SEC	Sw	MDC-8
DIGITAL EVENT TIMER-START	Sw	MDC-8
Digital Event Timer Indicator (no placard)	Window	MDC-11
DIGITAL EVENT TIMER-MIN	Sw	MDC-11
DIGITAL EVENT TIMER-RESET	Sw	MDC-11
DIGITAL EVENT TIMER-SEC	Sw	MDC-11
DIGITAL EVENT TIMER-START	Sw	MDC-11
DROGUE DEPLOY	Sw	MDC-5
EDS	Sw	MDC-16
EDS	CB (3)	MDC-25
EDS POWER	Sw	MDC-24
ELS	CB (3)	MDC-25
ELS LOGIC	Sw	MDC-8
EVENT TIMER	CB (2)	MDC-25
LES MOTOR FIRE	Sw	MDC-5
LIFT-OFF	Lt	MDC-5
LOCK/UNLOCK	Control	MDC-5
L/V AOA/SPS P_C	Ind	MDC-3
L/V AOA/SPS P_C	Sw	MDC-3
L/V ENGINE	Lt (8)	MDC-5
L/V GUID	Lt	MDC-5
L/V RATE	Lt	MDC-5
MAIN CHUTE RELEASE	Sw	MDC-16
MAIN DEPLOY	Sw	MDC-5
MAIN DEPLOY-AUTO	Sw	MDC-16
MASTER EVENT SEQ CONT-ARM	CB (2)	MDC-22
MASTER EVENT SEQ CONT-LOGIC	CB (2)	MDC-22
MASTER EVENT SEQ CONT-PYRO ARM	Sw (2)	MDC-24
MESC-LOGIC ARM	Sw (2)	MDC-25
NO AUTO ABORT	Lt	MDC-5
POST LDG BEACON LIGHTS	Sw	MDC-26
PYRO A-RCS FUEL DUMP	CB	LEB-150
PYRO A-SEQ A	CB	LEB-150
PYRO B-RCS FUEL DUMP	CB	LEB-150
PYRO B-SEQ B	CB	LEB-150

TELECOMMUNICATIONS—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
BIO-MED COMM-MNA	CB	MDC-25
BIO-MED COMM-MNB	CB	MDC-25
C-BAND	Sw	MDC-20
CENTRAL TIMING SYS-MNA	CB	MDC-22
CENTRAL TIMING SYS-MNB	CB	MDC-22
FLIGHT QUAL RCDR	Sw	MDC-19
RCDR/HF	Sw	MDC-13, -23, -26
INST PWR CONT		RHEB-204
ESSENTIAL 1 THRU 4	CB (4)	
NON-ESSENTIAL 5 THRU 10	CB (6)	
INSTRUMENTS-ESS-MNA	CB	MDC-22
INSTRUMENTS-ESS-MNB	CB	MDC-22
INSTRUMENTS-NONESS	CB	MDC-22
INSTRUMENTS-NONESS BUS	CB	MDC-22
INSTRUMENTS-RCDR NONESS	CB	MDC-22
INSTRUMENTS-SCIEN	CB	MDC-22
INTERCOM	Sw	MDC-13, -23, -26
INTERCOM BALANCE	Sw	MDC-13, -23, -26
NONESS BUS	Sw	MDC-22
POSTLANDING ANTENNA DEPLOY	Sw	MDC-25
POWER		MDC-13, -23, -26
POWER-PMP	Sw	MDC-20
POWER-SCE	Sw	MDC-20
RECOVERY-HF-ON/OFF	Sw	MDC-20
RECOVERY-HF-SSB/BCN/AM	Sw	MDC-20
RECOVERY-VHF BCN	Sw	MDC-20
S-BAND	Sw	MDC-13, -23, -26
S-BAND ANT	Ind	MDC-19
S-BAND ANTENNA	Sw	MDC-20
S-BAND-EMERG	Sw	MDC-20
S-BAND-OSC	Sw	MDC-20
S-BAND-PWR AMPL	Sw	MDC-20
S-BAND-VOICE-RNG/RNG ONLY	Sw	MDC-20
S-BAND-VOICE-TAPE	Sw	MDC-20
S-BAND-VOICE-TV	Sw	MDC-20
S-BAND-XPONDER/XPONDER PWR AMPL	Sw	MDC-20
TAPE RECORDER-FWD/REV	Sw	MDC-20
TAPE RECORDER-PLAY	Sw	MDC-20
TAPE RECORDER-RECORD/PLAY	Sw	MDC-20
TAPE RECORDER-SPEED	Sw	MDC-20
TELECOM-ESS	Sw	MDC-22
TELECOM-NONESS	Sw	MDC-22
TELECOMMUNICATIONS-GROUP 1 AC	CB	MDC-22
TELECOMMUNICATIONS-GROUP 2 AC	CB	MDC-22
TELECOMMUNICATIONS-GROUP 3	CB	MDC-22
TELECOMMUNICATIONS-GROUP 4	CB	MDC-22
TELECOMMUNICATIONS-GROUP 5	CB	MDC-22

TELECOMMUNICATIONS—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
TELECOMMUNICATIONS-PCM TLM AC	CB	MDC-22
TELECOMMUNICATIONS-SIG COND S-BAND PA AC	CB	MDC-22
TLM INPUTS-BIOMED	Sw	MDC-20
TLM INPUTS-PCM	Sw	MDC-20
UP DATA	Sw	MDC-20
UP TLM CMD	Sw	MDC-19
VHF-AM	Sw	MDC-13, -23, -26
VHF-AM RCVR	Sw	MDC-20
VHF-AM SQUELCH	Control	MDC-20
VHF-AM-T/R/REC	Sw	MDC-20
VHF-ANTENNA	Sw	MDC-20
VHF-FM	Sw	MDC-20
VOICE RECORD	Indicator	MDC-19
VOLUME	Control	MDC-13, -23, -26
VOX SENS	Control	MDC-13, -23, -26

ENVIRONMENTAL CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
BATTERY VENT	Valve	RHEB-203
Cabin air control louver	Control	LHFEB-303
CABIN AIR/AUTO/SUIT AIR	Sw	LEB-120
CABIN AIR FAN-1 & 2	Sw (2)	MDC-21
CABIN PRESSURE RELIEF	Valve (2)	LHEB-307
CABIN REPRESS	Valve	LHEB-314
CABIN TEMP	Valve	LHFEB 303
CABIN TEMP-AUTO	Control	MDC-13
CABIN TEMP-AUTO/MAN	Sw	MDC-13
CO_2-odor absorber diverter	Valve	LHEB-313
CO_2 PP HI	Light	MDC-11
DIRECT O_2	Valve	MDC-24
DRINKING WATER SUPPLY	Valve	LHFEB-304
ΔP SUIT COMPR	Ind	MDC-13
ECS-CABIN AIR FAN-1 & 2	CB (6)	MDC-22
ECS-GLYCOL PUMPS-AC 1 & AC 2	CB (6)	MDC-22
ECS-GLYCOL-PUMP 1/PUMP 2	Sw (2)	MDC-21
ECS-H_2O ACCUM-MNA & MNB	CB (2)	MDC-22
ECS-POT H_2O HTR-MNA & MNB	CB (2)	MDC-22
ECS-RADIATOR	Sw (4)	MDC-21
ECS RAD-OUTLET TEMP	Ind	MDC-13
ECS RAD OUT TEMP-1 & 2	Ind (2)	MDC-19
ECS-RAD VALVE-AC 1 & AC 2	CB (4)	MDC-22
ECS STEAM DUCT HTR-MNA & MNB	CB (2)	RHEB-206
ECS-SUIT COMPRESSORS-AC 1 & AC 2	CB (6)	MDC-22
ECS-TRANSDUCER-PRESS GROUPS 1 & 2	CB (4)	MDC-22
ECS-TRANSDUCER-TEMP-MNA & MNB	CB (2)	MDC-22
ECS-TRANSDUCER-WASTE & POT H_2O-MNA & MNB	CB (2)	MDC-22
EMERGENCY CABIN PRESSURE	Valve	LHEB-314
EVAP H_2O	Valve	LHEB-311
FLOW O_2	Ind	MDC-13
FOOD PREPARATION WATER-COLD & HOT	Valve (2)	LHFEB-305
GAS ANAL	CB	MDC-22
GLY ACCUM-QUANTITY	Ind	MDC-13
GLY EVAP WATER CONTROL BYPASS	Valve	LHEB-317
GLYCOL ACCUMULATOR	Valve	LHEB-312
GLYCOL EVAP-H_2O FLOW	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-AUTO/MAN	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-INCR/DECR	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-TEMP IN	Sw	MDC-13
GLYCOL EVAP TEMP IN	Valve	LHEB-311
GLYCOL PRESS RELIEF BYPASS-1 & 2	Valve (2)	LHEB-309
GLYCOL RESERVE	Valve	LHEB-311
GLYCOL RESERVOIR-BYPASS	Valve	LHEB-307
GLYCOL RESERVOIR-INLET	Valve	LHEB-307
GLYCOL RESERVOIR-OUTLET	Valve	LHEB-307
GLYCOL TEMP LOW	Light	MDC-11

ENVIRONMENTAL CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
GLYCOL TO RAD	Valve	LHEB-307
GLY EVAP-OUTLET TEMP	Ind	MDC-13
GLY EVAP STEAM PRESS	Ind	MDC-13
H_2O ACCUM-AUTO/MAN	Sw	MDC-13
H_2O ACCUM FAIL	Light	MDC-11
H_2O ACCUM-ON 1/ON 2	Sw	MDC-13
H_2O ACCUMULATOR-1 & 2	Valve (2)	LHEB-311
H_2O IND	Sw	MDC-13
INST PWR CONT-ESSENTIAL 2	CB	RHEB-204
MAIN REGULATOR	Valve	LHEB-314
O_2 FLOW HI	Light	MDC-11
O_2 PRESS IND	Sw	MDC-13
OXYGEN-ENTRY	Valve	LHEB-307
OXYGEN-S/M SUPPLY	Valve	LHEB-307
OXYGEN-SURGE TANK	Valve	LHEB-307
PART PRESS CO_2	Ind	MDC-13
PGA pressure	Ind (3)	PGA sleeve
PLSS FILL	Valve	LHEB-314
PLVC	Sw	LHEB-316
POST LANDING-VENT FAN	Sw	MDC-25
POST LANDING-VENT FAN-PL BUS/FLOAT BAG 2	CB	MDC-25
POTABLE TANK INLET	Valve	LHEB-315
POT H_2O HEATER	Sw	MDC-21
PRESS-CABIN	Ind	MDC-13
PRESS GLY DISCH	Ind	MDC-13
PRESS-SUIT	Ind	MDC-13
PRESSURE RELIEF	Valve	LHEB-315
START/OFF/PREHEAT	Sw	LEB-120
Suit circuit return air	Valve	LHEB-319
SUIT COMPRESSOR-COMPR 1/COMPR 2	Sw	MDC-21
Suit demand pressure regulator selector	Valve	LHEB-310
SUIT EVAP	Sw	MDC-13
SUIT EVAP	Valve	LHEB-311
SUIT EVAP GLYCOL	Valve	LHEB-311
SUIT FLOW	Valve (3)	LHFEB-300, -301, -302
SUIT FLOW RELIEF	Valve	LHEB-311
SUIT HT EXCH	Sw	LHEB-310
SUIT TEST	Valve	LHEB-310
SURGE TANK PRESSURE RELIEF	Valve	LHEB-308
TANK PRESSURE-O_2-1	Ind	MDC-13
TEMP-CABIN	Ind	MDC-13
TEMP-SUIT	Ind	MDC-13
WASTE H_2O TK REFILL	Sw	MDC-13
WASTE MANAGEMENT-OVBD DRAIN	Valve	RHEB-201
WASTE MANAGEMENT-SELECTOR	Valve	RHEB-201

ENVIRONMENTAL CONTROL SYSTEM—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
WASTE TANK INLET	Valve	LHEB-315
WASTE TANK SERVICING	Valve	LHEB 315
WATER & GLYCOL TANKS PRESSURE-REGULATOR-SELECTOR INLET	Valve	LHEB-314
WATER & GLYCOL TANKS PRESSURE-RELIEF-SELECTOR OUTLET	Valve	LHEB-314
WATER-QUANTITY	Ind	MDC-13

CAUTION AND WARNING SYSTEM—LOCATOR INDEX

Control/Display Name	Type	Panel Locator
AC BUS 1 FAIL	Lt	MDC-11
AC BUS 2 FAIL	Lt	MDC-11
AC BUS 1 OVERLOAD	Lt	MDC-11
AC BUS 2 OVERLOAD	Lt	MDC-11
AGAP TEMP	Lt	MDC-10
AGC PWR FAIL	Lt	MDC-10
CAUT/WARN-FAIL	Lt	MDC-11
CAUT/WARN-MNA & MNB	CB (2)	MDC-25
CAUT/WARN-MODE	Sw	MDC-11
CAUT/WARN-POWER	Sw	MDC-11
CDU FAIL	Lt	MDC-10
C/M RCS A	Lt	MDC-10
C/M RCS B	Lt	MDC-10
CO_2 PP HI	Lt	MDC-11
C/W	Sw	MDC-13
C/W LAMP TEST	Sw	MDC-23
F/C 1	Lt	MDC-11
F/C 2	Lt	MDC-11
F/C 3	Lt	MDC-11
F/C BUS DISCONNECT	Lt	MDC-11
GLYCOL TEMP LOW	Lt	MDC-11
GMBL LOCK	Lt	MDC-10
G&N ACCEL FAIL	Lt	MDC-10
G&N ERROR	Lt	MDC-10
H_2O ACCUM FAIL	Lt	MDC-11
H_2 PRESS	Lt	MDC-10
IMU FAIL	Lt	MDC-10
IMU TEMP	Lt	MDC-10
INV 1	Lt	MDC-11
INV 2	Lt	MDC-11
INV 3	Lt	MDC-11
MASTER ALARM	Lt	MDC-3
MASTER ALARM	Lt	MDC-18
MASTER ALARM	Lt	LEB-103
MN BUS A UNDERVOLT	Lt	MDC-11
MN BUS B UNDERVOLT	Lt	MDC-11
O_2 FLOW HI	Lt	MDC-11
O_2 PRESS	Lt	MDC-10
PITCH GMBL DR FAIL	Lt	MDC-11
S/M RCS A	Lt	MDC-10
S/M RCS B	Lt	MDC-10
S/M RCS C	Lt	MDC-10
S/M RCS D	Lt	MDC-10
SPS PRESS	Lt	MDC-11
SPS PU SNSR FAIL	Lt	MDC-11
SPS ROUGH ECO	Lt	MDC-10
SPS WALL TEMP HI	Lt	MDC-11
YAW GMBL DR FAIL	Lt	MDC-11

MISCELLANEOUS SYSTEMS – CONTROLS/DISPLAYS LOCATOR INDEX

Controls/Display Name	Type	Panel Locator
COUCH ATTEN-FLOODLIGHTS	CB (2)	MDC-25
ELS-FLOAT BAG 3	CB	MDC-25
FLOODLIGHTS-PRIMARY	Sw	MDC-23
FLOODLIGHTS-SECONDARY	Sw	MDC-23
FLOODLIGHTS-PRIMARY	Sw	MDC-26
FLOODLIGHTS-SECONDARY	Sw	MDC-26
LIGHTING-CLOCKS	Sw	LEB-100
LIGHTING-FLOODS-PRIMARY	Sw	LEB-100
LIGHTING-FLOODS-SEC	Sw	LEB-100
POST LANDING-FLOAT BAG	Sw (3)	MDC-25
POST LANDING-FLOAT BAG 1 PL BUS	CB	MDC-25
POST LANDING-VENT FAN-PL BUS-FLOAT BAG 2	CB	MDC-25
UPRIGHTING SYSTEM-COMPR NO. 1 AND NO. 2	CB	RHEB-205

SCIENTIFIC EXPERIMENTS—CONTROLS/DISPLAYS LOCATOR INDEX

Controls/Display Name	Type	Panel Locator
SCIEN EQUIP SEB 1	CB	MDC-22
SCIEN EQUIP SEB 2	CB	MDC-22
INSTRUMENTS—SCIEN (not used)	CB	MDC-22
SCIEN EQUIP HATCH	CB	MDC-22

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-1	ALTIMETER	Indicates altitude of command module up to 60,000 feet.	None	None	None	The altimeter is monitored to verify deployment of the drogue and main parachutes at the proper altitudes. An adjustable marker on the dial is set prior to launch. The marker is used as a reference for manual deployment of the main parachutes during an abort initiated prior to 61 seconds after lift-off.
MDC-2	FCSM controls					
	G&N/RESET/OVERRIDE switch					
	G&N	Receives power from the SCS-GROUP 1-MNA and B circuit breakers through the G&N mode switch, altitude mode switch, and ΔV switch in ON position. Applies power to the FCSM and the G&N, SCS ΔV gates. If unstable combustion is sensed, the FCSM automatically energizes relays that remove power from the G&N, SCS ΔV gates, automatically shutting the engine down; other relay contact points will illuminate the SPS ROUGH ECO caution and warning light on MDC-10.	SCS-GROUP 1 MNA MNB	G&N switch attitude switch V switch ON	None	Two-position toggle switch. Placed in G&N position when G&N ΔV mode is utilized.
	RESET/OVERRIDE	Applies power to the G&N, SCS ΔV gates, bypassing the FCSM system. If unstable combustion is sensed, the SPS engine will not shut down and the SPS ROUGH ECO caution and warning light on MDC-10 will not illuminate. Will also be utilized to RESET the FCSM system if an automatic shutdown has occurred.				Placed to this position when SCS ΔV mode is utilized. The ΔV switch placed to OFF will also RESET the FCSM as a backup to the RESET/OVERRIDE position.
	SCS RESET/OVERRIDE switch	Receives power from the SCS GROUP 1 - MNA and B circuit breakers through the G&N mode switch, attitude mode switch, and the ΔV switch in ON position. Applies power to the FCSM and the SCS ΔV gates. If unstable combustion is sensed, the FCSM automatically energizes relays that remove power from the SCS ΔV gates, automatically shutting the engine down; other relay contact points will illuminate the SPS ROUGH ECO caution and warning light on MDC-10.				Two-position toggle switch. Placed in SCS position when SCS ΔV mode is utilized.

CONTROLS AND DISPLAYS

Ref. No.	Nomenclature	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
	ΔV RESET/OVERRIDE	Applies power to the SCS ΔV gates bypassing the FCSM system. If unstable combustion is sensed, the SPS engine will not shut down and the SPS ROUGH ECO caution and warning light on MDC-10 will not illuminate. Will also be utilized to RESET the FCSM system if an automatic shutdown has occurred.	SCS - GROUP 1 MNA MNB	GDC switch attitude switch ΔV switch ON	None	Placed to this position when the ΔV mode is utilized. The ΔV switch placed to OFF would also RESET the FCSM as a backup to the RESET/OVERRIDE position.
	ΔV ACCEL Indicator	Displays S/C positive and negative g loads along spacecraft X axis and records maximum g readings encountered. A RESET knob enables manual reset of recording pointers to normal 1g position.	(TBD)	(TBD)	(TBD)	The indicator has three pointers; one for normal g indications and the other two for recording maximum +g and -g readings, respectively. Scale +16 to -6g, readable increments 0.2g. Sensor is located behind instrument face.

MAIN DISPLAY CONSOLE — PANEL 2

Panel	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-2 (Cont)	FDAI BRIGHTNESS control OFF INCR	Turns off FDAI panel lighting (white light) (MDC-4) and THRUST ON switch face lighting (MDC-7). Adjusts intensity of FDAI panel lighting and THRUST ON switch face lighting.	SCS—GROUP 2 AC 1 AC 2 (MDC-25)	A-C buses No. 1 and No. 2	None	
	FDAI SELF TEST switch SELF TEST (up) OFF	Normal SCS rate mode a. Removes rate gyro input from SCS rate electronics. b. Applies test signal to SCS rate electronics, causing negative deflection of all FDAI rate indicators to 4/5 full scale. Removes test signal from rate indicators and permits normal operation of FDAI.	SCS—GROUP 1 MN A MN B (MDC-25)	D-C main buses A and B		In backup SCS rate mode, the SCS rate electronics receive the sum of the SELF TEST and BMAG inputs. Therefore rate deflection will be 4/5 full scale (fixed) plus deflection caused by the analog of the rate signal, if any. SELF TEST is used each time the FDAI is activated.
MDC-3	L/V AOA/SPS P_c switch L/V AOA SPS P_c	Connects output of Q-ball to L/V AOA/SPS P_c indicator. Connects output of SPS engine combustion chamber pressure sensor to L/V AOA/SPS P_c indicator.	None	N/A	None	Two-position toggle switch which enables the crew to select applicable input to L/V AOA/SPS P_c indicator. The switch is placed in the L/V AOA position prior to lift-off, and in the SPS P_c position at approximately 1 minute and 40 seconds after lift-off.
	L/V AOA/SPS P_c indicator	Time-shared indicator with input determined by position of L/V AOA/SPS P_c switch. a. L/V AOA input: the indicator displays a percentage of ΔP measured by the Q-ball which is a function of pitch and yaw.		D-C voltage from S-IVB I. U.		Indicator range: 0 to 150%. Small changes in air pressures are sensed through four holes in the Q-ball. The indicator is monitored from 40 seconds to approximately one minute and 40 seconds after lift-off. It is red-lined at approximately 100 percent for the L/V AOA function. A decision for manual abort will be made when the indicator pointer reaches the red line and a movement is also noted on the FDAI.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-3 (Cont)		b. SPS P_c input: the indicator displays SPS engine combustion chamber pressure during SPS thrusting as percentage of reference pressure value.	INSTRUMENTS—ESS MN A MN B (MDC-22)	D-C voltage from signal conditioner	SP0661P (Combustion chamber pressure sensor)	Reference pressure value for SPS P_c input is 100 psia (nominal). Normal thrusting readout is 100 percent. Scale is graduated in % increments.
	MASTER ALARM switch-light	Red light illuminates to alert crewman in LH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/WARN MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	MASTER ALARM lights on MDC-3, -18, and LEB-103 are simultaneously illuminated and an audio alarm tone is sent to each headset. The C/W switch (MDC-13) is set to BOOST during the ascent phase only, preventing this MASTER ALARM switchlight from illuminating in order to avoid confusion with the adjacent red ABORT light. The switch-light loses its reset function during this time. The MASTER ALARM switch-light contains an integral pushbutton switch. Pressing the switch-light will reset the master alarm circuit, extinguishing the MASTER ALARM lights and shutting off the audio alarm.
	ABORT light	Illuminates red to indicate that an abort has been requested by the range safety officer or ground control.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch is ON (MDC-24)	BX0060X (EDS abort request A)	The light serves to alert the crew of an emergency situation where an abort is required immediately. The light is a backup to voice communications from ground control. Redundant bulbs are controlled by redundant commands through the UDL real-time command system.
	SPS switches GIMBAL MOTORS group PITCH 1, PITCH 2, YAW 1, YAW 2 switches START	Four operationally identical switches. Energizes motor switch in applicable overcurrent relay which, in turn, applies +28 vdc to the applicable gimbal actuator drive motor.	SPS—GIMBAL MOTOR CONTROL 1 PITCH BAT A PITCH 2 BAT B 1 YAW BAT A YAW 2 BAT B (MDC-25)	Battery buses A and B	None	Three-position toggle switch with upper (START) position spring-loaded to return switch to center (ON) position when released. PITCH 1 and YAW 1 switches control gimbal actuator primary drive motors. PITCH 2 and YAW 2 switches control gimbal actuator secondary drive motors. START position provides gimbal motor starting capability.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-3 (Cont)	ON OFF	Applies +28 vdc to over-under-current sensing circuitry in applicable overcurrent relay. Energizes motor switch in applicable overcurrent relay which removes +28 vdc from the current sensing circuitry and gimbal actuator drive motor.	SPS—GIMBAL MOTOR CONTROL 1 PITCH BAT A PITCH 2 BAT B 1 YAW BAT A YAW 2 BAT B (MDC-25)	Battery buses A and B	None	ON position provides for over or undercurrent sensing (under 6 amps or over 40 amps nominal). During primary channel operation an over or undercurrent will automatically cause power to be removed from the primary drive motor, clutch commands switched to the secondary channel, and applicable GMBL DR FAIL status indicator to illuminate (MDC-11). During secondary operation, pitch 2 motor circuit is protected by CB 1 and yaw 2 motor circuit is protected by CB 2. CB 1 and CB 2 are 70 amp circuit breakers located in the S/M. No status indicators are provided for the secondary control circuits. During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning is maintained by application of a quiescent current (60 +10, -5 ma) to the electromagnets of the extend and retract clutches when TVC 1 and 2 POWER switches (MDC 24) are on.
	INJECT PRE-VALVES group A (B) switch ON OFF	Two operationally identical switches. Each switch controls the pneumatic (GN_2) pressurization of the SPS engine valve-actuators within their respective half of a series/parallel propellant feed line configuration to the engine combustion chamber. Applies +28 vdc to SPS engine system A pilot pre-valve solenoid. Removes +28 vdc from SPS engine system A pilot pre-valve solenoid.	SPS—He VALVE MN A MN B (MDC-25)	D-C main buses A and B		Two-position toggle switch which must be in ON position (i.e., solenoid is actuated) before automatic or manual SPS engine valve-actuator control of the main propellant valves can be initiated.

MAIN DISPLAY CONSOLE—PANEL 4

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-4	Flight director attitude indicator Total attitude indication	Displays S/C total attitude, attitude errors, and angular rates. S/C inertial attitude is displayed by orientation of the 3-axis attitude ball, with readouts as follows: a. Roll attitude is read from the ball-driven movable index (roll bug) referenced to the calibrated bezel ring around the ball, with respect to S/C navigation axes only. b. Pitch and yaw are read directly from the calibrated surface of the ball, with respect to either the S/C body axes index or the navigation axes index. Two 30° red circular areas on the ball surface denote attitude regions in which G&N IMU gimbal lock or excessive SCS AGCU error can occur.	SCS— GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	A-C bus No. 1 or No. 2 (via SCS display/ AGAA ECA)		Total attitude indicator calibration Pitch: 0° - 360° (ball longitude) Yaw: 270° - 0° -90° (ball latitude) Roll: 0° - 360° (bezel ring) Total attitude indicator direction of positive (+) rotation Axis of rotation (other two axes fixed at 0°) / Direction of Ball Rotation pitch — up: from top to bottom yaw — right: from right to left. roll — right: counterclockwise Total attitude indication follows attitude deviations only in the following situations: a. When G&N system supplies inputs b. When [CSS + translation control CW + .05g + (ATTITUDE IMPULSE-ENABLE) + (SCS attitude mode) + (pitch disabled + yaw disabled + both roll disabled)] (BUR in any axis)'. (MTVC)'. (FDAI align)'.
	Attitude error indication	S/C attitude errors are displayed by three fly-to-type needles mounted on the bezel ring around the attitude ball, with the top, right, and bottom needles corresponding to roll, pitch, and yaw, respectively. The readouts denote one of the following: a. Difference between present S/C attitude and the S/C reference attitude stored in either the G&N ICDUs or the SCS AGCU. The readouts are always referenced to S/C body axes, except during G&N-controlled				Attitude error indicator calibration (full-scale deflection) Modes / Roll / Pitch / Yaw Monitor (G&N): ±25° / ±15° / ±15° G&N entry, SCS entry: ±25° / ±5° / ±5° All other modes: ±5° / ±5° / ±5°

Item	Nomenclature	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
(Cont)		entry when the roll error needle is referenced to the S/C navigation axis. The pitch and yaw error needles will be zero after 0.05 g switching in a G&N entry mode, and there will be no attitude error displayed after 0.05 g in an SCS entry mode. b. Difference between the present S/C reference attitude stored in the SCS AGCU and a desired attitude dialed into the attitude set/gimbal position display, with the ATTITUDE SET function engaged. Dialed in and stored attitudes are referenced to S/C navigation axes, with the difference angles inverted to body axes for display by the error needles.	SCS-GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	A-C bus No. 1 or No. 2 (via SCS display/ AGAA ECA		Attitude error indicator deflection for positive (+) rotational input commands Axis of Rotation (positive command) / Indicator Deflection from Zero (center) roll / left pitch / up yaw / left
	Angular rate indication	S/C angular velocities are displayed by three fly-to-type indicators mounted above, to the right of, and below the attitude ball corresponding to roll, pitch, and yaw, respectively. The readouts are always referenced to S/C body axes except during atmospheric entry (after 0.05 g) when the yaw rate indicator is referenced to the S/C stability axis. Inputs to the indicators are supplied by either the SCS rate gyros (normal) or the SCS BMAGs (backup).				Angular rate indicator calibration (full-scale deflection) Modes / Roll / Pitch / Yaw Monitor (G&N) G&N entry SCS entry / ±25°/sec / ±5°/sec / ±5°/sec G&N delta V SCS delta V / ±5°/sec / ±5°/sec / ±5°/sec G&N att cont SCS att cont SCS lcl vert / ±1°/sec / ±1°/sec / ±1°/sec Angular rate indicator deflection for positive (+) rotational input commands Axis of Rotation (positive command) / Indicator Deflection from Zero (center) roll / left pitch / up yaw / left

Label	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-5	Digital event timer	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59) are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is recorded, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	The event timer is a reference system only and is automatically reset to zero when an abort is automatically or manually initiated. The event timer starts automatically when lift-off occurs.
	L/V RATE light	Illuminates red to indicate that the permissible angular rates in any of pitch, roll, or yaw axes have been exceeded. Rates in excess of 20 degrees/seconds in roll and 5 degrees/second in pitch or yaw illuminate the rate light.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch (MDC-24) is ON.	BS0020X (Launch vehicle rate excessive A)	When used in conjunction with the angle-of-attack display and the attitude error reading of the FDAI, will indicate the necessity for manual abort initiation. The light also illuminates when an auto abort is initiated because of excessive rates.
	L/V GUID light	Illuminates red to indicate platform failure in the L/V guidance system (loss of attitude control).			BS0016X (Launch vehicle guidance fail A)	
	L/V ENGINES lights					All engine lights are yellow. The lights are used to indicate staging and the necessity for initiating a manual abort when two S-IB engines are operating below 90 percent of thrust. When enabled in the auto abort mode, an auto abort will be initiated with two engines below 90 percent of thrust.
	Light No. 1	Illuminates to indicate S-IB or S-IVB engine No. 1 operating below 90 percent of total thrust capability.			BS0030X (Engine No. 1 out A)	
	Light No. 2	Illuminates to indicate S-IB engine No. 2 operating below 90 percent of total thrust capability.			BS0032X (Engine No. 2 out A)	
	Light No. 3	Illuminates to indicate S-IB engine No. 3 operating below 90 percent of total thrust capability.			BS0034X (Engine No. 3 out A)	
	Light No. 4	Illuminates to indicate S-IB engine No. 4 operating below 90 percent of total thrust capability.			BS0036X (Engine No. 3 out A)	

Location	Nomenclature Function	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	Light No. 5	Illuminates to indicate S-IB engine No. 5 operating below 90 percent of total thrust capability.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch (MDC-24) is ON.	BS0038X (Engine No. 5 out A)	
	Light No. 6	Illuminates to indicate S-IB engine No. 6 operating below 90 percent of total thrust capability.			BS0040X (Engine No. 6 out A)	
	Light No. 7	Illuminates to indicate S-IB engine No. 7 operating below 90 percent of total thrust capability.			BS0042X (Engine No. 7 out A)	
	Light No. 8	Illuminates to indicate S-IB engine No. 8 operating below 90 percent of total thrust capability.			BS0044X (Engine No. 8 out A)	
	LIFT-OFF and NO AUTO ABORT lights					
	LIFT-OFF light	White light illuminates at lift-off.			BS0060X BS0061X (Lift-off signal A & B)	The LIFT OFF/NO AUTO ABORT switch/light combination should be pressed if the LIFT OFF light does not illuminate at lift off. (Refer to malfunction procedures.) The relay controlling the white light is reset 5 seconds after lift-off by a timer in the L/V instrumentation unit.
	NO AUTO ABORT light	Switch-light will illuminate red at lift-off if either of the LV-EDS auto abort systems has not been automatically enabled.			None	The astronaut will press the switch-light which will electrically enable the LV-EDS automatic abort system. If the light still does not go out, it indicates that one or both of the dual redundant EDS systems is not enabled. In this event, the crew must be prepared to imtiate a manual abort, if necessary.
	LES MOTOR FIRE switch	a. Backup switch to fire the launch escape motor. b. Backup switch to jettison the LES tower in the event the jettison motor failed to ignite	MASTER EVENTS SEQ CONT-A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	CD0101X LE/P_c motor fire initiate A CD0102X LE/P_c motor fire initiate B	The LES motor is normally (automatically) fired approximately 0.1 second by the MESC following abort initiation. It may be used for a back-up for the jettison motor only after normal means of TWR jettison has failed. This is assuming that the TWR separation nuts are fractured.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-5 (Cont)	CANARD DEPLOY switch	Backup switch to deploy the canard when it does not deploy automatically during an abort.	MASTER EVENTS SEQ CONT-A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	CD0120X CD0121X Canard deploy A and B	Push-type switch. The canard will normally (automatically) deploy 11 seconds after a LES abort initiation.
	ADAP SEP switch	a. Switch for normal CSM/S-IVB separation after the ascent phase of the mission. (Refer to adapter separation mechanism in section 2.) b. Backup switch for CSM/S-IVB separation if it does not separate automatically during an SPS abort. (Refer to SPS abort procedures.)			CD0125X Adapter/SM separate initiate A CD0126X Adapter/SM separate initiate B	Push-type switch to separate the adapter when an SPS abort cannot be initiated with the commanders translational control. SPS ullage and firing would be manual functions.
	APEX COVER JETT switch	Backup switch to jettison the C/M apex cover.	ELS A—BAT A-FLOAT BAG 3 ELS B—BAT B (MDC-25)		CD0230X Forward heat shield jettison A CD0231X Forward heat shield jettison B	Push-type switch to jettison the C/M apex cover if the automatic system fails during an abort or earth landing after a normal mission.
	DROGUE DEPLOY switch	Backup switch to deploy the drogue parachutes.			CE0001X Drogue deploy relay close A CE0002X Drogue deploy relay close B	Push-type switch. The drogue parachutes will normally (automatically) deploy 2 seconds after the 24,000 feet baro switch closes.
	MAIN DEPLOY switch	Backup switch to deploy the main parachutes.			CE0003X Main parachute deploy -drogue release relay A CE0004X Main parachute deploy -drogue release relay B	Push-type switch. The main parachutes will normally (automatically) deploy when the 10,000 feet baro switch closes during descent. The switch is also used to initiate manual deployment of the main parachutes during aborts initiated prior to 61 seconds after lift-off.

CONTROLS AND DISPLAYS

Location	Switch or Indicator Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-5 (Cont)	Backup switch guard control					
	LOCK	Locks the backup switches to prevent inadvertent operation.	N/A	N/A	None	
	UNLOCK	Unlocks and enables the backup switches to be pushed manually.				
MDC-6	ATTITUDE SET group					
	ROLL, PITCH, YAW thumbwheels and indicators	Enables manual insertion of a desired attitude reference into the SCS, either for AGCU alignment or for a commanded S/C attitude maneuver reference during SCS flight modes. Enable manual selection and display of desired roll, pitch, and yaw attitude settings referenced to S/C navigation axes.	SCS— GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	A-C bus No. 1 or No. 2	None	Yaw thumbwheel is marked with a stripe, denoting yaw angles of 75° and 285°, as a caution against dialing in settings at which G&N IMU gimbal lock or excessive SCS AGCU error can occur. Indicators provide digital type displays.
	FDAI ALIGN switch	a. Couples manually selected (dialed in) attitude settings into the SCS for alignment of the present S/C reference attitude stored in the AGCU to the desired reference attitude. b. Decouples normal SCS BMAG inputs to the AGCU and the BMAGS are free gyros until the switch is released. c. Aligns the FDAI attitude ball to the dialed-in attitude, referenced to S/C navigation axes, in SCS flight modes only.	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main bus A or B		Momentary-contact pushbutton switch which must be held engaged until alignment is completed. SCS AGCU alignment slew rates roll — 20°/sec pitch — 5°/sec yaw — 5°/sec Perform the FDAI/AGCU align function.

MAIN DISPLAY CONSOLE—PANELS 5 AND 6

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-6 (Cont)	ATT SET switch		SCS— GROUP 1 MN A MN B (MDC-25)	D-C main bus A or B	None	The attitude set function which enables S/C maneuver to a desired (dialed in) attitude is applicable to SCS flight modes only. The desired attitude is achieved by flying out the attitude error needles, using the rotation control.
	On (up)	a. Couples the attitude difference angles to the FDAI attitude error indicators, referenced to S/C body axes. b. Decouples normal SCS BMAG inputs to the FDAI attitude error indicators. (BMAGs continue to operate normally otherwise.)				
	OFF	Inhibits the attitude set function.				
	GIMBAL POSITION group	Provides display and manual control of gimbaled SPS engine thrust axis orientation with respect to S/C body axes.	SCS GROUP 1 AC 1 & AC 2 GROUP 2 AC 1 & AC 2 (MDC-25)	A-C bus No. 1 or No. 2		
	YAW, PITCH indicators	Provide display of engine gimbal position readouts with respect to S/C yaw and pitch (body) axes, respectively.		(via yaw and pitch ECAs)	CH3135V (pitch GPI amp demod out)	Yaw indicator and thumbwheel are calibrated in 0.5° increments from -3° to +13°. Center reading of +4° corresponds to yaw gimbal position null, due to engine offset for S/C CG.
	YAW, PITCH thumbwheels	Provide manual yaw and pitch input commands to respective engine gimbal position servos for alignment of SPS engine thrust axis through S/C CG, prior to SPS thrusting. Thumbwheel displacement in a positive direction will provide a relative positive gimbal position indicator display indicating nozzle positioning for a positive axis displacement when thrust is initiated.		(via display/ AGAA ECA)	None	Pitch indicator and thumbwheel are calibrated in 0.5° increments from -9° to +9°. Center reading of 0° corresponds to pitch gimbal position null. Trimming of gimbal positions by use of the thumbwheels is possible when performing MTVC. Group 2 circuit provides power to MTVC circuits.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-7	DIRECT ULLAGE switch	Provides backup capability for initiating ullage (+X translation) prior to SPS burns. a. Energizes injector valve direct coils of four +X SM RCS engines. b. Disengages automatic attitude hold capability in pitch and yaw axes.	SCS—DIRECT CONT MN A MN B (MDC-25)	D-C main bus A or B	None	Momentary-contact pushbutton switch which must be held engaged until ullage is completed. Translation control provides normal capability for initiating ullage.
	THRUST ON switch light	a. Switch actuation applies manual SPS engine thrust-on logic command to SCS electronics which energizes coils of SPS engine helium isolation valves (if SPS He switch on MDC-20 is in AUTO position) and pilot control valves. b. Switch face illumination indicates application of SPS engine thrust-on signal from G&N system or THRUST ON switch to SCS electronics. Light is extinguished when SPS engine thrust-off signal from G&N system, ΔV REMAINING counter, or flight combustion stability monitor is detected in SCS electronics.	SCS—GROUP 1 MN A MN B (MDC-25)		CH4320X (SPS solenoid control valve energized) CH4321X (SPS solenoid control valve energized)	Pushbutton momentary-contact-type switch. Provides normal SPS engine ignition control in SCS ΔV mode, backup control in G&N ΔV mode. FDAI BRIGHTNESS control must be on to provide switch face illumination. Switch face does not indicate application of thrust on/off commands via the NORMAL/OFF/DIRECT ON switch (MDC-7).
	NORMAL/OFF/DIRECT ON switch NORMAL OFF	Enables circuit capability for energizing of SPS fuel and oxidizer control solenoids by either AGC or THRUST ON switch stimuli, providing all other logic is complied with. Provides capability to remove power from the four SPS engine pilot control valve solenoids directly, thereby, terminating thrust.	SCS—DIRECT CONT MN A MN B (MDC-25)		None	Switch is a three-position lever-lock toggle switch. To set the switch in the NORMAL position or the DIRECT ON position, pull the lever out past the lever lock (shoulder stop) and move the lever up and down, respectively. The in-flight position of the switch is the OFF (center) position. DIRECT ON position provides capability of bypassing thrust on logic circuit and initiating SPS engine firing directly.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-7 (Cont)	DIRECT ON	Connects +28 vdc direct from circuit breaker to SPS pilot control valve solenoids. Energizes SPS driver relays K1 and K2, which provide power application to helium isolation valves and PUGS.	SCS DIRECT CONT MN A MN B (MDC-25)	D-C main buses A or B	None	The DIRECT ON switch overrides FCSM.
	ΔV SET switch	Enables desired ΔV to be placed on ΔV REMAINING display.	SCS GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	±15 vdc from DISP/ AGAA ECA		The ΔV set switch is a five-position switch with two + (ΔV increase) positions, two - (ΔV decrease) positions, and an OFF (center) position.
	Upper hardstop (uppermost position)	Enables increase of ΔV REMAINING display at rate of 64 digits per sec.				
	Upper softstop (upper middle position)	Enables increase of ΔV REMAINING display at rate of 2 digits per sec.				
	Center position	Provides inhibit to ΔV counter after TVC #1 power switch is turned on until a xX ullage is initiated, except when open.				
	Lower softstop (lower middle position)	Enables decrease of ΔV REMAINING display at rate of 2 digits/per sec.				
	Lower hardstop (bottommost position)	Enables decrease of ΔV REMAINING display at rate of 64 digits/per sec.				
	ΔV REMAINING indicator	Displays ΔV magnitude and/or ΔV REMAINING in feet per second.		DISP/AGAA ECA	CH3186V ΔV remaining	When the SPS engine is thrusting, the ΔV REMAINING indicator receives a signal from the SCS X-axis accelerometer, driving the indicator toward zero. The ΔV REMAINING display is activated when the TVC 1 POWER switch is set to either AC 1 or AC 2 position and the integrator circuit threshold of 5×10^{-4} g has been attained while performing a +X (only) translation maneuver. Acceleration sensing will begin at ullage or +X RCS translation initiation. An indicating range from -1000 (99,000) to 12,999 feet/second (f/s) is provided at an accuracy of ±1.5 percent or 0.75 f/s, whichever is greater.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-7 (Cont)			SCS GROUP 1 AC 1 GROUP 2 AC 2 (MDC-25)	DISP/AGAA ECA	CH38I6V ΔV remaining	When thrusting in SCS ΔV mode, thrust-off signal is terminated when ΔV REMAINING display reaches 00000. The thrust-off signal is inhibited by the AGC when operating in G&N ΔV mode. No inhibit is provided by the ΔV REMAINING display circuits when in the G&N ΔV mode.
MDC-8	DIRECT RCS switch	Provides capability for direct manual control of S/M or C/M-R S engines.	SCS DIRECT CONT MIN A MIN B (MDC-25)	D-C main buses A or B	None	DIRECT RCS position provides the crew with direct control of the S/M or C/M RCS engines for rotational maneuver commands. Direct control is achieved by positioning the rotation control to engage the direct switches for the desired axis change. Direct switches are engaged at 1 ±0.5 degree from any hard stop. All SCS electronics are bypassed during this function.
	DIRECT RCS (up)	Applies d-c power to rotation control, enabling direct manual control of S/M or C/M-RCS engines.				
	OFF	Removes manual direct control capability of the S/M or C/M-RCS engines.				
	LIMIT CYCLE switch	Provides manual capability to retain or inhibit SCS pseudo rate (limit cycling) during RCS engine operation.	None	None		The primary purpose of the LIMIT CYCLE switch is to provide the crew with the capability of manually inhibiting the pseudo rate circuit operation during maneuvering and the entry phase of the mission. For fuel conservation, the switch should be set to LIMIT CYCLE position when holding attitude with the S/M RCS. The LIMIT CYCLE position function is disabled when the breakout switches in the rotation control are actuated, or when manual translation is commanded.
	LIMIT CYCLE	Allows normal operation of SCS pseudo rate circuit, providing limit cycling of RCS engines during attitude control modes.				
	OFF	Prevents operation of SCS pseudo rate circuit in pitch, yaw, and roll ECAs.				
	ATT DEADBAND switch	Enables selection of attitude deadband control sensitivity.	SCS GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B		This switch selects a deadband in SCS that prevents attitude correction signals from being applied to the RCS until the attitude error exceeds the selected deadband.
	MAX	Selects maximum attitude deadband of ±4.2°.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Cont)	MIN	Selects minimum deadband of ±0.2°.	SCS—GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B	None	Minimum deadband is used only when tight attitude control is required; e.g., during navigational sightings and prior to and during ΔV maneuvers. No power to this switch during SCS or G&N entry modes; therefore, minimum deadband cannot be selected during entry.
	RATE GYRO switches	Provide manual capability to place the roll, pitch, or yaw BMAG in the backup rate mode of operation.				These switches place any or all of the BMAGs in backup rate mode of operation so that they may be used in place of the rate gyros to provide spacecraft rate stabilization. In addition, with any one of the RATE GYRO switches in the BMAG position and any one of the following selected, the remaining two BMAGs will automatically assume the backup rate mode of operation: .05G ENTRY switch to .05G ENTRY position, monitor mode selected, G&N attitude control mode selected, minimum impulse attitude control mode engaged, G&N entry mode selected, either rotation control out of neutral position, SCS local vertical, or one SCS channel disabled while in SCS attitude control mode.
	ROLL					
	NORMAL	Allows normal BMAG and rate gyro operation.				
	BMAG	Enables BMAG rate mode of operation removing rate gyro signal from rate indicators, etc.				
	PITCH					
	NORMAL	Allows normal BMAG and rate gyro operation.				
	BMAG	Enables BMAG rate mode of operation, removing rate gyro signal from rate indicators, etc.				
	YAW					
	NORMAL	Allows normal BMAG and rate gyro operation.				When in an SCS mode, the attitude reference capability is lost when any one of the BMAGs is in backup rate mode. Attitude information is maintained if operating in a G&N mode.
	BMAG	Enables BMAG rate mode of operation, removing rate gyro signal from rate indicators, etc.				
	.05G ENTRY switch	Enables the SCS for atmospheric flight during entry and after 0.05gs				.05G ENTRY switch is effective only when a G&N or SCS entry mode is selected.
	.05G ENTRY	a. Removes attitude error signals from pitch and yaw channels in G&N mode and pitch, yaw, and roll channels in SCS modes.				After .05G ENTRY position is selected, placing any one of the BMAGs in backup rate mode will automatically place all BMAGs in backup rate mode configuration. This

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC 8 (cont)	OFF	b. Increases the rate deadband from 0.2° per sec to 2° per sec. c. Energizes a circuit which couples a component of the roll rate signal into the yaw channel. Allows normal system operation.	SCS—GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B	None	results in loss of FDAI total attitude display, otherwise, total attitude display is provided. During entry the S/C is maneuvered about the stability roll axis rather than the body roll axis. Consequently the yaw rate gyro generates an undesirable rate signal. By coupling a component of the roll signal into the yaw channel, the undesirable signal is cancelled.
	LCL VERT switch LCL VERT (up) OFF	Enables SCS for local vertical mode operation. Selects SCS local vertical mode when used in conjunction with G&N/SCS switch and ATTITUDE/MONITOR/ENTRY switch. Disengages local vertical mode.			CH1103X (SCS local vertical mode control)	The local vertical mode maintains the S/C attitude with respect to the earths local vertical. With local vertical mode engaged, an orbit rate signal equivalent to pitch rate of approximately 4.1° per minute is applied to the pitch BMAG torque motor. This figure is for a 100 NM earth orbit. FDAI total attitude is referenced to local vertical. Attitude error values represent deviation from selected local vertical attitude. If the S/C is maneuvered after local vertical mode is selected, the 4.1° per minute orbit rate signal previously applied only to the pitch gyro will be applied to all three gyros. This is accomplished by summing and resolving the new stepper motor position outputs with the orbital rate signal in the nav-to-body transformation circuits.
	ΔV switch ΔV (up)	Enables SCS for G&N or SCS ΔV mode operation or MTVC. Applies a signal to the SCS electronics enabling the system for ΔV modes of operation and also enables manual thrust vector control (MTVC), of the translation control SW switch is closed.			CH0100X (G&NΔV mode) CH1100X (5cΔV mode) CH1104X (MTVC mode)	This switch works in conjunction with the G&N/SCS switch and the ATTITUDE/MONITOR/ENTRY switch. MTVC is actuated only when the ΔV switch is in the ΔV position and when the translation control is rotated CW. MTVC is independent of G&N/SCS switch. In the ΔV position, DC power is applied to the FCSM-G&N and FCSM-SCS switches (MDC-2).

Indicator	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
SCS (cont)	OFF	Inhibits ΔV and MTVC modes of operation and permits operation of the SCS in other modes.	SCS– GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B		
	G&N/SCS switch	Selects either G&N or SCS control of the various flight control modes.			CH0101X (G&N attitude control mode control) CH1101X (SCS attitude control mode)	The G&N/SCS switch works in conjunction with the other flight control mode switches. When the switch is positioned to G&N or SCS position, ΔV maneuvers and attitude control of the S/C is accomplished by the selected system.
	G&N (up)	Enables G&N control for the following modes: attitude control, entry, and ΔV maneuvers.				
	SCS	Enables SCS control for the following modes: attitude control, monitor, local vertical, entry, and ΔV maneuvers.				
	ATTITUDE/MONITOR/ENTRY switch	Selects one of the following basic flight control modes: attitude control, monitor, or entry.			CH0103X (Monitor mode control) CH0102X (G&N entry mode control) CH1102X (SCS entry mode)	The ATTITUDE/MONITOR/ENTRY switch works in conjunction with the G&N/SCS switch, the ΔV switch, and the LCL VERT switch to enable crew selection of the various flight control modes. For details of the switch positions required to select the flight control modes, refer to Normal/Backup Procedures. In the attitude or monitor modes, the rate deadband for all axes is 0.2 /sec. The rate deadband for all axes in entry mode is 2.0°/sec. This applies to either entry mode: SCS or G&N. Monitor position selects the G&N monitor mode independent of other mode switches.
	ATTITUDE	Enables G&N or SCS attitude control mode. (Refer to Remarks.)				
	MONITOR	Enables monitor mode. (Refer to Remarks.)				
	ENTRY	Enables G&N or SCS entry mode. (Refer to Remarks.)				
	SCS CHANNEL switches	Provides capability to manually deactivate the RCS engines.	SCS– A&C ROLL MN A MN B and GROUP 1 MN A and MN B (MDC-25)		None	These switches are used to disable the RCS engines in the event of a malfunction or whenever it may be operationally desirable; e.g., S/C three-axis free drift for purposes of propellant conservation. Direct control of the RCS is available, using the DIRECT MODE switch and the rotation control.
	A&C ROLL					
	On (up)	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronic, allowing normal RCS engine operation.				
	OFF	Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.				

Maneuver function - engine activation.

Switch	Function	S/M RCS Engine
A&C ROLL	Roll right	A13, C15
A&C ROLL	Roll left	A16, C14
B&D ROLL	Roll right	B9, D11
B&D ROLL	Roll left	B12, D10
PITCH	Pitch up	A3, C1
PITCH	Pitch down	A2, C4

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Cont)						Switch: YAW / YAW; Function: Yaw right / Yaw left; S/M RCS Engine: B7, D5 / B6, D8
	B&D ROLL On (up) OFF	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation. Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS– B&D ROLL MN A MN B and GROUP 1 MN A and MN B (MDC-25)	D-C main buses A or B	None	Switch: B&D ROLL / B&D ROLL / PITCH / PITCH / YAW / YAW; Function: Roll right / Roll left / Pitch up / Pitch down / Yaw right / Yaw left; C/M RCS Engine: A9, B11 / A12, B10 / A1, B3 / A2, B4 / A5, B7 / A8, B6 AC roll switch is applicable to S/M-RCS engines only and provides no function after CM/SM separation.
	PITCH On (up) OFF	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation. Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS– PITCH MN A MN B and GROUP 1 MN A and MN B (MDC-25)				These switches are used to disable the RCS engines in the event of a malfunction or whenever it may be operationally desirable; e.g., S/C free drift for purposes of propellant conservation. Direct control of the RCS is available, using the DIRECT RCS switch and the rotation control.
	YAW On (up) OFF	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation. Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS– MN A MN B and GROUP 1 MN A and MN B (MDC-25)				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-6 (Cont)	ELS LOGIC switch UP	Connects 28 vdc to the ELS logic arm circuitry. The circuitry is automatically armed during an LES abort if the MAIN DEPLOY-AUTO/MAN switch (MDC-16) is in the AUTO position.	ELS – A BAT A - FLOAT BAG 3 ELS – B BAT B (MDC-25)	Battery buses A and B	None	The logic switch is positioned up during entry or after an SPS abort to arm the ELS logic circuitry. This circuitry is armed automatically on LES aborts. The ELS is controlled by baroswitch closure and time-delay relays after being armed. The switch should never be positioned up under 42,000 feet except as backup during an LES abort. The LES tower, apex cover and parachutes might be jettisoned.
	OFF	Disconnects 28 vdc from ELS logic circuitry.				
	DIGITAL EVENT TIMER (MDC-6) RESET/UP/DOWN switch RESET	Reset the event timer (MDC-5) to zero.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B		The event timer is automatically reset to zero and starts counting up when an abort is automatically or manually initiated. The switch is momentary on towards the RESET position and maintain on in the other two positions.
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch START	Starts the event timer.				The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintain on in the other two positions. The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch TENS	Runs the MIN indicating drums in tens.				
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Panel)	SEC switch		EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	
	TENS	Runs the SEC indicating drums of the event timer in tens.				
	Center	No function.				
	UNITS	Runs the second SEC indicating drum in units.				
	COUCH UNLOCK switch		COUCH ATTEN MN A MN B FLOOD-LIGHTS (MDC-25)			The attenuators will be unlocked by a breakout (approximately 20gs) upon landing.
	UNLOCK	Inoperative				
	Down position					
	CM PROP JETT switches		RCS--C/M-S/M TRANSFER MN A MN B (MDC-25)			
	LOGIC switch					Two-position toggle switch.
	On (up)	Applies power to DUMP switch on MDC-8.				Switch must be in up position before power is available to the DUMP switch, PURGE switch, RCS HTRS switch, and circuitry controlling automatic transfer of engine firing commands from S/M RCS to C/M RCS.
		Applies power to the 0 to 61-second time delay (from lift-off) and the 18-second time delay after the abort is initiated.				
		Applies power to relay contact points that are closed upon receipt of an abort signal (from 0 to tower jettison) which applies power automatically to RCS transfer motors.				
		Applies power to the C/M RCS engine manual coils (excluding +P) manual coils when the DUMP switch is placed to the on position.				
	OFF	Applies power to the C/M RCS HTRS switch (RHFF.B-200).				
		Removes power and resets RCS logic circuitry.				

MAIN DISPLAY CONSOLE—PANEL 8

Switch	Switch Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
[illegible]	[illegible]	Removes power from C/M RCS SURS switch (RHEB-200).	PCM C/M-S/M TELEM MN A MN B (MA7-20)	D-C main buses A and B	None	
[illegible]	[illegible]	Energizes logic to LOGIC switch.				
[illegible]	[illegible]	Energizes relays required to activate C/M RCS propellant [illegible]				Guarded two-position toggle switch (activates explosive-operated valves). During normal entry, switch is placed to DUMP (up) position when main parachute line stretch is felt. Remaining propellants are then burned off through 10 of the 12 RCS engines.
	OFF	De-energizes relays.				The two positive pitch engines do not permit fuel dump or burn. DUMP switch will not be utilized during pad aborts or low altitude aborts, fuel only is retained on-board and the CM will land with fuel tanks full, but depressurized.
	PURGE switch					
	ON (up)	Energizes relays required to activate the following a. C/M RCS propellant system purge operation b. ECS gas chromatograph helium dump operation.				Two-position toggle switch. Switch manually set to the up position after C/M propellant suppiy has been depleted (approximately 86 seconds, after activation of FUEL DUMP/BURN switch, for 10-engine burn and 132 seconds for 5-engine burn). All four propellant tank lines are purged with helium to ensure that no hypergolic propellant remains in the propellant distribution or engine systems. (Purge operation approximately 10 seconds.) The LOGIC and DUMP switches must both be in the up position before the purge operation can be initiated. Switch will not be utilized during abort operations if fuel is retained on-board.
	OFF	De-energizes relays.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-9	Coaxial bracket MDC		N/A	None	None	
	Normal installation	Connects VHF recovery antenna No. 1 to the VHF recovery beacon and VHF recovery antenna No. 2 to the VHF/AM transmitter-receiver.				Change is implemented by manually disconnecting RF coaxial connector from VHF recovery antenna No. 1 or No. 2 connector and reconnecting to coaxial connector on cable to GFAE survival transceiver.
	Survival transceiver installation	Connects either recovery antenna No. 1 or No. 2 to the GFAE survival transceiver.				
	Crossover installation	Connect GFAE survival transceiver to recovery antenna No. 1 (right connector).				Permits two-way AM voice communications or beacon transmission on GFAE survivals transceiver (243.0 mc) over antenna No. 1 and VHF-AM two-way voice communication (296.8) on antenna No. 2.
		Connect GFAE survival transceiver to recovery antenna No. 2 (left connector).				Permits two-way AM voice communications or beacon transmission on GFAE survival transceiver (243.0 mc) over antenna No. 2 and VHF recovery beacon transmission (243.0 mc) on antenna No. 2.
MDC-10	G&N system status lights		CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B		Yellow lights indicate failure or out-of-tolerance condition when illuminated.
	CDU FAIL	Indicates a failure in one or more of the coupling display units.			CG5002X (CDU fail)	
	IMU FAIL	Indicates a failure in the inertial measurement unit.			CG5001X (IMU fail)	
	IMU TEMP	Indicates that the IMU temperature is out of tolerance, i.e., exceeds normal temperature by ±4°.			CG5006X (IMU temp light)	
	G&N ACCEL FAIL	Indicates a failure in one or more of the PIP accelerometers.			CG5000X (PIPA fail)	
	G&N ERROR	Indicates an IMU, CDU, accelerometer and/or AGC error.			CG5005X (Error detect)	
	GMBL LOCK	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than ±60 degrees with respect to the outer gimbal).			CG5003X (Gimbal lock warning)	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-10 (Cont)	AGC PWR FAIL	Indicates a power failure in the Apollo guidance computer.	CAUT/WARN MN A MN B (MDC-25)	D-C main buses A and B	CG5030X (Computer power fail light)	
	SCS status light AGAP TEMP	Illuminates when the temperature of any one of three BMAGs in the SCS attitude gyro accelerometer package varies from 170±2°F.			CH2030T (Combined attitude gyro temp)	When illuminated, the status light indicates an out-of-temperature condition in one or more of the three BMAGs. When light is out, BMAG outputs are usable.
	EPS status lights H_2 PRESS	Indicates hydrogen tank pressure is as follows: a. 220 psia or below b. 270 psia or above.			SF0039P (Press H_2 tank 1) SF0040P (Press H_2 tank 1)	Yellow lamp will illuminate if either or both H_2 tanks are above or below proper pressure limits. Pressure in H_2 tanks can be monitored by indicators on MDC-13.
	O_2 PRESS	Indicates oxygen tank pressure is as follows: a. 800 psia or below b. 950 psia or above.			SF0037P (Press O_2 tank 1) SF0039 (Press O_2 tank 2)	Yellow lamp will illuminate if either or both O_2 tanks are above or below proper pressure limits. Pressure in O_2 tanks can be monitored by indicators on MDC-13.
	RCS status lights	A and B lights are identical in operation within their respective systems. Indicates an underpressure condition in the fuel and oxidizer tanks of the respective system prior to system pressurization.			None	All lights are yellow. The RCS INDICATOR switch can be used in conjunction with the propellant indicating devices to isolate a malfunction to a specific temperature, or pressure, within a particular RCS package. A temperature transducer is located on the inner surface of each S/M-RCS quad. A pressure transducer is installed in the helium line of each S/M-RCS quad and each C/M-RCS system. When the status lights are out, the applicable system is operable.
	C/M RCS A, B	Indicates an over or underpressure condition (below 265 psia or above 325 psia) in the fuel and oxidizer tanks of the respective propellant system.				
	S/M RCS A, B, C, D	Indicates one of the following: a. Package temperature below 63°F or above 175°F (nominal)				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-10 (Cont)		b. Regulated helium pressure below 155 psia or above 215 psia (nominal).	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	
	SPS status light SPS ROUGH ECO	Indicates FCSM cut-off of SPS engine due to excessive engine vibration level.	CAUT/ WARN MN A MN B (MDC-25)			Yellow light. Delay time for cutoff is nominally 70±20 milliseconds at a vibration level of 180 g's peak-to-peak. Delay time will be 30 to 70 milliseconds at a vibration level of 360 g's peak-to-peak. Light will extinguish when FCSM circuitry is reset.
MDC-11	ECS status lights H_2O ACCUM FAIL	Indicates when a minimum of three oxygen bubbles are detected in water expelled from H_2O accumulators.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	The yellow light illuminates in event of water accumulator diaphragm rupture. Oxygen will then enter the waste water network. A sensor is placed in the accumulator water outlet line. Oxygen bubbles in the water are sensed as a change in voltage. When three positive pulse signals (corresponding to three bubbles) are received, a voltage divider is unbalanced, resulting in light illumination.
	GLYCOL TEMP LOW	Indicates when water-glycol from space radiator outlet decreases to -30°F.			CF0020T (Temp space radiator outlet)	The yellow light illuminates to indicate water-glycol is approaching the temperature where flow is reduced. Continuous temperature is displayed by ECS RAD-OUTLET TEMP indicator (MDC-13). Transducer is placed in line downstream of space radiator outlet in LHEB, and furnishes signal for light and indicator.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	CO_2 PP HI	Indicates when CO_2 partial pressure reaches 7.6 mm Hg.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CF0005P (Press CO_2 partial)	The yellow light illuminates at upper end of normal range. A CO_2-odor absorber filter change is required only if the illumination of the light is not the result of temporarily increased crew activities. Continuous partial pressure is displayed by PART PRESS - CO_2 indicator (MDC-13).
	O_2 FLOW HI	Indicates when total ECS oxygen flow reaches 1 lb per hr.			None	The red light illuminates at critical flow rate which, if continuous, indicates cabin leakage, oxygen subsystem leakage, or mismanagement of oxygen subsystem. Continuous O_2 flow is displayed by FLOW O_2 indicator (MDC-13).
	SPS status lights					
	PITCH GMBL DR. FAIL	Indicates an over or under-current has occurred in the primary drive motor of the pitch gimbal actuator.				Yellow lights. Light indicator is a constant visual aid to assist in evaluating functional status of engine gimbal drive components.
	YAW GMBL DR FAIL	Indicates an over or under-current has occurred in the primary drive motor of the yaw gimbal actuator.				
	SPS PRESS	Indicates oxidizer and/or fuel tank pressures (regulated helium pressures) are not within proper operating range (160 to 200 psia).				Yellow light. Two pressure transducers, one located in each (Ox and Fuel) regulated helium supply line, provide input to indicator. Continuous pressures are displayed by PRESSURE indicators on MDC-20.
	SPS WALL TEMP HI	Indicates wall temperature of SPS engine combustion chamber exceeds high operating temperature limit of 380°F.				Yellow light. Indicator input is provided by temperature sensor mounted in engine combustion chamber wall assembly.
	SPS PU SNSR FAIL	Indicates one of the following: a. An unbalance in the remaining SPS propellants from the desired ratio (by weight) in excess of 300 lb or 90 percent of critical unbalance.				Yellow light is functional only during SPS engine firing or when TEST/ AUTO/TEST switch (MDC-20) is in the TEST up or down position. Critical unbalance is that point at which the propellant utilization valve will no longer provide oxidizer adjustment

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)		b. Discrepancy of 300 lbs between the primary and auxiliary sensing systems.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	great enough to permit simulianeous propellant depletion.
	C&WS status light CAUT/WARN FAIL	Indicates when power supply voltage (positive or negative) is outside of the 11.7 to 13.9 volt normal range.				Switching to redundant power supply will extinguish status light. Audio portion of master alarm circuit will not operate, as the 12-volt tone generator power will be interrupted by a power supply failure.
	EPS status lights F/C-BUS DISCONNECT	Indicates a fuel cell has automatically disconnected from the d-c main buses.			SC2120X Fuel cell 1 bus A disconnect SC2121X Fuel cell 2 bus A disconnect SC2122X Fuel cell 3 bus A disconnect SC2125X Fuel cell 1 bus B disconnect SC2126X Fuel cell 2 bus B disconnect SC2127X Fuel cell 3 bus B disconnect	Yellow lamp illuminates when any fuel cell is disconnected from the S/M d-c bus A and/or B. The overload and reverse current units on each fuel cell automatically disconnect the fuel cell output from the bus when a reverse current >4 amps or a forward current >75 amps is sensed. The lamp will not illuminate when the affected fuel cell main bus switch is in the off position. Event indicators below the FUEL CELL-1, -2, and -3 MAIN BUS A and B switches indicate with a striped display which fuel cell is disconnected from which bus.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	F/C 1, F/C 2, and F/C 3	Indicates one of the following conditions exist in the respective fuel cell: a. H_2 flow rate below 0.028 lb/hr or above 0.153 lb/hr b. O_2 flow rate below 0.22 lb/hr or above 1.22 lb/hr c. pH factor of 9 or over	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	a. SC2139R Flow rate H_2 F/C 1 SC2140R Flow rate H_2 F/C 2 SC2141R Flow rate H_2 F/C 3 b. SC2142R Flow rate O_2 F/C 1 SC2143R Flow rate O_2 F/C 2 SC2144R Flow rate O_2 F/C 3 c. SC2160X pH factor water condition F/C 1 SC2161X pH factor water condition F/C 2 SC2162X pH factor water condition F/C 3	Yellow lights illuminate when any of the sensed parameters are out of tolerance. Switching the FUEL CELL INDICATORS switch (MDC-18) to the position indicated by the illuminated status lights and observing the fuel cell displays, enables the crew to determine which parameter is out of tolerance. Alarm trigger values are presented in the Function column.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)		d. F/C skin temperature below 360°F or above 500°F	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	d. SC2084T Temp F/C 1 skin SC2085T Temp F/C 2 skin SC2086T Temp F/C 3 skin	
		e. F/C condenser exhaust temperature below 155°F or above 175°F			e. SC2081T Temp F/C 1 cond exhaust SC2082T Temp F/C 2 cond exhaust SC2083T Temp F/C 3 cond exhaust	
		f. F/C outlet radiator temperature below -30°F			f. SC2087T Temp F/C 1 radiator outlet SC2088T Temp F/C 2 radiator outlet SC2089T Temp F/C 3 radiator outlet	

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)		g. H_2 regulator pressure above 75 psia	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	g. SC2069P H_2 pressure F/C 1 regulated SC2070P H_2 pressure F/C 2 regulated SC2071P H_2 pressure F/C 3 regulated	
		h. O_2 regulator pressure above 75 psia			h. SC2066P O_2 pressure F/C 1 regulated SC2067P O_2 pressure F/C 2 regulated SC2068P O_2 pressure F/C 3 regulated	
		i. N_2 regulator pressure above 70 psia.			i. SC2060P N_2 pressure F/C 1 regulated SC2061P N_2 pressure F/C 2 regulated	

MAIN DISPLAY CONSOLE—PANEL 11

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)			CAUT/ WARN MN A MN B (MDC-25	D-C main buses A and B	i. (Cont) SC2062P N_2 pressure F/C 3 regulated	
	INV 1 TEMP HI, INV 2 TEMP HI, and INV 3 TEMP HI	Indicates an overtemperature (241°F) exists in the respective inverter.			CC0175T (Temp static inverter 1) CC0176T (Temp static inverter 2) CC0177T (Temp static inverter 3)	The yellow inverter overtemperature lights illuminate at +241°F and above.
	MN BUS A UNDERVOLT and MN BUS B UNDERVOLT	Indicates a d-c voltage drop below 26.25 ± 0.1 vdc on the respective d-c main bus.			None	The yellow main d-c bus undervoltage lights will not illuminate when the affected main bus reset switch is in the OFF position.
	AC BUS 1 FAIL and AC BUS 2 FAIL	Indicates the following conditions exist in any of the three phases of the respective a-c bus: a. Undervoltage (95±3 vac) b. Overvoltage (130±2 vac)				The yellow a-c bus fail lights will not illuminate when affected a-c bus reset switch is in the OFF position. The inverters will not disconnect from the buses on an undervoltage condition, but will disconnect from bus on overload. Light must be reset.
	AC BUS 1 OVERLOAD and AC BUS 2 OVERLOAD	Indicates an overload (3Ø, 9 amps/Ø for 15±5 seconds or 1Ø, 11 amps for 5±1 second) exists on the respective a-c bus.				The inverter supplying the bus will be automatically disconnected at the time either of these yellow lights illuminate. Time versus overload is 5±1 seconds for a short circuit of 300-percent-rated current per phase and 10(-0, +5) seconds for a short circuit of 250-percent-rated current. Lamps will not illuminate when affected a-c bus reset switch is in the OFF position.
	CAUT/WARN switches POWER switch					The output of both power supplies is +12 and -12 vdc, which is used in the caution and warning system electronics.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	1	Applies d-c power to caution and warning system power supply No. 1.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Nominal switch position is 1.
	OFF	Removes d-c power from caution and warning system power supplies No. 1 and No. 2.				Power is still applied to the C&WS; however, the master alarm circuit and those status lights activated as the result of analog signals will be inoperative.
	2	Applies d-c power to caution and warning system power supply No. 2.				
	MODE switch					Power to C/M system status lights is not removed with switch in either position. Power is removed only by placing C/W switch (MDC-13) to ACK position.
	CSM	a. Applies d-c power to 15 S/M system status lights, permitting illumination of lights upon receipt of malfunction signals.				CSM mode is selected at all times prior to CSM separation. Power is applied to the following 15 S/M status lights: PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNSR FAIL, F/C BUS DISCONNECT, O_2 PRESS, H_2 PRESS, SPS PRESS, S/M RCS A, S/M RCS B, S/M RCS C, S/M RCS D, SPS WALL TEMP HI, F/C 1, F/C 2, and F/C 3.
		b. Applies d-c power to 4 S/M event channels, permitting circuitry to simulate lamp load when C/W switch is in ACK position.				Power is applied to the following 4 S/M event channels: PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNSR FAIL, and F/C BUS DISCONNECT.
		c. Opens d-c ground return path, inhibiting C/M RCS A and C/M RCS B lamp circuits prior to CSM separation.				
	C/M	a. Removes d-c power to 15 S/M system status lights. b. Removes d-c power to 4 S/M event channels. c. Completes d-c ground return path, enabling C/M RCS A and C/M RCS B lamp circuits after CSM separation.				C/M mode is selected subsequent to CSM separation.

Panel and Part Number	Name and Function	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
Sheet 11	DIGITAL EVENT TIMER window	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59) are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is reached, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	The event timer is a reference system only and is automatically reset to zero when an abort is automatically or manually initiated. The event timer starts automatically when lift-off occurs.
	DIGITAL EVENT TIMER switches					The event timer is automatically reset to zero and starts counting up when an abort is automatically or manually initiated. The switch is momentary on towards the RESET position and maintain on in the other two positions.
	RESET/UP/DOWN switch					
	RESET	Reset the event timer (MDC-5) to zero.				
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch					The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintain on in the other two positions. The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	START	Starts the event timer.				
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch					
	TENS	Runs the MIN indicating drums in tens.				
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				
	SEC switch					
	TENS	Runs the SEC indicating drums of the event timer in tens.				
	Center	No function.				
	UNITS	Runs the second SEC indicating drum in units.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (cont)	DIGITAL EVENT TIMER switches	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59, are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is recorded, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	This event timer is for reference only. The event timer starts automatically when lift-off occurs.
	RESET/UP/DOWN switch					
	RESET	Reset the event timer (MDC-11) to zero.				The switch is momentary on towards the RESET position and maintained on in the other two positions.
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch					
	START	Starts the event timer.				The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintained on in the other two positions. The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch					
	TENS	Runs the MIN indicating drums in tens.				
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				

Panel	Switch and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
	S/M RCS indicators		INSTRUMENTS—ESS MN A MN B (MDC-22)	D-C main buses A and B		Four indicators are identical in operation. Each one consists of a d'Arsonval-type meter with a fixed dial and movable pointer. Pointer movement is vertical, as observed from crew couch. Each indicator is capable of accepting input signals from the C/M or S/M RCS. Displayed information is determined by the position of the RCS INDICATORS switch.
	TEMP					
	PKG	Indicates temperature of S/M RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 200 F.)			Package temp: A-SR5065T B-SR5066T C-SR5067T D-SR5068T	
	He	Indicates temperature of S/M RCS helium supply for A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia, must be transposed to degrees. Refer to Remarks.)			He TANK TEMPERATURE: A-SR5013T B-SR5014T C-SR5015T D-SR5016T	The S/M RCS helium tank supply temperature is indicated as psia on this indicator. The range of the indicator is 0 to 400 psia, bottom to top scale. 0 psia is equivalent to 0 F and 400 psia is equivalent to 150°F. The indicated number (psia) on this indicator, plus the helium tank supply pressure readout (psia) would be utilized by the crew to determine on the nomogram the propellant quantity remaining in a given quad in percent.
	PRESS					
	He	Indicates helium tank pressure of S/M RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 5000 psia.)			He tank pressure: A-SR5001P B-SR5002P C-SR5003P D-SR5004P	
	MANF	Indicates regulated helium pressure of S/M-RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)			Regulated He press: A-SR5729P B-SR5776P C-SR5817P D-SR5830P	
	C/M RCS indicators					
	TEMP					
	He	Indicates helium tank temperature of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 200°F.)			He tank temp: A-CR0003T B-CR0004T	
	PRESS					
	He	Indicates helium tank pressure of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 5000 psia.)			He tank press: A-CR0001P B-CR0002P	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-12 (Cont)	F	Indicates regulated helium pressure to the fuel tank of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)	INSTRUMENTS—ESS MN A MN B (MDC-22)	D-C main buses A and B	Regulated He press (Fuel system) A-CR0005P B-CR0006P	
	OX	Indicates regulated helium pressure to the oxidizer tank of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)			Regulated He press (OX system) A-CR0011P B-CR0012P	
	RCS INDICATORS switch	Selects inputs to the propellant temperature, and pressure indicating devices. C/M sections A and B functions are identical within their respective systems. S/M sections A, B, C, and D functions are identical within their respective systems.	N/A	N/A	None	Six-position rotary switch. C/M section of switch, positions A and B, permits monitoring command module propellant systems A and B. S/M section of switch, positions A, B, C, and D permits monitoring service module propellant systems of quads A, B, C, and D.
	C/M section A (B)	Connects C/M RCS system A (B) signal outputs from temperature and pressure transducers to the appropriate indicating devices.				
	S/M section A (B, C, D)	Connects S/M RCS quad A (B, C, and D) signal outputs from temperature and pressure transducers and the propellant quantity sensing computer to the appropriate indicating devices.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-12 (Cont)	100-hour clock	Displays mission elapsed time in 10-hour increments up to 400 hours.	None	None	None	The indicator has two set-knobs. One starts, stops, and resets the clock; the other sets the hour and minute hands, and winds the clock.
MDC-13	C/W switch NORMAL	Applies d-c power to the following: a. Twenty-five C/M system status lights, permitting illumination of lights upon receipt of malfunction signals. b. One pole of CAUT/WARN-MODE switch, which in turn may apply power to 15 S/M system status lights. c. MASTER ALARM switch-light on MDC-3, permitting illumination of light upon receipt of malfunction signals.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Switch is set to NORMAL at all times other than during the ascent phase or when dark adaptation is required. With switch in this position and upon receipt of a malfunction signal, the appropriate system status light and the MASTER ALARM lights will illuminate, and an audio alarm tone is sent to each headset. Power is applied to the following 25 C/M system status lights: CDU FAIL, G&N ACCEL FAIL, AGC PWR FAIL, IMU FAIL, G&N ERROR, IMU TEMP, GMBL LOCK, AGAP TEMP, SPS ROUGH ECO, H_2O ACCUM FAIL, O_2 FLOW HI, AC BUS 1 FAIL, AC BUS 1 OVERLOAD, AC BUS 2 FAIL, AC BUS 2 OVERLOAD, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, INV 1 TEMP HI, INV 2 TEMP HI, INV 3 TEMP HI, C/M RCS A, C/M RCS B, GLYCOL TEMP LOW, CO_2 PP HI, and CAUT/WARN FAIL. For a list of the 15 S/M system status lights, refer to Remarks column of CAUT/WARN-MODE switch (MDC-11), CSM position.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	BOOST	a. Applies d-c power to 25 C/M system status lights, permitting illumination of lights upon receipt of malfunction signals. b. Applies d-c power to one pole of CAUT/WARN-MODE switch, which in turn may apply power to 15 S/M systems status lights. c. Removes d-c power from MASTER ALARM switch-light on MDC-3, preventing illumination of light upon receipt of malfunction signals during the ascent phase.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Switch set to BOOST at prelaunch to preclude the possibility of confusion on MDC-3 between the red MASTER ALARM light and the adjacent red ABORT light during the critical ascent phase.
	ACK	a. Removes d-c power from 25 C/M system status lights, preventing illumination of lights upon receipt of malfunction signals. b. Removes d-c power from one pole of CAUT/WARN MODE switch, thereby removing power to 15 S/M system status lights. c. Places push-switch function of both MASTER ALARM switch-lights into the d-c circuit of the system status lights. This prevents illumination of the system status lights upon receipt of malfunction signals until either push-switch is pressed to complete the circuit.				Switch is set to ACK to retain dark adaptation. With switch in this position and upon receipt of a malfunction signal, only the MASTER ALARM lights will illuminate and an alarm tone be sent to each headset. To determine the malfunction either MASTER ALARM switch-light may be pressed to illuminate the appropriate system status light. The light will remain illuminated only as long as the switch-light is pressed. Although upon release all system status lights are extinguished, they may be recalled as long as the malfunction exists by again pressing either switch-light.
	POWER switch	Controls power to senior pilots module in audio center equipment.	T/C GROUP 5 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position.
	PTT	Applies d-c power to audio and control circuits.				Intercom capability when cobra cable PTT/CW switch is in CW and transmit capability with PTT/CW switch in PTT.
	OFF	Removes power from senior pilots audio center equipment module and controls.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	VOX	a. Applies d-c power to audio and control circuits. b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.	T/C GROUP 5 (MDC-22)	Flight and postlanding bus	None	VOX operation permits voice transmission and transmitter keying of intercom, HF Recovery transceiver and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch		N/A	Audio center equipment		The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the senior pilots module of the audio center equipment to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	T/R	No effect. S-Band T/R function supplied by cobra cable PTT key.				
	OFF	Prevents senior pilot from transmitting or receiving voice over USBE.				
	REC	Enables senior pilot to receive voice from USBE.				
	RCDR/HF switch					Provides power ground through audio center VOX circuit for HF transceiver transmit-receive relay and voice recorder power relay.
	T/R	a. Enables senior pilot to transmit and receive voice over HF transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				
	OFF	Prevents senior pilot from transmitting or receiving voice over HF transceiver.				
	REC	Enables senior pilot to receive voice from HF transceiver when operating in AM or SSB mode.				
	VHF-AM switch					VHF-AM transmits, in addition to S-Band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switch must be at PTT, and audio center POWER switch must be at PTT.
	T/R	Enables senior pilot to transmit and receive voice over VHF-AM transmitter-receiver when operating in T/R mode.				
	OFF	Prevents senior pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				

MAIN DISPLAY CONSOLE—PANEL 13

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	REC	Enables senior pilot to receive voice from VHF-AM transmitter-receiver.	N/A	Audio center equipment	None	
	INTERCOM switch					
	T/R	Enables senior pilot to transmit and receive voice over the intercom system.				Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT/CW switch is at PTT.
	OFF	Prevents senior pilot from transmitting or receiving voice over intercom system.				
	REC	Enables senior pilot to receive voice from intercom system.				
	VOX SENS control	Increases or decreases sensitivity of voice-operated relay circuitry in senior pilots audio center module.				These three controls are thumbwheel-type potentiometers which may be rotated upward or downward, as required.
	INTERCOM BALANCE control	Increases or decreases level of audio signal received by senior pilot from RF equipment relative to that received from intercom bus.				Position 9 most sensitive.
	VOLUME control	Increases or decreases level of audio signal from senior pilots earphone amplifier to earphone.				
	TANK PRESSURE indicators					Displays for H_2 and O_2 tanks No. 1 and 2 operate prior to CSM separation only.
	H_2 group					
	Indicators 1 and 2	Displays H_2 tank No. 1 and No. 2 pressure and is used as follows: a. Determine tank heater performance. b. Detect leaks.	ESSENTIAL-3 (RHEB 204) and fuse in S/M	S/M INST PWR DIST	SF0039P (Press H_2 tank No. 1) SF0040P (Press H_2 tank No. 2)	The indicator function is controlled by pressure transducers located in H_2 tank No. 1 and No. 2 outlet lines. These transducers are also connected to C&WS, operating the H_2 PRESS light on MDC-10. H_2 operating range is 230 to 260 psia. Alarm trigger values are 220 psia low, and 270 psia high.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	O_2 group		ESSEN-TIAL-3 (RHEB 204) and fuse in S/M	S/M INST PWR DIST		
	Indicator 1	Displays pressure of O_2 tank No. 1 or ECS surge tank as selected by O_2 PRESS IND switch (MDC-13) and is used as follows: a. Determine tank heater performance. b. Detect leaks. c. Verify surge tank pressure.			SF0037P (Press O_2 tank No. 1 CF0006P (Press surge tank)	With O_2 PRESS IND switch at TANK 1, the indicator function is controlled by a pressure transducer located in O_2 tank No. 1 outlet line. Transducer also connected to C&WS, operating O_2 PRESS light on MDC-10. O_2 operating range is 865 to 935 psia. Alarm trigger values are 800 psia low and 950 psia high. With O_2 PRESS IND switch at SURGE TANK position, indicator displays signal from ECS surge tank pressure transducer.
	Indicator 2	Displays O_2 tank No. 2 pressure and is used as follows: a. Determine tank heater performance. b. Detect leaks.			SF0038P (Press O_2 tank No. 2)	The indicator function is controlled by a pressure transducer located in O_2 tank No. 2 outlet line. Transducer also connected to C&WS, operating O_2 PRESS light on MDC-10. O_2 operating range is 865 to 935 psia. Alarm trigger values are 800 psia low, and 950 psia high.
	TANK QUANTITY indicator H_2 group					
	Indicator 1	Displays quantity of H_2 remaining in tank No. 1.	CRYO-GENIC SYSTEM-QTY AMPL 1 AC 1 - ØC (MDC-22)	A-C bus No. 1 ØC	SF0030Q (Quantity H_2 tank No. 1)	H_2 quantity display range is 0 to 28 lb.
	Indicator 2	Displays quantity of H_2 remaining in tank No. 2.	CRYO-GENIC SYSTEM-QTY AMPL 2 AC 2 - ØC (MDC-22)	A-C bus No. 2 ØC	SF0031Q (Quantity H_2 tank No. 2)	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	O_2 group					
	Indicator 1	Displays quantity of O_2 remaining in tank No. 1.	CRYO-GENIC SYSTEM - QTY AMPL 1 AC 1 - ØC (MDC-22)	A-C bus No. 1 ØC	SF0032Q (Quantity O_2 tank No. 1)	O_2 quantity display range is 0 to 320 lb.
	Indicator 2	Displays quantity of O_2 remaining in tank No. 2.	CRYO-GENIC SYSTEM - QTY AMPL 2 AC 2 - ØC (MDC-22)	A-C bus No. 2 ØC	SF0033Q (Quantity O_2 tank No. 2)	
	H_2 HEATERS switches				None	Redundant heater elements in each H_2 tank requires 10 watts of power for each element.
	Switches 1 and 2	Controls d-c power to H_2 tanks No. 1 and 2 heater elements, respectively.	CRYO-GENIC SYSTEM - TANK HEATERS - H_2 - 1 MN A (MDC-22)	D-C main bus A		
	AUTO	Enables automatic pressure switches to control d-c power to H_2 tanks No. 1 and 2 heater elements.	CRYO-GENIC SYSTEM - TANK HEATERS - H_2 - 2 MN B (MDC-22)	D-C main bus B		Switch at AUTO position will apply d-c voltage to H_2 tanks No. 1 and 2 redundant heater elements when pressure switches in both tanks are in a low-pressure position at 230 psia or lower, and remove d-c voltage when either pressure switch is in a high-pressure position at 260 psia or higher.
	OFF	Disconnects d-c power from H_2 tanks No. 1 and 2 heater elements.				
	ON	Controls d-c power directly to H_2 tanks No. 1 and 2 heater elements.				Switch at ON (manual) position bypasses the pressure switches applying d-c voltage directly to the same redundant heater elements employed for automatic operation.

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	O_2 HEATERS switches				None	Redundant heater elements in each O_2 tank requires 77.5 watts of power for each element.
	Switches 1 and 2					
	AUTO	Controls d-c power to O_2 tanks No. 1 and 2 heater elements, respectively. Enables automatic pressure switches to control d-c power to O_2 tanks No. 1 and 2 heater elements.	CRYOGENIC SYSTEM - TANK HEATERS - O_2 - 1 MN A (MDC-22) CRYOGENIC SYSTEM - TANK HEATERS - O_2 - 2 MN B (MDC-22)	D-C main bus A D-C main bus B		Switch at AUTO position will apply d-c voltage to O_2 tanks No. 1 and 2 redundant heater elements when pressure switches in both tanks are in a low-pressure position at 865 psia or lower and will remove d-c voltage when either pressure switch is in a high-pressure position at 935 psia or higher.
	OFF	Disconnects d-c power from O_2 tanks No. 1 and 2 heater elements.				Switch at ON (manual) position bypasses the pressure switches, applying d-c voltage directly to the same redundant heater elements employed for automatic operation.
	ON	Controls d-c power directly to O_2 tanks No. 1 and 2 heater elements.				
	O_2 PRESS IND switch					TANK PRESSURE-1-O_2 indicator is shared by two pressure signals.
	TANK 1	Connects output of O_2 tank No. 1 pressure transducer to O_2 tank No. 1 TANK PRESSURE indicator (MDC-13).	ESSENTIAL -3 (RHEB 204) and fuse in S/M	S/M INSTR PWR DIST	SF0037P (Press O_2 tank 1)	Normal position of switch prior to CSM separation except for periodic surge tank readouts.
	SURGE TANK	Connects output of ECS SURGE TANK pressure transducer to O_2 tank No. 1 TANK PRESSURE indicator.	INSTRUMENTS ESS - MN A and MN B (MDC-22), also ESSENTIAL -2 (RHEB 204)	D-C main buses A and B	CF0006P (Press surge tank)	Normal position of switch following CSM separation.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	H_2 FANS switches				None	Redundant fan motors in each H_2 tank requires 63VA total.
	Switches 1 and 2	Controls a-c power to H_2 tanks No. 1 and 2 fan motors, respectively.	CRYOGENIC TANK FAN MOTORS -1- AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 1		
	AUTO	Applies a-c power to contacts on motor switch which controls 3Ø a-c power to circulating fan motors in H_2 tanks No. 1 and 2.				Switch at AUTO position will apply a-c voltage to H_2 tanks No. 1 and 2 redundant fan motors when pressure switches in both tanks are in a low-pressure position at 230 psia or lower and will remove a-c voltage when either pressure switch is in a high-pressure position at 260 psia or higher.
	OFF	Disconnects 3Ø a-c power from H_2 tanks No. 1 and 2 circulating fan motors.	CRYOGENIC TANK FAN MOTORS -2- AC 2 ØA ØB ØC (MDC-22)	A-C bus No. 2		
	ON	Controls 3Ø a-c power directly to circulating fan motors in H_2 tanks No. 1 and 2				Switch at ON (manual) position bypasses the pressure switches, applying a-c power directly to the same redundant H_2 tank fan motors employed for automatic operation.
	O_2 FANS switches					Redundant fan motors in each O_2 tank requires 148VA total.
	Switches 1 and 2		CRYOGENIC TANK FAN MOTORS -1- AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 1		
	AUTO	Applies a-c power to contacts on motor switch which controls 3Ø a-c power to circulating fan motors in O_2 tanks No. 1 and 2.				Switch at AUTO position will apply a-c power to O_2 tank No. 1 and 2 redundant fan motors when pressure switches in both tanks are in a low pressure position at 865 psia or lower and will remove a-c voltage when either pressure switch is in a high pressure position at 935 psia or higher.
	OFF	Disconnects 3Ø a-c power from O_2 tanks No. 1 and 2 circulation fan motors.	CRYOGENIC TANK FAN MOTORS -2- AC 2 ØA ØB ØC (MDC-22)	A-C bus No. 2		
	ON	Controls 3Ø a-c power directly to circulating fan motors in O_2 tanks No. 1 and 2.				Switch at ON (manual) position bypasses the pressure switches, applying a-c power directly to the same redundant O_2 tank fan motors employed for automatic operation.
	GLY EVAP STEAM PRESS indicator	Provides pressure indication of steam discharged from water-glycol evaporator.	ECS - TRANS-DUCER PRESS GROUPS 2 MN A MN B (MDC-22)	D-C main buses A and B	CF0034P (Press glycol evap out steam)	Normal steam duct pressure operating range is 0.97 to 0.145 psia.

MAIN DISPLAY CONSOLE—PANEL 11

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Panel	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	PRESS GLY DISCH indicator	Provides static pressure indication of water-glycol pump discharge	ECS-TRANS-DUCER-PRESS GROUPS 1 MN A MN B (MDC-22)	D-C main buses A and B	CF0016P (Press glycol pump outlet)	Normal water-glycol pump operating range indications are as follows: Prelaunch (GSE and onboard pumps): 14 to 18 psia Prelaunch (onboard pumps): 45 to 55 psia Normal flight: 37 to 45 psia Emergency flight: 37 to 45 psia
	FLOW O_2 indicator	Provides total rate-of-flow indication of oxygen supplied to the ECS downstream of the flow transducer.	ECS TRANS-DUCER - PRESS GROUPS 2 MN A MN B (MDC-22)		CF0035R (Flow rate ECS O_2)	Indicator will not show O_2 flow upstream of transducer, such as through PLSS FILL valve (LHEB-314), main regulator or surge tank relief valve action, or line leakage. O_2 FLOW HI system status light (red) is located on MDC-11 and illuminates at a flow rate of 1.0 lb/hr. Normal O_2 flow operating range indications are from 0.20 to 0.45 lb/hr during prelaunch and in flight.
	ΔP SUIT COMPR indicator	Provides pressure differential indication between suit compressor inlet and outlet manifolds to determine degree of compressor efficiency.	ECS TRANS-DUCER - PRESS GROUPS 1 MN A MN B (MDC-22)		CF0015P (Press suit compressor diff)	Suit compressor ΔP operating range indications are as follows: 0.7 to 0.9 psi during prelaunch 0.3 to 0.4 psi during normal space flight 0.2 to 0.3 psi during emergency space flight.
	GLY ACCUM-QUANTITY indicator	Provides quantity indication of water-glycol in accumulator.			CF0019Q (Quantity glycol accum)	Capacity of accumulator is 1.36 lb. Normal accumulator operating range indications are as follows: Prelaunch (GSE) and onboard pump): 0% Normal flight: 40 to 60% Emergency flight: 40 to 60%
	WATER-QUANTITY indicator	Provides quantity indication of waste water tank or potable water tank as selected by H_2O IND switch (MDC-13).	ECS TRANS-DUCER WASTE & POT H_2O MN A MN B (MDC-22)		CF0009Q (Quantity waste water tank) CF0010Q (Quantity potable H_2O tank)	Capacities of the water tanks are 36 lb of potable water and 56 lb of waste water. Water quantity indications are dependent upon a selected mission profile and specific times during the mission.

CONTROLS AND DISPLAYS

Location	Control and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	ECS RAD-OUTLET TEMP indicator	Provides temperature indication of water-glycol returned to C/M from S/M space radiators (or from GSE during prelaunch).	ECS TRANS-DUCER TEMP MN A MN B (MDC-22)	D-C main buses A and B	CF0020T (Temp space radiator outlet)	GLYCOL TEMP LOW system status light (yellow) is located on MDC-11, and illuminates at +30°F. Normal ECS radiator outlet temperature operating range is 30° to 102°F.
	GLY EVAP-OUTLET TEMP indicator	Provides temperature indication of water-glycol at outlet of water-glycol evaporator.			CF0016T (Temp glycol evap outlet liquid)	Normal water-glycol operating range indications are 40° to 50°F during prelaunch and 40° to 50.5°F in flight.
	TEMP indicators SUIT	Provides temperature indication of suit circuit atmosphere.			CF0008T (Temp suit supply manl)	Temperature sensor located in suit heat exchanger outlet duct. Normal suit circuit operating range indications are 45° to 55°F during prelaunch and in flight.
	CABIN	Provides average temperature indication of cabin atmosphere.			CF0002T (Temp cabin)	Sensor located near inlet to cabin air fans. Normal cabin operating range indications are 50° to 70°F during prelaunch and 70° to 80°F in flight.
	PRESS indicators SUIT	Provides pressure indication of suit circuit atmosphere.	ECS-TRANS-DUCER PRESS GROUPS 1 MN A MN B (MDC-22)		CF0012P (Press suit demand reg sense)	Pressure transducer located at demand regulator sensing port. Normal suit circuit operating range indications are as follows: 14.7 psia during prelaunch, 4.7 to 5.3 psia during normal flight mode, and 3.75±0.25 psia during emergency flight mode.

MAIN DISPLAY CONSOLE—PANEL 11

[illegible]	Nomenclature or Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	CABIN	Provides pressure indication of cabin atmosphere.	ECS - TRANS-DUCER - PRESS GROUPS 2 MN A MN B (MDC-22)	D-C main buses A and B	CF0001P (Pressure cabin)	Pressure transducer located inside LHFEB. Normal cabin operating range indications are as follows: 14.7 psia during prelaunch, 4.8 to 5.2 psia during normal space flight, and 0.0 psia during emergency space flight.
	PART PRESS CO_2 indicator	Provides partial pressure indication of CO_2 in suit circuit atmosphere.	ECS - TRANS-DUCER - PRESS GROUPS 2 MN A (MDC-22)	D-C main bus A	CF0005P (Press CO_2 partial)	CO_2 sensor is located between inlet and outlet manifolds of suit circuit in LHEB. The CO_2 partial pressure normal metabolic operating range is 0.0 to 7.6 mm Hg, and the emergency metabolic operating range is 7.6 to 15.0 mm Hg. Both ranges are for an unlimited length of time. CO_2 PP HI system status light (MDC-11) illuminates at 7.6 mm Hg. This indicates CO_2 level has risen to the upper end of the normal operating range.
	H_2O ACCUM switches AUTO 1/MAN/ AUTO 2 switch				None	In automatic mode, 10-second pulse signal for accumulator operation is received from CTE.
	AUTO 1	a. Removes d-c power from H_2O ACCUM-ON 1/ON 2 switch (MDC-13). b. Applies d-c power to No. 1 cyclic accumulator control unit to automatically time and actuate No. 1 cyclic accumulator valve for 10 seconds every 10 minutes.	ECS-H_2O ACCUM-MN A (MDC-22)	D-C main bus A		
	MAN	a. Removes d-c power from No. 1 and No. 2 cyclic accumulator control units. b. Applies d-c power to H_2O ACCUM-ON 1/ON 2 switch, permitting manual control of No. 1 or No. 2 cyclic accumulator valves.	ECS-H_2O ACCUM-MN A MN B (MDC-22)	D-C main buses A and B		Switch position selects manual backup mode, permitting manual cyclic accumulator valve actuation in event both cyclic accumulator automatic control units should fail.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	AUTO 2	a. Removes d-c power from H_2O ACCUM-ON 1/ON 2 switch. b. Applies d-c power to No. 2 cyclic accumulator control unit to automatically time and actuate No. 2 cyclic accumulator valve for 10 seconds every 10 minutes.	ECS - H_2O ACCUM-MN B (MDC-22)	D-C main bus B	None	
	ON 1/ON 2 switch					
	ON 1	Back up switch position to apply d-c power to solenoid valve of No. 1 cyclic accumulator, manually controlling oxygen flow to accumulator.	ECS - H_2O ACCUM-MN A (MDC-22)	D-C main bus A		Switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
	Off (center)	Removes power from both solenoid valves, shutting off oxygen flow to either accumulator.				
	ON 2	Back up switch position to apply d-c power to solenoid valve of No. 2 cyclic accumulator, manually controlling oxygen flow to accumulator.	ECS - H_2O ACCUM-MN B (MDC-22)	D-C main bus B		This switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
	WASTE H_2O TK REFILL switch		POT H_2O HTR MN B (MDC-22)			Switch positions are not momentary; therefore, water quantity indicators must be monitored to prevent overfilling.
	1	Applies d-c power to solenoid valve of S/M water tank No. 1, permitting water flow to refill C/M water tanks.				Potable tank will fill first, unless POTABLE TANK INLET valve is closed. Flow is at the rate of 2.92 lb per minute.
	OFF	Removes power from both solenoid valves.				
	2	Applies d-c power to solenoid valve of S/M water tank No. 2, permitting water flow to refill C/M water tanks.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	SUIT EVAP switch AUTO	Applies a-c power to the following to automatically regulate suit circuit temperature by the water-glycol or water evaporation cooling modes: a. Suit evaporator wetness control unit b. Steam pressure control unit c. Diverter valve control unit.	ECS-GLYCOL PUMPS - AC 1 ØB (MDC-22)	A-C bus No. 1	None	The AUTO position must be selected in conjunction with the use of the SUIT HT EXCH switch (LHEB-310). The control unit temperature sensor is located in the suit evaporator outlet. The suit temperature indicator sensor, however, is located at the suit heat exchanger outlet duct. The MAN position is selected in event of failure of any automatic control unit.
	MAN	Removes a-c power from the following to permit manual override operation of SUIT EVAP GLYCOL valve (LHEB-314): a. Suit evaporator wetness control unit b. Steam pressure control unit c. Diverter valve control unit.				
	H_2O IND switch POT	Selects potable water tank quantity signal for display on WATER-QUANTITY indicator (MDC-13).	ECS-TRANSDUCER - WASTE & POT H_2O - MN A M N B (MDC-22)	D-C main buses A and B		WATER-QUANTITY indicator is shared by two quantity signals.
	WASTE	Selects waste water tank quantity signal for display on WATER-QUANTITY indicator.				
	GLYCOL EVAP switches H_2O FLOW switch AUTO	a. Applies a-c power to water control section. b. Closes circuit from control section to water control valve for automatically regulating water inflow to water-glycol evaporator.	ECS - GLYCOL PUMPS - AC 1 ØC (MDC-22)	A-C bus No. 1		
	Off (center)	Removes a-c power from water control section and d-c power from water control valve.				Water control valve is solenoid-operated.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	ON	Manual backup mode to apply d-c power to solenoid-operated water control valve, which opens valve and permits water to enter water-glycol evaporator.	ECS - POT H_2O HTR MN A MN B (MDC-22)	D-C main buses A and B	None	This switch position is not momentary. Close coordination between switch actuation and the GLY EVAP-OUTLET TEMP indicator (MDC-13) is necessary to obtain correct water-glycol temperature and/or to prevent flooding the evaporator.
	STEAM PRESS group					Steam pressure control valve full-travel requires 58 seconds (max).
	AUTO/MAN switch					
	AUTO	a. Removes a-c power from GLYCOL EVAP - STEAM PRESS - INCR/DECR switch (MDC-13). b. Applies a-c power to steam pressure control section. c. Closes circuit from control section to steam pressure control valve to automatically regulate pressure in steam duct.	ECS-GLYCOL PUMPS-AC 1 ØC (MDC-22)	A-C bus No. 1		
	MAN	a. Removes a-c power from steam pressure control section. b. Opens circuit from control section to steam pressure control valve. c. Applies a-c power to GLYCOL EVAP-STEAM PRESS-INCR/DECR switch.				This switch position selects manual backup mode, permitting manual operation of steam pressure control valve actuator in event of steam pressure control section malfunction.
	INCR/DECR switch					
	INCR	Applies a-c power to actuator of steam-pressure control valve, which moves valve in the closed direction and increases the steam duct pressure.				This switch position is momentary. Until motor-driven steam pressure control valve reaches its maximum limit, short periods of switch activation result in proportional increases in steam duct pressure. Valve full-travel requires 58 seconds (max).
	Off (center)	Removes a-c power from valve actuator.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	DECR	Applies a-c power to actuator of steam pressure control valve, which moves valve in the open direction and decreases the steam duct pressure.	ECS-GLYCOL PUMPS-AC 1 ØC (MDC-22)	A-C bus No. 1	None	This switch position is momentary. Until motor-driven steam pressure control valve reaches it maximum limit, short periods of switch activation result in proportional decreases in steam duct pressure. Valve full-travel requires 58 seconds (max).
	TEMP IN switch		ECS-GLYCOL PUMPS-AC 1 ØA (MDC-22)			Temperature control unit sensor is located at inlet to water-glycol evaporator.
	AUTO	Applies a-c power to water-glycol temperature control unit, which automatically regulates temperature of coolant entering evaporator by mixing hot and cold water-glycol.				Water-glycol evaporator temperature control valve full travel requires 37.5 seconds (max).
	MAN	Removes a-c power from water-glycol temperature control unit, permitting manual override operation of GLYCOL EVAP TEMP IN valve (LHEB-311) by T-handle tool.				Manual control of water-glycol evaporator temperature control valve is required in event of failure of automatic control unit. Close coordination between valve adjustments and GLY EVAP-OUTLET TEMP and ECS RAD-OUTLET TEMP indicators (MDC-13) is necessary to obtain correct water-glycol temperature.
	CABIN TEMP controls					Temperature control unit sensor is located at inlet to cabin air fans; also, an anticipator (sensor) is located at outlet of cabin air fans.
	AUTO/MAN switch					
	AUTO	Applies a-c power to cabin temperature control unit to automatically regulate temperature of water-glycol flow through cabin heat exchanger.	ECS-CABIN AIR FAN 2 ØC (MDC-22)	A-C bus No. 2		Cabin temperature control valve full travel requires 25 seconds (max).
	MAN	Removes a-c power from cabin temperature control unit, permitting manual override operation of the CABIN TEMP control valve (LHFEB-303) by properly positioning control knob.				Manual control of cabin temperature control valve is required in event of failure of automatic control unit. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary.

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	AUTO control INCR (upward)	Thumbwheel permits manual adjustment of cabin temperature automatic control unit. The higher the number selected, the greater proportional increase in cabin temperature.	None	None	None	Cabin temperature can be selected between 70° and 80°F. Numbers on thumbwheel do not correspond to any temperature.
MDC-14 AGC DSKY panel	COMP FAIL light	Indicates AGC malfunction.	G&N - COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	
	KEY RLSE light	Internal AGC program needs DSKY circuits to continue program.				Request for operator to press KEY RLSE pushbutton.
	UPTEL switch ACCEPT BLOCK	Controls acceptance of telemetered data from MSFN. Allows AGC to accept data from MSFN. Inhibits AGC reception of MSFN data.			GG5021X (AGC alarm 2)	
	ACTIVITY lights UPTL COMP	Indicates activity the computer is presently engaged in. AGC is receiving data link information by telemetry. AGC is engaged in computation.				
	PROGRAM indicator	A two-digit display indicating the number of the program (major mode) presently in progress.			None	On-board data provides definition of PROGRAM, NOUN, and VERB digits.
	VERB indicator	A two-digit display indicating verb code selected.				
	NOUN indicator	A two-digit display indicating noun code selected.				
	REGISTER 1 indicator	Displays contents of selected register or memory location. First component of extended-length data word, if applicable.				Displays may be selected manually or by AGC program.

MAIN DISPLAY CONSOLE—PANELS 13 AND 14

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-14 (Cont)	REGISTER 2 indicator	Displays contents of selected register or memory location. Second component of extended-length data word, if applicable.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	
	REGISTER 3 indicator	Displays contents of selected register or memory location. Third component of extended-length data word, if applicable.				Displays may be selected manually or by AGC program.
	BRIGHTNESS control	Varies brightness of electro-luminescent data displays: REGISTER 1, REGISTER 2, and REGISTER 3.				
	KEY RLSE pushbutton	Enables program control of DSKYs. Releases operator control of DSKY circuits.				
	ERROR RESET pushbutton	Resets alarm light relays. AGC recycles to start of current operation.				Verifies alarms. Alarms triggered by transients should not repeat.
	Keyboard switches	Provide for entering data into or commanding operation of the AGC.				Pushbutton-type switches (selectors). Each key generates a specific 5-bit key code denoting the instruction or number being selected.
	CLEAR	Place all zeros (logic 0s) in register being loaded.				
	VERB	Sets computer to accept next two digits as verb code.				
	NOUN	Sets computer to accept next two digits as noun code.				
	ENTER	Transfers contents of input register to central processor and initiates execution of instructions.				
	+	Denotes data to follow has positive decimal value.				
	-	Denotes data to follow has negative decimal value.				
	0 to 9	Enters the binary equivalent of the key pressed.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15	H_2 PURGE LINE HTR switch		FUEL CELL 1 - PURGE and FUEL CELL 2 - PURGE (MDC-22)	D-C main buses A and B	None	Two-position double-pole toggle switch provides heater power during H_2 purge of fuel cells. Positioned to ON 30 min before H_2 purge.
	ON	Applies +28 vdc power to two 2-watt heaters in fuel cell H_2 vent line.				
	OFF	Remove +28 vdc power from heaters.				Positioned to OFF after completing H_2 purge.
	HELIUM 1 switches	Four functionally identical switches. Each switch controls one helium isolation valve in the HELIUM 1 half of a parallel helium pressurization system. Each of the four RCS packages contains identical systems.	RCS-PROP *ISOL* MN A MN B (MDC-25)			Each switch is a three-position toggle switch, spring-loaded, causing it to return to the center position after setting it to the ON or OFF position. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator mechanism. Each valve also contains an open and close mechanical latching feature.
	A (B, C, D)					
	ON	Energizes helium isolation valve solenoid that drives the valve to the open position.				
	Center	Removes solenoid excitation; valve remains in last commanded position.				
	OFF	Energizes helium isolation valve solenoid that drives the valve to the closed position.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15 (Cont)	HELIUM 1 event indicators		RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action.
	A (B, C, D)	Striped-line display indicates closed condition of valve controlled by switch located directly above event indicator. Gray display indicates open condition.				
	HELIUM 2 switches	Four functionally identical switches. Each switch controls one helium isolation valve in the HELIUM 2 half of a parallel helium pressurization system. Each of the four RCS packages contain identical systems.				Each switch is a three-position toggle switch, spring loaded, causing it to return to the center position after placing it to the ON or OFF positions. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator mechanism. Each valve is mechanically latched open and spring-loaded closed.
	A (B, C, D)					
	ON	Energizes helium isolation valve solenoid that drives the valve to the open position.				
	Center	Removes solenoid excitation; valve remains in last commanded position.				
	OFF	Energizes helium isolation valve solenoid that drives the valve to the closed position.				
	HELIUM 2 event indicators					Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action.
	A (B, C, D)	Striped-line display indicates closed condition of valve controlled by switch located directly above event indicator. Gray display indicates open condition.				
	PROPELLANT switches	Four functionally identical switches. Each switch controls two isolation valves (one fuel, one oxidizer) within each of the four S/M RCS packages.				Each switch is a three-position toggle switch, spring-loaded, causing it to return to the center position after placing it to the ON or OFF positions. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator. Each valve is magnetically latched open and spring-loaded closed.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15 (Cont)	A (B, C, D) ON	Energizes propellant isolation valve solenoids that drive two valves to the open position.	RCS–PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	
	Center	Removes solenoid excitation; valves remain in last commanded position.				
	OFF	Energizes propellant isolation valve solenoids that drive two valves to the closed position.				
	PROPELLANT event indicators A (B, C, D)	Striped-line display indicates closed condition of valves controlled by switch located directly above event indicator. Gray display indicates open condition.				Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action. Indicator will function (striped-line display) if either valve is in a closed position.
	C/M-S/M SEP switches Switch 1 and 2 Up	Activates systems A and B to perform the following functions: a. C/M-S/M deadface b. C/M-RCS pressurize c. C/M-S/M separation d. Transfer entry batteries to d-c main buses A and B e. C/M-S/M separation pyro control shut-off f. RCS control transfer g. C/M-S/M separation signal to SMJC.	MASTER EVENT SEQ CONT A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0023X CM-SM separate relay close A CD0024X CM-SM separate relay close B	The switches are spring-loaded to the down position. The two switches are guarded redundant switches.
	Down	Off position.				
	C/M RCS PRPLNT group	Two functionally identical switches. Each switch controls two isolation valves (one fuel, one oxidizer) within its respective propellant system.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B		Each switch is a three-position switch. Switch is spring-loaded from the OFF position to center position only. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator mechanism. Each valve also contains an open and close latching feature.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15 (Cont)	A (B) switch ON	Energizes propellant isolation valve solenoids that drive two valves to the open position.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	
	Center	Removes solenoid excitation; valves remain in last commanded position.				
	OFF	Energizes propellant isolation valve solenoids that drive two valves to the closed position.				
	A (B) event indicators	Striped-line display indicates closed condition of valves controlled by switch located directly above event indicator. Gray display indicates open condition.				Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action. Indicator will function (striped-line display) if either valve is in a closed position.
MDC-16	ELS switch AUTO	a. Prepares ELS for automatic enabling during LES abort. b. Allows the ELS to function automatically during descent of C/M.		MESC logic bus through Z12 ELS activate relays	None	Normal position of switch.
	MAN	Disconnects logic arming circuitry from ELS controller.				Switch is set to the MAN position after drogue parachute deployment during an abort initiated prior to 61 seconds after lift-off. The main parachutes must be deployed manually with the MAIN DEPLOY pushbutton (MDC-5) after the switch is set to the MAN position. If the main parachutes are deployed manually, the MAIN DEPLOY-AUTO switch must be set back to AUTO to allow 14-second timer to enable parachute release after touchdown.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-16 (Cont)	ABORT SYSTEM switches					
	OX DUMP switch					
	AUTO	Enables circuitry through a 61-second timer to automatically dump the C/M RCS oxidizer during a pad or low-altitude abort prior to 61 seconds after lift-off.	MASTER EVENT SEQ CONT-A LOGIC B-BAT A BAT B (MDC-22)	Logic bus in the master event sequence controller	None	The 61-second timer, enabled by CM PROP JETT-LOGIC switch (MDC-8), starts at lift-off. The auto dump capability is disabled after the 61-seconds. Dump time is approximately 11 seconds.
	RCS CMD AUTO	Disables the auto oxidizer dump and allows the G&N/SCS system to be automatically enabled upon C/M-S/M separation to control the command module RCS during descent.				During normal ascent, the OX DUMP switch is moved to the RCS CMD AUTO position 61 seconds after lift-off.
	2 ENG OUT switch		None	L/V-IU batteries	L/V telemetry via IU	
	AUTO	Activates the EDS for a two-engine out automatic abort capability by de-energizing the two-engine out auto abort deactivate relays.				
	OFF	Deactivates the EDS for a two-engine out automatic abort capability by energizing the two-engine out auto abort deactivate relays.				The two-engine out auto abort capability is also shutoff automatically by the IU.
	L/V RATES switch					
	AUTO	Activates the EDS for an excessive rates automatic abort capability by de-energizing the excessive rates auto abort deactivate relays.				
	OFF	Deactivates the EDS for an excessive rates automatic abort capability by energizing the excessive rates auto abort deactivate relays.				The excessive rates auto abort capability is also shut off automatically by the IU.

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MAIN DISPLAY CONSOLE—PANEL 1

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-1 (Cont)	MODE switches					The two switches are guarded.
	LES MODE	Enables systems A and B to use the launch escape system in case of an abort.	MASTER EVENT SEQ CONT - A LOGIC B - BAT A (MDC-22)	a. Battery buses A and B when the MESC LOGIC/OFF switch is in the LOGIC position b. EDS change over bus	None	
	TWR JETT SPS MODE	Initiates jettison of the LES tower and arms system A and B of the SPS abort circuitry.			CD0105X Tower jettison A CD0106X Tower jettison B	After LET jettison, all aborts must be manually initiated and made in the SPS mode.
	REACTION CONTROL SYS group					
	CMD switch		MASTER EVENT SEQ CONT - A ARM B BAT A BAT B (MDC-22)	Battery buses A and B		Three-position toggle switch, spring-loaded to the center position. Switch allows manual inhibit-enable of SCS inputs to the automatic coils of the C/M or S/M RCS engines. Inhibit-enable functions provide backup capability to MESC control of the RCS latching relay.
	ON	Energizes latching relay, connecting SCS jet selection logic to RCS engines.				
	Center	Enables MESC automatic control of latching relay.			None	Switch is momentarily set to ON after adapter separation. This function is accomplished automatically by the MESC 0.8 seconds after initiation of adapter separation with the ADAPT SEP pushbutton (MDC-5). If LES abort occurs after T + 61 seconds, the MESC automatically closes the relay 1 second after abort initiation. If an SPS abort occurs, the MESC automatically closes the relay 2.5 seconds after abort initiation. The MESC baroswitch input automatically causes the relay to open at approximately 24,000 feet during C/M descent.
	OFF	De-energizes latching relay, disconnecting SCS jet selection logic from RCS engines.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-16 (Cont)	C/M PRESS switch Up	Activates helium isolation squib valves in both systems A and B.	MASTER EVENT SEQ CONT - A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	None	
	Down	No function.				
	TRANS switch C/M	Energizes motor switch causing the following: a. Connects C/M RCS engines to SCS jet selection logic control circuits. b. Disables translation controls.	RCS-C/M - S/M TRANSFER MN A MN B (MDC-25)	D-C main buses A and B		Three-position switch, spring-loaded to the center position. Switch provides manual backup for automatic transfer function.
	Center	Enables MESC automatic control of motor switch.				
	S/M	Energizes motor switch, causing contacts to close which connect S/M RCS engines to SCS jet selection logic control circuits.				
	EDS switch AUTO	Prepares the L/V EDS auto abort circuitry for automatic enabling at lift-off.	MASTER EVENT SEQ CONT - A LOGIC B - BAT A BAT B (MDC-22)	Battery buses A and B		Two-position toggle switch.
	OFF	All auto abort capabilities are disabled.				
	MAIN CHUTE RELEASE switch Up	Releases the main parachutes from the command module.	MASTER EVENT SEQ CONT - A LOGIC B - BAT A BAT B (MDC-22)	MESC logic buses A and B	CE0321X CE0322X (Main chute disconnect relays A and B)	The switch is electrically enabled when the 10,000 feet baroswitch closes during descent and will release the parachutes when actuated. The switch should never be moved to the up (release) position until after landing impact. The switch is spring-loaded to the down position and guarded.
	Down	Disables the parachutes release circuitry.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18	MASTER ALARM switch-light	Red light illuminates to alert crewman in RH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	MASTER ALARM lights on MDC-3, -18, and LEB-103 are simultaneously illuminated, and an audio alarm tone is sent to each headset. The MASTER ALARM switch-light contains an integral push-switch. Pressing the switch-light will reset the master alarm circuit, extinguishing the MASTER ALARM lights and shutting off the audio alarm.
	pH HI event indicator Striped-line display	Indicates pH factor of water from selected fuel cell is over 9, indicating a leakage of KOH electrolyte into the potable water supply.			SC2160Z (pH factor water condition F/C No. 1)	A pH factor of 7 designates pure water. (Water is potable with a pH factor below 9.) Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The pH HI event indicator is part of the C&WS.
	Gray display	Indicates pH factor of water from selected fuel cell is below 9.			SC2161Z (pH factor water condition F/C No. 2) SC2162Z (pH factor water condition F/C No. 3)	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	F/C RAD TEMP LOW event indicator Striped-line display Gray display	Indicates selected fuel cell glycol temperature at radiator outlet has dropped to -30°F or less. Indicates selected fuel cell glycol temperature at radiator outlet is above -30°F.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2087T (Temp F/C No. 1 radiator outlet) SC2088T (Temp F/C No. 2 radiator outlet) SC2089T (Temp F/C No. 3 radiator outlet)	Glycol operating range is -50° to +300°F. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The F/C RAD TEMP LOW event indicator is part of the C&WS.
	FUEL CELL indicators FLOW group H_2 indicator	Indicates flow rate of H_2 into selected fuel cell.			SC2139R (Flow rate H_2 F/C No. 1) SC2140R (Flow rate H_2 F/C No. 2) SC2141R (Flow rate H_2 F/C No. 3)	Normal operating range (indicator green band) is 0.036 lb/hr to 0.163 lb/hr. Alarm limits to caution and warning system are 0.028 lb/hr lower, 0.153 lb/hr upper. Sensors for the indicator are located in the F/C H_2 inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15 (Cont)	O_2 indicator	Indicates flow rate of O_2 into selected fuel cell.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2142R (Flow rate O_2 F/C No. 1) SC2143R (Flow rate O_2 F/C No. 2) SC2144R (Flow rate O_2 F/C No. 3)	Normal operating range (indicator green band) is 0.288 lb/hr to 1.304 lb/hr. Alarm limits to caution and warning system are 0.22 lb/hr lower, 1.22 lb/hr upper. Sensors for the indicator are located in the FUEL CELL O_2 inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).
	MODULE TEMP group SKIN indicator	Indicates skin temperature of selected fuel cell.			SC2084T (Temp F/C No. 1 skin) SC2085T (Temp F/C No. 2 skin) SC2086T (Temp F/C No. 3 skin)	Normal indication is 385° to 500°F. Alarm limits to caution and warning system are 360°F lower, 500°F upper. Sensors for the indicator are located in the pressurized portion of the fuel cells. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).
	COND EXH indicator	Indicates temperature of selected fuel cell condenser exhaust.			SC2081T (Temp F/C No. 1 cond exhaust) SC2082T (Temp F/C No. 2 cond exhaust) SC2083T (Temp F/C No. 3 cond exhaust)	Condenser exhaust operating range is 155°F to 175°F. Alarm limits to caution and warning system are 155°F to 175°F. Sensors for the indicator are located in the exhaust manifolds of the fuel cell condensers. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	REG OUT PRESS HI event indicators		CAUT/WARN-MN A MN B (MDC-25)	D-C main buses A and B		Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The REG OUT PRESS HI event indicators are part of the C&WS.
	H_2 event indicators					Sensors for the indicator are located in the hydrogen pressure regulators.
	Striped-line display	Indicates when output pressure of H_2 regulator rises to 75 psia or greater on selected fuel cell.			SC2069P (H_2 pressure F/C No. 1 regulated)	
	Gray display	Indicates pressure is less than 75 psia.			SC2070P (H_2 pressure F/C No. 2 regulated)	Normal regulator output pressure is 61.5 psia.
					SC2071P (H_2 pressure F/C No. 3 regulated)	
	O_2 event indicator					Sensors for the indicator are located in the F/C oxygen pressure regulators.
	Striped-line display	Indicates when output pressure of O_2 regulator rises to 75 psia or greater on selected fuel cell.			SC2066P O_2 pressure F/C No. 1 regulated)	
	Gray display	Indicates pressure is less than 75 psia.			SC2067P O_2 pressure F/C No. 2 regulated)	Normal regulator output pressure is 63.5 psia.
					SC2068P O_2 pressure F/C No. 3 regulated)	

MAIN DISPLAY CONSOLE—PANEL 18

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	N_2 event indicator Striped-line display	Indicates when output pressure of N_2 regulator rises to 70 psia or greater on selected fuel cell.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2060P (N_2 pressure F/C No. 1 regulated) SC2061P (N_2 pressure F/C No. 2 regulated) SC2062P (N_2 pressure F/C No. 3 regulated)	Sensors for the indicator are located in the nitrogen pressure regulators.
	Gray display	Indicates pressure is less than 70 psia.				Normal regulator output pressure is 53 psia.
	FUEL CELL switches Purge group Switches 1, 2 and 3 H_2 PURGE	Accomplish purging of selected fuel cell. Opens purge valve on H_2 side of selected fuel cell to purge impurities from H_2 electrodes.	FUEL CELL 1 - PURGE (MDC-22)		None	When purging the selected fuel cell, the C&WS will alarm if the reactants flow rate increases beyond the maximum normal flow rate. Purging (when operating at a 1420 w/fuel cell power level) is accomplished every 7 hours, alternating every 3-1/2 hours between O_2 and H_2. O_2 purge time (switch ON) is 2 minutes and H_2 purge time (switch ON) is 80 seconds. O_2 and H_2 maximum flow rates during purge is 0.6 and 0.75 lb/hr above normal flow rates, respectively. Effect of purge can be monitored by FUEL CELL INDICATORS switch and DC INDICATORS switch and their associated displays.
	Center (off)	Disconnects power from selected F/C O_2 or H_2 purge valve, closing valve (normal switch position).	FUEL CELL 2- PURGE (MDC-22)			
	O_2 PURGE	Opens purge valve on O_2 side of selected fuel cell to purge impurities from O_2 electrodes.	FUEL CELL 3- PURGE (MDC-22)			
	REACTANTS group	Provides ON - OFF control of reactant flow (H_2 and O_2) for selected fuel cells.				These switches control solenoid valves, which accomplish control of reactant flow.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	Switches 1, 2 and 3 ON (Center) OFF	Momentary switch position connects d-c power to selected fuel cell O_2 and H_2 shutoff valve actuators, driving valves to open position. Valves remain in last selected position (normal switch position). Momentary switch position connects d-c power to selected fuel cell O_2 and H_2 shutoff valve actuators, driving valves to closed position.	FUEL CELL 1 - H_2 & O_2 VALVE (MDC-22) FUEL CELL 2 - H_2 & O_2 VALVE (MDC-22) FUEL CELL 3 - H_2 & O_2 VALVE (MDC-22)	Battery relay bus	SC2323X (Fuel cell No. 1 shut-off monitor) SC2324X (Fuel cell No. 2 shutoff monitor) SC2325X (Fuel cell No. 3 shut-off monitor)	Event indicators, located directly below their respective switches, display striped lines when both H_2 and O_2 shutoff valves are in closed (abnormal) position. **Warning** Do not inadvertently position REACTANT switches OFF. Loss of fuel cell may result.
	Event Indicators 1, 2 and 3 Striped-line display Gray display	Indicates when H_2 and O_2 shutoff valves are closed on selected fuel cell. Indicates normal (open) position of valves.	FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)		SC2323X (Fuel cell No. 1 shut-off monitor) SC2324X (Fuel cell No. 2 shut-off monitor) SC2325X (Fuel cell No. 3 shut-off monitor)	Event indicators function in conjunction with their respective switches located directly above.
	MAIN BUS A group Switches 1, 2 and 3 ON (Center)	Controls fuel cells No. 1, 2 and 3 electrical output to d-c main bus A. Momentary switch position connects electrical output of selected fuel cell to d-c main bus A. Connects C&W alarm and F/C - BUS DISCONNECT indicator light (MDC-11) to selected fuel cell motor switch (normal position of switch).	FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)		SC2120X (Fuel cell No. 1 bus A disconnect SC2121X (Fuel cell No. 2 bus A disconnect) SC2122X (Fuel cell No. 3 bus A disconnect)	When fuel cell main bus switches are placed to ON position, power is applied to a motor-driven switch located in an overload and reverse current sensing unit in the S/M. This accomplishes actual switching function required to apply output of selected fuel cell to d-c main bus A. Only one F/C BUS DISCONNECT status light (MDC-11) for all three F/C's.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	OFF	Disconnects electrical output of selected fuel cell from d-c main bus A.	FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)	Battery relay bus	SC2120X (Fuel cell No. 1 bus A disconnect) SC2121X (Fuel cell No. 2 bus A disconnect) SC2122X (Fuel cell No. 3 bus A disconnect)	
	Reset switch	Provides capability of resetting d-c main bus A undervoltage protection circuit.	SNSR UNIT - DC BUS - A (MDC-21)		None	D-C main bus A undervoltage sensing circuit energizes MN BUS A UNDER-VOLT warning light (MDC-11) when d-c voltage drops below 26.25 vdc.
	RESET	*Momentary switch position resets d-c main bus A undervoltage sensing unit.*				
	(Center)	Connects MN BUS A UNDER-VOLT warning light to d-c bus A undervoltage sensing circuit.				
	OFF	Disconnects MN BUS A UNDER-VOLT warning light from d-c bus A undervoltage sensing circuit.				
	Event Indicators 1, 2 and 3		FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)		SC2120X (Fuel cell No. 1 bus A disconnect) SC2121X (Fuel cell No. 2 bus A disconnect) SC2122X (Fuel cell No. 3 bus A disconnect)	Event indicators function in conjunction with their respective switches located directly above.
	Striped-line display	Indicates when selected F/C is removed from d-c main bus A.				
	Gray display	Indicates selected F/C is connected to bus.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	MAIN BUS B group					
	Switches 1, 2 and 3	Controls fuel cells No. 1, 2 and 3 electrical output to d-c main bus B.	FUEL CELL 1 - BUS CONT (MDC-22)	Battery relay bus	SC2125X (Fuel cell No. 1 bus B disconnect)	When fuel cell main bus switches are placed to ON position, power is applied to a motor-driven switch located in an overload and reverse current sensing unit in the S/M. This accomplishes actual switching function required to apply output of selected fuel cell to d-c main bus B. Only on F/C BUS DISCONNECT status light (MDC-11) for all three fuel cells.
	ON	Momentary switch position connects electrical output of selected fuel cell to d-c main bus B.	FUEL CELL 2 - BUS CONT (MDC-22)		SC2126X (Fuel cell No. 2 bus B disconnect)	
	(Center)	Connects C&W alarm and F/C BUS DISCONNECT indicator light (MDC-11) to selected fuel cell motor switch (normal position of switch).	FUEL CELL 3 - BUS CONT (MDC-22)		SC2127X (Fuel cell No. 3 bus B disconnect)	
	OFF	Disconnects electrical output of selected fuel cell from d-c main bus B.				
	Reset Switch	Provides capability of resetting d-c main bus B undervoltage protection circuit.	SNSR UNIT - DC BUS - B (MDC-21)		None	D-C main bus B undervoltage sensing circuit energizes MN BUS B UNDER-VOLT warning light (MDC-11) when d-c voltage drops below 26.25 vdc.
	RESET	Momentary switch position resets d-c main bus B undervoltage sensing circuit.				
	(Center)	Connects MN BUS B UNDER-VOLT warning light to d-c bus B undervoltage sensing circuit.				
	OFF	Disconnects MN BUS B UNDER-VOLT warning from d-c bus B undervoltage sensing circuit.				
	Event Indicators 1, 2 and 3)		FUEL CELL 1 - BUS CONT (MDC-22)		SC2125X (Fuel cell No. 1 bus B disconnect)	Event indicators function in conjunction with their respective switches located directly above.
	Striped-line display	Indicates when selected fuel cell is removed from d-c main bus B.	FUEL CELL 2 - BUS CONT (MDC-22)		SC2126X (Fuel cell No. 2 bus B disconnect)	
	Gray display	Indicates selected fuel cell is connected to bus.	FUEL CELL 3 - BUS CONT (MDC-22)		SC2127X (Fuel cell No. 3 bus B disconnect)	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	FUEL CELL INDICATORS switch	Selects desired fuel cell to be monitored by the fuel cell display indicators.		Dependent on position (insignificant)	None	Indicators associated with switch are as follows: a. FLOW indicators H_2 and O_2 b. MODULE TEMP indicators SKIN and COND EXH c. REG OUT PRESS HI - O_2 d. REG OUT PRESS HI - H_2 e. REG OUT PRESS HI - N_2 f. pH HI g. F/C RAD TEMP LOW. **NOTE** Items a and b are analog signals. Items c through g are ON-OFF signals (event indicators).
	1	Applies selected outputs of fuel cell No. 1 to fuel cell display indicators.				
	2	Applies selected outputs of fuel cell No. 2 to fuel cell display indicators.				
	3	Applies selected outputs of fuel cell No. 3 to fuel cell display indicators.				
	BATTERY CHARGER switch	Controls a-c and d-c power to battery charger, and selects battery to be charged.	BATTERY CHARGER-MN A MN B AC PWR (MDC-22)	D-C main bus A and B and a-c bus No. 1 or No. 2	CC0214V (D-C voltage bat charger out)	Switch actuates battery charger input power control relay, routing a-c and d-c voltages through relay contacts to battery charger. Current flow is negligible when a battery is fully charged. MAIN BUS TIE switches (MDC-22) for selected battery must be off before a battery can be charged. A-C power for the battery charger is selected from a-c bus No. 1 or a-c bus No. 2 by the BAT CHGR switch (MDC-22).
	OFF	Disconnects electrical power from battery charger.				
	A	Controls a-c and d-c power to battery charger and routes output of battery charger to entry battery A.			CC0215C (D-C current bat charger out)	
	B	Controls a-c and d-c power to battery charger and routes output of battery charger to entry battery B.				
	C	Controls a-c and d-c power to battery charger and routes output of battery charger to post-landing battery C.				
	SUIT PACK	No function.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	DC VOLTS meter	Indicates d-c voltage of selected source, unit, or bus.		As selected by DC INDICATORS switch.	Refer to DC INDICATORS switch.	Meter functions in conjunction with DC INDICATORS switch. DC VOLTS meter range is 20 to 45 vdc.
	DC AMPS meter	Indicates d-c current of sele ed source, unit, or bus.				Meter functions in conjunction with DC INDICATORS switch. DC AMPS meter range is 0 to 100 amperes, 0 to 5 amperes expanded scale battery charger output.
	DC INDICATORS switch	Selects power source, bus, or unit to be monitored by DC VOLT and DC AMPS meters.				In some cases, only current or voltage is indicated by DC VOLTS and DC AMPS meters. In other cases, both voltage and current are indicated. These are listed in the function column associated with each position. The DC VOLTS meter will read slightly below 20 vdc when not in use. The DC AMPS meter will read zero amperes when not connected to a load.
	FUEL CELL -1	Applies output of fuel cell No. 1 shunt to DC AMPS meter.		Fuel cell No. 1	SC2113C (D-C current F/C No. 1 output)	
	FUEL CELL -2	Applies output of fuel cell No. 2 shunt to DC AMPS meter.		Fuel cell No. 2	SC2114C (D-C current F/C No. 2 output)	
	FUEL CELL -3	Applies output of fuel cell No. 3 shunt to DC AMPS meter.		Fuel cell No. 3	SC2115C (D-C current F/C No. 3 output)	
	MAIN BUS - A	Applies voltage of d-c main bus A to DC VOLTS meter.	SNSR UNIT - DC BUS - A (MDC-21)	D-C main bus A	CC0206V (D-C voltage main bus A)	
	MAIN BUS - B	Applies voltage of d-c main bus B to DC VOLTS meter.	SNSR UNIT - DC BUS - B (MDC-21)	D-C main bus B	CC0207V (D-C voltage main bus B)	
	BAT BUS - A	Applies both voltage and current of battery bus A to DC VOLTS and DC AMPS meters.		Battery bus A	CC0210V (D-C voltage battery bus A) CC0222C (D-C current battery A)	MASTER EVENT SEQ CONT-LOGIC-BAT A c/b (MDC-22) controls d-c voltage indication (voltage only) and measurement for telemetry.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	BAT BUS -B	Applies both voltage and current of battery bus B to DC VOLTS and DC AMPS meters.		Battery bus B	CC0211V (D-C voltage battery bus B) CC0223C (D-C current battery B)	MASTER EVENT SEQ CONT-LOGIC-BAT B c/b (MDC-22) controls d-c voltage indication (voltage only) and measurement for telemetry.
	BAT CHARGER	Applies both voltage and current output of battery charger to DC VOLT and DC AMFS meter (inner scale 0 to 5 amps).		Battery charger	CC0214V (D-C voltage battery charger out) CC0215C (D-C current battery charger out)	Charger current output will be according to charge required by battery (up to 2.5 amps).
	BAT C	Applies both voltage and current outputs of battery C to DC VOLTS and DC AMPS meters.	BAT CHGR BAT C (LEB-150)	Battery C	CC0212V (D-C voltage post-landing battery) CC0224C (D-C current post-landing battery)	Listed C/B will control d-c voltage indication and measurement for telemetry.
	PYRO BAT-A	Applies pyro battery A voltage to DC VOLTS meter when SEQ A cb is closed.	PYRO A - SEQ A	Pyro battery A		Normally closed cb. Open circuit monimal voltage of 37.2 vdc will be read on meter.
		Applies entry battery A voltage to DC VOLTS meter when BAT A to PYRO BUS TIE cb is closed.	BAT A TO PYRO BUS TIE	Entry battery A		Normally open cb. Open circuit nominal voltage of 37.2 vdc, or load voltage of 28 vdc will be read on meter.
	PYRO BAT-B	Applies pyro battery B voltage to DC VOLTS meter when SEQ B cb is closed.	PYRO B - SEQ B	Pyro battery B		Normally closed cb. Open circuit nominal voltage of 37.2 vdc will be read on meter.
		Applies entry battery B voltage to DC VOLTS meter when BAT B to PYRO BUS TIE cb is closed.	BAT B TO PYRO BUS TIE	Entry battery B		Normally closed cb. Open circuit nominal voltage of 37.2 vdc, or load voltage of 28 vdc will be read on meter.
	AC INVERTER switches				Refer to AC INDICATORS switch	Interlocking circuitry between AC INVERTER-AC BUS 1 and AC BUS 2 switches (MDC-18) prevents more than one inverter from being connected to any one bus at the same time.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	Switch 1	Controls d-c power to a-c inverter No. 1 by actuating a motor-driven switch which accomplishes actual switching function.	INVERTER CONTROL - 1 (MDC-22)	Battery relay bus	Refer to AC INDICATORS switch	Circuit breakers associated with delivering power to AC INVERTER No. 1 from d-c main bus A is INVERTER PWR - No. 1 - MN A on main circuit breaker panel (RHEB-203).
	MN A	Applies d-c power to a-c inverter No. 1.				
	OFF	Disconnects d-c power from a-c inverter No. 1.				
	Switch 2	Controls d-c power to a-c inverter No. 2 by actuating a motor-driven switch which accomplishes actual switching function.	INVERTER CONTROL - 2 (MDC-22)			Circuit breaker associated with delivering power to AC INVERTER No. 2 from d-c main bus B is INVERTER PWR - No. 2 - MN B on main circuit breaker panel (RHEB-203).
	MN B	Applies d-c power to a-c inverter No. 2.				
	OFF	Disconnects d-c power from a-c inverter No. 2.				
	Switch 3	Controls d-c power to a-c inverter No. 3 by actuating one of two motor-driven switches depending on bus selected.	INVERTER CONTROL - 3 (MDC-22)			Inverter No. 3 can receive power from either d-c main bus A or d-c main bus B. Associated circuit breakers are INVERTER PWR - No. 3 - MN A and - MN B (RHEB-203).
	MN A	Applies d-c power from main bus A to a-c inverter No. 3.				
	OFF	Disconnects d-c power from a-c inverter No. 3.				
	MN B	Applies d-c power from main bus B to a-c inverter No. 3.				
	AC BUS 1 group					Actuates a motor-driven switch which accomplishes actual switching function.
	Switch 1	Controls a-c output of inverter No. 1 to a-c bus No. 1	INVERTER CONTROL - 1 (MDC-22)			
	ON	Applies a-c output of inverter No. 1 to a-c bus No. 1				
	OFF	Disconnects a-c output of inverter No. 1 from a-c bus No. 1.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	Switch 2	Controls a-c output of inverter No. 2 to a-c bus No. 1.	INVERTER CONTROL - 2 (MDC-22)	Battery relay bus	Refer to AC INDICA-TORS switch	
	ON	Applies a-c output of inverter No. 2 to a-c bus No. 1.				
	OFF	Disconnects a-c output of inverter No. 2 from a-c bus No. 1.				
	Switch 3	Controls a-c output of inverter No. 3 to a-c bus No. 1.	INVERTER CONTROL - 3 (MDC-22)			
	ON	Applies a-c output of inverter No. 3 to a-c bus No. 1.				
	OFF	Disconnects a-c output of inverter No. 3 to a-c bus No. 1.				
	RESET/OFF switch	Provides capability of resetting a-c bus No. 1 over undervoltage and overload sensing unit. Also releases relay which reconnects the operating inverter to a-c bus No. 1, if it had been tripped off due to overvoltage or overload.	SNSR UNIT - AC BUS - 1 (MDC-21)		None	Resetting a-c bus 1 over-undervoltage and overload sensing unit also turns AC BUS 1 FAIL and AC BUS 1 OVERLOAD caution and warning lights off. Circuit breaker associated with the a-c sensing lines on a-c bus No. 1 is AC SNSR SIG - AC1 (MDC-25).
	RESET	Momentary position resets a-c bus No. 1 over-undervoltage and overload sensing unit.				
	(Center)	Energizes a-c bus No. 1 over-undervoltage and overload sensing unit.				
	OFF	Disconnects a-c bus No. 1 over-undervoltage and overload sensing unit from system.				
	AC BUS 2 group				Refer to AC INDICA-TORS switch	Actuates a motor-driven switch which accomplishes actual switching function.
	Switch 1	Controls output of inverter No. 1 to a-c bus No. 2.	INVERTER CONTROL - 1 (MDC-22)			
	ON	Applies output of inverter No. 1 to a-c bus No. 2.				
	OFF	Disconnects output of inverter No. 1 from a-c bus No. 2.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC 18 (Cont)	Switch 2	Controls output of inverter No. 2 to a-c bus No. 2.	INVERTER CONTROL - 2 (MDC-22)	Battery relay bus	Refer to AC INDICATORS switch	
	ON	Applies output of inverter No. 2 to a-c bus No. 2.				
	OFF	Disconnects output of inverter No. 2 from a-c bus No. 2.				
	Switch 3	Controls output of inverter No. 3 to a-c bus No. 2.	INVERTER CONTROL - 3(MDC-22)			
	ON	Applies output of inverter No. 3 to a-c bus No. 2.				
	OFF	Disconnects output of inverter No. 3 from a-c bus No. 2.				
	RESET/OFF switch	Provides capability of resetting a-c bus No. 2 over-undervoltage and overload sensing unit. Also releases relay which reconnects the operating inverter to a-c bus No. 2 if it has been tripped off due to over-voltage or overload.	SNSR UNIT-AC BUS - 2 (MDC-21)		None	Resetting a-c bus No. 2 over-undervoltage and overload sensing unit also turns AC BUS 2 FAIL and AC BUS 2 OVERLOAD caution and warning lights (MDC-11) ON. Circuit breaker associated with sensing lines on a-c bus No. 2 is AC SNSR SIG - AC2 (MDC-25).
	RESET	Resets a-c bus No. 2 over-undervoltage and overload sensing unit.				
	(Center)	Energizes a-c bus No. 2 over-undervoltage and overload sensing unit.				
	OFF	Disconnects a-c bus No. 2 over-undervoltage and overload sensing unit from the system.				
	AC VOLTS meter	Indicates a-c voltage of selected source and phase.	AC SNSR SIG - AC 1 AC 2 (MDC-25)	As selected by AC INDICATORS switch	Refer to AC INDICATORS switch	Meter functions in conjunction with AC INDICATORS switch. AC VOLTS meter range is 90 to 130 vac.
	FREQ CPS meter	Indicates frequency of selected source and phase.				FREQ CPS meter range is 380 to 420 cps.
	AC INDICATORS switch	Provides means of monitoring 3Ø voltage and frequency output of a-c inverters.				Operating rnage for phase A, B, and C (a-c bus No. 1 or a-c bus No. 2) is 115 ±2 vac 400 cps, during emergency mode 393 to 407 cps. Only phase A frequency measurement of a-c buses 1 and 2 are telemetered to MSFN ground stations.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-18 (Cont)	BUS 1 group		AC SNSR SIG - AC1 (MDC-25)	A-C bus No. 1		
	ØA	Applies a-c phase A voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.			CC0200V (A-C voltage main bus 1 phase A)	
					CC0213F (Frequency a-c bus 1 phase A)	
	ØB	Applies a-c phase B voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.			CC0201V (A-C voltage main bus 1 phase B)	
	ØC	Applies a-c phase C voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.			CC0202V (A-C voltage main bus 1 phase C)	
	BUS 2 group		AC SNSR SIG - AC2 (MDC-25)	A-C bus No. 2		
	ØA	Applies a-c phase A voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.			CC0203V (A-C voltage main bus 2 phase A)	
					CC0217F (Frequency a-c bus 2 - phase A)	
	ØB	Applies a-c phase B voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.			CC0204V (A-C voltage main bus 2 - phase B)	
	ØC	Applies a-c phase C voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.			CC0205V (A-C voltage main bus No. 2 phase C)	

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-19	ECS RAD OUT TEMP-1 indicator	Provides temperature indication of water-glycol at outlet of 6-tube circuit of radiator 1 (S/M sector V).	INSTRU-MENT-NONESSEN-TIAL (MDC-22) also NONESSEN-TIAL -9 (RHEB-204)	NONESSEN-TIAL BUS No. 1 (D-C main buses A or B)	SF0671T (Tank ECS radiator outlet 1)	Sensors located in outlet lines of radiators 1A and 2A on S/M forward bulkhead. Normal radiator outlet temperatures should not decrease below 30°F.
	ECS RAD OUT TEMP-2	Provides temperature indication of water-glycol at outlet of 6-tube circuit of radiator 2 (S/M sector II).			SF0672T (Tank ECS radiator outlet 2)	
	S-BAND ANT indicator	Indicates relative strength of signal being received by USBE.	N/A	USBE	CT0147V (S-Band RCVR AGC voltage)	Signal strength meter that operates off of voltage obtained from AGC circuitry in USBE. No calibration, tune for maximum signal by switching S-band antennas or rotating S/C for optimum reception.
	UP TLM CMD switch		T/C-GROUP 5 (MDC-22)	Flight and postlanding bus	None	DPDT switch, spring-loaded in the OFF position.
	RESET	Applies 28 vdc to the reset windings of all real-time command relays in the UDL RTC relay box. This cancels any real-time commands previously received via the UDL and returns control to the S/C.				
	OFF	None				
	FLIGHT QUAL RCDR switch		RCDR NON ESS (MDC-22)	FQR (Refer to Remarks.)	CT0013X (Tape motion monitor R&D)	Power to the switch is provided by the FQR control logic. The non-essential bus supplies 28-vdc power to the FQR through the RCDR NON ESS circuit breaker (MDC-22). Three-phase a-c power from the TELCOM-NON ESS switch is supplied to the FQR through the T/C - GROUP 1 AC circuit breaker (MDC-22).
	RECORD	Activates FQR electronic circuits and tape transport mechanism to record flight qualification data. Tape moves in forward direction at 15 IPS.				
	F/C VALVES					
	RESET	Provides +28 vdc to motor switch to disconnect holding voltage applied to the open solenoids of F/C 1, 2, and 3 reactant shutoff valves.	FUEL CELL 1 H_2 and O_2 VALVE and FUEL CELL 2 H_2 and O_2 VALVE (MDC-22)	BATTERY RELAY BUS	None	Switch operated to momentary RESET position only after earth orbit insertion.
	OFF	Normal position of switch.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-19 (Cont)	STOP	Remove power from FQR electronic circuits and tape transport mechanism. Tape is locked in place.	FUEL CELL 1 H_2 and O_2 VALVE and FUEL CELL 2 H_2 and O_2 VALVE (MDC-22)	BATTERY RELAY BUS	None	NOTE The total record time for the FQR is 30 minutes. Since there are no dumping capabilities, the FQR must be used conservatively.
	REWIND	Activates FQR tape transport mechanism to rewind tape. Tape moves in reverse direction at 120 IPS.				The rewind function is provided to allow the crewman to back the tape up to the beginning in case a launch hold occurs after the tape has begun to run or inadvertently left in RECORD. MSFN will direct time of rewind.
	VOICE RECORD event indicator		RCDR NON ESS (MDC-22)	DC NON ESS BUS No. 1		
	Gray area	Voice recorder inactive				Visible when not recording or when tape supply is exhausted.
	Striped area	Voice recorder tape is in motion.				Recording in progress.
	F/C VALVES switch		FUEL CELL 1-H_2&O_2 VALVE (MDC-22) FUEL CELL 2-H_2&O_2 VALVE (MDC-22)	Battery Relay Bus	None	Motor switch activated by GSE, provides open side of all F/C reactant valves with holding voltage to prevent inadvertent closing of reactant valves during launch, ascent, and orbital insertion.
	RESET	Momentary switch position actuates motor switch to remove holding voltage from open side of all F/C reactant valves.				NOTE To shut down a fuel cell when holding voltage is still applied to F/C reactant valves, F/C VALVES switch must be reset prior to closing F/C reactant valves.
	(Down)	Normal switch position disconnects power to motor switch.				Once the F/C reactant valves holding voltage is removed, F/C VALVES switch is inoperative.
	SPS LINE HEATER switch		SPS GAUGING MN A MN B (MDC-25)	D-C MAIN BUS A and B	None	The SPS HEATER switch provides power to the SPS electrical strip heaters mounted on the tank feed and engine feed line, brackets, and the injector valve assembly of the engine. The SPS HEATER switch will enable power to 26 electrical system A element strip heaters or will enable power to the 26 electrical system B element strip heaters, which will provide temperature control to the SPS engine compartment, thus the propellants.
	A	Provides power to the 26 electrical system A element strip heaters on the tank feed and engine feed line brackets and the injector valve assembly. Switch would be placed to A if the propellant temperature indicator on panel 20 indicated -40°F (propellant temperature equivalent to +40°F).				
	OFF	Removes power from electrical system A or B element strip heaters. Switch placed to OFF when propellant temperature indicator on panel 20 indicated +80°F (equivalent to propellant temperature of +120°F).				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-19 (Cont)	B	Provides power to the 26 electrical system B element strip heaters on the tank feed and engine feed line brackets and the injector valve assembly. If switch was not placed to A, would be placed to B when the propellant temperature indicator on panel 20 is at -40°F (equivalent to +40°F propellant temperature).	SPS GAUGING MN A MN B (MDC-25)	D-C MAIN BUS A and B	None	

MAIN DISPLAY CONSOLE – PANEL 19

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20	S-BAND switches		T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	
	XPONDER/OFF/ XPONDER PWR AMPL switch	Activates USBE, with or without S-band PA, and PMP circuitry which is required for S-band operations.				
	XPONDER	a. De-energizes holding relay K2 in circuit utilization box which: 1. Applies 3-phase a-c power from the T/C - GROUP 2 AC circuit breaker to the USBE power supply 2. Applies 28-vdc power from the T/C - GROUP 5 circuit breaker to the 20 VDC voltage regulator in the PMP. (Refer to Remarks.)				This position can be selected to conserve power if S-band communications are good enough to permit operations without the S-band PA equipment. The 20 vdc regulator in the PMP supplies power to those circuits in the PMP which are required for S-band emergency voice, emergency key, and UDL operations.
		b. Applies 28-vdc power to the S-BAND ANTENNA switch.				
	OFF	a. Energizes holding relay K2 in circuit utilization box which removes power from circuits described in Function a, XPONDER position. b. Removes 28-vdc power from the S-BAND ANTENNA switch.				
	XPONDER PWR AMPL	a. (Same as for XPONDER position, Function a.)				This position will normally be selected for S-band communications to ensure adequate strength of transmitted signal. After selecting this position, a 90-second delay occurs to allow for warmup before application of B+ and switching of RF signal to the PA.
		b. (Same as for XPONDER position, Function b.)				
		c. Energizes relay K1 in circuit utilization box which applies 3-phase a-c power from the T/C - SIG COND S-BAND PA AC circuit breaker (MDC-22) to the S-BAND PA.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	PWR AMPL switch		N/A	S-band PA internal circuitry	None	Supplies ground for S-band PA control relays. Effective only when S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch is in XPONDER PWR AMPL position.
	HIGH	Selects high-power (20-watt) output mode of S-BAND PA.				
	LOW	Selects low-power (5-watt) output mode of S-BAND PA.				
	OSC switch			USBE		Supplies ground for USBE control circuitry.
	PRIM	Selects primary oscillator frequency for USBE transmitter. It is obtained from USBE receiver VCO that is controlled by frequency of received S-band carrier to ensure doppler accuracy.				The primary oscillator is selected for all S-band operations unless USBE receiver has a malfunction.
	SEC	Selects secondary oscillator frequency for USBE transmitter. It is obtained from a crystal-controlled auxiliary oscillator.				The S-BAND-VOICE-RNG/RNG ONLY switch must also be in the off (center) position to enable selection of the secondary oscillator. (The secondary oscillator will be selected automatically when ever the S-BAND-EMER switch is set to VOICE.)
	VOICE group	Used to determine USBE/PMP mode and select data to be transmitted via S-band carrier. Only one of the three switches may be moved from the OFF (center) position at any one time. With all three switches at the OFF (center) position the USBE will transmit real-time voice and PCM data in a PM mode.				Three DP3T switches; one pole of each is used to control PMP circuits; the other pole is used to control USBE circuits. Voice transmission controlled by cobra cable PTT pushbutton when audio centers (MDC-13, -23, -26) POWER switch is at either PTT or VOX. Cobra cable PTT/CW switches must be at PTT.
	RNG/RNG ONLY switch			USBE and PMP internal circuitry (Refer to Remarks.)		Supplies ground returns for USBE and PMP control circuits.
	RNG	Enables PM transmission of received PRN ranging code in addition to real-time voice and PCM data.				Closes a dicde switch in the USBE transmitter which allows the PRN ranging signal from the USBE receiver to be modulated in the PM circuit.
	Off (center)	(Refer to VOICE group Function.)				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	RNG ONLY	Enables PM transmission of received PRN ranging code and real-time voice. PCM data is eliminated to reduce bandwidth and increase range.	N/A	USBE and PMP internal circuitry (Refer to Remarks.)	None	Removes power from PCM processing circuits in PMP.
	TAPE switch					One pole of this switch supplies ground for USBE control circuits. The other pole supplies 28-vdc control power obtained from the PMP power supply to PMP control circuits.
	TAPE	Enables FM transmission of real-time voice and stored PCM and/or analog data, as follows: a. Supplies 28-vdc control power to TAPE RECORDER—PLAY switch (MDC-20). b. Selects FM output mode of PMP. c. Selects FM transmission mode of USBE.				Refer to TAPE RECORDER—PLAY switch (MDC-20) Function and Remarks for further discussion of recorded data transmission capabilities.
	Off (center)	(Refer to VOICE group Function.)				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	TV switch TV Off (center)	Enables FM transmission of real-time video data from the TV camera along with real-time voice and PCM data, as follows: a. Closes diode switch in PMP to pass video signal to FM mixer. b. Selects FM output mode of PMP. c. Selects FM transmission mode of USBE (Refer to VOICE group Function.)	N/A	USBE and PMP internal circuitry (Refer to Remarks.)	None	One pole of this switch supplies ground for USBE control circuits. The other pole supplies 28-vdc control power obtained from the PMP power supply to PMP control circuits. ON/OFF slide switch on TV camera handle must also be set to ON.
	EMERG switch VOICE	Enables transmission of voice or CW code over the S-band carrier with nonessential PMP circuitry disabled. Enables FM transmission of real-time voice only, as follows: a. Activates a-c power control relay in PMP, turning off 28-vdc power supply that supplies power to non-essential PMP circuits. b. Deactivates voice control relay in PMP, allowing voice signal from audio center equipment to bypass PMP voice processing circuits and go directly to USBE. c. Selects auxiliary oscillator and PM transmission mode in USBE. (Voice signal is applied directly to the auxiliary oscillator.)	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus and USBE internal circuitry		Switch applies 28-vdc control power to PMP circuits; supplies ground for USBE circuits. Voice transmission possible when audio center (MDC-13, -23, or -26) POWER switch is at either PTT or VOX and cobra cable PTT push-button pressed, cobra cable PTT/CW switch must be at PTT.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	Off (center)	Allows normal USBE and PMP operation.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus and USBE internal circuitry	None	
	KEY	Enables PM transmission of CW code, as follows: a. Activates a-c power control relay in PMP, turning off 28-vdc power supply that supplies power to non-essential PMP circuits. b. Applies 28-vdc power to emergency key circuitry in PMP. c. Selects PM transmission mode in USBE. Either the primary or secondary (auxiliary) oscillator frequency may be used.				Keying of transmitted CW code is accomplished by pressing the PTT pushbutton on cobra cables. (The cobra cable PTT/CW toggle switch must be set to CW.)
	Up-DATA switch			Flight and postlanding bus		
	S-BAND	Activates UDL equipment in S-band mode by applying 28-vdc power to UDL power supply only (UHF/FM receiver portion of UDL equipment is disabled).				Reception of up-data from the MSFN in the S-band mode is via the USBE receiver and PMP up-data discriminator.
	Off (center)	Removes power from UDL equipment.				
	UHF	Activates UDL equipment in UHF mode by applying 28-vdc power to UDL power supply, UHF/FM receiver, and mode switch, all contained in UDL equipment.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	S-BAND ANTENNA switch	Applies 28-vdc control power to 2-KMC antenna switch, either directly or via the USBE threshold selector (when in AUTO position).	N/A	S-BAND - XPONDER/ OFF/ XPONDER PWR AMPL switch (MDC-20)	None	The 28-vdc power is supplied to the S-BAND ANTENNA switch when the S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) is in the XPONDER or XPONDER PWR AMPL position. This power comes from the flight and postlanding bus via the T/C-GROUP 5 circuit breaker (MDC-22). When in automatic mode, selection is made by a threshold selector in the USBE. Selection is based on strength of received signal. Upper or lower antenna selected manually. S-BAND ANTENNA meter (MDC-19) indicates received signal strength at selected antenna.
	AUTO	Permits automatic selection of SCIN antenna for S-band transmission and reception.				
	UPPER	Selects the upper (-Z) SCIN antenna for S-band transmission and reception.				
	LOWER	Selects the lower (+Z) SCIN antenna for S-band transmission and reception.				
	VHF-AM controls			VHF/AM transmitter-receiver internal circuitry		
	SQUELCH control					
	Rotated upward or downward as required	Increases or decreases sensitivity of squelch gate. Position 9 most sensitive.				Squelch gate sensitivity determines strength of received signal that is required to permit detected audio to pass to audio center equipment.
	T/R/OFF/REC switch		T/C - GROUP 4 (MDC-22)	Flight and postlanding bus		
	T/R	Applies power to transmitter and receiver circuitry in VHF/AM transmitter-receiver.				In the T/R mode the transmitter operates in standby with filaments lit; B+ is not applied until keying occurs by closing PTT pushbutton on cobra cable when PTT/CW switch is at PTT.
	OFF	Removes power from VHF/AM transmitter-receiver.				
	REC	Applies power to receiver circuitry only in VHF/AM transmitter receiver.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	RCVR switch 1 2	Selects VHF/AM receive frequency No. 1 (296.8 mc). Selects VHF/AM receive frequency No. 2 (259.7 mc).	N/A	VHF/AM transmitter-receiver internal circuitry	None	Receive 1 frequency is used for simplex communications. Receive 2 frequency is used for duplex communications.
	C-BAND switch 1 PULSE	Activates C-band transponder in 1-pulse mode, as follows: a. Activates holding relay K3 in circuit utilization box which applies 3-phase a-c power from T/C - GROUP 1 AC circuit breaker (MDC-22) to C-band transponder power supply. b. Applies control to decoder circuit to select 2-pulse mode.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus		The 1 PULSE mode is selected only when C-band tracking is required by a MSFN station having no capability for 2-pulse operations. One-pulse mode will be responsive to a 1- or 2-pulse MSFN station. One-pulse operation may be changed by UDL to 2-pulse mode.
	Off (center)	Deactivates C-band transponder equipment.				UDL may turn on C-band in 2-pulse mode.
	2 PULSE	Activates C-band transponder in 2-pulse mode, as follows: a. Activates holding relay K3 in circuit utilization box which applies 3-phase a-c power from T/C - GROUP 1 AC circuit breaker (MDC-22) to C-band transponder power supply. b. Applies control to decoder circuit to select 2-pulse mode.				The 2-pulse mode is selected for launch and when C-band tracking is required by MSFN stations having capability for 2-pulse operation. Activation of the C-band transponder in the 2-pulse mode can also be commanded by MSFN by a UDL real-time command.
	VHF-FM switch ON	Activates VHF/FM transmitter by energizing a relay that applies 3-phase a-c power from the T/C - GROUP 1 AC circuit breaker (MDC-22) to its power supply.				The VHF/FM transmitter is the primary means for transmitting PCM TLM, real time or stored. Activation of the VHF/FM transmitter can also be commanded by the MSFN by a UDL real-time command. This command occurs simultaneously with a command to the PCM TLM equipment for high bit-rate PCM.
	OFF	Deactivates VHF/FM transmitter.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	RECOVERY switches		T/C - GROUP 3 (MDC-22)	Flight and postlanding bus	None	
	VHF-BCN switch					
	ON	Applies 28-vdc power to activate VHF recovery beacon.				A CW signal is transmitted at 3-second intervals for a period of 2 seconds (2 seconds on, 3 seconds off). Activate following dereefing of main parachutes.
	OFF	Removes 28-vdc power from VHF recovery beacon.				
	HF group		T/C - GROUP 4 (MDC-22)			
	ON/OFF switch					
	ON	Activates HF transceiver, as follows: a. Applies 28-vdc power to receiver and oscillator circuits b. Applies 28-vdc control power to transmitter and antenna switching relays. (Refer to Remarks.)				Activate following deployment of HF recovery antenna. The transmitter keying relay controls application of 28-vdc power to transmitter circuits. The antenna switching relay disconnects antenna from receiver input and connects it to transmitter output. This provides for simplex HF operation. These relays will not energize until a ground return path is provided by keying the transmitter or selecting the beacon mode of operation.
	OFF	Deactivates HF transceiver.				
	SSB/BCN/AM switch		N/A			Supplies ground for mode control circuits.
	SSB	Selects SSB mode of HF transceiver.				
	BCN	a. Selects BCN mode of HF transceiver. b. Provides ground to voice recorder power control relay				In the BCN mode, the HF transceiver emits a continuous unmodulated carrier. This mode will also energize the voice recorder power control relay, circumventing the normal VOX control.
	AM	Selects AM mode of HF transceiver.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	TAPE RECORDER switches					
	PLAY switch	Applies 28-vdc control power to appropriate PMP circuits and relays to select DSE outputs for transmission via USBE.	N/A	S-BAND–VOICE TAPE switch, (MDC-20)	None	The PMP power supply, when activated, supplies 28 vdc to the S-BAND–VOICE–TAPE switch (MDC). When the TAPE position is selected, this 28 vdc is supplied to the TAPE RECORDER–PLAY switch.
	PCM	Selects stored PCM data only.				PCM and NORM perform same function.
	NORM	Selects stored PCM and analog data. No real-time PCM data can be transmitted in this mode.				
	SPEED switch	Applies 28-vdc control power from TAPE RECORDER–FWD/REV switch (FWD or REV position) to DSE control logic.		TAPE RECORDER-FWD/REV switch, FWD or REV position	CT0012X	DSE control logic reverts to 15 ips (NORM) tape speed if power to FWD/REV switch is lost.
	HIGH	Selects high tape speed (120 IPS).				Used during DSE tape rewind and for playback of recorded LBR used for recording and playback of HBR.
	Norm (center)	Selects nor nal tape speed (15 IPS).				
	LOW	Selects low tape speed (3.75 IPS).				Used while recording LBR only. DSE cannot dump in LOW.
	RECORD/PLAY switch	Applies 28-vdc control power to DSE control logic.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus		
	RECORD	Activates DSE record electronics.				DSE control logic requires the switch to be placed at other than OFF and FWD or REV selected prior to tape motion.
	Off (center)	None				
	PLAY	Activates DSE playback electronics.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	FWD/REV switch		T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	
	FWD	Applies 28-vdc control power to: a. DSE control logic to activate tape transport in forward direction. b. TAPE RECORDER–SPEED switch.				DSE control logic requires this switch to be placed at other than OFF and RECORD or PLAY selected prior to tape motion.
	Off (center)	Removes 28 vdc from control logic and SPEED switches.				This position used for rewind and also during reverse data dump.
	REV	Applies 28-vdc control power to: a. DSE control logic to activate tape transport in reverse direction b. TAPE RECORDER–SPEED switch.				
	PWR switches					This switch set to ON prior to launch and should remain on throughout entire mission.
	SCE switch					
	ON	Activates "latch" coil of relay in SCE, applying 3-phase a-c power from SIG COND S-BAND PA AC circuit breaker (MDC-22) to SCE power supply.				
	OFF	Activates "unlatch" coil of relay in SCE, removing 3-phase a-c power.				
	PMP switch					OFF position causes loss of normal voice, TV, ranging and S-band PCM TLM.
	ON	Allows 3-phase a-c power from T/C - GROUP 2 AC circuit breaker to be applied to PMP 28 vdc power supply.				
	OFF	Activates relay in PMP to remove 3-phase a-c power from PMP 28 vdc power supply.				

MAIN DISPLAY CONSOLE—PANEL 20

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	TLM INPUTS switches		N/A	PCM/TLM Equipment and TAPE RECORDER-RECORD/PLAY switch	None	Supplies 28-vdc control power from TAPE RECORDER—RECORD/PLAY switch (RECORD position) to the DSE control logic and ground for programmer control circuitry in the PCM/TLM equipment.
	PCM switch					
	HIGH	a. Selects wide-band PCM TLM data mode (51.2 KBPS bit-rate) in PCM/TLM equipment. b. Selects normal-speed assurance mode of DSE.				The low (1.6 KBS) PCM bit-rate cannot also be commanded by the MSFN by an UDL real-time-command in this position.
	LOW	a. Selects narrow-band PCM TLM data mode (1.6 KBPS bit-rate) in PCM/TLM equipment. b. Selects low-speed assurance mode in DSE.				UDL command from MSFN may change bit rate to high (51.2 kbs). Switch will, however, remain in LOW.
	BIOMED switch		BIOMED COMM—MN B (MDC-25) & T/C - GROUP 5 (MDC-22)	D-C main bus B & flight & postlanding bus (Refer to Remarks.)		Supplies 28-vdc power from BIOMED COMM—MN B circuit breaker to physiological amplifier of selected astronaut, and supplied 28 vdc from T/C - GROUP 5 circuit breaker to control transmission of proper PCM signal to indicate position of switch to MSFN.
	1	Selects operational biomedical data from command pilot for transmission or storage in DSE.				
	2	Selects operational biomedical data from senior pilot for transmission or storage in DSE.				
	3	Selects operational biomedical data from pilot for transmission or storage in DSE.				
	VHF ANTENNA switch	Applies 28-vdc control power to VHF antenna switch latching relay circuits.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus		
	RECOVERY	Connects VHF recovery antenna No. 2 to VHF multiplexer.				This position not used until after parachute deployment and disreefing.
	UPPER	Connects VHF portion of SCIN antenna on the -Z axis to VHF multiplexer.				Upper and lower antennas manually selected to permit most advantageous reception and transmission of VHF-AM communications and VHF-FM telemetry.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	LOWER	Connects VHF portion of SCIN antenna on the +Z axis to VHF multiplexer	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	Lower antenna will burn off on entry.
	He TANK indicators		INSTRU-MENTS—ESS MN A MN B (MDC-22)	D-C main buses A and B		
	PRESS	Indicates SPS helium storage tank pressure when SPS TANK PRESS switch (MDC-20) is in the He position.			SP0001P (He tank pressure)	Each indicator consists of d-Arsonval-type meter with fixed dial and movable pointer. Pointer movement is vertical as observed from crew couch.
	N_2 TK PRESS	Indicates SPS gaseous nitrogen storage tank pressure of engine pneumatic valve control system A and B when SPS TANK PRESS switch (MDC-20) is in the N_2 A or N_2 B position, respectively.			SP0600P (N_2 A tank pressure) SP0601P (N_2 B tank pressure)	Pressure indicator display is in psia, and range is 0 to 5000 psia.
	PRESSURE indicators					Four indicators are identical in operation. Each consists of d'Arsonval-type meter with fixed dial and movable pointer. Pointer movement is vertical as observed from crew couch. Each indicator is calibrated in psia with range of 0 to 300 psia.
	FUEL	Provides constant monitoring of SPS fuel tank regulated helium pressure.			SP0006P (fuel tank pressure)	
	OX	Provides constant monitoring of SPS oxidizer tank regulated helium pressure.			SP0003P (oxidizer tank pressure)	
	ENG INLET group					
	FUEL	Provides constant monitoring of SPS fuel pressure at the engine main propellant valves.			SP0010P (fuel line engine inlet)	
	OX	Provides constant monitoring of SPS oxidizer pressure at the engine main propellant valves.			SP0009P (oxidizer line engine inlet)	
	TEMPERATURE indicator					Same indicator as helium tank press.
	ENGINE INLET PROPELLANT TEMP	Propellant temperature is monitored in the engine fuel feed line plumbing at the gimbal ring of the engine. The indicator displays the measurement as noted in the Remarks column:			SP0048T (fuel line engine inlet)	Propellant temperature is indicated in degrees Fahrenheit. The range of the indicator is -100° to +200°F. When the indicator reads -40°F (equivalent propellant temperature of +40°F) the SPS HEATER switch is placed to position A or B. When the indicator reads +80°F (equivalent propellant temperature +120°F) the SPS HEATER switch is placed to OFF. The indicator has red line markings at +80°F and -40°F.

MAIN DISPLAY CONSOLE—PANEL 20

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	SPS ENGINE INJECT VALVE indicators 1 (2, 3, 4)	Provides visual indication of SPS engine main propellant valves open or closed condition (one oxidizer and one fuel valve per pair and one indicator for each pair of valves).	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	Valve position: A-1 SP0022H A-2 SP0023H B-3 SP0024H B-4 SP0025H **NOTE** Separate pickoffs for display and T/M signals.	Four identical indicators. Each is needle-movement-type meter with inputs supplied by position potentiometer located on valve actuator arm. Left needle deflection indicates CLOSE; right deflection indicates OPEN.
	SPS TANK PRESS switch He N_2A N_2B	Connects SPS helium storage tank pressure output to He TANK PRESS indicator (MDC-20). Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system A to TK PRESS indicator (MDC-20). Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system B to TK PRESS indicator (MDC-20).	N/A	N/A	None	Three-position toggle switch used to select SPS helium or nitrogen tank pressure input to He TANK PRESS or N_2 TK PRESS indicator on MDC-20.
	SPS HELIUM switches (two, left hand and right hand) AUTO OFF	Two operationally identical switches. Provides for automatic application and removal of power from helium isolation valve solenoid. Removes power from helium isolation valve solenoid.	SPS-He VALVE MN A MN B (MDC-25)	D-C main buses A and B		Each switch is a three-way toggle switch. With this switch in the AUTO position, valve opening and closing is controlled automatically by G&N system and/or SCS. Complete manual control of valve position can be maintained by utilizing ON - OFF switch positions. D-C main buses A and B provide power to helium pressurizing systems A and B, respectively.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	ON	Applies power to helium isolation valve solenoid.	SPS-He VALVE MN A MN B (MDC-25)	D-C main buses A and B	None	Each switch controls helium flow to one of two redundant pressure regulator assemblies.
	SPS HELIUM event indicators (two)	Striped-line display indicates open conditions of valve controlled by switch located directly below indicator. Gray display indicates closed condition.				Two identical indicators. Each is two-condition device with striped-line display controlled by solenoid action and gray display controlled by permanent magnet action.
	QUANTITY display windows OXID FUEL	Digital counter display window indicating total oxidizer tank quantity remaining (in pounds times 20). Digital counter display window indicating total fuel tank quantity remaining (in pounds times 10).	SPS—GAUGING MN A MN B AC 1 AC 2 (MDC-25)	400-cps a-c input from quantity gauging system control unit		Digital display in oxidizer quantity (OXID) window and fuel quantity (FUEL) window represent remaining tank quantities and are marked X20 and X10, respectively. These markings facilitate determination of correct remaining propellant quantities. Since desired oxidizer/fuel ratio is 2:1, digital display in both windows should be identical when propellant ratio is correct.
	UNBALANCE indicator	Indicates unbalance of remaining SPS propellants.				Indicator is graduated into six major divisions, each representing 100 pounds of propellant unbalalnce. Upper half indicates increased oxidizer flow required; lower half, decreased flow. Indicator needle at 0 (horizontal position) indicates desired propellant ratio.
	TEST/AUTO/TEST switch TEST (up) AUTO TEST (down)	Applies simulated input to propellant quantity gauging and utiliziation system control unit, causing digital display counters and UNBALANCE indicator to function for test check. Normal operating position. Applies simulated input for same purposes as TEST (up) position, except in reverse polarity.		D-C and a-c test inputs from quantity gauging system control unit		Three-position toggle switch, spring-loaded to AUTO position. TEST position allows for visual check of proper electrical and mechanical operation of propellant indicating devices. In addition to indicator checks, TEST position may be used to aid in isolating a malfunction in either primary or auxiliary propellant quantity sensing system. Test rate for OXID digits is approximately 3 digits/second; FUEL 1.5 digits/second.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	OXID FLOW switch		SPS—GAUGING MN A MN B AC 1 AC 2 (MDC-25)	D-C and a-c test inputs from quantity gauging system control unit	None	Three-position toggle switch used as required to regulate oxidizer flow rate to maintain proper propellant utiliziation. Remaining propellant SPS unbalance may be determined by monitoring UNBALANCE meter or by calculations, utilizing information displayed in OXID and FUEL quantity digital display windows. Maximum PU valve response time from increase to decrease position in 3.5 seconds.
	INCREASE	Supplied increased signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. INCREASE position — 46.65 lb/sec.				
	NORM	Supplies normal signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. NORM position — 45.27 lb/sec at 70°F and 168±4 PSIG.				
	DECREASE	Supplies decreased signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. DECREASE position — 43.87 lb/sec.				
	OXID FLOW event indicators					Two identical indicators. Each is a two-condition device controlled by servo action. When propellant utilization valve is in normal oxidizer flow rate position, gray display will appear in both indicator windows.
	Upper indicator	Striped-line display indicates propellant utilization valve is in increased oxidizer flow rate position; gray display indicates it is not.				
	Lower indicator	Striped-line display indicates propellant utilization valve is in decreased oxidizer flow rate position; gray display indicates it is not.				
	VALVE switch			D-C input from quantity gauging system		Two-position toggle switch which provides manual selection of primary or secondary gates in propellant utilization valve. The PU valve secondary gate is capable of adjusting for increased, decreased, or normal oxidizer flow area regardless of a primary gate failure in any position.
	PRI	Applies power to propellant utilization valve primary servo amplifier.				
	SEC	Applies power to propellant utilization valve secondary servo amplifier.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	SENSOR switch		SPS—GAUGING MN A MN B AC 1 AC 2 (MDC-25)	400-cps a-c input from quantity gauging system control unit	None	Three-position toggle switch, with switch in NORM position during normal operation. This switch, when used in conjunction with TEST switch (MDC-20), can be useful in isolating a malfunction in propellant quantity sensing system.
	PRI	Applies output from primary propellant quantity sensing system to propellant quantity indicating and warning devices.				
	NORM	Applies outputs from both primary and auxiliary sensing systems to propellant quantity warning devices and output from primary propellant sensing system to propellant quantity indicating devices.				
	AUX	Applies output from auxiliary propellant sensing system to propellant quantity indicating and warning devices.				
MDC-21	SUIT COMPRESSOR selector switch				None	Only one suit compressor is normally operated at a time, with second compressor for standby redundancy.
	COMPR 1					
	AC 2	Applies a-c power to motor of suit compressor No. 1 from bus No. 2.	ECS-SUIT COM-PRESSORS AC 2 ØA ØB ØC (MDC-22)	A-C bus No. 2		Output of each compressor is as follows: a. Prelaunch mode - 32.7 cfm and ΔP of 0.7 to 0.9 psi. b. Normal mode - 35 cfm and ΔP of 0.3 to 0.4 psi. c. Emergency mode - 33.6 cfm and ΔP of 0.2 to 0.3 psi.
	AC 1	Applies a-c power to motor of suit compressor No. 1 from bus No. 1.	ECS-SUIT COM-PRESSORS AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 1		
	OFF	Removes a-c power from motors of suit compressors.				
	COMPR 2					
	AC 1	Applies a-c power to motor of suit compressor No. 2 from bus No. 1.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	AC 1/1 AC 2/2	Applies a-c power to the following motors: a. NO. 1 suit compressor from bus NO. 1. b. NO. 2 suit compressor from bus NO. 2.	ECS-SUIT COM-PRESSORS AC 1 ϕ A ϕ B ϕ C and AC 2 ϕ A ϕ B ϕ C (MDC-22)	A-C buses No. 1 and 2	None	Switch position permits simultaneous operation of both suit compressors during periods of high suit heat loads.
	ECS GLYCOL pump selector switch					Only one water-glycol pump can be operated at a time, with second pump for standby redundancy. Pump design specification figures are 200 lb/hr flow at a pressure rise of 29.5 psi, with a pump inlet of 7.5±1.5 psig at 100°F (max). Actual flow varies inversely with system pressure drop.
	PUMP 1 AC 2	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 2	ECS-GLYCOL PUMPS-AC 2 ϕ A ϕ B ϕ C (MDC-22)	A-C bus No. 2		
	AC 1	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 1	ECS-GLYCOL PUMPS-AC 1 ϕ A ϕ B ϕ C (MDC-22)	A-C bus No. 1		
	OFF	Removes a-c power from motors of water-glycol pumps.				
	PUMP 2 AC 1	Applies a-c power to motor of No. 2 water-glycol pump from bus No. 1				

MAIN DISPLAY CONSOLE—PANEL 21

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	AC 2	Applies a-c power to motor of No. 2 water-glycol pump from bus No. 2.	ECS-GLYCOL PUMPS-AC 2 ∅A ∅B ∅C (MDC-22)	A-C bus No. 2	None	
	CABIN AIR FAN switches 1 switch ON	Applies a-c power to motor of No. 1 cabin air fan, directing airflow through cabin heat exchanger.	ECS-CABIN AIR FAN 1 ∅A ∅B ∅C (MDC-22)	A-C bus No. 1		Cabin air fans No. 1 and No. 2 are operated simultaneously to obtain adequate cooling. Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off). In event of malfunction, fan No. 1 is turned off and fan closure cover manually installed over inlet to prevent backflow.
	OFF	Removes a-c power from motor of No. 1 cabin air fan.				
	2 switch ON	Applies a-c power to motor of No. 2 cabin air fan, directing airflow through cabin heat exchanger.	ECS-CABIN AIR FAN 2 ∅A ∅B ∅C (MDC-22)	A-C bus No. 2		Cabin air fans No. 1 and No. 2 are operated simultaneously to obtain adequate cooling. Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off). In event of malfunction, fan No. 2 is shut down and fan closure cover is manually installed over inlet to prevent backflow.
	OFF	Removes a-c power from motor of No. 2 cabin air fan.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	POT H_2O HEATER switch				None	Two heating elements totaling 45 watts (20 and 25 watts each) are mounted at separate locations inside the food preparation water unit. Operating simultaneously, they heat the water from an inlet temperature of 60°F to 154±4°F. The maximum time to heat 1.9 lb of water (reservoir capacity) is approximately 2 hours.
	MN A	Applies d-c power to potable water heater from main bus A.	ECS-POT H_2O HTR MN A (MDC-22)	D-C main bus A		
	OFF	Removes d-c power from potable water heater.				
	MN B	Applies d-c power to potable water heater from main bus B.	ECS-POT H_2O HTR MN B (MDC-22)	D-C main bus B		
	ECS RADIATOR switches					Under most normal conditions all space radiator valves are placed in the open position. Exceptions to this are during ground checkout and ascent. The only other time a valve is closed is when a radiator circuit is isolated in event of leakage. Space radiator valves, which must be in the full open or full closed position, require 17 seconds (max) for full travel.
	Group 1					
	A (on)	Applies a-c power to actuator of space radiator isolation valve 1A to place valve in open position, permitting water-glycol flow to the six-tube circuit of the radiator located in S/M sector V (-Y axis).	ECS-RAD VALVE AC 1 1A (MDC-22)	A-C bus No. 1 ØA		
	OFF	Applies a-c power to actuator of space radiator isolation valve 1A to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	B (on)	Applies a-c power to actuator of space radiator isolation valve 1B to place valve in open position, permitting water-glycol flow to the four-tube circuit of the radiator located in S/M sector V (-Y axis).	ECS-RAD VALVE AC 2 1B (MDC-22)	A-C bus No. 2 ØA		
	OFF	Applies a-c power to actuator of space radiator isolation valve 1B to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	Group 2				None	
	A (on)	Applies a-c power to actuator of space radiator isolation valve 2A to place valve in open position, permitting water-glycol flow to the six-tube circuit of the radiator located in S/M sector II (+Y axis).	EGS-RAD VALVE AC 2 2A (MDC-22)	A-C bus No. 2 ØC		
	OFF	Applies a-c power to actuator of space radiator isolation valve 2A to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	B (on)	Applies a-c power to actuator of space radiator isolation valve 2B to place valve in open position, permitting water-glycol flow to the four-tube circuit of the radiator located in S/M sector II (+Y axis).	ECS-RAD VALVE AC 1 2B (MDC-22)	A-C bus No. 1 ØB		
	OFF	Applies a-c power to actuator of space radiator isolation valve 2B to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	RCS HEATERS circuit breakers A MN B (20 amp)	Applies power from d-c main bus B to the following: a. SM RCS quad A package heater b. Normally open contacts of relay activated by CM RCS HTR5 switch (RIFEB-200) for CM RCS system B engine injector valve direct coils utilized for engine preheating.	N/A	+28 vdc		Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by a white placard.

MAIN DISPLAY CONSOLE—PANEL 21

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	B MN A (20 amp)	Applies power from d-c main bus A to the following: a. SM RCS quad B package heater b. Normally open contacts of relay activated by CM RCS HTRS switch (RHFEB-200) for CM RCS system A engine injector valve direct coils utilized for engine preheating.	N/A	+28 vdc	None	
	C MN B (5 amp)	Applies power from d-c main bus B to package heater in S/M RCS quad C.				
	D MN A (5 amp)	Applies power from d-c main bus A to package heater in S/M RCS quad D.				
	SNSR UNIT circuit breakers					
	DC BUS group					
	A (5 amp)	Applies d-c power from battery relay bus through MAIN BUS A-RESET switch to d-c main bus A undervoltage sensing unit.				Sensing unit is inoperative when MAIN BUS A-RESET switch is in the OFF position.
	B (5 amp)	Applies d-c power from battery relay bus through MAIN BUS B-RESET switch to d-c main bus B undervoltage sensing unit.				Sensing unit is inoperative when MAIN BUS B-RESET switch is in the OFF position.
	AC BUS group					
	1 (5 amp)	Applies d-c power from battery relay bus through AC BUS 1-RESET switch to a-c bus No. 1 over-undervoltage and overload sensing unit.				Sensing unit is inoperative when AC BUS 1-RESET switch is in the OFF position.
	2 (5 amp)	Applies d-c power from battery relay bus through AC BUS 2-RESET switch to a-c bus No. 2 over-undervoltage and overload sensing unit.				Sensing unit is inoperative when AC BUS 2-RESET switch is in the OFF position.

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22	FUEL CELL PUMP switches				None	Two parallel pump motors are associated with each fuel cell. One motor drives the H_2 circulating pump and the water separation centrifuge. The other motor drives the glycol circulating pump. Switches are located between bus and c/b's.
	Switch 1	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 1 pump motors.	FUEL CELL 1 - CIR & SEP MOTORS (MDC-22)			
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 1 pump motors.		A-C bus No. 1		
	OFF	Disconnects 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 1 pump motors.		A-C bus No. 2		
	Switch 2	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 2 pump motors.	FUEL CELL 2 - CIR & SEP MOTORS (MDC-22)			
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 2 pump motors.		A-C bus No. 1		
	OFF	Disconnect 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 2 pump motors.		A-C bus No. 2		
	Switch 3	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 3 pump motors.	FUEL CELL 3 - CIR & SEP MOTORS (MDC-22)			
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 3 pump motors.		A-C bus No. 1		
	OFF	Disconnects 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 3 pump motors.		A-C bus No. 2		

MAIN DISPLAY CONSOLE—PANEL 22

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	MAIN BUS TIE switches					
	BAT A & C/AUTO/OFF switch		BATTERY CHARGER-BAT A CHGE (MDC-22)	Battery bus A		
	BAT A & C	Allows manual control of bus tie motor switch to: a. Connect battery bus A to d-c main bus A and battery C to d-c main bus B. b. Disconnect BATTERY CHARGER selector switch (MDC-18) from battery bus A and battery C.				Actuates motor-driven switch which accomplishes actual switching function.
	AUTO	In the event of an LES abort or normal CSM separation, this position allows the C/M RCS control box to control bus tie motor switch connecting battery bus A to d-c main bus A and battery C to d-c main bus B and disconnects BATTERY CHARGER selector switch (MDC-18).				
	OFF	Allows manual control of motor switch to: a. Disconnect battery bus A from d-c main bus A and battery C from d-c main bus B. b. Connects BATTERY CHARGER selector switch (MDC-18) to battery bus A and battery C.				
	BAT B & C/AUTO/OFF switch		BATTERY CHARGER-BAT B CHGE (MDC-22)	Battery bus B		
	BAT B & C	Allows manual control of bus tie motor switch to: a. Connect battery bus B to d-c main bus B and Battery C to d-c main bus A. b. Disconnects BATTERY CHARGER selector switch (MDC-18) from battery bus B and battery C.				Actuates motor-driven switch which accomplishes actual switching function.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	AUTO	In the event of an LES abort or normal CSM separation, this position allows the C/M RCS control box to control bus tie motor switch connecting battery bus B to d-c main bus B and battery C to d-c main bus A, and disconnects BATTERY CHARGER selector switch (MDC-18).	BATTERY CHARGER-BAT B CHGE (MDC-22)	Battery bus B	None	
	OFF	Allows manual control of motor switch to: a. Disconnects battery bus B from d-c main bus B and battery C from d-c main bus A. b. Connect BATTERY CHARGER selector switch (MDC-18) to battery bus B and battery C.				Switch works with BATTERY CHARGER selector switch (MDC-18) to enable battery charger operation.
	BAT CHGR switch	Provides means of selecting a-c bus No. 1 or a-c bus No. 2 for battery charger a-c power source.	BATTERY CHARGER-AC PWR (MDC-22)			
	AC 1	Controls 30 a-c power from a-c bus No. 1 to battery charger during battery charging operation.		A-C bus No. 1		
	AC 2	Controls 30 a-c power from a-c bus No. 2 to battery charger during battery charging operation.		A-C bus No. 2		
	NON ESS BUS switch					Equipment associated with this switch is: a. Scientific equipment bay No. 1 — NON ESS BUS NO. 2 b. Scientific equipment bay No. 2 c. Scientific equipment hatch d. Flight qualification recorder — NON ESS BUS NO. 1 e. Nonessential instrumentation f. Voice recorder flag
	MN A	Connects nonessential bus No. 1 and No. 2 to d-c main bus A.		D-C main bus A		
	OFF	Disconnects nonessential buses from d-c main buses				
	MN B	Connects nonessential bus No. 1 and No. 2 to d-c main bus B.		D-C main bus B		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	G&N VIEWER switch	Provides means of selecting a-c bus No. 1 or a-c bus No. 2 for LEB panel brightness control, SCT and SXT reticle lights and signal conditioner.	VIEWER AC 1 and AC 2 (MDC-22)		None	
	AC 1	Selects 3Ø a-c power from a-c bus No. 1		A-C bus No. 1		
	AC 2	Selects 3Ø a-c power from a-c bus No. 2		A-C bus No. 2		
	TELCOM switches					Equipment associated with this switch is: a. Unified S-band equipment b. Premodulation processor c. Signal conditioning equipment d. S-band power amplifier.
	ESS switch	Provides control of 3Ø a-c power to the TELECOMMUNICATIONS-GROUP - 2 and SIG CONDS-BAND PA (MDC-22) telecommunications (T/C) equipment which is essential to safety of flight.				
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to essential T/C equipment controlled by TELECOMMUNICATIONS - GROUP - 2 and SIG COND S-BAND PA (MDC-22).	None	A-C bus No. 1		
	OFF	Disconnects 3Ø a-c power from essential T/C equipment.		A-C bus No. 2		
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to essential T/C equipment.				
	NONESS switch	Provides control of 3Ø a-c power to TELECOMMUNICATIONS-GROUP - 1 and PCM TLM (MDC-22) telecommunications (T/C) equipment which is not essential to safety of flight.				Equipment associated with this switch is: a. PCM telemetry b. VHF/FM transmitter c. C-band transponder d. Data storage equipment e. Flight qualification recorder f. Voice recorder
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to nonessential T/C equipment.				
	OFF	Disconnects 3Ø a-c power from nonessential T/C equipment.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to nonessential T/C equipment.		A-C bus No. 2		

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	FUEL CELL 1 circuit breaker		N/A		None	
	CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 1 switch to C/B, and to circulator and separator pump motors in fuel cell 1. b. Provides ØA power to pH sensor probe.		115 vac 400 cps 3Ø		Opened after operation of F/C VALVES-RESET switch (MDC-19).
	H_2 & O_2 VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 1 - REACTANTS switch (MDC-18), and to F/C VALVES-RESET switch (MDC-19).		+28 vdc		
	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 1 bus disconnect control through FUEL CELL 1 - MAIN BUS A and MAIN BUS B switches (MDC-18). b. Provides power to reactants event indicator.				
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C 1 purge valve control through FUEL CELL 1 - O_2 PURGE - H_2 PURGE switch (MDC-18), and to H_2 PURGE LINE HTR switch (MDC-15).				H_2 PURGE LINE HTR switch (MDC-15) positioned to ON 30 minutes prior to an H_2 purge operation.
	FUEL CELL 2 circuit breakers			115 vac 400 cps 3Ø		
	CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 2 switch to C/B, and to circulator and separator pump motors in fuel cell 2. b. Provides ØA power to pH sensor probe.				

MAIN DISPLAY CONSOLE—PANEL 22

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	H_2 & O_2 VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 2 - REACTANTS switch (MDC-18), and to F/C VALVES-RESET switch (MDC-19).	N/A	+28 vdc	None	Opened after operation of F/C VALVES-RESET switch (MDC-19).
	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 2 bus disconnect control through FUEL CELL 2 - MAIN BUS A and MAIN BUS B switches (MDC-18). b. Provides power to reactants event indicator.				
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C 2 purge valve control through FUEL CELL 2 - O_2 PURGE - H_2 PURGE switch (MDC-18), and to H_2 PURGE LINE HTR switch (MDC-15).				H_2 PURGE LINE HTR switch (MDC-15) positioned ON 30 minutes prior to an H_2 purge operation.
	FUEL CELL 3 circuit breakers					
	CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 3 switch to C/B, and to circulator and separator pump motors in fuel cell 3. b. Provides ØA power to pH sensor probe.		115 vac 400 cps 3Ø		
	H_2 & O_2 VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 3 - REACTANTS switch (MDC-18).		+28 vdc		Opened after operation of F/C VALVES-RESET switch (MDC-19).

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 3 bus disconnect control through FUEL CELL 3 - MAIN BUS A and MAIN BUS B switches (MDC-18) b. Provides power to reactants event indicator.	N/A	+28 vdc	None	
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C purge valve control through FUEL CELL 3 - O_2 PURGE - H_2 PURGE switch (MDC-18).				
	INVERTER CONTROL circuit breakers 1 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 1 and AC INVERTER 3 switches (MDC-18).				
	2 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 2 and AC INVERTER 1 switches (MDC-18).				
	3 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 2 and AC INVERTER 3 switches (MDC-18).				
	MASTER EVENT SEQ CONT circuit breakers ARM group BAT A (5 amp)	Applies d-c power from battery bus A to the following switches: a. MESC-LOGIC ARM switches 1 and 2 (MDC-25) b. MASTER EVENT SEQ CONT-PYRO ARM switches 1 and 2 (MDC-24) c. LES MOTOR FIRE switch (MDC-5) d. CANARD DEPLOY switch (MDC-5)				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		e. ADAPT SEP switch (MDC-5) f. REACTION CONTROL SYSTEM - C/M PRESS switch (MDC-16) g. REACTION CONTROL SYSTEM - CMD/ON/OFF switch (MDC-16) h. C/M - S/M SEP switches 1 and 2 (MDC-15).	N/A	+28 vdc	None	
	BAT B (5 amp)	Applies d-c power from battery bus B to the following switches: a. MESC-LOGIC ARM switches 1 and 2 (MDC-25) b. MASTER EVENT SEQ CONT - PYRO ARM switches 1 and 2 (MDC-24) c. LES MOTOR FIRE switch (MDC-5) d. CANARD DEPLOY switch (MDC-5) e. ADAPT SEP switch (MDC-5) f. REACTION CONTROL SYSTEM - C/M PRESS switch (MDC-16) g. REACTION CONTROL SYSTEM - CMD/ON/OFF switch (MDC-16) h. C/M - S/M SEP switches 1 and 2 (MDC-15).				
	LOGIC group BAT A (15 amp)	a. Applies d-c power from battery bus A to the logic A bus in the master event sequence controller when the MESC - LOGIC ARM switches 1 and 2 (MDC-25) are in the LOGIC ARM position. The logic bus in turn provides power to the ABORT SYSTEM—MODE switches 1 and 2 and, during LES aborts, to the ABORT SYSTEM—OX DUMP switch.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		b. Arms the abort switch in commanders translation control c. Provides part of the power to the LES and SPS abort circuitry.	N/A	+28 vdc	None	
	BAT B (15 amp)	a. Applies d-c power from battery bus B to the logic B bus in the master event sequence controller when the MESC - LOGIC ARM switches 1 and 2 (MDC-25) are in the LOGIC ARM position. The logic bus in turn provides power to the ABORT SYSTEM—MODE switches 1 and 2 and, during LES aborts provides power to the ABORT SYSTEM—OX DUMP switch. b. Arms the abort switch in commanders translation control. c. Provides part of the power for the LES and SPS abort circuitry.				
	DC SNSR SIG circuit breakers					Unit receives power from battery relay bus through circuit breakers on MDC-21.
	MN A (5 amp)	Applies power from d-c main bus A to d-c undervoltage sensing unit and DC INDICATORS switch.				
	MN B (5 amp)	Applies power from d-c main bus B to d-c undervoltage sensing unit and DC INDICATORS switch.				
	CENTRAL TIMING SYS circuit breakers		None			The CTE contains two power supplies for redundancy, No. 1 and No. 2. If either one fails, the other will provide sufficient power for the CTE.
	MN A (5 amp)	Applies 28-vdc power to CTE power supply No. 1		D-C main bus A		
	MN B (5 amp)	Applies 28-vdc power to CTE power supply No. 2		D-C main bus B		
	SCIEN EQUIP circuit breakers					Compartment A scientific equipment outlet is located in the LEB. (See figure 4-13.)
	SEB-1 (20 amp)	Applies power from non-essential bus to scientific equipment outlet in component A.		NON ESS BUS NO. 2 +28 vdc		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	SEB-2 (20 amp)	Applies power from non-essential bus to scientific equipment outlet in compartment B. (Proposed)	None	NON ESS BUS NO. 2 +28 vdc	None	(See figure 4-13.)
	BAT RLY BUS circuit breakers					
	BAT A (20 amp)	Applies d-c power from battery bus A through an isolation diode to battery relay bus.				
	BAT B (20 amp)	Applies d-c power from battery bus B through an isolation diode to battery relay bus.				
	BATTERY CHARGER circuit breakers			+28 vdc		
	BAT A CHGE (10 amp)	Applies d-c power from battery bus A to MAIN BUS TIE - BAT A & C switch (MDC-22) and through contacts of bus tie motor switch to position A of BATTERY CHARGER selector switch (MDC-18).				
	BAT B CHGE (10 amp)	Applies d-c power from battery bus B to MAIN BUS TIE - BAT B & C switch (MDC-22) and through contacts of bus tie motor switch to position B of BATTERY CHARGER selector switch (MDC-18).				
	MN A (5 amp)	Applies power from d-c main bus A, through an isolation diode, to BATTERY CHARGER selector switch (MDC-18) and d-c contacts of battery charger input-power control relay.				
	MN B (5 amp)	Applies power from d-c main bus B, through an isolation diode, to BATTERY CHARGER selector switch (MDC-18) and d-c contacts of battery charger input-power control relay.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	AC PWR (2 amp)	Applies power from a-c bus No. 1 or a-c bus No. 2 to contacts of battery charger input-power control relay.	None	115 vac 400 cps 3 phase	None	
	TELECOMMUNICATIONS circuit breakers GROUP number 1 AC (2 amp)	Applies 115-vac 3-phase power to: a. VHF-FM transmitter via internal power control relay controlled by VHF/FM switch (MDC-20) b. C-band transponder via power control relay K3 in circuit utilization box; relay is controlled by C-BAND switch (MDC-20) c. DSE; controlled by TAPE RECORDER switches (MDC-20) and logic circuitry in DSE d. FQR; controlled by FLIGHT QUAL RCDR switch (MDC-19) and logic circuitry in FQR. e. Voice recorder power converter, controlled by RCDR/HF-T/R and POWER-VOX switches MDC-13, -23, -26.		A-C bus No. 1 or 2		A-C bus supplying power to this equipment is determined by position of TELCOM—NON ESS switch (MDC-22).
	2 AC (2 amp)	Applies 115-vac 3-phase power to: a. USBE power supply via power control relay K2 in circuit utilization box, relay is controlled by S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) b. PMP power supply via internal power control relay, controlled by PWR-PMP switch and S-BAND-EMERG switch (MDC-20).				A-C bus supplying power to this equipment is determined by position of TELCOM—ESS switch (MDC-22).

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	3 (5 amp)	Applies 28-vdc power to: a. Engineer's audio center POWER switch (MDC-23) b. RECOVERY—VHF-BCN switch (MDC-20) c. Commander's left microphone amplifier d. Engineer's right microphone amplifier.	None	Flight and Postlanding Bus	None	
	4 (10 amp)	Applies 28-vdc power to: a. Commander's audio center POWER switch (MDC-26) b. VHF/AM transmitter-receiver and HF transceiver keying relay coils c. RECOVERY—HF—ON/OFF switch (MDC-20) d. VHF-AM—T/R/OFF/REC switch (MDC-20) e. Navigator's left microphone amplifier f. Commander's right microphone amplifier.				
	5 (7.5 amp)	Applies 28-vdc power to: a. Navigator's audio center POWER switch (MDC-13) b. TAPE RECORDER—FWD/REV switch (MDC-20) c. TAPE RECORDER—RECORD/PLAY switch (MDC-20) d. POWER—SCE switch (MDC-20) e. POWER—PMP switch (MDC-20) f. S-BAND—EMERG switch (MDC-20) g. VHF-FM—ON/OFF switch (MDC-20)				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		h. S-BAND—PWR AMPL switch (MDC-20) i. C-BAND—1 PULSE/2 PULSE switch (MDC-20) j. S-BAND PA equipment k. TV equipment l. DSE m. USBE power control relays n. UP-DATA switch (MDC-20) and up-data link equipment o. VHF ANTENNA switch (MDC-20) p. S-BAND ANTENNA switch through S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) q. Engineer's left microphone amplifier r. Navigator's right microphone amplifier s. BIO-MED PCM/TLM	None	Flight and Postlanding Bus	None	
	PCM TLM (2 amp)	Applies 115 vac 3-phase power to PCM/telemetry equipment.		AC NON ESS BUS 1 or 2		A-C bus supplying power to this equipment is determined by position of TELCOM—NON ESS switch (MDC-22).
	SIG COND S-BAND PA AC (2 amp)	Applies 115 vac 3-phase power to: a. SCE power supply via internal latching relay controlled by PWR-SCE switch (MDC-20) b. S-band PA power supplies via power control relay K1 in circuit utilization box; relay is controlled by S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20).				A-C bus supplying power to this equipment is determined by position of TELCOM—ESS switch (MDC-22).
	SCIEN EQUIP HATCH circuit breaker (20 amp)	Applies power from nonessential bus to No. 2 to scientific equipment receptacle below RH and LH observation windows.		DC NON ESS BUS NO. 2 +28 vdc		(See figures 5-3 and 5-4)

MAIN DISPLAY CONSOLE—PANEL 22

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	ECS circuit breakers		None	+28 vdc	None	
	H_2O ACCUM group					
	MN A (5 amp)	Applies power from d-c main bus A to the following: a. H_2O ACCUM-AUTO 1/MAN/AUTO 2 switch (MDC-13) b. H_2O accumulator pump failure detection unit.				
	MN B (5 amp)	Applies power from d-c main bus B to the following: a. H_2O ACCUM-AUTO 1/MAN/AUTO-2 switch (MDC-13) b. H_2O accumulator pump failure detection unit.				
	GAS ANAL circuit breaker			115 vac 400 cps 3ϕ		
	AC 1 (2 amp)	Applies ϕA a-c power to gas chromatograph package (GFE) located in scientific equipment compartment of LEB.				
	INSTRUMENTS circuit breakers			D-C main bus A		
	ESS group					
	MN A (15 amp)	Applies 28-vdc power to ESSENTIAL - 1, -2, -3, & -4 circuit breakers on INST PWR CONT panel (RHEB-204).				
	MN B (15 amp)	Applies 28-vdc power to ESSENTIAL - 1, -2, -3, & -4 circuit breakers on INST PWR CONT panel (RHEB-204).		D-C main bus B		
	NON ESS BUS (5 amp)	None				
	NON ESS (15 amp)	Applies 28-vdc power to NON ESSENTIAL-5 through -10 circuit breakers on INST PWR CONT panel (RHEB-204).		D-C main bus A or B		

MAIN DISPLAY CONSOLE—PANEL 22

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	RCDR NON ESS (5.0 amp)	Applies 28-vdc power to FQR. Applies 28-vdc power to VOICE RECORD event indicator (MDC-19)	None	D-C main bus A or B	None	The nonessential buses No. 1 and No. 2 obtain 28 vdc power from D-C main bus A or B, depending on position of NON ESS BUS switch (MDC-22).
	SCIEN (7.5 amp)	Applies power from nonessential bus No. 1 for scientific instruments. (Not used.)				
	GUIDANCE & NAVIGATION circuit breakers			+28 vdc		
	IMU HTR group					
	MN A (7.5 amp)	Applies power from d-c main bus A to IMU heaters.				
	MN B (7.5 amp)	Applies power from d-c main bus B to IMU heaters.				
	IMU group		N/A			
	MN A (25 amp)	Applies power from d-c main bus A to IMU.				
	MN B (25 amp)	Applies power from d-c main bus B to IMU.				
	COMPUTER group					
	MN A (10 amp)	Applies power from d-c main bus A to AGC.				
	MN B (10 amp)	Applies power from d-c main bus B to AGC.				
	OPTICS group					
	MN A (10 amp)	Applies power from d-c main bus A to optics.				
	MN B (10 amp)	Applies power from d-c main bus B to optics.				
	VIEWER group			115 vac 400 cps ØB		
	AC 1 (1 amp)	Applies power from a-c bus No. 1 to G&N VIEWER switch.				
	AC 2 (1 amp)	Applies power from a-c bus No. 2 G&N VIEWER switch.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	ENVIRONMENTAL CONTROL SYSTEM circuit breakers		N/A		None	
	CABIN AIR FAN - 1 group					
	AC 1 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies 3Ø power from a-c bus No. 1 to the following: a. CABIN AIR FAN - 1 switch MDC-21) b. Waste management blower switch (RHEB-201).		115 vac 400 cps 3Ø		
	CABIN AIR FAN -2 group					
	AC 2 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies power from a-c bus No. 2 to the following: a. 3Ø to CABIN AIR FAN-2 switch (MDC-21) b. ØC to CABIN TEMP - AUTO/MAN switch (MDC-13).				
	GLYCOL PUMPS group					
	AC 1 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies power from a-c bus No. 1 to the following: a. 3Ø to ECS GLYCOL pump switch (MDC-21) b. ØA to GLYCOL EVAP - TEMP IN switch (MDC-13) c. ØB to SUIT EVAP switch (MDC-13) d. ØC to GLYCOL EVAP - STEAM PRESS - AUTO/MAN switch (MDC-13). e. ØC to GLYCOL EVAP - H_2O FLOW switch (MDC-13).				
	AC 2 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies 3Ø power from a-c bus No. 2 to ECS GLYCOL pump switch (MDC-21).				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	TRANSDUCER group WASTE & POT H_2O MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. Waste water tank b. Potable water tank.	N/A	+28 vdc	None	
	MN B (5 amp)	Applies power from d-c main bus B to the following pressure transducer: a. Waste water tank b. Potable water tank.				
	PRESS GROUPS-1 MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. Suit b. Compressor ΔP c. Water-glycol pump discharge d. Water-glycol accumulator (quantity) e. Water-gly evap steam.				
	MN B (5 amp)	Applies power from d-c main bus B to the following pressure transducers: a. Suit b. Compressor ΔP c. Water-glycol pump discharge d. Water-glycol accumulator (quantity) e. Water-gly evap steam.				
	PRESS GROUPS-2 MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. O_2 flow rate b. O_2 supply regulator outlet (telemetered only)				

MAIN DISPLAY CONSOLE—PANEL 22

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		c. Cabin d. CO_2 partial pressure.	N/A	+28 vdc	None	
	MN B (5 amp)	Applies power from d-c main bus B to the following pressure transducers: a. O_2 flow rate b. O_2 supply regulator outlet (telemetered only) c. Cabin d. CO_2 partial pressure.				
	TEMP group					
	MN A (5 amp)	Applies power from d-c main bus A to the temperature transducer power supply, and in turn to the following transducer amplifiers: a. Water-gly evap liquid outlet b. Cabin c. Suit d. Steam duct (telemetered only) e. Space radiator outlet.				
	MN B (5 amp)	Applies power from d-c main bus B to the temperature transducer power supply, and in turn to the following transducer amplifiers: a. Water-gly evap liquid outlet b. Cabin c. Suit d. Steam duct (telemetered only) e. Space radiator outlet.				
	SUIT COMPRESSORS group					
	AC 1 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies power from a-c bus No. 1 to SUIT COMPRESSOR switch (MDC-21).		115 vac 400 cps 3Ø		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	AC 2 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies power from a-c bus No. 2 to SUIT COMPRESSOR switch (MDC-21).	N/A	115 vac 400 cps 3Ø	None	
	RAD VALVE group AC 1 1A (2 amp)	Applies ØA power from a-c bus No. 1 to ECS - RADIATOR-1-A switch (MDC-21).				
	2B (2 amp)	Applies ØB power from a-c bus No. 1 to ECS - RADIATOR-2-B switch (MDC-21).				
	AC 2 1B (2 amp)	Applies ØA power from a-c bus No. 2 to ECS - RADIATOR-1-B switch (MDC-21).				
	2A (2 amp)	Applies ØC power from a-c bus No. 2 to ECS - RADIATOR-2-A switch (MDC-21).				
	POT H_2O HTR group MN A (5 amp)	Applies power from d-c main bus A to the following: a. POT H_2O HEATER switch (MDC-21) b. GLYCOL EVAP - H_2O FLOW switch (MDC-13).		+28 vdc		
	MN B (5 amp)	Applies power from d-c main bus B to the following: a. POT H_2O HEATER switch (MDC-21) b. GLYCOL EVAP - H_2O FLOW switch (MDC-13) c. WASTE H_2O TK REFILL switch (MDC-13).				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	CRYOGENIC TANK FAN MOTORS circuit breakers		N/A		None	
	AC 1 group					
	ØA (2 amp)	Applies a-c ØA power from a-c bus No. 1 ØA to: a. H_2 FANS - 1 switch (MDC-13) b. O_2 FANS - 1 switch (MDC-13).		115 vac ØA		
	ØB (2 amp)	Applies a-c ØB power from a-c bus No. 1 ØB to: a. H_2 FANS - 1 switch (MDC-13) b. O_2 FANS - 1 switch (MDC-13).		115 vac ØB		
	ØC (2 amp)	Applies a-c ØC power from a-c bus No. 1 ØC to: a. H_2 FANS - 1 switch (MDC-13) b. O_2 FANS - 1 switch (MDC-13).		115 vac ØC		
	AC 2 group					
	ØA (2 amp)	Applies a-c ØA power from a-c bus No. 2 ØA to: a. H_2 FANS - 2 switch (MDC-13) b. O_2 FANS - 2 switch (MDC-13).		115 vac ØA		
	ØB (2 amp)	Applies a-c ØB power from a-c bus No. 2 ØB to: a. H_2 FANS - 2 switch (MDC-13) b. O_2 FANS - 2 switch (MDC-13).		115 vac ØB		
	ØC (2 amp)	Applies a-c ØC power from a-c bus No. 2 ØC to: a. H_2 FANS - 2 switch (MDC-13) b. O_2 FANS - 2 switch (MDC-13).		115 vac ØC		

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	CRYOGENIC SYSTEM circuit brrakers		N/A	+28 vdc	None	
	TANK HEATERS group					
	H_2 circuit breakers					
	MN A (5 amp)	Applies power from d-c main bus A to H_2 HEATERS switch (MDC-13).				
	MN B (5 amp)	Applies power from d-c main bus B to H_2 HEATERS switch (MDC-13).				
	O_2 circuit breakers					
	MN A (15 amp)	Applies power from d-c main bus A to O_2 HEATERS switch (MDC-13).				
	MN B (15 amp)	Applies power from d-c main bus B to O_2 HEATERS switch (MDC-13).				
	QTY AMPL group			115 vac 400 cps ØC		
	AC1-ØC (2 amp)	Applies power from a-c bus No. 1 (ØC) to H_2 and O_2 No. 1 tanks signal conditioning boxes.				
	AC2-ØC (2 amp)	Applies power from a-c bus No. 2 (ØC) to H_2 and O_2 No. 2 tanks signal conditioning boxes.				
MDC-23	FLOODLIGHTS control		COUCH ATTEN MN A MN B FLOOD-LIGHTS (MDC-25)	D-C main buses A and B	None	FLOODLIGHTS controls on MDC-23, -26, and LEB-100 are functionally identical and each controls the flood-lights in its respective area.
	PRIMARY rheostat					The rheostat control may be adjusted for desired brightness of primary
	OFF	Removes power from C/M primary floodlights.				
	BRIGHT	Indicates maximum floodlight brightness has been reached.				
	SECONDARY switch					
	ON	Illuminates secondary floodlights.				
	OFF	Removes power from secondary floodlights.				

MAIN DISPLAY CONSOLE—PANELS 22 AND 23

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	C/W LAMP TEST switch		CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	None	Lamp check of G&N condition lights and the MASTER ALARM light on LEB-103 is accomplished by pressing CHECK CONDITION LAMPS switch (LEB-105).
	1	Completes d-c ground return path for test illumination of system status lights on MDC-10 and the MASTER ALARM switch-lights on MDC-3 and -18.				Master alarm tone is not activated by test illumination of lights.
	OFF	Opens d-c ground return path of lamp test circuit, extinguishing system status lights on MDC-10 and -11.				
	2	Completes d-c ground return path for test illumination of system status lights on MDC-11.				
	POWER switch	Controls power to pilots module in audio center equipment.	T/C— CROUP 3 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position.
	PTT	Applies d-c power to audio and control circuits.				Intercom capability when cobra cable PTT/CW switch is in CW and transmit when switch is in PTT.
	OFF	Removes power from pilots audio center equipment module and controls.				
	VOX	a. Applies d-c power to audio and control circuits b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.				VOX operation permits voice transmission and transmitter keying of intercom, HF recovery transceiver and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch		N/A	Audio center equipment		The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the pilots module of the audio center equipment to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	T/R	No effect. S-band T/R function supplied by cobra cable PTT key.				
	OFF	Prevents pilot from transmitting or receiving voice over USBE.				
	RCV	Enables pilot to receive voice from USBE.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	RCDR HF switch		N A	Audio center equipment	None	Provides power ground through audio center VOX circuit for HF transceiver transmit-receive relay and voice recorder power relay.
	T/R	a. Enables pilot to transmit and receive voice over HF transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				
	OFF	Prevents pilot from transmitting or receiving voice over HF transceiver.				
	RCV	Enables pilot to receive voice from HF transceiver when operating in AM or SSB mode.				
	VHF AM switch					VHF-AM transmits, in addition to S-band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switches must be at PTT, and audio center POWER switch must be at PTT.
	T/R	Enables pilot to transmit and receive voice over VHF/AM transmitter-receiver when operating in T/R mode.				
	OFF	Prevents pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				
	RCV	Enables pilot to receive voice from VHF-AM transmitter-receiver.				
	INTERCOM switch					Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT CW switch is at PTT.
	T/R	Enables pilot to transmit and receive voice over the intercom system.				
	OFF	Prevents pilot from transmitting or receiving voice over intercom system.				
	RCV	Enables pilot to receive voice from intercom system.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	VOX SENS control	Increase or decreases sensitivity of voice-operated relay circuitry in pilots audio center module.	N/A	Audio center equipment	None	These three controls are thumbwheel-type potentiometers which may be rotated upward or downward, as required.
	INTERCOM BALANCE control	Increases or decreases level of audio signal received by pilot from RF equipment relative to that received from intercom bus.				Position 9 *most sensitive*
	VOLUME control	Increases or decreases level of audio signal from pilot's ear-phone amplifier to earphone.				
MDC-24	EDS POWER switch ON OFF	Supplies entry battery A, B, and C power to the EDS buses 1, 2, and 3. Removes power from EDS buses 1, 2, and 3.	EDS-1, 2, 3 BAT A BAT C and BAT B (MDC-25)	Battery buses A, B, and entry battery C	None	Closing of the EDS POWER switch provides power to the EDS display circuitry and also supplies power for the EDS auto abort initiating circuitry.
	MASTER EVENT SEQ CONT—PYRO ARM switches Switches 1 and 2 PYRO ARM SAFE	Energizes relays in the MESC which perform the following: a. Connects pyro battery A to the MESC pyro bus A b. Connects pyro battery B to the MESC pyro bus B c. Connects pyro battery A to the C/M RCSC pyro bus A d. Connects pyro battery B to the C/M RCSC pyro bus B. Removes pyro battery power from the MESC pyro buses A and B, and RCS controllers.	MASTER EVENT SEQ CONT-A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0005V DC voltage pyro bus A CD0006V DC voltage pyro bus B	Lever lock-type switches are locked in the SAFE position and must be unlocked before they can be set to PYRO ARM position. The lock and guard assembly must be unlocked with a key prior to hatch closeout. The range safety officer will have possession of the key.
	SCS GROUP 2 controls TVC 2 POWER switch AC 1	Applies a-c power to the gimbal positioning portion of the following: a. Yaw ECA b. Pitch ECA c. Redundant gimbal trim pot.	SCS—GROUP 2 AC 1 (MDC-25)	A-C bus No. 1		TVC 2 POWER switch supplies power to the redundant TVC electronics. Switch must be set to AC 1 or AC 2 position during any ΔV maneuver. It will provide the backup TVC capability required for automatic switchover from TVC 1 in the event of a malfunction. MTVC can only be accomplished using TVC 2 electronics. The TVC 2 power switch also provides power to the MTVC electronics.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	OFF	Removes a-c power from units supplied by AC 1 and AC 2 positions.	SCS—GROUP 2 AC 1 (MDC-25)	A-C bus No. 1	None	
	AC 2	Applies a-c power to the following: a. Yaw ECA b. Pitch ECA c. Redundant gimbal trim pot.	SCS—GROUP 2 AC 2 (MDC-25)	A-C bus No. 2		
	ROTATION CONTROL POWER switch					Switch is a three-position toggle and must be in either the 1 or 2 position for normal rotation control operation.
	AC 1	Applies a-c power to the following: a. Command pilot's rotation control b. Senior pilot's rotation control c. Pitch ECA d. Yaw ECA e. Roll ECA	SCS—GROUP 2 AC 1 (MDC-25)	A-C bus No. 1 ØA		This switch has no affect on the rotation control direct mode function. Power for the two rotation controls is provided through the yaw, pitch, and roll ECAs. The power applied to yaw, pitch, and roll ECAs is demodulator reference voltage for rotation control output signals.
	OFF	Removes a-c power from units supplied by positions 1 and 2.				
	AC 2	Applies a-c power to the following: a. Command pilot's rotation control b. Senior pilot's rotation control c. Pitch ECA d. Yaw ECA e. Roll ECA	SCS—GROUP 2 AC 2 (MDC-25)	A-C bus No. 2 ØA		
	BMAG POWER switch					The power applied to DISPLAY/AGAA ECS is used to operate the BMAGs, torquing amplifiers, and preamplifiers in the AGAA. The power applied to pitch, yaw, and roll ECAs is demodulator reference voltage for BMAG error signal.
	AC 1	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Yaw ECA d. Roll ECA e. Attitude gyros spin motor power through DISPLAY/AGAA ECA	SCS—GROUP 2 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	CFF	Removes a-c and d-c power from units supplied by position AC 1 and AC 2.	SCS—GROUP 2 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A	None	Provides power for backup rate function.
	AC 2	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECS b. Pitch ECA c. Yaw ECA d. Roll ECA e. Attitude gyros spin motor power through DISPLAY/AGAA ECA.	SCS—GROUP 2 AC 2 MN B (MDC-25)	A-C bus No. 2 D-C main bus B		
	SCS GROUP 1 controls PARTIAL SCS POWER switch AC 1	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Roll ECA d. Auxiliary ECA e. Yaw ECA f. Velocity change indicator g. Attitude set/gimbal position indicator.	SCS—GROUP 1 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A		Switches are three-position rotary type. Refer to section 6, Normal/Backup Procedures, for the various switch positions required for the flight control modes. D-C voltage is provided to AS/GPI and the FDAI ALIGN switch. Three-phase a-c voltage is provided for the following: a. Aux ECA demodulator reference voltages and AGCU power supplies b. FDAI total attitude display motor, and associated electronics. Phase A a-c voltage is provided for the following: a. FDAI error needles b. FDAI ball drive servo amplifier c. FDAI rate needles for backup rate d. FDAI self-test circuit e. AS/GPI gimbal position excitation voltage f. Square wave generator reference voltage g. AGCU amplifier demodulator reference voltage.
	OFF	Removes a-c and d-c power from units supplied by AC 1 and AC 2 positions.				
	AC 2	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Roll ECA d. Auxiliary ECA e. Yaw ECA f. Velocity change indicator g. Attitude set/gimbal position indicator.	SCS—GROUP 1 AC 2 MN B (MDC-25)	A-C bus No. 2 D-C main bus B		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	RATE GYRO POWER switch				None	The RATE GYRO POWER switch applies three-phase, 115-vac power to the rate gyro assembly.
	AC 1	Applies a-c power to the following: a. Rate gyro assembly. b. Yaw ECA c. Pitch ECA d. Roll ECA e. Display/AGAA ECA.	SCS—GROUP 1 AC 1 (MDC-25)	A-C bus No. 1		Phase A, 115-vac power is provided for the following: a. Roll, pitch, yaw ECA rate demodulator reference voltage. b. Roll, pitch, and yaw rate demodulators reference in display/AGAA ECA.
	OFF	Removes a-c power from units supplied by AC 1 and AC 2 positions.				
	AC 2	Applies a-c power to the following: a. Rate gyro assembly b. Yaw ECA c. Pitch ECA d. Roll ECA e. Display/AGAA ECA.	SCS—GROUP 1 AC 2 (MDC-25)	A-C bus No. 2		
	TVC 1 POWER switch					The TVC 1 POWER switch applies 115 vac and 28 vdc to the pitch and yaw TVC power supplies in the TVC electronics.
	AC 1	a. Applies a-c power to the pitch and yaw ECAs. b. Applies d-c power to the DISPLAY/AGAA ECA c. X-axis accelerometer.	SCS—GROUP 1 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A		Provide necessary power for operating the ΔV REMAINING electronics. After completion of a burn, the switch must be placed to OFF then on to reactivate the ΔV inhibit circuit.
	OFF	Removes a-c and d-c power from units supplied by AC 1 and AC 2 positions.				Provides power to the X-axis accelerometer on associated electronics through circuits in the display/AGAA ECA.
	AC 2	a. Applies a-c power to the pitch and yaw ECAs. b. Applies d-c power to the DISPLAY/AGAA ECA. c. X-axis accelerometer	SCS—GROUP 1 AC 2 MN B (MDC-25)	A-C bus No. 2 D-C main bus B		

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	DIRECT O_2 metering valve		N/A	N/A	None	Valve has a shaft rotation of 1-3/4 turns from OPEN to close, and is manually controlled by a T-handle tool. This tool is stowed in DIRECT O_2 valve socket for use in positioning other valves accessible to crewman in LH couch. A second T-handle tool is stowed in LHEB-314 for operating valves in that area.
	OPEN (ccw)	Permits controlled flow of oxygen directly into suit circuit.				Valve is opened in event of contamination or inability of demand pressure regulator to maintain minimum pressure. It may also be opened for cooling during descent, if necessary. In full open position flow rate is 0.66 pound/minute for approximately 5 minutes.
	Close (cw)	Shuts off flow of oxygen directly into suit circuit.				Normal position of valve is closed.
MDC-25	POSTLANDING controls		N/A		None	
	FLOAT BAG 1 PL BUS circuit breaker (5 amp)	Applies d-c power from the flight and postlanding bus to the POST-LANDING-FLOAT BAG switch No. 1 (MDC-25).		+28 vdc		
	VENT FAN group					
	PL BUS-FLOAT BAG 2 circuit breaker (5 amp)	Applies d-c power from flight and postlanding bus to the following: a. FLOAT BAG switch 2 (MDC-25) b. VENT FAN-HIGH/LOW/OFF switch (MDC-25).				
	HIGH/LOW/OFF switch		POST-LANDING—VENT FAN PL BUS—FLOAT BAG 2 (MDC-25)	Flight and postlanding bus		Prior to switch actuation, lockpins installed in both vent valves must be pulled.
	HIGH	Applies d-c power to the following: a. Inlet and outlet vent valve motors, placing valves in open position. b. Vent fan motor for high flow output.				Output of cabin vent fan in HIGH is 150 cfm. Cabin vent valve full travel requires 1.5 seconds (max).

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	LOW	Applies d-c power to the following: a. Inlet and outlet vent valve motors, placing valve in open position. b. Vent fan motor for low flow output.	POST-LANDING—VENT FAN PL BUS—FLOAT BAG 2 (MDC-25)	Flight and postlanding bus	None	Output of cabin vent fan in LOW is 100 cfm. Cabin vent valve full travel requires 1.5 seconds (max).
	OFF	Removes d-c power from motor of cabin vent fan, and applies power to motors of inlet and outlet cabin vent valves, placing valves in closed position.				Both vent valves will be immediately closed by activation of the PLV attitude switch when the C/M becomes inverted or rolls beyond a specified limit. Switch must be set to OFF position before reactivating the PLV.
	FLOAT BAG group Switch 1 FILL	Starts two compressors which inflate flotation bag No. 1	POST-LANDING—FLOAT BAG 1 PL BUS (MDC-25)			Lever lock-type switch. Flotation bag No. 1 is located on the +Y axis in the forward compartment of the C/M.
	Center	Neutral (off) position.				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 1				The switch must remain in the VENT position during launch and throughout flight.
	Switch 2 FILL	Starts two compressors which inflate flotation bag No. 2.	POST-LANDING—VENT FAN-PL BUS-FLOAT BAG 2 (MDC-25)			Lever lock-type switch. Flotation bag No. 2 is located on the +Z axis in the forward compartment of the C/M.
	Center	Neutral (off) position.				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 2.				The switch must remain in the VENT position during launch and throughout flight.
	Switch 3 FILL	Starts two compressors which inflate flotation bag No. 3.	ELS-A BAT A—FLOAT BAG 3 (MDC-25)	Battery bus A		Lever lock-type switch Flotation bag No. 3 is located on the +Z axis in the forward compartment of the C/M.
	Center	Neutral (off) position				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 3				The switch must remain in the VENT position during launch and throughout flight.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	ANTENNA DEPLOY switches		PYRO A GROUP—SEQ A and PYRO B group - SEQ B (LEB-150)	Pyro bus A and pyro bus B in the MESC when the MASTER EVENT SEQ CONT—PYRO switches A and B are in the ARM position	None	
	DEPLOY					Two-position toggle switch that is set to A after landing when C/M is in upright position.
	A	Connects 28 vdc to the postlanding antenna deploy circuitry.				
	OFF	Normal position, no function.				
	B	Connects 28 vdc to the postlanding antenna deploy circuitry. Backup switch for DEPLOY switch A.				Two-position toggle switch that is set to B after landing when C/M is in upright position.
	OFF	Normal position, no function.				
	MESC—LOGIC ARM switches		MASTER EVENT SEQ CONT-A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0200V D-C voltage logic bus A CD0201V D-C voltage logic bus B	Lever lock-type switches.
	Switches 1 and 2					
	LOGIC ARM	Energizes relays in both MESC which perform the following: a. Connects battery bus A to the MESC A logic bus A b. Connects battery bus B to the MESC B logic bus B.				
	OFF	Removes 28 vdc from MESC logic buses A and B.				
	EVENT TIMER circuit breakers		N/A	+28 vdc	None	
	MN A (5 amp)	Applies d-c power from d-c main bus A to event timer switches (MDC-8).				
	MN B (5 amp)	Applies d-c power from d-c main bus B to event timer switches (MDC-8).				
	COUCH ATTEN - FLOOD-LIGHTS circuit breakers					
	MN A (15 amp)	Applies d-c power from d-c main bus A to the following controls: a. FLOODLIGHTS-PRIMARY rheostat (MDC-26).				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	MN B (15 amp)	b. LIGHTING-FLOODS-PRIMARY rheostat (LEB-100) c. FLOODLIGHTS-SECONDARY switch (MDC-23) d. COUCH UNLOCK switch (MDC-8) e. LIGHTING-FLOODS-CLOCKS switch (LEB-100)	N/A	+28 vdc	None	
		Applies d-c power from d-c main bus B to the following controls: a. FLOODLIGHTS-PRIMARY rheostat (MDC-23) b. LIGHTING-FLOODS-SEC switch (LEB-100) c. FLOODLIGHTS-SECONDARY switch (MDC-26) d. COUCH UNLOCK switch (MDC-8).				
	STABILIZATION & CONTROL SYSTEM circuit breakers (top row) DIRECT CONT group MN A (30 amp)	Applies power from d-c main bus A to the following: a. DIRECT RCS switch on MDC-8 b. DIRECT ULLAGE switch on MDC-7 c. NORMAL/OFF/DIRECT ON switch on MDC-7 d. Arms command pilot's rotation control for direct commands through direct RCS switch				
	MN B (30 amp)	Applies power from d-c main bus B to the following: a. DIRECT RCS switch on MDC-8 b. DIRECT ULLAGE switch on MDC-7				

MAIN DISPLAY CONSOLE—PANEL 25

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)		c. NORMAL/OFF/DIRECT ON switch on MDC-7 d Arms senior pilot's rotation control for direct commands, through direct RCS switch.	N/A	+28 vdc	None	
	A & C ROLL group					
	MN A (20 amp)	Applies power from d-c main bus A to A & C ROLL channel switch on MDC-8.				
	MN B (20 amp)	Applies power from d-c main bus B to A & C ROLL channel switch on MDC-8.				
	B & D ROLL group					
	MN A (20 amp)	Applies power from d-c main bus A to B & D ROLL channel switch on MDC-8.				
	MN B (20 amp)	Applies power from d-c main bus B to B & D ROLL channel switch on MDC-8.				
	PITCH group					
	MN A (20 amp)	Applies power from d-c main bus A to PITCH channel switch on MDC-8.				
	MN B (20 amp)	Applies power from d-c main bus B to PITCH channel switch on MDC-8.				
	YAW group					
	MN A (20 amp)	Applies power from d-c main bus A to YAW channel switch on MDC-8.				
	MN B (20 amp)	Applies power from d-c main bus B to YAW channel switch on MDC-8.				

Maneuver function - engine activation

SCS CB	Function	S/M RCS Engine
A&C ROLL MN A	roll right	A13
A&C ROLL MN B	roll right	C15
A&C ROLL MN A	roll left	A16
A&C ROLL MN B	roll left	C14
B&D ROLL MN A	roll right	B9
B&D ROLL MN B	roll right	D11
B&D ROLL MN A	roll left	B12
B&D ROLL MN B	roll left	D10
PITCH MN B	pitch up	A3
PITCH MN A	pitch up	C1
PITCH MN A	pitch down	A2
PITCH MN B	pitch down	C4
YAW MN A	yaw right	B7
YAW MN B	yaw right	D5
YAW MN B	yaw left	B6
YAW MN A	yaw left	D8

SCS CB	Function	C/M RCS Engine
B&D ROLL MN A	roll right	A9
B&D ROLL MN B	roll right	B11
B&D ROLL MN A	roll left	A12
B&D ROLL MN B	roll left	B10
PITCH MN A	pitch up	A1
PITCH MN B	pitch up	B3
PITCH MN A	pitch down	A2
PITCH MN B	pitch down	B4
YAW MN A	yaw right	A5
YAW MN B	yaw right	B7
YAW MN A	yaw left	A8
YAW MN B	yaw left	B6

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	STABILIZATION & CONTROL SYSTEM controls (bottom row)				None	
	FDAI LTG switch	Controls application of a-c power to the FDAI brightness control on MDC-2 for FDAI lighting and for illumination of the lamp in the THRUST ON switch on MDC-7.	SCS—GROUP 2 AC 1 or AC 2	A-C bus 1 or a-c bus 2		
	AC 1	Applies a-c bus 1 phase B power to FDAI brightness control.				
	OFF	Removes all a-c power from FDAI brightness control.				
	AC 2	Applies a-c bus 2 phase B power to FDAI brightness control.				
	GROUP 1 circuit breakers		N/A	115 vac 400 cps 3 phase		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to the following switches on MDC-24: a. SCS POWER b. RATE GYRO POWER c. TVC 1 POWER.				
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to the following switches on MDC-24: a. SCS POWER b. RATE GYRO POWER c. TVC 1 POWER.				
	GROUP 2 circuit breakers					
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to the following switches on MDC-24: a. BMAG POWER b. ROTATION CONTROL POWER c. TVC 2 POWER				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	AC 2 (2 amp)	Applies power from a-c bus No. 2 to the following switches on MDC-24: a. BMAG POWER b. ROTATION CONTROL POWER c. TVC 2 POWER.	N/A	115 vac 400 cps 3 phase	None	
	GROUP 1 circuit breakers			+28 vdc		
	MN A (15 amp)	Applies power from d-c main bus A to the following: a. SCS POWER switch on MDC-24 b. TVC 1 POWER switch on MDC-24 c. SCS switches on MDC-8 d. Translation control prior to CM-SM separation.				
	MN B (15 amp)	Applies power from d-c main bus B to the following: a. SCS POWER switch on MDC-24 b. TVC 1 POWER switch on MDC-24 c. SCS switches on MDC-8 d. Translation control prior to CM-SM separation.				
	GROUP 2 circuit breakers					
	MN A (15 amp)	Applies power from d-c main bus A to the following: a. BMAG POWER switch on MDC-24 b. Command pilot's rotation control c. Command pilot's translation control.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetr/ Code No. and Identity	Remarks
MDC-25 (Cont)	MN B (15 amp)	Applies power from d-c main bus B to the following: a. TVC 2 POWER switch on MDC-24 b. Senior pilot's rotation control c. Senior pilot's translation control.	N/A	+28 vdc	None	
	BIO MED COMM circuit breakers					
	MN A (5 amp)	Used on unmanned mission only.				
	MN B (5 amp)	Applies power from d-c main bus B to TLM INPUTS—BIO MED switch (MDC-20).		D-C main bus B		
	SERVICE PROPULSION SYSTEM circuit breakers					
	GAUGING group					
	MN A (5 amp)	Applies power from d-c main bus A to the following propellant utilization and gauging subsystem control unit circuits: a. Self-test b. Primary power supply only when SPS engine ignition driver relay is energized.				
	MN B (5 amp)	Applies power from d-c main bus B to propellant utilization and gauging subsystem control unit auxiliary power supply only when SPS engine ignition driver relay is energized.		+28 vdc		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to AC 1 contacts of SPS GAUGING switch on MDC-25.		115 vac 400 cps ØC		
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to AC 2 contacts of SPS GAUGING switch on MDC-25.				

MAIN DISPLAY CONSOLE—PANEL 25

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	He VALVE group					
	MN A (7.5 amp)	Applies power from d-c main bus A to the following: a. Left-hand SPS HELIUM switch (MDC-20) b. INJECT PRE-VALVES A switch (MDC-3) c. FCSM-G&N switch (MDC-2) d. FCSM-SCS switch (MDC-2)	N/A	+28 vdc	None	
	MN B (7.5 amp)	Applies power from d-c main bus B to the following: a. Right-hand SPS HELIUM switch (MDC-20) b. INJECT PRE-VALVES B switch (MDC-3) c. FCSM-G&N switch (MDC-2) d. FCSM-SCS switch (MDC-2).				
	GIMBAL MOTOR CONTROL group					
	1 - PITCH - 2					
	BAT A (15 amp)	Applies power from battery bus A to SPS GIMBAL MOTORS PITCH 1 switch on MDC-3.				
	BAT B (15 amp)	Applies power from battery bus B to SPS GIMBAL MOTORS PITCH 2 switch on MDC-3.				
	1 - YAW - 2					
	BAT A (15 amp)	Applies power from battery bus A to SPS GIMBAL MOTORS YAW 1 switch on MDC-3.				
	BAT B (15 amp)	Applies power from battery bus B to SPS GIMBAL MOTORS YAW 2 switch on MDC-3.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	G&N SYNC switch	Provides manual maneuver capability in G&N attitude control mode.	SCS GROUP 2 MN A	D-C main bus A	None	When the G&N SYNC switch is returned to OFF and the rotation control is returned to detent, the G&N system will maintain S/C attitude within the selected deadband limits. This switch will not be used per procedural constraint.
	On (up)	Permits detent switch in rotational control to place CDUs in a follow mode.				
	OFF	Does not affect G&N attitude control mode.				
	SPS GAUGING switch		SPS—GAUGING AC 1 AC 2 (MDC-25)	A-C bus No. 1		Three-position toggle switch which controls application of a-c power to propellant quantity utilization and gauging system control unit. Power for control unit self-test circuitry is applied directly by switch. Power for propellant quantity measuring circuitry is applied only when engine ignition driver relay is energized by engine firing signal.
	AC 1	Applies a-c power to the following: a. Quantity gauging system control unit self-test circuitry. b. Normally open contacts of SPS engine ignition driver relay.				
	OFF	Removes all a-c power.				
	AC 2	Applies a-c power to the following: a. Quantity gauging system control unit self-test circuitry. b. Normally open contacts of SPS engine ignition driver relay.		A-C bus No. 2		
	AC SNSR SIG circuit breakers		N/A	115 vac 400 cps 3 phase		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to a-c over-undervoltage and overload sensing unit to AC INDICATORS switch (MDC-18).				
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to a-c over-undervoltage and overload sensing unit and to AC INDICATORS switch (MDC-18).				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	REACTION CONTROL SYSTEM circuit breakers		N/A		None	
	PROP ISOL group					
	MN A (10 amp)	Applies power from d-c main bus A to the following: a. SM RCS quads B and D HELIUM 1, HELIUM 2, and PROPELLANT switches. b. CM RCS system A PROPELLANT switch. c. Microswitch in each isolation valve controlled by switches listed in steps a and b. Microswitch controls event indicator operation. d. RCS control box relay contacts which cause automatic closure of system A fuel and oxidizer isolation valves in the event of an abort initiation prior to T + 61 seconds.				
	MN B (10 amp)	Applies power from d-c main bus B to the following: a. SM RCS quads A and C HELIUM 1, HELIUM 2, and PROPELLANT switches. b. CM RCS system B PROPELLANT switch. c. Microswitch in each isolation valve controlled by switches listed in steps a and b. Microswitch controls event indicator operation.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	C/M - S/M TRANSFER group	d. RCS control box relay contacts which cause automatic closure of system B fuel and oxidizer isolation valves in the event of an abort initiated prior to T + 61 seconds.	N/A	+28 vdc	None	
	MN A (15 amp)	Applies power from d-c main bus A to the following: a. RCS TRANSFER switch (MDC-16) b. C/M PROPELLANT JETT group LOGIC switch (MDC-8) c. C/M RCS HTRS switch RHFEB-200 d. C/M RCS He DUMP switch (MDC-26)				
	MN B (15 amp)	Applies power from d-c main bus B to the following: a. RCS TRANSFER switch (MDC-16) b. C/M PROPELLANT JETT group LOGIC switch (MDC-8) c. C/M RCS HTRS switch RHFEB-200 d. C/M RCS He DUMP switch (MDC-26).				
	CAUT/WARN circuit breakers					
	MN A (10 amp)	Applies power from d-c main bus A to caution and warning system.				
	MN B (10 amp)	Applies power from d-c main bus B to caution and warning system.				
	EDS-1, 2, 3 circuit breakers					
	BAT A (5 amp)	Applies d-c power from battery bus A to the EDS POWER switch (MDC-24).				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	BAT C (5 amp)	Applies d-c power from entry battery C to the EDS POWER switch (MDC-24).	N/A	+28 vdc	None	
	BAT B (5 amp)	Applies d-c power from battery bus B to the EDS POWER switch (MDC-24).				
	ELS-A, B circuit breakers					
	BAT A - FLOAT BAG 3 (10 amp)	Applies d-c power from battery bus A to the following: a. ELS LOGIC switch (MDC-8) b. APEX COVER JETT switch (MDC-5) c. MAIN DEPLOY switch (MDC-5) d. MAIN DEPLOY switch (MDC-5) e. POST LANDING-FLOAT BAG - switch 3 (MDC-25).				
	BAT B (10 amp)	Applies d-c power from battery bus B to the following: a. ELS LOGIC switch (MDC-8) b. APEX COVER JETT switch (MDC-5) c. DROGUE DEPLOY switch (MDC-5) d. MAIN DEPLOY switch (MDC-5)				
MDC-26	FLOODLIGHTS controls		COUCH ATTEN MN A MN B FLOOD-LIGHTS (MDC-25)	D-C main buses A and B	None	FLOODLIGHTS controls on MDC-23, -26, and LEB-100 are functionally identical and each controls the floodlights in its respective area. The rheostat control may be adjusted for desired brightness of primary floodlights.
	PRIMARY rheostat					
	Off	Removes power from C/M primary floodlights.				
	Bright	Indicates maximum floodlight brightness has been reached.				
	SECONDARY switch					
	ON	Illuminates secondary floodlights.				
	OFF	Removes power from secondary floodlights.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-26 (Cont)	POST LDG BEACON switch		N/A	Beacon light battery	None	
	LIGHT	Applies power to the beacon lights.				
	OFF	Removes power from the beacon lights.				
	POWER switch	Controls power to command pilot's module in audio center equipment	T/C — GROUP 4 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position. Intercom capability when cobra cable PTT/CW switch is in C/W and transmit when switch is at PTT.
	PTT	Applies d-c power to audio and control circuits.				
	OFF	Removes power from command pilot's audio center equipment module and controls.				
	VOX	a. Applies d-c power to audio and control circuits. b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.				VOX operation permits voice transmission and transmitter keying of intercom, HF recovery transceivers and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch		N/A	Audio center equipment		The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the command pilot's module of the audio center equipment, to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	T/R	No effect. S-band T/R function supplied by cobra cable PTT key.				
	OFF	Prevents command pilot from transmitting or receiving voice over USBE.				
	RCV	Enables command pilot to receive voice from USBE.				
	RCDR/HF switch					Provides power ground through audio center VOX circuit for HF transceiver transmit-receive relay and voice recorder power relay.
	T/R	a. Enables command pilot to transmit and receive voice over H-F transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				
	OFF	Prevents command pilot from transmitting or receiving voice over H-F transceiver.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-26 (Cont)	RCV	Enables command pilot to receive voice from H-F transceiver when operating in AM or SSB mode.	N/A	Audio center equipment	None	
	VHF AM switch					VHF-AM transmits, in addition to S-band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switch must be at PTT and audio center POWER switch must be at PTT.
	T/R	Enables command pilot to transmit and receive voice over VHF-AM transmitter-receiver when operating in T/R mode.				
	OFF	Prevents command pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				
	RCV	Enables command pilot to receive voice from VHF-AM transmitter-receiver.				
	INTERCOM switch					Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT/CW switch is at PTT.
	T/R	Enables command pilot to transmit and receive voice over the intercom system.				
	OFF	Prevents command pilot from transmitting or receiving voice over intercom system.				
	RCV	Enables command pilot to receive voice from intercom system.				
	VOX SENS control	Increases or decreases sensitivity of voice-operated relay circuitry in command pilot audio center module.				These three control are thumb-wheel-type potentiometers which may be rotated upward or downward, as required.
	INTERCOM BALANCE control	Increases or decreases level of audio signal received by command pilot from R-F equipment relative to that received from intercom bus.				Position 9 most sensitive.
	VOLUME control	Increases or decreases level of audio signal from command pilot earphone amplifier to earphone.				

CONTROLS AND DISPLAYS

		Energizes relays required to activate CM/SM helium purge operation. Deenergizes relays.					
		Permits ac power from CM primary floodlights. Indicates that CM floodlight brightness has been reduced.					
		Illuminates secondary floodlights. Permits power from secondary floodlights.					
		Brightly illuminates the integral lighting for the mechanical clocks on EHE EB-306. Disconnects power from the lighting circuit to the clocks. Dimly illuminates the integral lighting for the mechanical clocks on EHE EB-306.					

MAIN DISPLAY CONSOLE - PANEL 2
EQUIPMENT BAY PANEL 100

Location	Nomenclature and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
1 FB-1D1	IMU-CDU DIFFERENCE indicator	Displays the difference between the IMU gimbal angles and the CDU shaft angles in degrees.	G&N-IMU MN A MN B (MDC-22)	D-C main buses A and B	None	A three-dial panel meter. The signals applied to the meter are the demodulated outputs of the CDU single speed receivers. Depending upon the IMU mode, the differences shown can represent the following: a. Misalignment of the IMU b. Error in the orientation of the spacecraft c. Error in the CDU display of actual gimbal angles.
	TRANSFER switch MANUAL COMPUTER	Controls selection of ISS operating modes. Enables manual selection of ISS operating modes through the use of MODE switches. Enables AGC selection of ISS operating modes by setting mode relays directly.				SPST toggle switch
	MANUAL ALIGN switch	Causes the IMU gimbals to align CDU angles.				SPST momentary contact pushbutton. Used in conjunction with CDU MAN mode pushbutton to coarse align the IMU gimbals.
	MODE switches	Allow selection and display of ISS operating modes.				SPST illuminates pushbutton switches. Computer controlled when TRANSFER switch is in COMPUTER position. Manually controlled when TRANSFER switch is in MANUAL position.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-101 (Cont)	ZERO ENC	Selects zero encoder mode of ISS operation. This mode sets the shafts and encoders of the CDUs and CDU registers in the computer to zero.	G&N—IMU MN A MN B (MDC-22)	D-C main buses A and B	None	CDUs must be zeroed whenever the G&N system is turned on.
	COARS ALIGN	Selects coarse align mode of IMU operation. This mode positions the stable member of the IMU. Selects coarse align mode of ISS operation. This mode positions the stable member to within 1.5° of desired inertial reference attitude.				In this mode, the CDUs are driven to angles commanded by the AGC. These angles define an inertial reference.
	FINE ALIGN	Selects fine align mode of ISS operation. This mode completes stable member alignment to desired inertial reference attitude.				Upon completion of the fine align mode, the stable member is fine aligned to an inertial reference and the CDU readouts indicate gimbal angles relative to that reference.
	CDU MAN	Selects manual CDU mode of ISS operation. This mode provides for backup-manual alignment of the stable member. Stable member drives to CDU angles when MANUAL ALIGN switch is depressed.				Actuation of CDU MAN switch energizes a relay which removes the excitation to the CDU motors to lock the CDUs in position.
	ATT CONT	Selects attitude control mode of IMU operation. Selects attitude control mode of ISS operation. This mode provides attitude and velocity change sensing with respect to the space stabilized stable member.				The attitude error signals generated in this mode represent the difference between IMU gimbal angles and CDU angles.
	ENTRY	Selects entry mode of ISS operation. This mode is similar to attitude control mode; however, the gain of the roll control loop is increased by a factor of 16 to increase roll rate and decrease response time.				This mode is used during spacecraft entry into the earth atmosphere.
LEB-102	CDU angle display readouts 2X TRUNNION, SHAFT ANGLE, OUTER GIMBAL (ROLL), INNER GIMBAL (PITCH), MIDDLE GIMBAL (YAW)	Provide visual representation of ICDU and OCDU angles.			None	Drum-type readout. Reads down to 0.001 degree. Five such readouts are on this panel: two for optics and three for inertial CDUs.

LOWER EQUIPMENT BAY—PANELS 101 AND 102

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-103	G&N condition lights	Warning lights denote detected malfunction.	G&N—IMU MN A MN B (MDC-22)	D-C main buses A and B		Yellow caution lights.
	PGNS	Indicates an IMU, CDU accelerometer and/or AGC failure.			CG5005X (Error detect)	
	AGC PWR FAIL	Indicates a failure in the Apollo guidance computer power supply.			CG5030X (Computer power fail light)	
	IMU FAIL	Indicates a failure in the inertial measurement unit.			CG5001X (IMU fail)	
	CDU FAIL	Indicates a failure in one or more of the coupling display units.			CG5002X (CDU fail)	
	ACCEL FAIL	Indicates a failure in one or more of the PIPAs.			CG5000X (PIPA fail)	
	GIMBAL LOCK	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than ±60° with respect to outer gimbal).			CG5003X (Gimbal lock warning)	
	IMU TEMP	Indicates that the IMU temperature is out of tolerance, i.e., exceeds normal temperature by ±4°F (if IMU TEMP MODE switch is in AUTO OVERRIDE or PROPORTIONAL positions).			CG5006X (IMU temp light)	
	ZERO ENCODER	Indicates that the CDU encoders are being zeroed; lamp is extinguished after all encoders have been zeroed. (Remains illuminated for approximately 30 seconds. If AGC commanded zero encode mode, indicator may be illuminated for approximately 60 seconds.)			CG5007X (Zero encoder light)	White light.
	IMU DELAY	IMU coarse alignment to CDU angles taking place. Stable member is caged. Remains illuminated for approximately 100 seconds.			CG5008X (IMU delay light)	White light. Illuminates only at initial IMU turn-on or immediately after switching from standby operation.

Location	Nomenclature Function	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
(cont)	MASTER ALARM light	Red light illuminates to alert crewmembers at lower equipment bay of malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	Upon illumination of MASTER ALARM light, the MASTER ALARM switch-lights on MDC-3 and -18 are simultaneously illuminated and an audio tone is sent to each headset. The MASTER ALARM light does not contain an integral switch. Light may be extinguished only by pressing the MASTER ALARM switch-light on MDC-3 or -18.
[illegible]	Sextant	Optical instrument for measuring the angle between two objects.	None	None	None	The SXT is a dual line-of-sight instrument used to determine the following: a. The angle between a landmark and a star. b. The angle between a star line of sight and the navigation base. c. Tracking an unknown landmark. This information is used by the AGC for the following: a. Determine spacecraft position. b. Calculate required ΔV corrections. c. To fine align the IMU. The SXT has a 1.8° field of view with a magnification of 28.
	Scanning telescope	Optical instrument used for the following: a. Tracking a landmark in earth orbit. b. Identifying and centering a star within the sextant field of view.				The scanning telescope has a 60° field of view and a 1X magnification (long relief eyepiece - 0.6X).
	TRUNNION control	Enables manual positioning of the trunnion angles.				These controls are manually operated by means of a universal tool. They are used in the event of optics electronic failure.
	SHAFT control	Enables manual positioning of the shaft angles.				
	TRUNNION ANGLE display	Provides a mechanical readout of the SCT trunnion angle that is commanded manually or by the computer.				Drum-type readouts in degrees, mechanically connected to the scanning telescope (SCT) trunnion and shaft drives, respectively. (SXT angles are identical.)
	SHAFT ANGLE display	Provides a mechanical readout of the SCT shaft angle that is commanded manually or by the computer.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105	Optics hand controller	Provides electrical commands to the optics shaft and trunnion drive motors.	G&N-OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	SP4T, five-position switch, spring-loaded to center OFF position, direction of target movement with respect to controller movement depends upon mode selected by CONTROLLER MODE switch. Rate of image movement is proportional to amount of hand controller movement.
	CHECK COOLANT switch	When pressed, applies power to floodlamps behind the display and control panel. Enables the crew to view the IMU quick-disconnect couplings through CHECK COOLANT windows.				Pushbutton switch, momentary contact.
	CHECK COOLANT windows (two)	Permit observation of IMU coolant supply system quick-disconnect couplings for detecting leaks.	None	None		
	AGC code numbers display (not shown)	Provides the crew with a quick reference for computer code numbers.				Panel inscribed, nonreplaceable.
	MARK switch	Supplies an interrupt signal to the AGC which commands it to read the optics CDU angles, the time, and the IMU gimbal angles (if the IMU is operating).	G&N-OPTICS MN A MN B (MDC-22)	D-C main buses A and B		Pushbutton, SPST, momentary-contact switch. If MARK is satisfactory, computer proceeds normally. If MARK is unsatisfactory, flight crew inhibits computer processing of data by making DSKY entry of V52E.
	PANEL BRIGHTNESS control	Provides adjustment of the illumination level of all integrally lighted G&N system controls and displays. In addition, the control provides power to the lamp in the THRUST ON switch.				Thumbwheel potentiometer.
	CHECK MODE LAMPS switch	Applies power to all MODE indicators on the IMU control panel LEB-101.				Pushbutton, SPST, momentary-contact switch. Used to check operation of the MODE lamps.
	CHECK CONDITION LAMPS switch	Applies power to all condition (caution and warning) lamps on panel LEB-103.				Pushbutton, SPST, momentary-contact switch. Used to check the operation condition of the condition lamps.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	CONDITION LAMPS switch		G&N-IMU MN A MN B (MDC-22)	D-C main buses A and B	None	SPST toggle switch.
	ON	Applies d-c power to G&N condition lamps.				
	OFF	Removes d-c power from lamps.				
	ATTITUDE IMPULSE group		SCS — GROUP 1 AC 1 AC 2 (MDC-25)	Essential bus		
	Attitude impulse control	A control stick used to apply small rotational thrust impulses to the spacecraft by means of the service module reaction jets.				SP6T, seven-position switch, spring-loaded to center off. The control is used to apply one or any combination of pitch, roll, or yaw minimum thrust impulses to the S/C providing rate damping impulses of 2.4 arc-minutes/second/pulse or less. One pulse is produced each time the control is moved from the center position.
	ENABLE switch	Enables the attitude impulse control.				Toggle-type, solenoid-held-to-on microswitch. The SCS must be in the G&N or SCS attitude control modes to enable solenoid holding. Attitude impulse is not enabled in the SCS local vertical mode. To enable the attitude impulse control circuit, the LIMIT CYCLE switch must also be ON.
	ON	Supplies a signal to the G&N and SCS systems which disables the active S/C attitude control mode, allowing the S/C to drift freely, and enables the attitude impulse control.				
	OFF	Disables the attitude impulse control.				
	IMU TEMP MODE group		G&N IMU HTR MN A MN B (MDC-22)	D-C main buses A and B		
	Mode switch	Enables the crew to select any one of the four modes of IMU temperature controls.				Rotary, four-position, three-wafer switch.
	PROPORTIONAL	Temperature control is furnished by same control circuit used in AUTO/OVERRIDE mode.				PROPORTIONAL mode is used if a malfunction occurs in the temperature indicating circuit, causing cycling to the EMERGENCY mode.
	BACKUP	Temperature control is furnished by temperature sensing circuits.				BACKUP mode is used if a malfunction occurs in the normal control circuit. In this mode, the IMU TEMP light will illuminate when the heaters are off and will extinguish when the heaters are on. MSFN must monitor

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	AUTO OVERRRIDE	Normal mode of temperature control. If IMU temperature exceeds normal tolerances by ±4°F, system automatically switches to emergency mode and IMU TEMP light illuminates.	G&N IMU HTR MN A MN B (MDC-22)	D-c main buses A and B	None	the IMU temperature. Manual switching to emergency mode is necessary if the temperature becomes excessive. When a malfunction occurs, the temperature alarm relays turn off the control heaters. Emergency heaters continue to operate under the control of an emergency mercury thermostat. When the temperature returns to within 1°F of normal, the IMU TEMP light extinguishes and the system switches back to the normal control mode. A thermostat provides overheat protection for the IMU by opening the emergency heater circuit when the temperature exceeds 130°F. When this temperature drops below 128°F, the thermostat closes the circuit to reactivate the heaters. Pushbutton, DPST, momentary-contact switch.
	EMERGENCY	IMU temperature is controlled to approximately 130°F by means of mercury thermostat and emergency heaters.				
	ZERO switch	Used to check calibration of IRIG and PIPA temperature monitoring devices.				Pushbutton, momentary-contact switch. When it is pressed, the IMU TEMP indicator (LEB-103) should be illuminated. If not, a malfunction exists in the system.
	GAIN switches	Used to check temperature alarm circuit.				
	IRIG	Simulates low temperature error (-5°F) to check IRIG temperature sensors and also tests alarm circuit				
	PIPA	Simulates high temperature error (+5°F) to check PIPA temperature sensors and also test alarm circuits.				
	MAP AND DATA VIEWER group	None	None	None		Function deleted as a result of map and data viewer deactivation.
	OPTICS group		G&N OPTICS MN A MN B (MDC-22)	D-C main buses A and B		Single pole, three-position toggle switch
	SLAVE TELESCOPE switch	Slaves SCT trunnion axis to SXT trunnion.				
	STAR LOS					

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	LANDMARK LOS 0°	Drives SCT trunnion to zero independently of CDU trunnion.	G&N OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	Zero position is parallel to SXT shaft axis.
	OFFSET 25°	Drives telescope trunnion to 25° offset from shaft axis.				This will bring the star and landmark within the 60° field-of-view of the SCT, while rotating about the shaft axis.
	OPTICS HOLD	Opens input to motors to prevent CDU creep				SPST, toggle switch.
	Mode switch	Selects optics mode of operation.				Rotary, three-position switch.
	ZERO OPTICS	Optics and CDU resolvers are driven to zero. AGC register is set to all zeros.				Completed in approximately 60 seconds.
	MANUAL	Normal operating position enabling crew to position optics by means of optics hand controller.				In this position, the crew may select either the DIRECT or RESOLVED controller mode of operation.
	COMPUTER	Optics are automatically positioned by the AGC. Panel-mounted controls are disabled.				
	CONTROLLER SPEED switch	Provides attenuation of shaft and trunnion slew commands from optics hand controller. Direct Mode Maximum Drive Rates Trunnion / Shaft HI: 8.8°/sec / 17.3°/sec MED: 1.05°/sec / 2.06°/sec LOW: 0.105°/sec / 0.206°/sec Resolved Mode Maximum Drive Rates Trunnion / Shaft HI: 8.8°/sec / 8.8°/sec MED: 1.05°/sec / 1.05°/sec LOW: 0.105°/sec / 0.105°/sec				Single-pole, three-position toggle switch. Attenuated output is applied to the MODE switch.
	CONTROLLER MODE switch	Controls control stick output configuration.				SPDT, two-position, toggle switch.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	DIRECT	Applies control movements directly to CDUs. Right/left movement commands shaft rotation. Up/down movement commands trunnion angle increase/decrease.	G&N—OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	Target moves about arcs with speed of target movement varying with magnitude of angle.
	RESOLVED	Applies control stick movements to angular resolving circuits before applying commands to the CDUs.				Target moves horizontally and vertically at a linear rate.
LEB-106	Alarm condition indicators	Indicate abnormal conditions of computer operation.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B		
	PROG ALM	AGC program error detected.			CG5020X (AGC alarm 1)	Observe REGISTER displays for numerical flag denoting malfunction.
	COUNTER FAIL	Counter increment instruction not executed or not completed within 10 msec of initiation.			CG5026X (AGC alarm 7)	If malfunction is counter-increment not completed within 10 msec, the TC TRAP indicator will illuminate.
	RUPT LOCK	No interrupt within 80 msec or interrupt not completed within 10 msec.			CG5028X (AGC alarm 9)	
	TC TRAP	Transfer control not executed within 10 msec or not completed within 10 msec.			CG5029X (AGC alarm 10)	
	SCALER FAIL	100-pps signal from scaler A of computer timing section failed.			CG5024X (AGC alarm 5)	
	PARITY FAIL	Parity error exists in data word from memory.			CG5025X (AGC alarm 6)	
	TM FAIL	Telemetry data rate incorrect or transmission incorrect.			CG5022X (AGC alarm 3)	
	CHECK FAIL	Incorrect DSKY operation attempted.			CG5023X (AGC alarm 4)	
	KEY RLSE	Computer program cannot proceed until operator releases DSKY control.			CG5027X (AGC alarm 8)	Not a failure. Operator will press KEY RELEASE pushbutton. Computer will resume computation.

CONTROLS AND DISPLAYS

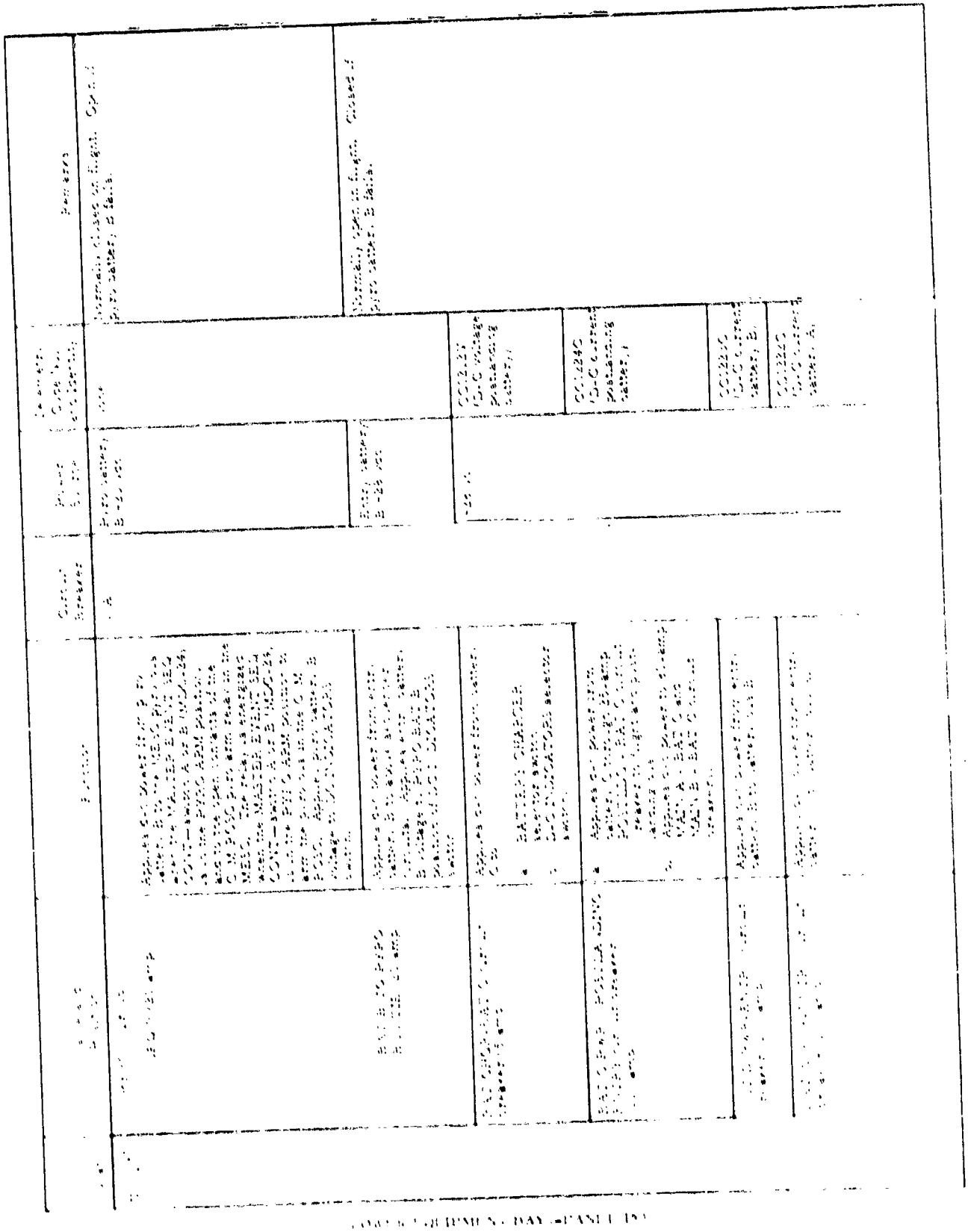
Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-106 (Cont)	ACTIVITY lights	Indicates activity the computer is presently engaged in.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	CG5021X (AGC alarm 2)	
	UPTL	Computer is receiving information from telemetry up-data link.				
	COMP	Computer is engaged in computation.			None	On-board data provides definition of PROGRAM, NOUN, and VERB digits.
	PROGRAM indicator	A two-digit display, indicating the number of the program (major mode) presently in progress.				
	VERB indicator	A two-digit display, indicating verb code selected.				Displays may be commanded manually or by AGC.
	NOUN indicator	A two-digit display, indicating noun code selected.				
	REGISTER 1 indicator	Displays contents of selected register or memory location. First component of extended data word, if applicable.				
	REGISTER 2 indicator	Displays contents of selected register or memory location. Second componet of extended data word, if applicable.				
	REGISTER 3 indicator	Displays contents of selected register or memory location. Third component of extended data word, if applicable.				
	BRIGHTNESS control	Varies brightness of electroluminescent data displays: REGISTER 1, REGISTER 2, and REGISTER 3.				
	KEY RELEASE pushbutton	Enables program control of DSKY. Releases operator control of DSKY circuits.				
	TEST ALARM pushbutton	Illuminates the alarm displays for bulb test.				

LOWER EQUIPMENT BAY—PANEL 106

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-106 (Cont)	ERROR RESET pushbutton	Resets alarm light relays. AGC recycles to start of current operation.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	Verifies alarms. Alarms triggered by transients should not repeat.
	Keyboard switches	Provide for entering data into or commanding operations of the AGC.				Pushbutton-type switches (selectors). Each key generates a specific 5-bit keycode denoting the instruction or number being selected.
	CLEAR	Places all zeros (logic 0s) in register being loaded.				
	VERB	Prepares computer to accept next two digits as verb code.				
	NOUN	Prepares computer to accept next two digits as noun code.				
	ENTER	Transfers contents of input register to central processor and initiates execution of instructions.				
	+	Denotes data to follow has positive decimal value.				
	−	Denotes data to follow has negative decimal value.				
	0 to 9	Enters binary equivalent of key pressed.				
LEB-107	AGC MODE switch		G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	SPDT, toggle switch
	ON	Applies normal power to AGC.				
	STANDBY	Applies power timing section of AGC.				In STANDBY, AGC maintains timing signals and other circuits necessary to restart. STANDBY operation is used to conserve electrical power.
LEB-120	Gas chromotograph controls		GAS ANAL—AC 1 (MDC-22)	A-C bus No. 1 (ØA)		The gas chromotograph (GFE) is serviced and installed by ground support personnel prior to flight crew ingress. The unit operates on 80-minute cycles, during which it identifies 28 gas components.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-120 (Cont)	CABIN AIR/AUTO/ SUIT AIR switch		GAS ANAL—AC 1 (MDC-22)	A-C bus No. 1 (ØA)	CTO 108K (Gas analysis suit and cabin)	
	CABIN AIR	Selects C/M cabin atmosphere for gas component sampling.				Switch set to CABIN AIR position on command from MSFN.
	AUTO	Permits suit circuit and C/M cabin atmospheres to be alternately sampled for gas components.				Normal position of switch.
	SUIT AIR	Selects suit circuit atmosphere for gas component sampling.				Switch set to SUIT AIR position on command from MSFN.
	START/OFF/ PREHEAT switch				None	Oven requires 7 watts for preheat period and 5 watts during operation.
	START	Applies a-c power to operational portion of gas chromatograph.				Normal position of switch after completion of preheat operation.
	OFF	Removes a-c power from warmup oven and operational portion of gas chromatograph.				
	PREHEAT	Applies a-c power to oven for required preheating prior to unit being placed in operation.				A minimum of 30 minutes warmup is required before switch is set to START position.
	AMPL-CAL switch	Push-type switch for use during bench calibration only.				
LEB-150	Pyro battery circuit breakers		N/A	Pyro battery A +23 vdc	None	Thermal, push-pull, manual reset type circuit breakers with the amperage rating of each denoted by a white placard.
	PYRO A group					
	SEQ A (20 amp)	Applies d-c power from pyro battery A to the MESC pyro bus when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position, and to the open contacts of the C/M RCSC pryo arm relay in the MESC. The relay is energized when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position to arm the pyro bus in the C/M RCSC. Applies pyro battery A voltage to DC INDICATORS switch.				Normally closed in flight. Opened if pyro battery A fails.
	BAT A TO PYRO BUS TIE (20 amp)	Applies d-c power from entry battery A to above sequencer circuits, and entry battery A voltage to PYRO BAT A position of DC INDICATORS switch.	N/A	Entry battery A +28 vdc	None	Normally open in flight. Closed if pyro battery A fails.

CONTROLS AND DISPLAYS



Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHFEB 200	C/M RCS HTRS switch On (up) OFF	Activates relays which apply +28 vdc to the direct coils of all C/M RCS engine solenoid valves. Deactivates relays which remove +28 vdc from the direct coils of all C/M RCS engine solenoid valves.	RCS—HEATERS A MN B B MN A (MDC-21)	+28 vdc	None	Two-position toggle switch, used to pre-heat all C/M RCS engine valves in order to preclude propellant freezing when system is pressurized prior to entry. Switch is enabled by CM PROP JETT-LOGIC switch (MDC-8) in the ON (up) position.
	DC VOLTS meter (auxiliary)	Indicates d-c voltage of selected measurement points.	N/A	Instrumentation signal conditioners	Refer to TEST SELECT switch (RHFEB-97)	Meter functions in conjunction with FUNCTION SELECT and TEST SELECT switches located directly below meter. Meter range is 0 to 5 vdc.
	FUNCTION SELECT switch A OFF B	Selects A or B wafer of TEST SELECT switch. Connects Aux DC VOLTS meter to wafer A of TEST SELECT switch. Disconnects Aux DC VOLTS meter from circuit. Connects Aux DC VOLTS meter to wafer B of TEST SELECT switch.				FUNCTION SELECT switch in conjunction with the TEST SELECT switch makes possible 24 measurement points for the Aux DC VOLTS meter.
	TEST SELECT switch 1 (A) 1 (B)	Selects two groups of 12 measurements, depending on position of FUNCTION SELECT switch, A or B. Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 nitrogen regulator. Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -P engine (No. 2) system A.			SC2060P (N_2 pressure F/C 1 regulated) CR2205T (Temp ox. valve -P engine system A	TEST SELECT switch has two independent wafers, each containing 12 contacts. N_2 pressure range is 0 to 75 psia. Temperature range is -50° to +250°F.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHFEB-200 (Cont)	2 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 nitrogen regulator.	N/A	Instrumentation signal conditioners	SC2061P (N_2 pressure F/C 2 regulated)	N_2 pressure range is 0 to 75 psia.
	2 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, +Y engine (No. 7) system B.			CR2203T (Temp ox. valve +Y engine system B.	Temperature range is -50° to +250°F.
	3 (A)	Applies a d-c measurement to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 nitrogen regulator.			SC2062P (N_2 pressure F/C 3 regulated)	N_2 pressure range is 0 to 75 psia.
	3 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -P engine (No. 4) system B.			CR2204T (Temp ox. valve -P engine system B	Temperature range is -50° to +250°F.
	4 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 oxygen regulator.			SC2066P (O_2 pressure F/C 1 regulated)	O_2 pressure range is 0 to 75 psia.
	4 (B)	Applies a d-c measurement voltage to DC VOLTS meter which indicates temperature of C/M oxidizer valve cw engine (No. 11) system B.			CR2206T (Temp ox. valve cw engine system B)	Temperature range is -50° to +250°F.
	5 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 oxygen regulator.			SC2067P (O_2 pressure F/C 2 regulated)	O_2 pressure range is 0 to 75 psia.
	5 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates PIPA temperature.			CG2300T (PIPA temperature)	Temperature range TBD.
	6 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 oxygen regulator.			SC2068P (O_2 pressure F/C 3 regulated)	O_2 pressure range is 0 to 75 psia.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHFEB-200 (Cont)	6 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates IRIG temperature.	N/A	Instrumentation signal conditioners	CG2301T (IRIG temperature)	Temperature range TBD.
	7 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 hydrogen regulator.			SC2069P (H_2 pressure F/C 1 regulated)	H_2 pressure range is 0 to 75 psia.
	7 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates IMU heater current.			CG2302C (IMU heater current)	IMU heater current range is from 0 to 5 amperes.
	8 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 hydrogen regulator.			SC2070P (H_2 pressure F/C 2 regulated)	H_2 pressure range is 0 to 75 psia.
	8 (B)	Applies a d-c measurement to Aux DC VOLTS meter which indicates IMU blower current.			CG2303C (IMU blower current)	IMU blower current range is from 0 to 5 amperes.
	9 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 hydrogen regulator.			SC2071P (H_2 pressure F/C 3 regulated)	H_2 pressure range is 0 to 75 psia.
	9 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates pressure of battery compartment manifold.			CC0188P (Press. bat. compartment manifold)	Battery compartment manifold pressure range is 0 to 18 psia.
	10 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 1 radiator outlet.			SC2087T (Temp F/C 1 radiator outlet)	F/C 1 radiator outlet temperature range is -50° to +300°F.
	10 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of ECS radiator inlet.			SF0665T (ECS radiator inlet temp)	ECS radiator inlet temperature sensor range is +60° to +150°F. Minimum inlet temperature is 75°F.
	11 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 2 radiator outlet.			SC2088T (Temp F/C 2 radiator outlet)	F/C 2 radiator outlet temperature range is -50° to +300°F.

RH FORWARD EQUIPMENT BAY — PANEL 200

RH FORWARD EQUIPMENT BAY-PANELS 200 AND 207

RH EQUIPMENT BAY-PANEL 201

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEEB-209 (Cont)	11 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, ccw engine (No. 12) system A	N/A	Instrumentation signal conditioner)	CR2201T (Temp ox. valve ccw engine system A)	Temperature range is -50 to +250°F.
	12 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 3 radiator outlet.			SC2089T (Temp F/C 3 radiator outlet)	F/C 3 radiator outlet temperature range is -50° to +300°F.
	12 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -Y engine (No. 8) system A.			CR2202T (Temp ox. valve -Y engine system A)	Temperature range is -50° to +250°F.
RHEEB-207	SCIENTIFIC EQUIPMENT receptacle switch		SCIEN EQUIP. HATCH (MDC-22)	+28 vdc	None	
	ON	Applies d-c power from nonessential bus No. 2 to SCIENTIFIC EQUIPMENT receptacle for M09A experiment 16 mm sequence camera.				
	OFF	Removes d-c power from SCIENTIFIC EQUIPMENT receptacle.				
RHEB-201	WASTE MANAGEMENT panel		N/A	N/A	None	
	OVBD DRAIN valve					This shutoff valve is manually controlled by bar knob.
	DUMP	Connects WMS overboard dump line from selector valve to outside atmosphere, permitting dumping urine and fecal odors overboard.				The valve is operated in conjunction with the SELECTOR valve. Valve is set to DUMP position after setting SELECTOR valve to URINE FECES position. Upon completion of dumping or venting operation, OVBD DRAIN valve is set to OFF position before SELECTOR valve is set to OFF position.
	OFF	Closes WMS overboard dump line to outside atmosphere.				
	SELECTOR valve					This valve is manually controlled by bar knob.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-201 (Cont)	URINE FECES	a. Connects waste management dump line to overboard dump line. b. Closes switch that applies a-c power to WMS blower.	ECS-CABIN AIR FAN-1-AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 1	None	Blower operation in this valve position is not functional due to WMS modifications. Valve is placed to URINE FECES position for dumping urine collected in the Urine Sample Volume Measurement System (USVMS), or for venting odors originating during fecal canister usage. This valve position is selected in conjunction with the OVBD DRAIN valve. Valve is set to URINE FECES position before setting OVBD DRAIN valve to DUMP position. Upon completion of dumping or venting operation, SELECTOR valve is set to OFF position after OVBD DRAIN valve is set to OFF position.
	VACUUM	a. Connects vacuum cleaner line to WMS blower. b. Closes switch that applies a-c power to WMS blower.				With valve to VACUUM position, WMS blower is activated and blower exhaust is directed into C/M cabin.
	OFF	a. Closes all valve ports, deactivating waste management system. b. Removes a-c power from WMS blower.	None	None		
RHEB-202	WASTE MANAGEMENT ACCESS panel BATTERY VENT valve		N/A	N/A	None	
	VENT	Permits gases generated by C/M batteries to be vented into the urine/water dump line.				This valve is manually controlled by a bar knob. Normal position of valve is VENT to dump overboard gases generated by C/M batteries.
	CLOSE	Shuts off the venting of C/M batteries into the urine/water dump line.				Valve is closed in event of battery vent system leakage, which would permit C/M atmosphere leakage to space.
RHEB-203	MAIN A circuit breakers BAT BUS A (80 amp)	Applies d-c power from battery bus A to d-c main bus A through contacts of main bus tie bat A motor switch.	N/A	+28 vdc	None	

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-203 (Cont)	BAT C (80 amp)	Applies d-c power from battery C to d-c main bus A through contacts of main bus tie bat B motor switch.	N/A	+28 vdc	None	
	MAIN B circuit breakers					
	BAT C (80 amp)	Applies d-c power from battery C to d-c main bus B through contacts of main bus tie bat A motor switch.				
	BAT BUS B (80 amp)	Applies d-c power from battery bus B to d-c main bus B through contacts of main bus tie bat B motor switch.				
	POST LDG circuit breakers					These circuit breakers remain disengaged during flight and are engaged (pushed in) prior to CSM separation.
	BAT BUS A (25 amp)	Applies d-c power from battery bus A to flight and postlanding bus.				
	BAT BUS B (25 amp)	Applies d-c power from battery bus B to flight and postlanding bus.				
	BAT C (25 amp)	Applies d-c power from 100-amp BAT C PWR circuit breaker to flight and postlanding bus.				
	MAIN A (10 amp)	Applies power from d-c main bus A to flight and postlanding bus.				
	MAIN B (10 amp)	Applies power from d-c main bus B to flight and postlanding bus.				
	INVERTER PWR circuit breakers					
	NO. 1 INV A (75 amp)	Applies power from d-c main bus A to inverter No. 1.				
	No. 2 INV B (75 amp)	Applies power from d-c main bus B to inverter No. 2.				

RH EQUIPMENT BAY—PANEL 203

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-203 (Cont)	NO. 3 group		N/A	+28-vdc	None	
	MN A (70 amp)	Applies power from d-c main bus A to inverter No. 3.				
	MN B (70 amp)	Applies power from d-c main bus B to inverter No. 3.				
RHEB-204	INST PWR CONT circuit breaker		INSTRU-MENTS-ESS MN A and/or MN B (MDC-22)	D-C main bus A or d-c main bus B	None	
	ESSENTIAL group					
	1 (7.5 amp)	Applies +28-vdc power to RCS and structural operational instrumentation.				
	2 (7.5 amp)	Applies +28-vdc power to ELS, EPS, and ECS surge tank operational instrumentation.				
	3 (7.5 amps)	Applies +28-vdc power to operational instrumentation in S/M.				
	4 (5 amp)	(Spare)				
	NON ESSENTIAL group		INSTRU-MENTS-NONESS (MDC-22)	Non-essential bus No. 1		
	5 (5 amp)	(Spare)				
	6 (5 amp)	(Spare)				
	7 (5 amp)	(Spare)				
	8 (10 amp)	Applies 28-vdc power to flight qualification instrumentation.				
	9 (10 amp)	Applies 28-vdc power to flight qualification instrumentation and to ECS radiator outlet temperature sensors.	INSTRU-MENTS-NONESS (MDC-22)	Non-essential bus No. 1	None	
	10 (10 amp)	(Spare)				
RHEB-205	UPRIGHTING SYSTEM circuit breakers		N/A	+28-vdc	None	
	COMPR NO. 1 (25 amp)	Applies d-c power from battery bus A to the control motor switch of compressor No. 1.				The compressors are turned on and off by manual actuations of the POST LANDING-FLOAT BAG switches on MDC-25.
	COMPR NO. 2 (25 amp)	Applies d-c power from battery bus B to the control motor switch of compressor No. 2.				These circuit breakers remain disengaged during flight and are engaged only after landing

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-207	ECS STEAM DUCT HTR circuit breakers		N/A	28 vdc	None	
	MN A (5 amp)	Applies power from d-c main bus A to the following: a. Steam duct heater b. Urine/water dump nozzle heater.				There are no switches to control the operation of the heaters. When the circuit breakers are activated, power is applied directly to corresponding 3-watt heating elements of the steam duct heaters, and to the 5.7-watt urine/water dump nozzle heater. Normally, both the steam duct and urine/water dump nozzle heaters are in operation for the total length of the mission.
	MN B (5 amp)	Applies power from d-c main bus B to the following: a. Steam duct heater b. Urine/water dump nozzle heater.				
RHEB-208	INV PHASE LOCK	Central timing signal to inverters supplied through inverter phase synchronizer to provide in-phase a-c power to a-c bus 1 and 2 when a separate inverter is powering each a-c bus.	None	A-C ØB of inverter 1, 2, or 4	None	Normal position during flight (PSU draws power with control switch in either position).
	OFF	Provides central timing signal directly to inverters.				Position if phase synchronizer unit fails.
LHFEB-300, -301, -302	Suit flow control valve		N/A	N/A	None	There are three suit connector assemblies in the cabin. Although they vary slightly in appearance, their function is identical, thus suit flow control valve data is covered once. The three suit connector assemblies are located at LHFEB-300, -301, and -302, and are controlled by sliding levers.
	OFF	Closes valve, shutting off flow of oxygen to suit connector.				Suit hose may be connected or disconnected only with the valve in the OFF position. The number of suit flow control valves placed to either the CABIN FLOW or the SUIT FULL FLOW positions should always equal the number of crewmen in the C/M.

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHFEB-300, -301, -302 (Cont)	CABIN FLOW	Partially opens valve, permitting oxygen flow into cabin (or suit) at a rate compatible to the requirements of one crewman.	N/A	N/A	None	This valve position may be used for reduced flow to the PGA (suit connected), or for normal flow to the cabin for shirtsleeve mode (suit not connected). Suit hose is not disconnected from suit connector panel when going to shirtsleeve mode.
	SUIT FULL FLOW	Fully opens valve, permitting oxygen flow to suit at a rate compatible to the requirements of one crewman.				With the valve in SUIT FULL FLOW position (suit connected), the flow is at the rate of 17 lb/hr minimum. However, the flow rate will vary along the suit flow adjustment range from SUIT FULL FLOW to CABIN FLOW positions.

LH FORWARD EQUIPMENT BAY—PANELS 300, 301, AND 302

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHFEB-300, -301, -302	CONTROL LEVER RELEASE	Permits free movement of valve control lever by releasing lever locking mechanism.	N/A	N/A	None	When release pushbutton is pressed, locking detent is removed from notch. The release pushbutton must be pressed to permit movement of the control lever in and out of the OFF position. This prevents inadvertent valve movement out of the closed position when suit hose is disconnected, and into the closed position when the suit hose is connected.
LHFEB-303	CABIN TEMP valve H (heat)	Manual backup mode position of cabin temperature control valve to increase cabin temperature.	N/A	N/A	None	Motor-operated valve is manually controlled by integral knob. Rotational movement from H to C is approximately 1/2 turn. Backup mode control knob is used in event of malfunction of cabin temperature control components. This is a dual valve on a single shaft permitting water-glycol flow to heat exchanger to be regulated. Rotation toward the H (heat) position results in proportional increase in cabin temperature by directing warm water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary. Rotation towards the C (cool) position results in proportional decrease in cabin temperature by directing cool water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary.
	C (cool)					
	Cabin air control louver	Manually operated louver for adjusting direction of airflow from cabin air fans.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHFEB-304	DRINKING WATER SUPPLY shutoff valve		N/A	N/A	None	Shutoff valve manually controlled by T-handle tool.
	ON	Permits flow of potable water to water delivery unit.				Normal position of valve is on.
	OFF	Turns off flow of potable water to water delivery unit.				Valve is closed in event of leak in water delivery unit.
LHFEB-305	FOOD PREPARATION WATER supply unit					
	COLD valve	Upon actuation, permits metered amount of cold water (50°F) to food reconstitution nozzle.	N/A	N/A	None	Cold or hot water is metered at a rate of 1.00±0.05 ounce per valve actuation. Upon release, valves return to closed position.
	HOT valve	Upon activation, permits metered amount of hot water (154±4°F) to food reconstitution nozzle.				
LHFEB-306	GMT clock	Mission elapsed time indicator.	N/A	N/A	None	This clock has a 24-hour dial face with standard second, minutes, and hour hands. A time-set screw, at the bottom left of the dial face, is used to synchronize the clock with Greenwich mean time.
	TO EVENT and FROM EVENT timers	Provides crew with a means of monitoring and timing events.				Each timer has a 10-hour dial face with second, minute, hour and 10-hour hands. A knob at the bottom left of each timer is used to set the timer hands. Each timer can be reset, started, or stopped by a push-control at the top right of the timer.
LHFEB-318	SCIENTIFIC EQUIPMENT receptacle switch		SCIEN EQUIP. HATCH (MDC-22)	+28 vdc	None	
	ON	Applies d-c power from nonessential bus No. 2 to SCIENTIFIC EQUIPMENT receptacle for COAS and 16 mm sequence camera.				
	OFF	Removes d-c power from SCIENTIFIC EQUIPMENT receptacle.				

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307	CABIN PRESSURE RELIEF valves		N/A	N/A	None	There are two cabin pressure-relief valves that normally operate automatically to provide positive and negative cabin pressure relief. The upper manual control (three valve positions) and the lower manual control (four valve positions) can override their corresponding relief valves to the CLOSE and NORMAL positions, while only the lower manual control can override its corresponding relief valve to the DUMP position. Horizontal pressure must be applied to move controls out of detent. Both relief valves are closed for prelaunch checkout and during C/M RCS propellant dump, while either one or both relief valves are closed in flight in event of valve malfunction. Normal position of controls for flight period between ascent and entry. Valves are limited to the partially open position to prevent rapid cabin decompression in event valves fail open.
	CLOSE	Manual override position to close either cabin pressure-relief valve.				
	NORMAL	Manual override position to partially restrict travel of either cabin pressure-relief valve in the automatic mode.				

LH EQUIPMENT BAY—PANEL 307

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)	BOOST ENTRY	Neutral position of override mechanism to permit both cabin pressure-relief valves full travel in the automatic mode.	N/A	N/A	None	Except for time required to dump RCS propellants during descent, both controls are normally set to the BOOST ENTRY position for the ascent and entry phases.
	DUMP	Manual override position of lower control to open corresponding cabin pressure-relief valve.				Valve is opened to intentionally vent cabin to outside atmosphere in event of contamination or fire. Mechanical safety latch must be off to set lever in dump position.
	GLYCOL TO RAD valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water-glycol from C/M to space radiators in S/M.				Normal position of valve is OPEN.
	CLOSE	Shuts off flow of water-glycol from C/M to space radiators in S/M.				Valve is closed prior to CSM separation to shut off water-glycol flow to S/M.
	GLYCOL RESERVOIR controls					
	INLET valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water-glycol from system into reservoir.				Valve is opened to direct water-glycol flow through reservoir during prelaunch and ascent phases and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR BYPASS valves.
	CLOSE	Shuts off flow of water-glycol from system into reservoir.				Valve is closed upon completion of ascent phase to isolate reservoir from system.
	BYPASS valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Opens bypass line permitting flow around water-glycol reservoir.				Valve is opened upon completion of ascent phase to bypass and isolate reservoir from system, and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR INLET valves.
	CLOSE	Closes bypass line that permits flow around water-glycol reservoir.				Valve is closed to direct water-glycol flow through reservoir during prelaunch and ascent phases.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)	OUTLET valve		N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water-glycol from outlet of reservoir into system.				Valve is opened to direct water-glycol flow through reservoir during prelaunch and ascent phases, and is operated in conjunction with GLYCOL RESERVOIR INLET and GLYCOL RESERVOIR BYPASS valves.
	CLOSE	Shuts off flow of water-glycol from outlet of reservoir into system.				Valve is closed upon completion of ascent phase to isolate reservoir from system.
	OXYGEN controls					
	ENTRY valve					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow from 1-lb entry oxygen tank into C/M oxygen supply subsystem.				Valve furnishes 1 lb of oxygen as a redundant supply to the normal surge tank quantity of 3.7 lb.
	OFF	Shuts off flow between 1-lb entry tank and C/M oxygen supply subsystem.				
	FILL	Permits flow from C/M oxygen supply subsystem to bypass the check valve and thus fill the 1-lb entry tank.				Tank filled to approximately 900 psig at a rate of 0.66 pounds/minute.
	S/M SUPPLY valve					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of oxygen to C/M from supply in S/M.				Normal position of valve is ON.
	OFF	Shuts off flow of oxygen to C/M from supply in S/M.				Valve is closed prior to CSM separation to prevent C/M entry oxygen supply from flowing overboard in event of check valve failure.
	SURGE TANK valve					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of oxygen to and from surge tank.				Normal position of valve is ON, permitting surge tank to carry out function of supplying additional oxygen.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)			N/A	N/A	None	beyond the normal maximum flow capability from the S/M, and for entry. Set O_2 PRESS IND switch (MDC-13) to SURGE TANK to obtain indication. Valve is closed to preserve surge tank supply in event cryogenic oxygen tank pressure drops to 900 psig or below.
	OFF	Shuts off flow of oxygen to and from surge tank.				
LHEB-308	SURGE TANK PRESSURE RELIEF shutoff valve		N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool. Rotational movement from OPEN to close is 1/4 turn. OPEN position enables relief valve to function when surge tank pressure increases to 1045±25 psig. Valve is closed only if surge tank relief valve fails open.
	OPEN (cs)	Opens line from surge tank to relief valve permitting relief function.				
	Close (ccw)	Closes line from surge tank to relief valve eliminating relief function.				
LHEB-309	GLYCOL PRESS RELIEF BYPASS valves		N/A	N/A	None	Except for ascent and entry, one pressure-relief valve is selected for use at a time, with the second valve for standby redundancy.
	Valve 1					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of water-glycol to No. 1 water-glycol pressure-relief valve.				Normal position of valve No. 1 when valve No. 2 is OFF.
	OFF	Shuts off flow of water-glycol to No. 1 water-glycol pressure-relief valve.				Normal position of valve No. 1 when valve No. 2 is ON, or in event of malfunction of No. 1 pressure-relief valve.
	Valve 2					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of water-glycol to No. 2 water-glycol pressure-relief valve.				Normal position of valve No. 2 when valve No. 1 is OFF.
	OFF	Shuts off flow of water-glycol to No. 2 water-glycol pressure-relief valve.				Normal positon of valve No. 2 when valve No. 1 is ON, or in event of malfunction of No. 2 pressure relief valve.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-310	O_2 DEMAND REGULATOR		N/A	N/A	None	Valve is manually controlled by T-handle tool.
	1	Directs regulated oxygen (100±10 psig) to No. 1 suit demand pressure regulator.				Valve set to position 1 in event of malfunction of No. 2 demand pressure regulator.
	1 & 2	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 suit demand pressure regulators.				Both demand pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning.
	2	Directs regulated oxygen (100±10 psig) to No. 2 suit demand pressure regulator.				Valve set to position 2 in event of malfunction of No. 1 demand pressure regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 suit demand pressure regulators.				Valve set to OFF position only if both suit demand pressure regulators malfunction.
	SUIT TEST valve					Valve is operated by an integral lever.
	PRESS	Routes regulated oxygen flow (100±10 psig) directly into suit circuit through a pressurization orifice at a maximum buildup rate of 4 psig per minute for PGA/suit circuit tests.				With valve in PRESS position, suit circuit will increase 4.25 psia above the nominal pressure of 5.0±0.3 psia. Approximately 75 seconds must be allowed for suit circuit pressure to reach maximum. This test may be performed at ground checkout or during flight.
	DEPRESS	Shuts off O_2 flow to suit circuit upon completion of test, permitting reduction of pressure buildup at an average bleedoff rate of 4 psig per minute.				Approximately 75 seconds must be allowed for the increased suit circuit pressure to bleed back to the nominal 5.0±0.3 psia.
	OFF	Permits normal O_2 flow to suit circuit through suit demand pressure regulator.				Normal position of valve when not conducting a PGA/suit circuit test. Valve must not be set to off position before suit circuit has returned to nominal pressure.
	SUIT HT EXCH switch					Regardless of switch position, the SUIT EVAP switch (MDC-13) must be in AUTO position for automatic control of suit circuit temperature.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-310 (Cont)	GLY/EVAP	Places suit circuit temperature control complex in full automatic mode, whereby, cooling is accomplished either by water-glycol or water evaporation.	N/A	N/A	None	In the GLY/EVAP position, the switch is open. This prevents shorting across the circuit of the suit heat exchanger air outlet temperature sensor, and permits the sensor to automatically activate the water evaporation mode if the temperature reaches 60°F or more. In the EVAP position, the switch is closed. This shorts across the circuit of the suit exchanger air outlet temperature sensor, and creates the same effect as an overtemp condition (above 60°F) on this sensor. This switch position is selected for cabin cold-soak operation, or if suit temperature control complex malfunctions.
	EVAP	Overrides full automatic mode of suit heat exchanger temperature control complex by positioning the water-glycol diverter valve in the bypass position, thereby, initiating the automatically controlled water evaporation cooling mode.				
LHEB-311	SUIT EVAP GLYCOL valve		N/A	N/A	None	Motor-operated valve is manually controlled by T-handle tool. Normal position of valve is ON to permit the automatic suit temperature control complex to select the water-glycol or water evaporation cooling mode. Valve is set to OFF position for backup cabin cold-soak operation or in event of suit temperature control malfunction. Movement of diverter valve mechanically operates switch that activates water evaporation cooling mode.
	ON	Manual override position of water-glycol diverter valve, routing coolant flow to the suit heat exchanger for suit circuit cooling.				
	OFF	Manual override position of water-glycol diverter valve, bypassing coolant flow around suit heat exchanger and activating water evaporation cooling mode.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
ECS 11 (cont)	SUIT FLOW RELIEF valve		N/A	N/A	None	Valve is manually controlled by T-handle tool.
	AUTO	Removes override lever from poppet valve, permitting automatic pressure-relief action to take place at a ΔP of 5 (+0.6, -0.2) inches H_2O.				Normal position of valve is AUTO to maintain constant suit flow in event of suit circuit flow resistance fluctuations.
	OFF	Applies override lever to poppet valve holding valve in closed position.				Valve is manually closed in event of its failure to close when in the automatic mode.
	GLYCOL EVAP TEMP IN valve					Motor-operated valve is manually controlled by T-handle tool. Rotational movement from HEAT to cool is just over 1/4 turn.
	HEAT (ccw)	Manual backup mode position of water-glycol temperature control valve to increase temperature of water-glycol entering evaporator.				Backup mode is used in event of malfunction of water-glycol temperature control components. Rotation toward the HEAT position results in a proportional temperature increase by changing the mixture ratio of hot-to-cold water-glycol. Close coordination between valve adjustments and GLY EVAP — OUTLET TEMP indicator (MDC-13) is necessary to obtain correct water-glycol temperature.
	Cool (ccw)	Manual backup mode position of water-glycol temperature control valve to decrease temperature of water-glycol entering evaporator.				Rotation toward the cool position results in a proportional temperature decrease by changing the mixture ratio of cold-to-hot water-glycol. Close coordination between valve adjustments and GLY EVAP — OUTLET TEMP indicator is necessary to obtain correct water-glycol temperature.
	H_2O ACCUMULATOR selector valves					Valves manually controlled by T-handle tool.
	Valve 1					
	MAN	Routes regulated oxygen (100±10 psig) to No. 1 cyclic accumulated, bypassing solenoid shutoff valve.				Valve position is selected only when No. 2 accumulated has failed and No. 1 solenoid shutoff valve cannot be operated automatically or by

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-311 (Cont)			N/A	N/A	None	manually selected electrical impulse. Valve will then be positioned to MAN for approximately 10 seconds every 30 minutes.
	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line to No. 1 cyclic accumulator.				
	RMTE	Routes regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 1 cyclic accumulator.				Normal position of valve is RMTE, permitting automatic (CTE) or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.
	Valve 2					Valve manually controlled by T-handle tool.
	MAN	Routes regulated oxygen (100±10 psig) to No. 2 cyclic accumulator, bypassing solenoid shutoff valve.				Valve position is selected only when No. 1 accumulator has failed and No. 2 solenoid shutoff valve cannot be operated automatically or by manually selected electrical impulse. Valve will be positioned to MAN for approximately 10 seconds every 30 minutes.
	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line to No. 2 cyclic accumulator.				
	RMTE	Routes regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 2 cyclic accumulator.				Normal position of valve is RMTE permitting automatic CTE or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.
	GLYCOL RESERVE valve					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of water-glycol from reservoir into system.				Valve is opened to refill water-glycol system following the discovery and isolation of a leak.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-311 (Cont)	OFF	Shuts off flow of water-glycol from reservoir into system.	N/A	N/A	None	Normal position of valve is OFF to isolate water-glycol reservoir from system.
	EVAP H_2O valve					Valve is manually controlled by T-handle tool.
	AUTO	Permits water flow to water-glycol evaporator solenoid-operated water inflow control valve.				Normal position of valve.
	OFF	Shuts off water flow to water-glycol evaporator water inflow control valve.				Valve is manually closed to prevent flooding water-glycol evaporator in event solenoid valve facts open.
	SUIT EVAP selector valve					Valve is manually controlled by T-handle tool.
	AUTO	Routes flow of water to solenoid-operated water inflow control valve for suit circuit evaporative cooling.				Valve set to AUTO position during all automatic suit temperature control operations.
	OFF	Shuts off flow of water to water inflow control valve and bypass line to suit evaporator.				Valve set to OFF position in event water inflow control valve fails open.
	MAN	Bypasses flow of water around water inflow control valve, routing it directly into the suit evaporator.				Valve set to MAN position for manual backup mode of evaporative cooling. This method is effective only if the steam-pressure control valve is in any position other than close. A malfunction in the temperature control components could leave the steam pressure control valve in any position.
LHEB-312	GLYCOL ACCUMULATOR shutoff valve		N/A	N/A	None	Shutoff valve is manually controlled by torque wrench and 10-inch driver.
	On (ccw)	Permits flow of water-glycol from system to and from water-glycol accumulator.				Normal position of valve is on, permitting accumulator to carry out function of damping surges and oscillations, and maintaining pump inlet pressure.
	OFF (cw)	Shuts off flow of water-glycol from system to water-glycol accumulator.				Valve is closed to isolate a leaking accumulator from water-glycol system.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-313	CO_2-odor absorber diverter valve		N/A	N/A	None	The diverter valve linkage includes a mechanical interlock that assures cover removal of only the canister that has been isolated from the suit flow.
	UP	Shuts off suit circuit flow to canister B and diverts the full flow to canister A.				
	Center	Neutral position of valve permitting equal suit circuit flow to each canister.				
	Down	Shuts off suit circuit flow to canister A and diverts the full flow to canister B.				
LHEB-314	MAIN REGULATOR selector valve		N/A	N/A	None	Selector valve is manually controlled by integral knob.
	NORMAL	Directs supply of oxygen from S/M to No. 1 and No. 2 main pressure regulator and relief valves.				Regulators No. 1 and No. 2 are selected for simultaneous use under normal conditions.
	1	Directs supply of oxygen from S/M to No. 1 main pressure regulator and relief valve.				Valve set to position 1 in event of malfunction of No. 2 main pressure regulator and relief valve.
	OFF	Shuts off supply of oxygen from S/M to No. 1 and No. 2 main pressure regulator and relief valves.				
	2	Directs supply of oxygen from S/M to No. 2 main regulator and relief valve.				Valve set to position 2 in event of malfunction of No. 1 main pressure regulator and relief valve.
	WATER & GLYCOL TANKS PRESSURE controls					Selector valve is manually controlled by T-handle tool.
	REGULATOR-SELECTOR INLET valve					
	NORMAL	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators for reduction to 20±-psig tank pressure.				Both tank pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning. **Caution** If the SELECTOR INLET valve is placed to position 1 or 2, the SELECTOR OUTLET valve must be placed to the corresponding position (or NORMAL) to prevent shutting off supply of oxygen for pressurizing the water tanks and water-glycol reservoir.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-SE4 (Cont)	1	Directs regulated oxygen (100±10 psig) to No. 1 tank pressure regulator for reduction to 20±2-psig tank pressure.	N/A	N/A	None	Valve is set to position 1 in event of malfunction of No. 2 tank pressure regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators.				With valve in OFF position, tank pressurization system is isolated from regulated oxygen supply.
	2	Directs regulated oxygen (100±10 psig) to No. 2 tank pressure regulator for reduction to 20±2-psig tank pressure.				Valve is set to position 2 in event of malfunction of No. 1 tank pressure regulator.
	RELIEF-SELECTOR OUTLET valve					Selector valve is manually controlled by T-handle tool.
	NORMAL	Directs oxygen pressure from potable and waste water tanks to No. 1 and No. 2 tank pressure regulator relief valves.				Both tank pressure-relief valves are selected for simultaneous use under normal conditions for redundancy in event of one relief valve malfunctioning.
						There is no meter to indicate pressurization of potable and waste water tanks and glycol reservoir.
						Caution If the SELECTOR OUTLET valve is placed to position 1 or 2, the SELECTOR INLET valve must be placed to the corresponding position (or NORMAL) to prevent shutting off supply of oxygen for pressurizing the water tanks and water-glycol reservoir.
	1	Directs oxygen pressure from potable and waste water tanks to No. 1 tank pressure regulator relief valve.				Valves set to position 1 in event of malfunction of No. 2 tank pressure regulator relief valve.
	OFF	Shuts off oxygen pressure from potable and waste water tanks to No. 1 and No. 2 tank pressure regulator relief valves.				With valve in OFF position, any increase in oxygen pressure is trapped and cannot be relieved.
	2	Directs oxygen pressure from potable and waste water tanks to No. 2 tank pressure regulator relief valve.				Valve set to position 2 in event of malfunction of No. 1 tank pressure regulator relief valve.
	PLSS FILL valve	Manual shutoff valve controlling filling of PLSS tank with oxygen from supply in surge tank.				Valve is manually controlled by integral T-handle. Rotational movement from open to CLOSE is approximately 2 turns.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-314 (Cont)			N/A	N/A	None	Normal position of valve is closed. Valve is opened when used in conjunction with adjacent PLSS FILL connector.
	EMERGENCY CABIN PRESSURE selector valve					Selector valve is manually controlled by T-handle tool.
	NORMAL	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators.				Both emergency regulators are selected for simultaneous use under normal conditions, for redundancy in event of emergency decompression as a result of cabin wall puncture.
	1	Directs regulated oxygen (100±10 psig) to No. 1 emergency cabin pressure regulator.				Valve set to position 1 in event of malfunction of No. 2 emergency regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators				Valve is set to OFF position whenever all crewmen are suited. With valve in OFF position, both emergency regulators are isolated from regulated oxygen supply.
	2	Directs regulated oxygen (100±10 psig) to No. 2 emergency cabin pressure regulator.				Valve set to position 2 in event of malfunction of No. 1 emergency regulator.
	PRESS TO TEST pushbutton	Permits No. 1 and No. 2 emergency cabin pressure regulators to be simultaneously tested for operational verification.				With pushbutton pressed, vents to reference pressure chambers of both regulators are closed off. This allows an artificial reference pressure to build up which results in regulator operation. This test may be accomplished at ground checkout or during flight.
	CABIN REPRESS manual valve					Shutoff valve is manually controlled by integral knob. Rotational movement from OPEN to close is approximately 3/4 turn.
	OPEN (cw)	Directs oxygen into cabin up to the maximum flow rate of 7.2 lb per hr. Poppet-type valve is an independent unit of the cabin pressure regulator assembly.				Both normal cabin pressure regulators are in use simultaneously and cannot be selected or turned off. In the event both regulators fail in the closed or fail-safe position, the manual shutoff valve is used to maintain cabin pressure. Valve is also used to repressurize cabin after decompression.
	Close (ccw)	Shuts off oxygen flow into cabin.				

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
EHEB (Cont)	TOOL STOWAGE receptacle	Fish-mounted receptacle for storing universal T-handle tool used in positioning numerous manually operated valves.	N/A	N/A	None	A second T-handle tool is stowed in socket of suit circuit DIRECT O_2 metering valve (MDC-24) for use in positioning those valves accessible to crewman in LH couch.
EHEB 315	WASTE TANK SERVICING valve		N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water into waste water tank from ground servicing connection.				Valve is opened when used in conjunction with adjacent WASTE TANK SERVICING connector.
	CLOSE	Shuts off flow of water into waste water tank from ground servicing condition.				
	PRESSURE RELIEF selector valve					Selector valve is manually controlled by integral lever.
	BOTH	Directs flow of excess potable or waste water to No. 1 and No. 2 pressure relief valves.				Both pressure relief valves are selected for simultaneous use under normal conditions, for redundancy in event of one relief valve malfunctioning.
	1	Directs flow of excess potable or waste water to No. 1 pressure relief valve.				Valve set to position 1 in event No. 2 pressure relief valve malfunctions.
	OFF	Shutoff flow of excess potable and waste water to No. 1 and No. 2 pressure relief valves.				With valve in OFF position, excess water cannot be dumped overboard. Unless both relief valves fail to open, this valve position is used for ground checkout only.
	2	Directs flow of excess potable and waste water to No. 2 pressure relief valve.				Valve set to position 2 in event No. 1 pressure relief valve malfunctions.
	POTABLE TANK INLET valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water from fuel cells into potable water tank.				Normal position of valve is OPEN.
	CLOSE	Shuts off flow of water from fuel cells into potable water tank.				Valve set to CLOSE position to isolate potable water tank in event water from fuel cells becomes contaminated.

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-315 (Cont)	WASTE TANK INLET valve		N/A	N/A	None	Shutoff function of this relief-shutoff valve is manually controlled by T-handle tool.
	AUTO	Permits flow of water from fuel cells into waste water tank when relief valve differential pressure reaches 6.0±0.5 psi.				Normal position of valve is AUTO. If potable water tank is full or waste tank is empty, water from fuel cells will flow into waste water tank when relief valve reaches 6.0±0.5 psid.
	CLOSE	Shuts off flow of water from fuel cells to differential pressure-relief valve and waste water tank.				Valve set to CLOSE position in event relief valve fails open, prematurely permitting potable water flow into waste water tank.
LHEB-316	PLVC switch		POSTLANDING VENT FAN - PL BUS/FLOAT BAG 2 (MDC-25)	Flight and Postlanding Bus	None	
	NORMAL	Applies d-c power to pendulum-type attitude sensing switch of PLV system during normal postlanding operations.				Switch set to NORMAL position to permit normal operation of attitude sensing switch (to close PLV valves) when C/M becomes inverted or tilts beyond a specified limit.
	OPEN	Applies d-c power directly to PLV valves, placing valves in open position in event of abnormal postlanding operations.				Switch set to OPEN position in event of attitude sensing switch failure, or to aid crew to escape from inverted C/M.
LHEB-317	GLY EVAP WATER CONTROL BYPASS valve		N/A	N/A	None	LHEB-317 consists of two components. A manually operated water control valve installed in the LHEB, and a plug-in unit to measure glycol evaporator wick temperature stowed in the C/M cabin. Data on plug-in unit TBD.
	ON	Permits flow of water directly into water-glycol evaporator by bypassing solenoid-operated water inflow control valve.				Valve set to ON position in event of water-glycol evaporator temperature control failure.
	OFF	Shuts off flow of water bypassing water-glycol evaporator inflow control valve.				Normal position of valve is OFF.
LHEB-319	SUIT CIRCUIT RETURN SHUT-OFF VALVE		N/A	N/A	None	Shutoff valve is manually controlled by knurled knob.
	O (open)	Permits flow of cabin gases to enter suit circuit for processing.				Normal position of valve is open.
	C (closed)	Shuts off flow of cabin gases entering suit circuit.				Valve is closed during ascent and descent, as access to valve is blocked. Valve is also closed to isolate suit circuit in event of cabin contamination.

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
Left Armrest, LH Couch	Translation controls Normal position In/out Left/right Up/down	Actuates all switches located within the control to the open position. Applies +X or -X translation command signal to SCS electronics. Applies +Y or -Y translation command signal to SCS electronics. Applies +Z or -Z translation command signal to SCS electronics.	SCS-GROUP 1 MNS A MNS B (MDC-25)	D-C main bus A or B	None	Two nearly identical translation controls are installed in the S/C. The functions are identical with one exception: the PCW switch function is not available from the No. 2 control. S/C translation are accomplished by use of S/M RCS only. Physically, the No. 1 control is identified by the presence of yellow diagonal striping on the top and right hand side. A push-to-talk mike switch is located on the control handle. When pressed, the switch enables audio transmission capability in certain modes of communication system operation. The electrical cabling plugs, for the two translation controls, are connected at the LHEB

LEFT ARMREST, LH COUCH — CREW COUCHES
PRESSURE GARMENT ASSEMBLY

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
Left Armrest LH Couch (Cont)	CCW (rotation)	a. Initiates manual abort command signal to the MESC. b. Provides a backup for CSM/booster separation after all stages are expended.	MASTER EVENT SEQ CONT — A LOGIC B BAT A BAT B (MDC-22)	Battery buses A and B	None	The translation control must be in the neutral position prior to engaging MESC logic A and B circuit breakers. Failure to confirm neutral positioning could result in an inadvertent abort or separation. Due to a positive detent the translation control must be manually returned to neutral from the CCW or CW position. This function is used when normal booster separation fails to occur.
	CW (rotation)	a. Engages manual thrust vector control mode during G&N or SCS ΔV. ΔV switch must be in the ΔV position prior to selecting MTVC. b. Disengages automatic attitude control during G&N or SCS attitude hold.	SCS— GROUP 2 MN A MN B (MDC-25)	D-C main bus A or B		This position may be used to place the S/C in free drift, and at the same time provide S/C attitude information on the FDAI depending on mode selected.
Crew Couches	Rotation controls	Provides manual control of C/M - S/M attitude in all axes.	SCS— GROUP 2 AC 1 AC 2 (MDC-25)	A-C bus No. 1 or A-C bus No. 2	None	Two identical rotation controls are installed in the S/C. The function of both controls is identical. The electrical cabling plugs for the two rotation controls are connected at the RH couch junction box.
	Forward/back (movement)	a. Commands S/C rotation in the pitch axis. b. Provides manual control of SPS engine pitch gimbal after MTVC is engaged.	SCS— DIRECT CONT MN A MN B (MDC-25)	D-C main bus A or B		When using a control, S/C rotation can be commanded two ways, either by proportional rate commands or by direct on commands. Proportional rate command is obtained by utilization of the SCS electronics, and is considered the normal method. Direct on commands are available when the DIRECT RCS switch is used in conjunction with the rotation control.
	Left/right (movement)	Commands S/C rotation in the roll axis.	SCS— GROUP 2 MN A MN B (MDC-25)			
	CW/CCW (rotation)	a. Commands S/C rotation in the yaw axis. b. Provides manual control of SPS engine yaw gimbal after MTVC is engaged.				
Pressure Garment Assembly	PGA pressure indicator	Indicates oxygen pressure (PSIA) inside pressure garment assembly.	None	None	None	The indicator is located on the left sleeve between wrist and elbow, on top of arm. The indicator range is from 2 to 10 psia.

SECTION 4

PERFORMANCE

INTRODUCTION.

This section contains information on crew display instrument markings, instrument accuracy consumable requirements, thrusting data (as available), and S/C operational constraints and limitations.

4.1 CREW DISPLAY INSTRUMENT MARKINGS AND ACCURACY DATA.

Paragraphs 4.1.1 through 4.1.7.4 include information on instrument markings and instrument accuracy. Adjoining tabular lists provide accuracy data for each indicator scale and list the measurement number of the signal which is monitored on each indicator scale. Some indicators can, by selection, monitor more than one signal; in which case, the measurement number of all signals monitored by the indicator are listed. Selector switch and indicator functions are covered in detail in section 2.

Some of the system indicators shown in the associated illustrations (figures 4-1 through 4-12) are provided with vertical or horizontal green-colored bands to show normal operating ranges, vertical yellow bands to show permissible operating ranges requiring caution, and horizontal red bands or lines to show system limitations. The color markings, operating ranges, and limitations for these system indicators are as follows:

System	Indicator Scale	Color Marking	Operating Range or Limitation
SPS (MDC-20) (figure 4-1)	PROP TEMP	Red	80°F (upper limit) and -40°F (lower limit)
	PRESSURE-FUEL	Green	170 to 195 psia (normal band)
	PRESS-OX	Green	Same as PRESSURE-FUEL scale.

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System	Indicator Scale	Color Marking	Operating Range or Limitation
	PRESSURE-ENG INLET-FUEL	Green	STATIC 170 to 195 psia (normal band)
			FIRE 135 to 165 psia (normal band)
	PRESSURE-ENG INLET-OX	Green	Same as PRESSURE-ENG INLET-FUEL scale.
SPS (MDC-3) (figure 4-11)	L/V AOA/SPS P_c indicator	Green	SPS FIRE 65 to 125% (normal band)
EPS (MDC-13) (figure 4-3)	TANK PRESSURE-H_2-1	Green	230 to 265 psia (normal band)
	TANK PRESSURE-H_2-2	Green	Same as TANK PRESSURE-H_2-1 scale.
	TANK PRESSURE-O_2-1	Green	865 to 935 psia (normal band)
	TANK PRESSURE-O_2-2	Green	Same as TANK PRESSURE-O_2-1 scale
(MDC-18) (figure 4-5)	FUEL CELL-FLOW-H_2	Green	0.03 to 0.15 lb/hr (normal band)
	FUEL CELL-FLOW-O_2	Green	0.25 to 1.20 lb/hr (normal band)
	FUEL CELL-MODULE TEMP-SKIN	Green	385° to 495°F (normal band)
	FUEL CELL-MODULE TEMP-COND EXH	Green	157.5° to 172.5°F (normal band)
ECS (MDC-13) (figure 4-9)	PRESS GLY DISCH	Green	35 to 55 psia (normal band)
	TEMP-SUIT	Green	45° to 65°F (normal band)
	PRESS-SUIT	Red	3.4 psia (low limit line)

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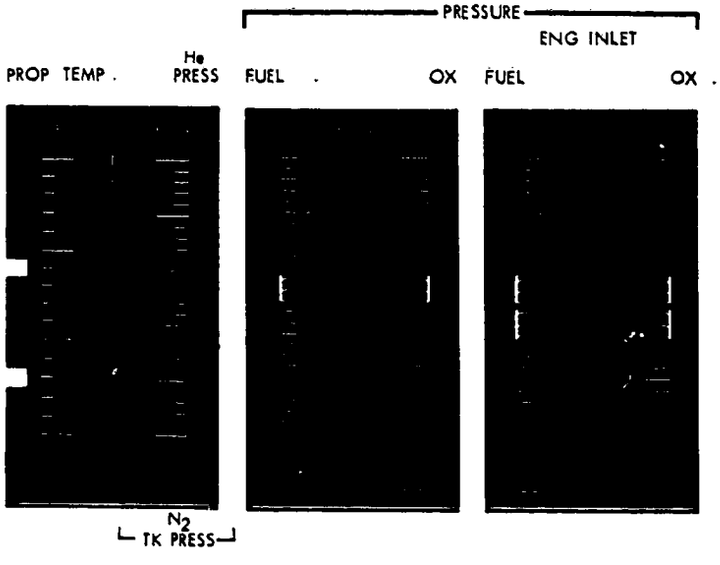
System	Indicator Scale	Color Marking	Operating Range or Limitation
	PRESS-CABIN	Red	4.7 psia (low limit line)
	PART PRESS-CO_2	Red Yellow	15 mm Hg (high limit line) 7.6 to 15 mm Hg (caution band)
PGA (figure 4-9)	PGA pressure indicator	Red Green	2.0 to 3.5 psia (emergency band) 3.5 to 10 psia (normal band)

4.1.1 SERVICE PROPULSION SYSTEM INDICATORS.

Instrument markings for the SPS indicators (MDC-20) are shown in figure 4-1. The indicators present a visual display of SPS temperatures and pressures. Visual displays of SPS fuel and oxidizer remaining aboard the S/C are shown in the adjacent OXID-FUEL QUANTITY display windows (as selected by the SPS quantity SENSOR switch). (Refer to section 3.)



NOTE: Red lines on the propellant temperature scale show upper limit of 80°F and lower limit of -40°F. Vertical green color bands show normal operating ranges for fuel and oxidizer pressure (170 to 195 psia) and engine inlet pressures for STATIC (170 to 195 psia) and FIRE (135 to 165 psia).

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Figure 4-1. Service Propulsion System Indicators

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The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
PROP TEMP	SP 0002 T	±5°F at 75°F ±10°F at 0° and 150°F
He PRESS	SP 0001 P	±100 psia at 75°F ±150 psia at 0° and 150°F
Tk PRESS-N_2	SP 0600 P (Primary) SP 0601 P (Secondary)	±100 psia at 75°F ±150 psia at 0° and 150°F
PRESSURE-FUEL	SP 0006 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-OX	SP 0003 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-ENG INLET-FUEL	SP 0010 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-ENG INLET-OX	SP 0009 P	±5 psia at 75°F ±10 psia at 0° and 150°F

4.1.2 REACTION CONTROL SYSTEM INDICATORS.

Instrument markings for the S/M and C/M RCS indicators (MDC-12) are shown in figure 4-2. The indicators present a visual display of system temperatures and pressures. Visual displays of S/M RCS fuel and oxidizer remaining are shown on the adjacent PROPELLANT QUANTITY indicator (as selected by the RCS INDICATORS switch). (Refer to section 3.)

The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
S/M RCS-TEMP PKG	SR 5065 T (Quad A) SR 5066 T (Quad B) SR 5067 T (Quad C) SR 5068 T (Quad D)	±5°F at 75°F ±10°F at 0° and 150°F

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Indicator Scale	Measurement Number	Indicator Accuracy
S/M RCA-PRESS-H_e	SR 5001 P (Quad A) SR 5002 P (Quad B) SR 5003 P (Quad C) SR 5004 P (Quad D)	±100 psia at 75°F ±150 psia at 0° and 150°F
S/M RCS-PRESS-MANF	SR 5729 P (Quad A) SR 5776 P (Quad B) SR 5817 P (Quad C) SR 5830 P (Quad D)	At 75°F, ±5 psia from 140 to 340 psia and ±10 psia over balance of scale. At 0° and 150°F, ±10 psia from 145 to 340 psia and ±15 psia over balance of scale.
S/M RCS-TEMP H_e	SR 5013 T (Quad A) SR 5014 T (Quad B) SR 5015 T (Quad C) ST 5016 T (Quad D)	Same as S/M RCS-PRESS-MANF indicator
C/M RCS-H_e TEMP	CR 0003 T (System A) CR 0004 T (System B)	±5°F at 75°F ±10°F at 0° and 150°F
C/M RCS-PRESS-H_e	CR 0001 P (System A) CR 0002 P (System B)	±100 psia at 75°F ±150 psia at 0° and 150°F
C/M RCS-PRESS-F	CR 0005 P (System A) CR 0006 P (System B)	Same as S/M RCS-PRESS-MANF indicator.
C/M RCS-PRESS-OX	CR 0011 P (System A) CR 0012 P (System B)	Same as S/M RCS-PRESS-MANF indicator.

4.1.3 ELECTRICAL POWER SYSTEM INDICATORS.

4.1.3.1 <u>EPS (Cryogenic Storage) Tank Pressure Indicators.</u>

Instrument markings for the EPS (cryogenic storage) tank pressure indicators (MDC-13) are shown in figure 4-3. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

NOTE TANK PRESSURE-O_2-1 scale is used to display cryogenic storage tank 1 pressure or ECS surge tank pressure as selected by O_2 PRESS IND toggle switch located immediately below the display.

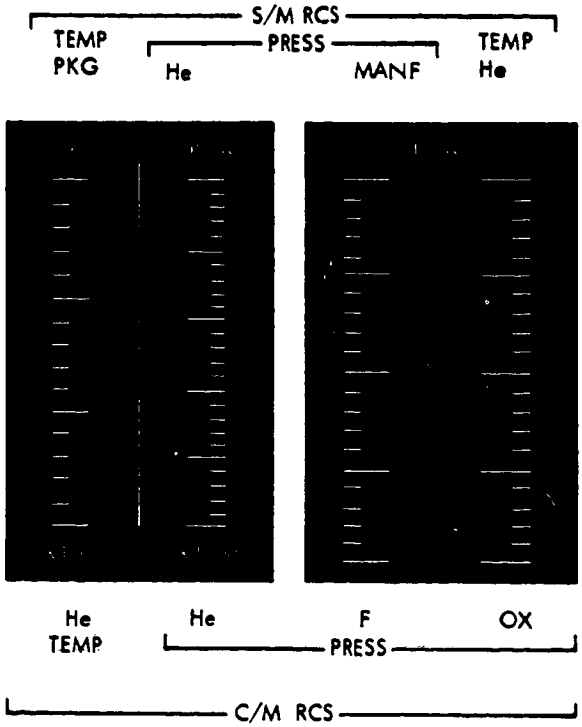

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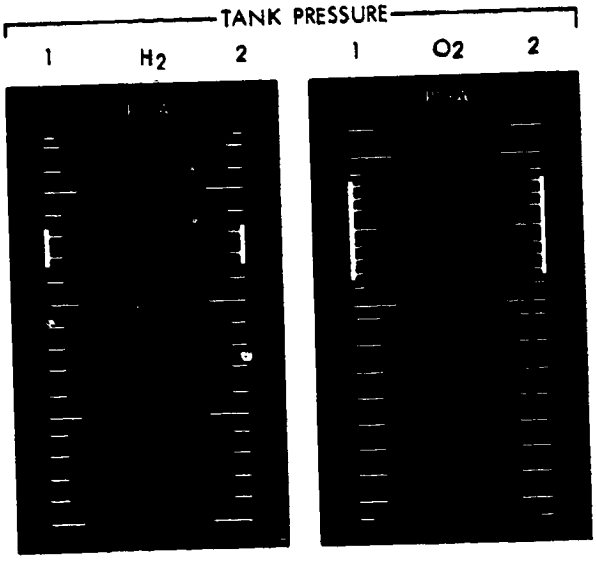
Figure 4-2. S/M and C/M Reaction Control System Indicators

Indicator Scale	Measurement Number	Indicator Accuracy
TANK PRESSURE-H_2-1	SF 0039 P	±5 psia at 75°F ±10 psia at 0° and 150°F
TANK PRESSURE-H_2-1	SF 0040 P	Same as TANK PRESSURE-H_2-1 indicator.
TANK PRESSURE-O_2-1	SF 0037 P (Storage tank) CF 0006 P (Surge tank)	At 75°F, ±5 psia at 850 to 950 psia and ±3% of remaining scale. At 0° and 150°F, ±10 psia at 850 to 950 psia and 4% of remaining scale.
TANK PRESSURE-O_2-2	SF 0038 P	Same as TANK PRESSURE-O_2-2 indicator.



NOTE: Vertical green color bands on the indicators show normal operating ranges for hydrogen tank pressures (230 to 265 psia) and oxygen tank pressures (865 to 935 psia).

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Figure 4-3. EPS (Cryogenic Storage) Tank Pressure Indicators

4.1.3.2 EPS (Cryogenic Storage) Tank Quantity Indicators.

Instrument markings for the EPS (cryogenic storage) tank quantity indicator (MDC-13) are shown in figure 4-4. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
TANK QUANTITY-H_2-1	SF 0030 Q	±0.5 lb at 75°F ±1.0 lb at 0° and 150°F
TANK QUANTITY-H_2-2	SF 0031 Q	Same as TANK QUANTITY-H_2-1 indicator.
TANK QUANTITY-O_2-1	SF 0032 Q	±5.0 lb at 75°F ±10.0 lb at 0° and 150°F
TANK QUANTITY-O_2-2	SF 0033 Q	Same as TANK QUANTITY-O_2-1 indicator.

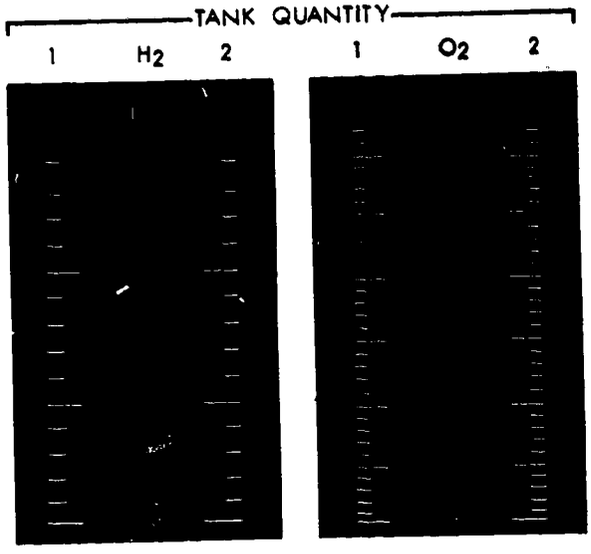
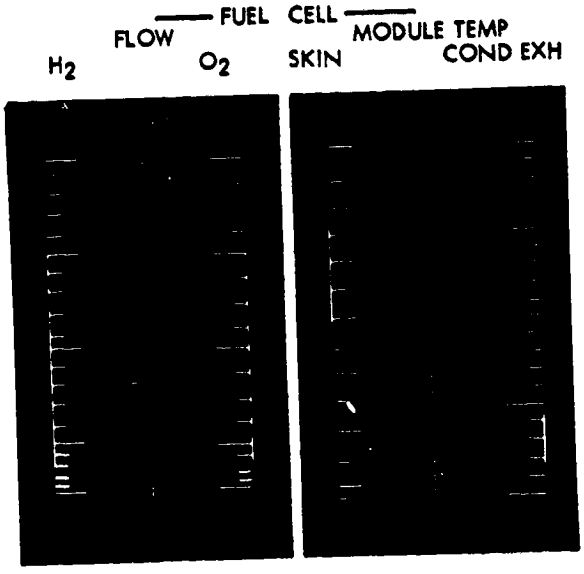


Figure 4-4. EPS (Cryogenic Storage) Tank Quantity Indicators

4.1.3.3 EPS Fuel Cell Power Plant Indicators.

Instrument markings for the EPS fuel cell power plant indicators (MDC-18) are shown in figure 4-5. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
FUEL CELL-FLOW-H_2	SC 2139 R (F/C 1) SC 2140 R (F/C 2) SC 2141 R (F/C 3)	±0.005 lb/hr at 75°F ±0.0075 lb/hr at 0° and 150°F
FUEL CELL-FLOW-O_2	SC 2141 R (F/C 1) SC 2143 R (F/C 2) SC 2144 R (F/C 3)	±0.05 hr/hr at 75°F, and at 0° and 150°F.
FUEL CELL-MODULE TEMP-SKIN	SC 2084 T (F/C 1) SC 2085 T (F/C 2) SC 2086 T (F/C 3)	At 75°F, ±7°F for 400° to 550° scale and 3% of remaining scale. At 0° and 150°F, ±14°F for 400° to 500° scale and 3% of remaining scale.
FUEL CELL-MODULE TEMP-CONT EXH	SC 2081 T (F/C 1) SC 2082 T (F/C 2) SC 2083 T (F/C 3)	±3°at 75°F ±5°F at 0° and 150°F



NOTE: Vertical green color bands on the indicators show normal operating ranges for hydrogen flow (0.03 to 0.15 lb/hr), oxygen flow (0.25 to 1.20 lb/hr), module skin temperature (385° to 495°F), and the condenser exhaust temperature (157.5° to 172.5°F).

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Figure 4-5. EPS Fuel Cell Indicators

4.1.3.4 EPS Volts, Amperes, and Frequency Meters.

Instrument markings for the EPS-volts, amperes, and frequency meters (MDC-18) are shown in figure 4-6. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
DC VOLTS	CC 0206 V (Main Bus A) CC 0207 V (Main Bus B) CC 0210 V (Bat Bus A) CC 0211 V (Bat Bus B) CC 0212 V (Post Ldg Bat) CC 0214 V (Bat Charger Output) CC 0227 V (Pyro Bat A) CC 0228 V (Pyro Bat B)	At 75°F, ±0.25 volts for 25 to 37 volts scale and ±1.0 volt for balance of scale. At 0° and 150°F, ±0.5 volts for 25 to 37 volts scale and ±1.0 volt for balance of scale.
DC AMPS	CC 0222 C (Bat Bus A) CC 0223 C (Bat Bus B) CC 0224 C (Post Ldg Bat) SC 2113 C (F/C 1 Output) SC 2114 C (F/C 2 Output) SC 2115 C (F/C 3 Output)	±1.0% of full scale at 75°F ±2.0% of full scale at 0° to 150°F

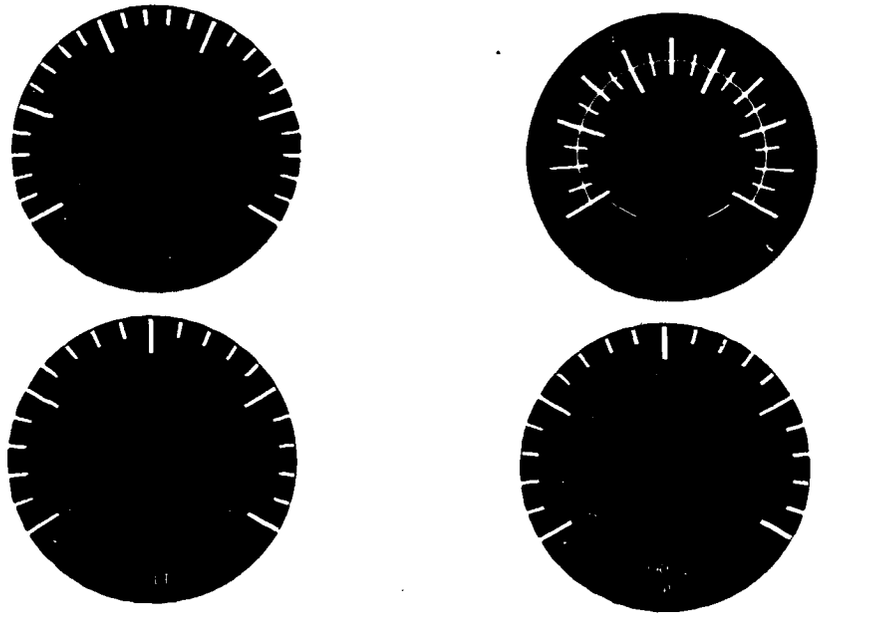

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Figure 4-6. EPS Volts, Amperes, and Frequency Meters

Indicator Scale	Measurement Number	Indicator Accuracy
CHGR (Inner Scale)	CC 0215 C (Bat Charger Output)	Same as DC AMPS scale
AC VOLTS	CC 0200 V (Bus 1 ØA) CC 0201 V (Bus 1 ØB) CC 0202 V (Bus 1 ØC) CC 0203 V (Bus 2 ØA) CC 0204 V (Bus 2 ØB) CC 0205 V (Bus 2 ØC)	Between 0° and 150°F, ±1.0 volt for the 105 and 125 volts scale and ±2.0 volts for balance of scale. At 0° and 150°F, ±2.0 volts for the 105 and 125 volts scale.
FREQ CPS	CC 0213 F (Bus 1 ØA) CC 0181 F (Bus 1 ØB) CC 0182 F (Bus 1 ØC) CC 0217 F (Bus 2 ØA) CC 0183 F (Bus 2 ØB) CC 0184 F (Bus 2 ØC)	From 50° to 110°F, ±1 cycle at 400 cycles. From 0° to 150°F, ±2 cycles at 400 cycles and ±2.5 cycles for balance of scale.

4.1.4 ENVIRONMENTAL CONTROL SYSTEM INDICATORS.

4.1.4.1 ECS Pressure and Slow-Rate Indicators.

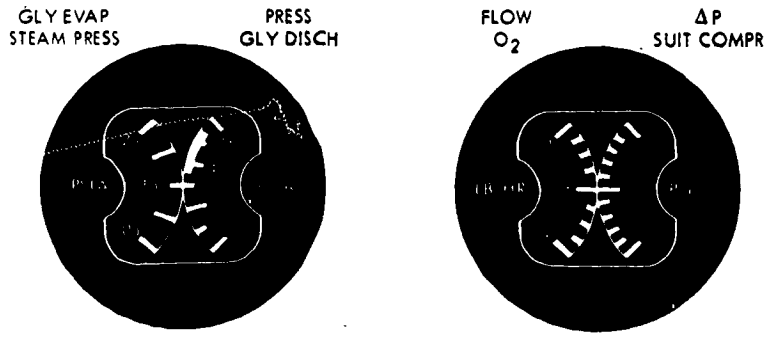
Instrument markings for the ECS pressure and rate-of-flow indicator (MDC-13) are shown in figure 4-7. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
GLY EVAP STEAM PRESS	CF 0034 P	±5% of full scale between 0° and 150°F
PRESS GLY DISCH	CF 0016 P	Same as above.
FLOW O_2	CF 0035 R	Same as above.
ΔP SUIT COMPR	CF 0115 P	Same as above.

4.1.4.2 ECS Quantity and Outlet Temperature Indicators.

Instrument markings for the ECS quantity and outlet temperature indicators (MDC 13 and 14) are shown in figure 4-8. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
GLY ACCUM-QUANTITY	CF 0019 Q	±5% full-scale 0° to 150°F
WATER QUANTITY	CF 0010 Q (Potable Water) CF 0009 Q (Waste Water)	Same as above.
ECS RAD-OUTLET TEMP	CF 0020 T	Same as above.
GLY EVAP-OUTLET TEMP	CF 0018 T	Same as above.
ECS RAD OUT TEMP-1	SF 0671 T	Same as above.
ECS RAD OUT TEMP-2	SF 0672 T	Same as above.



NOTE: The green color band on the glycol discharge scale indicates a normal operating range of 35 to 55 psia.

SM-2A-695E

Figure 4-7. ECS Pressure and Flow Indicators

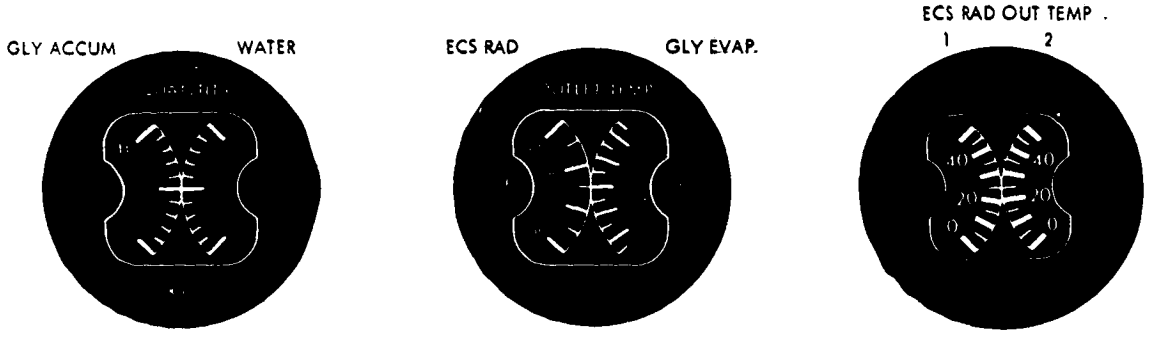


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Figure 4-8. ECS Quantity and Outlet Temperature Indicators

4.1.4.3 ECS Suit and Cabin Temperature/Pressure Indicators.

Instrument markings for the ECS suit and cabin temperature/pressure indicators are shown in figure 4-9. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

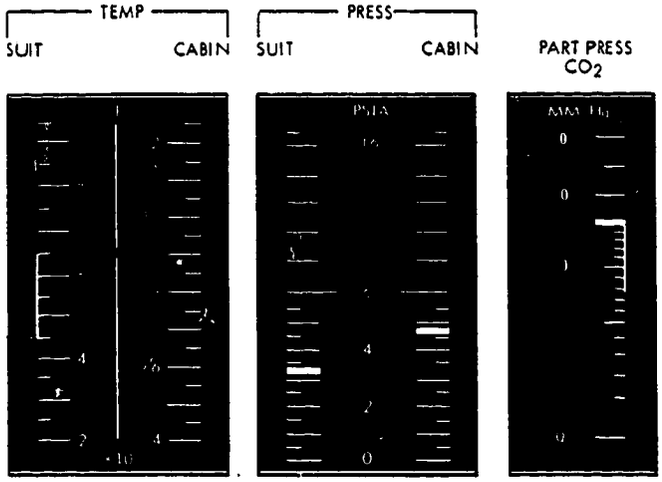
Indicator Scale	Measurement Number	Indicator Accuracy
TEMP-SUIT	CF 0008 T	±2.5°F overall at 0° to 150°F.
TEMP-CABIN	CF 0002 T	Same as above.
PRESS-SUIT	CF 0012 P	At 75°F, ±0.25 psia between 0 and 6 psia and ±3% for remainder of scale. At 0° and 150°F, ±0.375 psia between 0 and 6 psia, and ±4% for remainder of scale.
PRESS-CABIN	CF 0001 P	Same as PRESS-SUIT scale.
PART PRESS-CO_2	CF 0005 P	At 75°F, ±0.5 mm between 0 and 15 mm Hg, and ±1.0 mm for remainder of scale. At 0° and 150°F, ±1.0 mm between 0 and 15 mm Hg, and 1.5 mm for remainder of scale.
PGA Pressure Indicator	None	±2 psia overall at normal temperature range.

4.1.5 TELECOMMUNICATION SYSTEM METERS.

Instrument markings for the telecommunication system meters are shown in figure 4-10.

4.1.5.1 Auxiliary DC VOLTS Meter.

The auxiliary DC VOLTS meter, located on RHFEB-200 (figure 4-10), is used to monitor selected measurements for which there is either no other crew display or the crew display is an event indicator capable of displaying only in-tolerance and out-of-tolerance conditions. The voltmeter is used in conjunction with the adjacent FUNCTION SELECT and TEST SELECT



PGA PRESSURE INDICATOR (LEFT FOREARM)

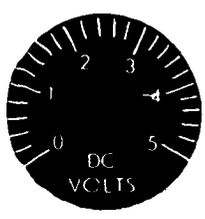
NOTES: 1. A vertical green color band shows the normal operating range for the suit temperature (45° to 65°F). Red horizontal lines show limits for suit pressure (3.4 psia), cabin pressure (4.7 psia), and CO_2 pressure (15 mm Hg). A vertical yellow color band shows the caution range for CO_2 pressure (7.6 to 15 mm Hg).

2. The PGA pressure indicator presents an operating range from 2 to 10 psia and a green and red color band. The green band (3.5 to 10 psia) shows normal pressure required during space flight. The red band (3.5 to 2 psia) shows the emergency limitations for crew safety. During ground operations, the indicator needle will be pegged beyond 10 psia because of atmospheric pressure.

SM-2A-697C

Figure [illegible]. ECS Suit and Cabin Temperature/Pressure Indicators

S-BAND ANT



Auxiliary DC VOLTS Meter

S-BAND ANT Meter

SM-2A-693C

Figure [illegible]. Telecommunication System Meters

switches to monitor 13 EPS, 6 RCS, 4 G&N and 1 ECS analog measurements. Refer to Controls and Displays (section 3) for information on which measurements are selected for monitoring by the auxiliary DC VOLTS meter.

The voltmeter provides a reading between 0 and 5 volts of the selected measurement. By use of a voltmeter conversion chart an interpolation of the value for the selected measurement can be made. (Refer to section 2.)

NOTE The accuracy of the auxiliary DC VOLTS meter (for the full scale) is ±1 percent at 75°F and ±2 percent at 0° and 150°F.

4.1.5.2 S-Band ANT Meter.

The S-Band ANT meter, on MDC-19 (figure 4-10), utilizes the automatic gain control (AGC) signal in the S-Band receiver to display, in a clockwise direction, the relative magnitude of signals received by the unified S-band equipment (USBE). The meter is used in determining the correct S-band antenna and S/C attitude for optimum S-band performance.

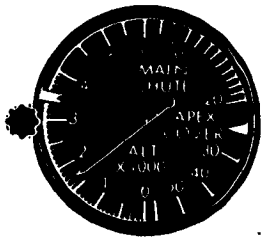
NOTE The accuracy of the S-BAND ANT meter (for the full scale) is ±5 percent at temperatures between 0°and 150°F.

4.1.6 SEQUENTIAL SYSTEMS INDICATORS.

Instrument markings for the sequential systems indicators are shown in figure 4-11. The indicators present visual displays required during launch, in-flight SPS operation, and the earth landing sequence of events. (Refer to paragraphs 4.1.6.1 and 4.1.6.2.)

4.1.6.1 Barometric Pressure Indicator (Altimeter).

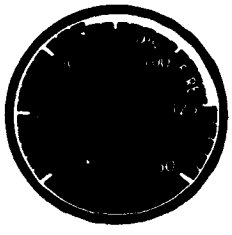
The barometric pressure indicator, an altimeter on MDC-1 (figure 4-11), is used in conjunction with the earth landing system (ELS) and indicates the pressure altitude of the S/C under low-altitude, low-Mach conditions. This altimeter is monitored during the earth landing phase of the mission to verify that the ELS sequencer is initiating various phases of landing system deployment at the proper pressure altitude points. A knob, located left of the altimeter dial face, is used in setting the adjacent marker (to display the corrected main parachute deploy altitude for low-altitude aborts). The adjustable marker, based



Barometric Pressure Indicator (Altimeter)

NOTE:

The green band on the L/V AOA SPS Pc indicator shows normal operating pressures (65 to 125°a) for the SPS combustion chamber during engine operation in space flight.



L/V AOA-SPS P_C Indicator

SM-2A-700F

Figure 4-11. Sequential System Indicators

on barometric pressure, is set prior to launch. (Refer to paragraph 4.4.2.2 for altimeter error and C/B base pressure effects.)

NOTE The accuracy of the altimeter is ±100 feet from 0 to 4000 feet and 5 percent of the altimeter reading from 4000 to 60,000 feet.

4.4.2.6 L/V AOA/SPS P_c Indicator.

The L/V AOA/SPS P_c indicator, on MDC-3 (figure 4-11), is used to display the launch vehicle angle of attack (in percentage of pressure from the Q-ball) during launch. After launch vehicle separation from the S/C, the gauge is used to display SPS combustion chamber pressure during engine operation. Inputs to this time-shared gauge are determined by the position of the L/V AOA/SPS P_c switch, located on the same panel.

NOTE The accuracy of the L/V AOA/P_c indicator (for the full scale) is 1 percent at 75°F and 2 percent at 0° and 150°F.

4.4.2.7 MISCELLANEOUS INDICATORS.

Instrument markings for mechanically operated indicators such as clocks, timers, and an accelerometer are shown in figure 4-12 and described in paragraphs 4.4.2.7.1 through 4.4.2.7.4.

NOTE The accuracy of the S/C clocks and timers at temperatures between 60° and 90°F (and zero gravity) will not exceed ±5 seconds for 10 consecutive days (the arithmetic average of the daily rates). For environmental conditions above or below this temperature range, the average of daily rates for 5 consecutive days will not exceed 30 seconds.

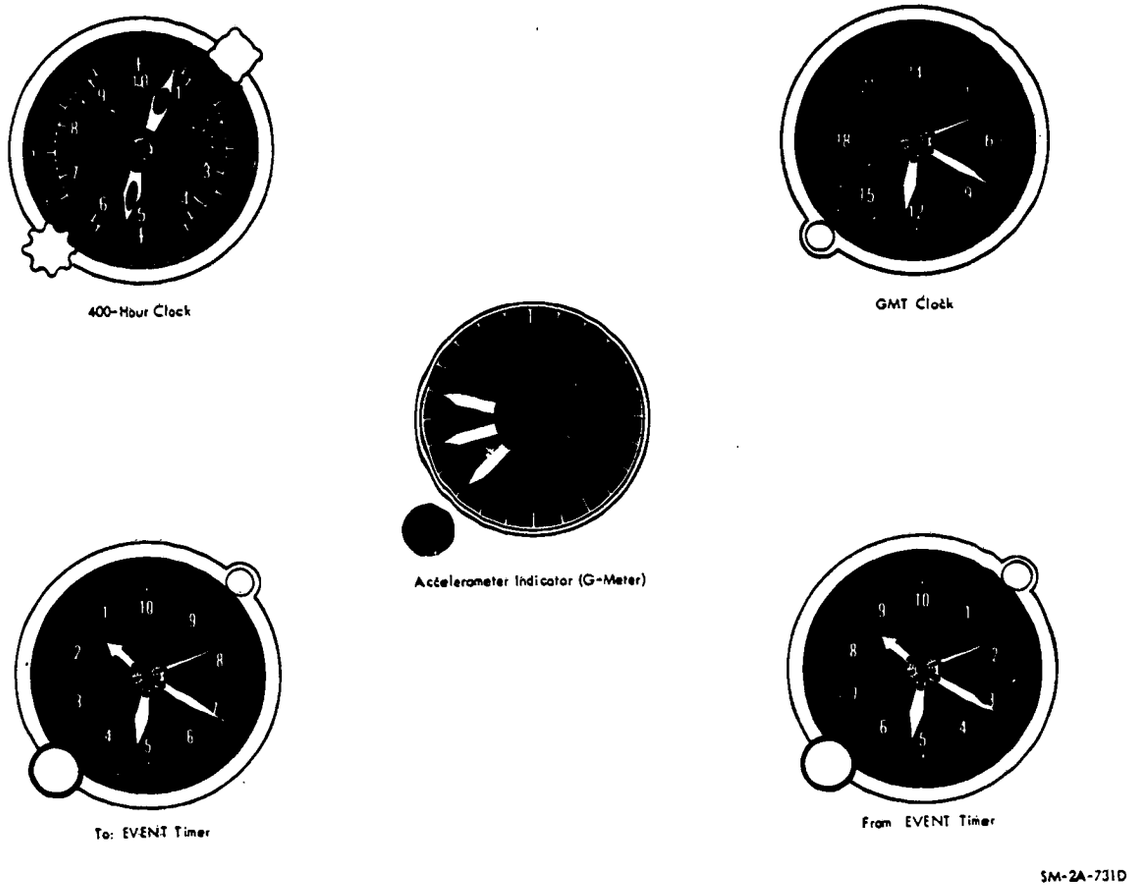


Figure 4-12. Miscellaneous Indicators

4.1.7.1 Mission-Elapsed Time (400-Hour) Clock.

The 400-hour clock, on MDC-12 (figure 4-12), has a 10-hour dial face with second, minute, and hour hands. A display window is also provided to show mission elapsed time in 10-hour increments up to 400 hours (when window display returns to 0.000). The hour and minute hands are set by a knob at the bottom left of the dial face. A knob at the top right of the dial is used to reset, start, and stop the clock. This clock is illuminated when the floodlights switch on MDC-27 is actuated.

4.1.7.2 GMT (Greenwich Mean Time) Clock.

The GMT clock, LHFEB-306 (figure 4-12), has a 24-hour dial face with standard second, minute, and hour hands. A time-set screw, at the bottom left of the dial face, is used to

synchronize the clock with Greenwich mean time. This clock illuminates when the CLOCKS-BRT-OFF-DIM switch (LEB-98) is actuated.

TO EVENT and FROM EVENT Timers.

The TO EVENT and FROM EVENT timers, on LHFEB-306 (figure 4-12), have 10-hour dial faces with second, minute, hour, and 10-hour hands. A knob at the bottom left of each timer is used to set the timer hands. Each timer can be reset, started, or stopped by a pushbutton control at the top right of the timer. These timers illuminate when the CLOCKS-BRT-OFF-DIM switch (LEB-100) is actuated.

Accelerometer Indicator (G-Meter).

The accelerometer indicator or g meter, on MDC-2 (figure 4-__), is provided with an indicating pointer for showing S/C positive and negative g loads. In addition to the indicating pointer, there are two recording pointers (one for positive and one for negative g loads) which follow the indicating pointer to its maximum attained travel. The recording pointers will remain at the maximum positive and negative positions attained to provide a record of maximum g loads encountered. To return the recording pointers to the normal 1-g position, it is necessary to press the RESET knob on the lower left-side of the accelerometer.

NOTE The accuracy of the g meter is ±0.2 g from 0 to 4 g's, ±0.3 g at 6 g's, ±0.4 g from 8 to 10 g's, and ±0.75 g at 15 g's.

CONSUMABLE REQUIREMENTS.

Information relating to S/C 014 consumable materials for the RCS, SPS, EPS, and ECS is provided in this section. For detailed consumable data, refer Mission Modular Data Book (MMDB).

S/M RCS PROPELLANT CONSUMPTION DATA.

Propellant consumables utilized by the 16 S/M RCS engines provide thrust for three-axes rotational and translational control of the spacecraft (after S/C separation from the launch vehicle and until C/M-S/M separation prior to entry). The oxidizer/fuel ratio (by weight) for each engine is [illegible] at a propellant flow rate of [illegible] lb/sec. Nominal values for

the individual S/M RCS consumables (maximum usable tank capacity of 790 pounds) are as follows:

Consumables	Storage Tank	Weight per Tank		Delivery Rate to Engine (lb/sec)
		Filled (lb)	Maximum Usable (lb)	
Nitrogen tetroxide (N_2O_4) (oxidizer)	4	138.1	131.7	0.241
50% unsymmetrical diamethylhydrazine and 50% hydrazine (UDMH/ N_2H_4) (fuel)	4	69.7	65.8	0.119
Helium (He) (pressurant)	4	0.52	0.52	N/A

4.2.1.1 Manual Attitude Control Maneuvers

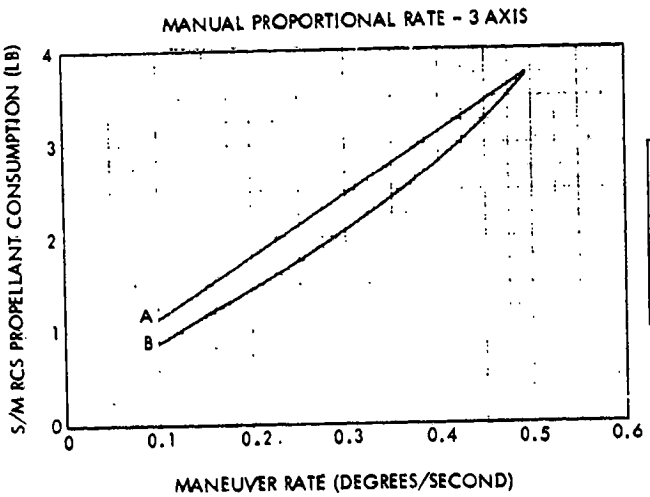
S/M RCS propellant consumption rates for manual attitude control maneuvers (proportional and direct control) are presented in figure 4-13. Assumptions applicable to the curves shown in figure 4-13 are as follows:

- The dynamic disturbances accounted for are SPS propellant slosh, the earth orbit aerodynamics and gravity gradient, ECS steam venting, and rotating EPS and ECS equipment.
- A nominal maneuver of 5.0±0.5 degrees per axis.
- This data may be ratioed to account for different maneuver angles. The propellant consumption must be decreased by 10 percent for a 30-degree maneuver and increased by 20 percent for a 100-degree maneuver.

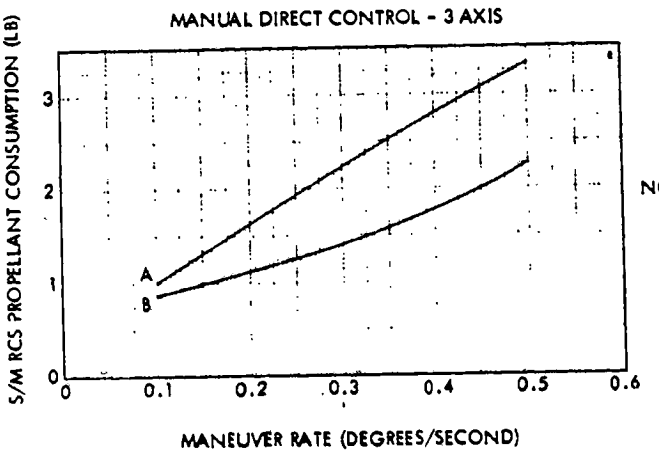
The manual single-axis maneuver propellant consumption is the same as the single-axis maneuver in paragraph 4.2.1.2.

4.2.1.2 Automatic Attitude Control Maneuvers and Attitude Hold.

S/M RCS propellant consumption rates for G&N control maneuvers (attitude control and attitude hold), versus S/C



CURVE	WEIGHT (LB)	INERTIA (SLUG-FEET SQUARED)		
		I_{XX}	I_{YY}	I_{ZZ}
A	29,500	15,800	53,500	54,000
B	22,300	12,600	40,000	38,700



NOTE: WEIGHTS AND INERTIAS FOR CURVES A AND B ARE SAME AS SHOWN ON UPPER CHART.

TYPICAL MMDB INFORMATION

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Figure 4-13. S/M RCS Propellant Consumption During Manual Attitude Control Maneuvers

weight, are presented in figure 4-14. The same assumptions in paragraph 4.2.1.1 also apply to figure 4-14, in addition to the following:

- Non-maneuvered axes are held with a narrow deadband of ±0.2 degree while the other axes are moved.
- A specific impulse (I_{sp}) for a single jet RCS firing per axis that equals 180 seconds.
- A maneuver rate of 0.5 degree per second.

The S/M RCS propellant consumption rates for the attitude thermal (barbecue) control mode versus S/C weight are presented in figure 4-15. Applicable additional assumptions are as follows:

- Attitude hold in pitch and yaw are at a deadband of ±4.2 degrees.
- Roll axis spin is 0.5 degree per second.

The S/M RCS propellant consumption required to damp free drift rates (caused by dynamic disturbances) versus time in free drift are presented in figure 4-16.

4.2.1.3 Translation Maneuvers.

S/M RCS propellant consumption required for settling SPS propellants versus S/C weight, for three configurations of RCS engine utilization, is presented in the upper chart of figure 4-17. The lower chart shows propellant required for RCS +X axis delta velocity maneuvers. Assumptions applicable to both charts in figure 4-17 are as follows:

- The RCS engine thrust equals 100 pounds.
- I_{sp} at attitude correction equals 185 seconds.
- I_{sp} at translation equals 278 seconds.
- Dynamic disturbances (stated in paragraph 4.2.1.1) are neglected.
- Roll control propellant requirements are neglected.

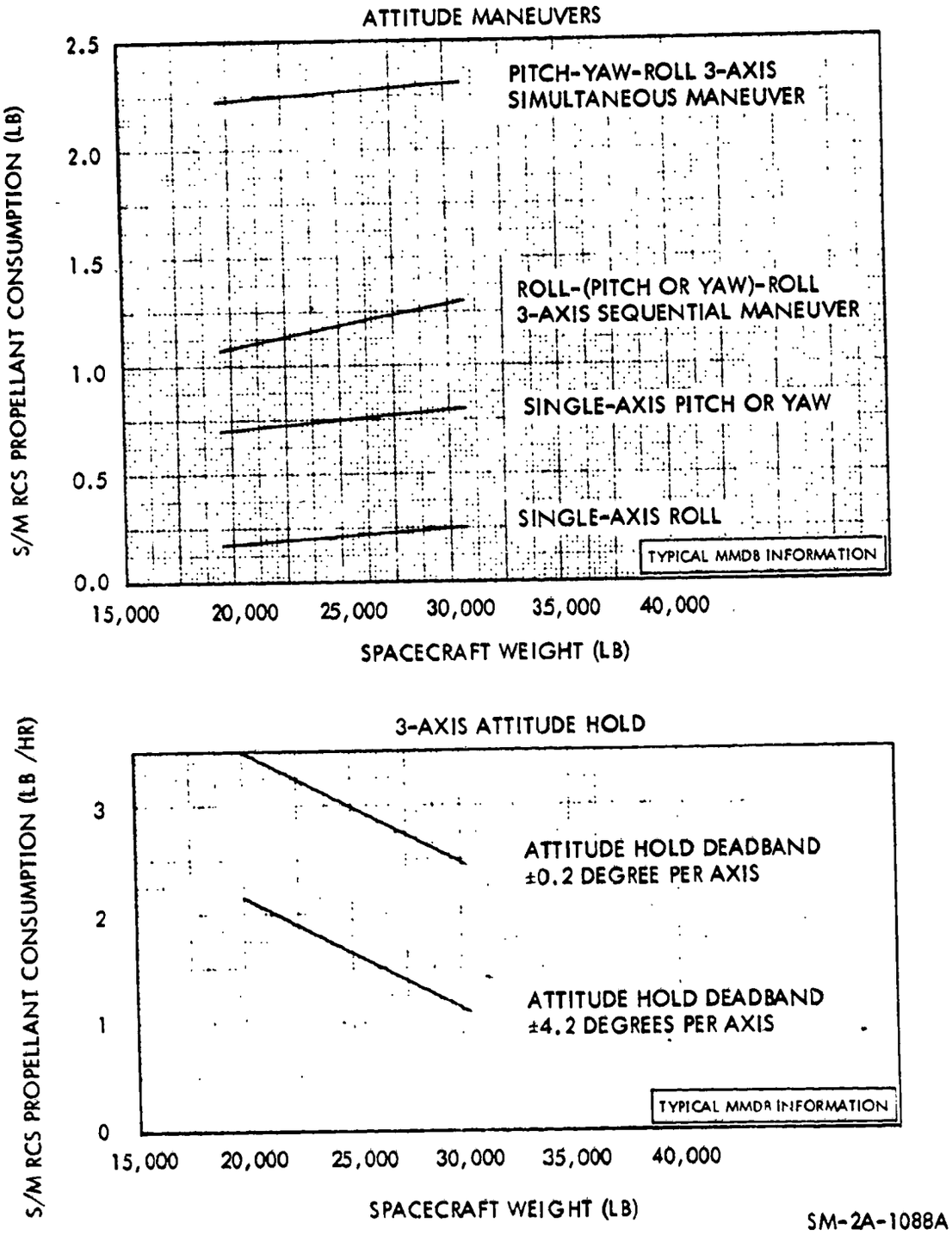


Figure 4-14. S/M RCS Propellant Consumption During Attitude Control Maneuvers and Attitude Hold

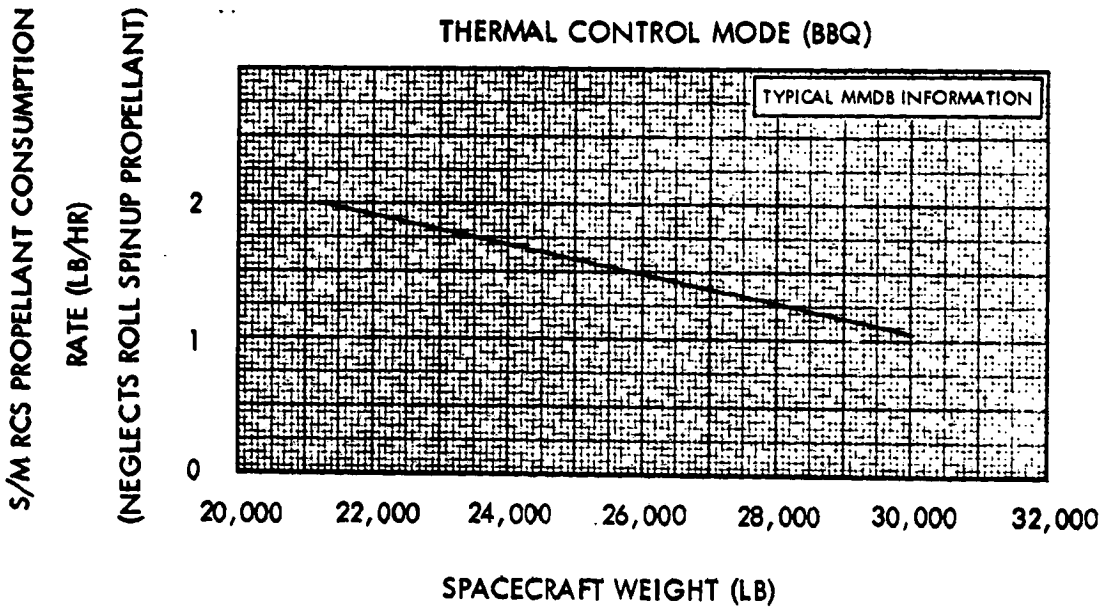


Figure 4-15. S/M RCS Propellant Consumption for Thermal Control Modes

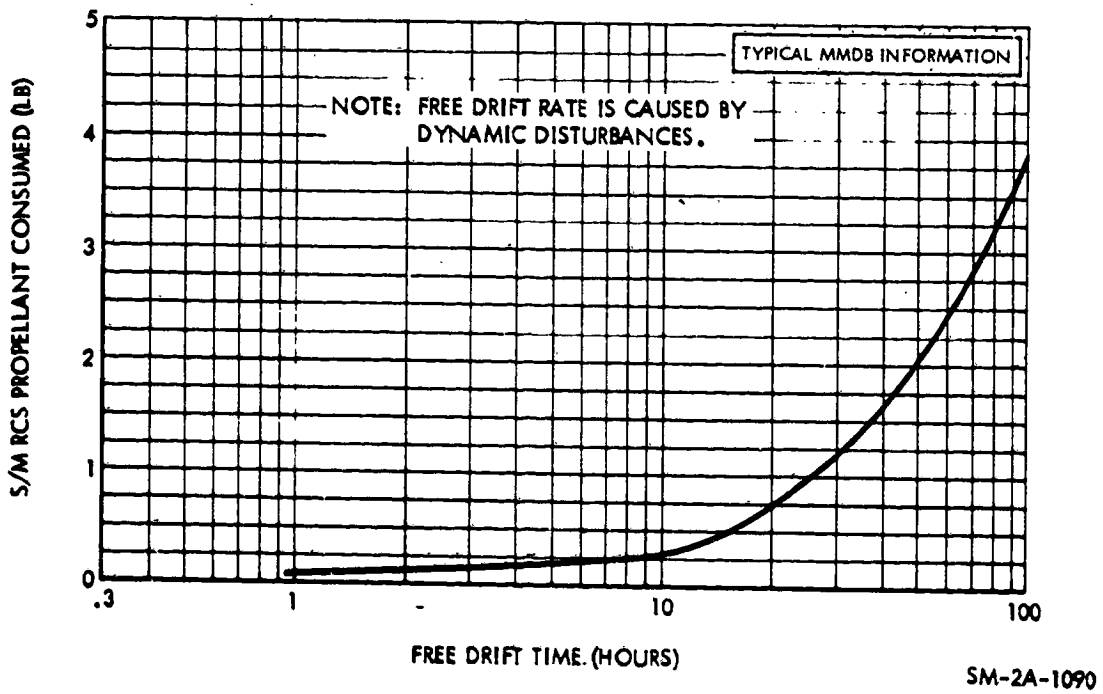
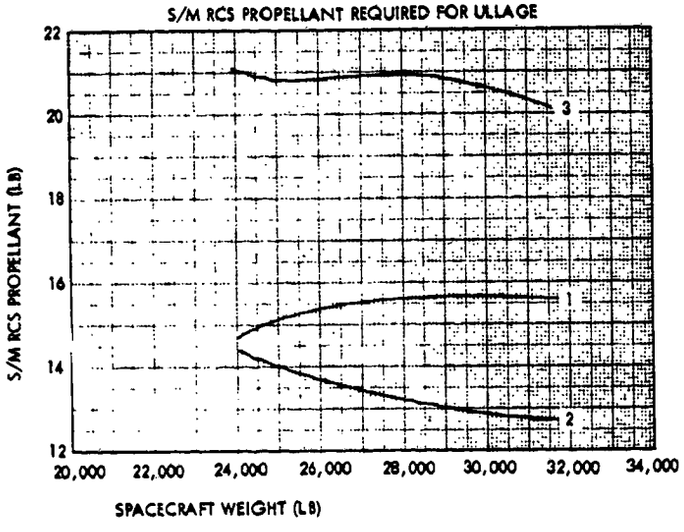
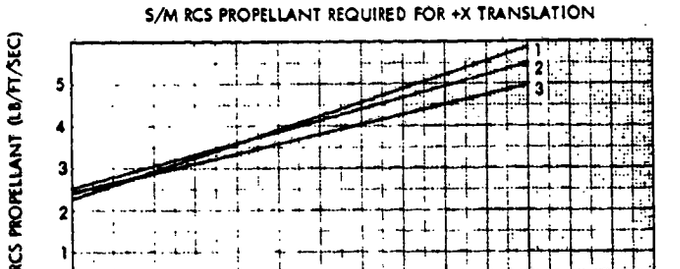


Figure 4-16. S/M RCS Propellant Consumption for Damping Out Free Drift Rate

CONFIGURATION	AXIS	S/M RCS ENGINES USED FOR			
		DISABLED	ATTITUDE CONTROL		PLUS X TRANSLATION
			POSITIVE	NEGATIVE	
ONE	PITCH	3 & 4	1	2	2 & 1
	YAW	6 & 5	7	8	NONE
TWO	PITCH	2 & 1	3	4	NONE
	YAW	7 & 8	5	6	6 & 5
THREE	PITCH	NONE	3 & 1	2 & 4	2 & 1
	YAW	NONE	7 & 5	6 & 8	6 & 5





NOTE:

Curves 1, 2, and 3 represent same engine configuration as above.

TYPICAL MMDB INFORMATION

SM-2A-1091A

Figure 4-17. S/M RCS Propellant Consumption for SPS Propellant Settling and Translation Maneuvers

4.2.1.4 Attitude Hold Following SPS Burn.

S/M RCS propellant consumption required for attitude hold in three axes, immediately following an SPS burn and extending over a 10-minute period after the SPS burn, is presented in the upper chart of figure 4-18. (This curve includes the total RCS requirement and should not be added to the results obtained from figure 4-14. However, after the end of the 10-minute slosh damping period, the rates in the lower chart of figure 4-14 should be used.) For attitude holds delayed after the termination of an SPS burn, both charts in figure 4-18 are used for adjusting RCS propellant consumption rates.

4.2.2 C/M RCS PROPELLANT CONSUMPTION DATA.

Propellant consumables utilized by the 12 C/M RCS engines provide thrust for three-axes rotational and attitude control of the C/M (after an abort or during normal entry). The oxidizer/fuel ratio (by weight) for each of the four roll engines is 2.1±0.09:1 at a propellant consumption rate of 0.345 lb/sec. The oxidizer/fuel ratio (by weight) for each of the eight remaining engines is 2.0±0.09:1 at a propellant consumption rate of 0.342 lb/sec. Any remaining propellant, including the helium used as a pressurant, is ejected prior to C/M touchdown (for all mission modes). Nominal values for the individual C/M RCS consumables (usable tank capacity of 225 pounds) are as follows:

Consumables	Storage Tank	Weight per Tank: Filled (lb)	Weight per Tank: Usable (lb)	Delivery Rate to Engine
Nitrogen tetroxide (N_2O_4) (oxidizer)	2	89.2	75.0	0.228 lb/sec (oxidizer/fuel ratio of 2:1) 0.234 lb/sec (oxidizer/fuel ratio of 2.1:1)
Monomethylhydrazine (MMH) (fuel)	2	45.2	37.5	0.114 lb/sec (oxidizer/fuel ratio of 2:1) 0.111 lb/sec (oxidizer/fuel ratio of 2.1:1)
Helium (He) (pressurant)	2	0.52	0.52	N/A

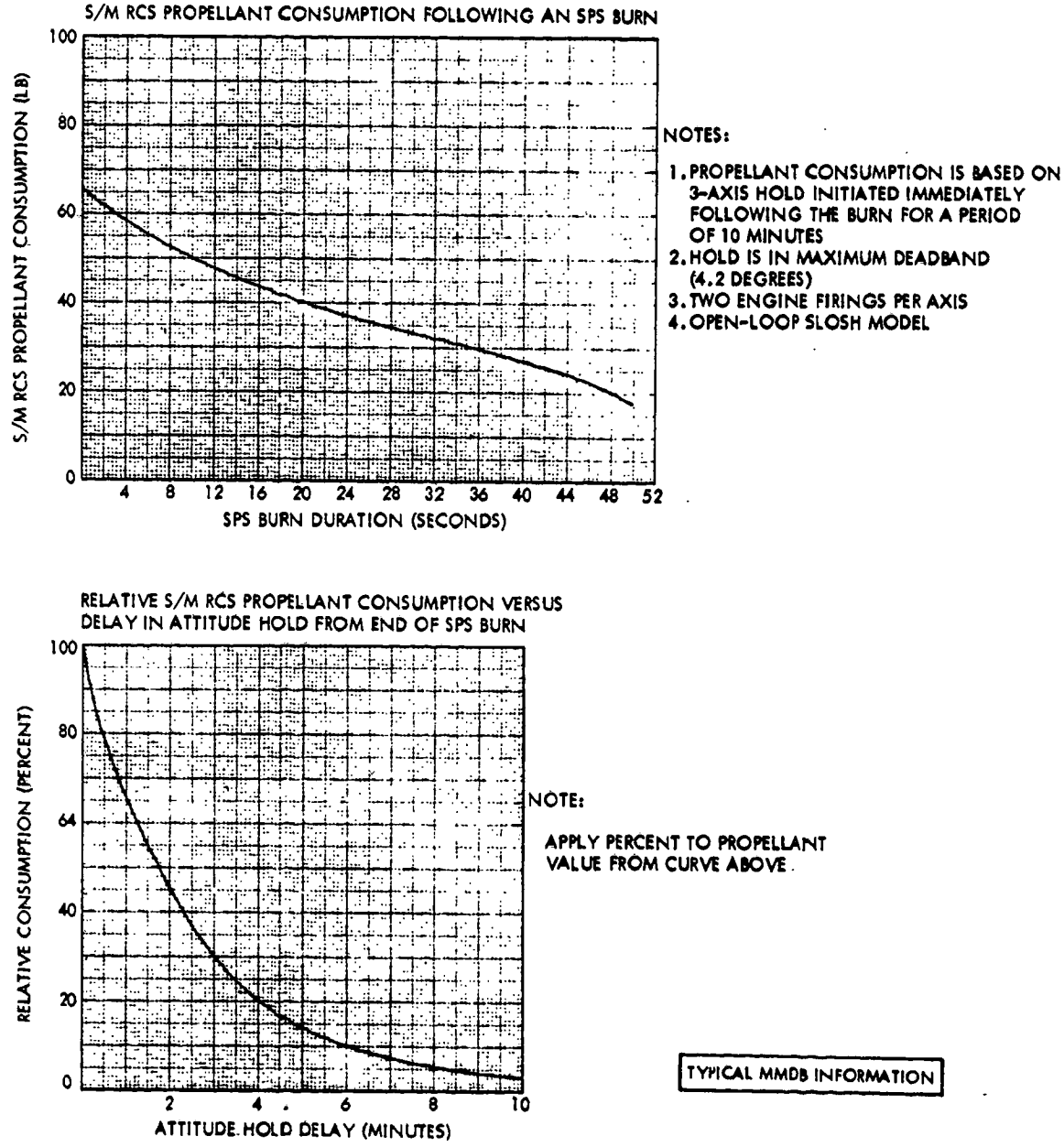


Figure 4-18. S/M RCS Attitude Hold Propellant Consumption Following SPS Burn

Representative C/M RCS propellant consumption time histories are presented in figure 4-19 for nominal and off-nominal single-system RCS entries. The curves include pre-entry propellant expended (5 pounds for nominal and 9 pounds for off-nominal rates).

4.2.3 SPS PROPELLANT CONSUMPTION DATA.

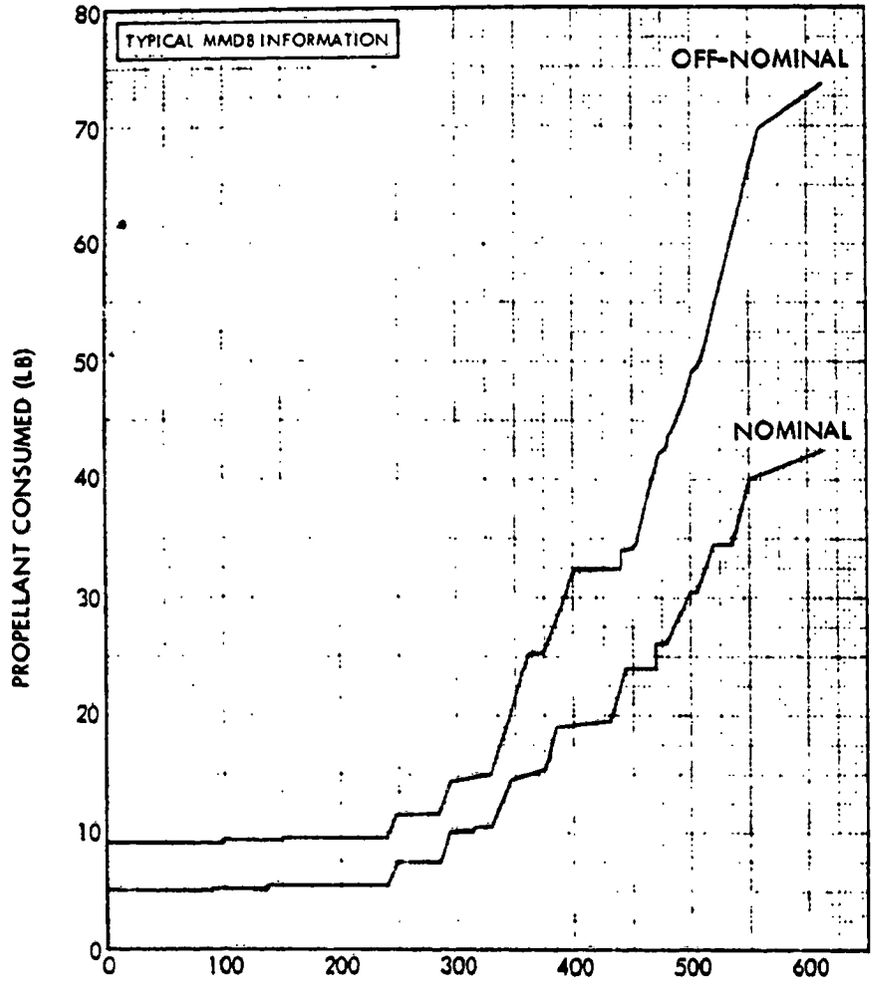
Propellant consumables utilized by the SPS engine (at 69.09 lb/sec) provide thrust for significant spacecraft velocity changes after booster separation. Nominal values for the SPS consumables are as follows:

Consumables	Storage (and Sump) Tank	Weight per Tank		Delivery Rate to Engine
		Filled (lb)	Usable (lb)	
Nitrogen tetroxide (N_2O_4) (oxidizer)	1	30,600	27,333	46.06 lb/sec
50% unsymmetrical dimethylhydrazine (UDMH/N_2H_4) (fuel)	1	15,300	13,677	23.03 lb/sec
Helium (He) (pressurant)	2	48.2	48.2	N/A

NOTE Storage tanks for the SPS fuel and oxidizer also include a sump tank. S/C 012 will not be scheduled to carry the possible total propellant load of about 45,900 pounds.

Spacecraft weight is plotted against characteristic velocity for nominal and minimum values of specific impulse. (See figure 4-20.) A sample path traces a typical solution for propellant weight when initial weight, specific impulse, and characteristic velocity change are given. Arrows on the chart, starting with an initial value for weight (W_1) indicate the direction of flow for the sample problem. It is important to note that the characteristic velocity (V_c) scale does not represent values of ΔV remaining aboard the S/C, but is intended to serve as a reference only on which increments (ΔV_c) may be taken as shown in the sample.

In order to account for a 4500 pound-seconds loss for each SPS engine start, 14.5 pounds of propellant must be added to the



	NOMINAL	OFF-NOMINAL
V_g	24, 216 FPS	24, 216 FPS
γ_g	-1.65 DEG	-1.65 DEG
α	156 DEG	156 DEG
β	0 DEG	0 DEG
ϕ_{EN}	0 DEG	0 DEG
$C\ell_o$	-0.0004 DEG	-0.00006
GUST	NONE	HALF SINE WAVE
σ	52.7 DEG	52.7 DEG
RANGE	1547 N/M	1547 NM

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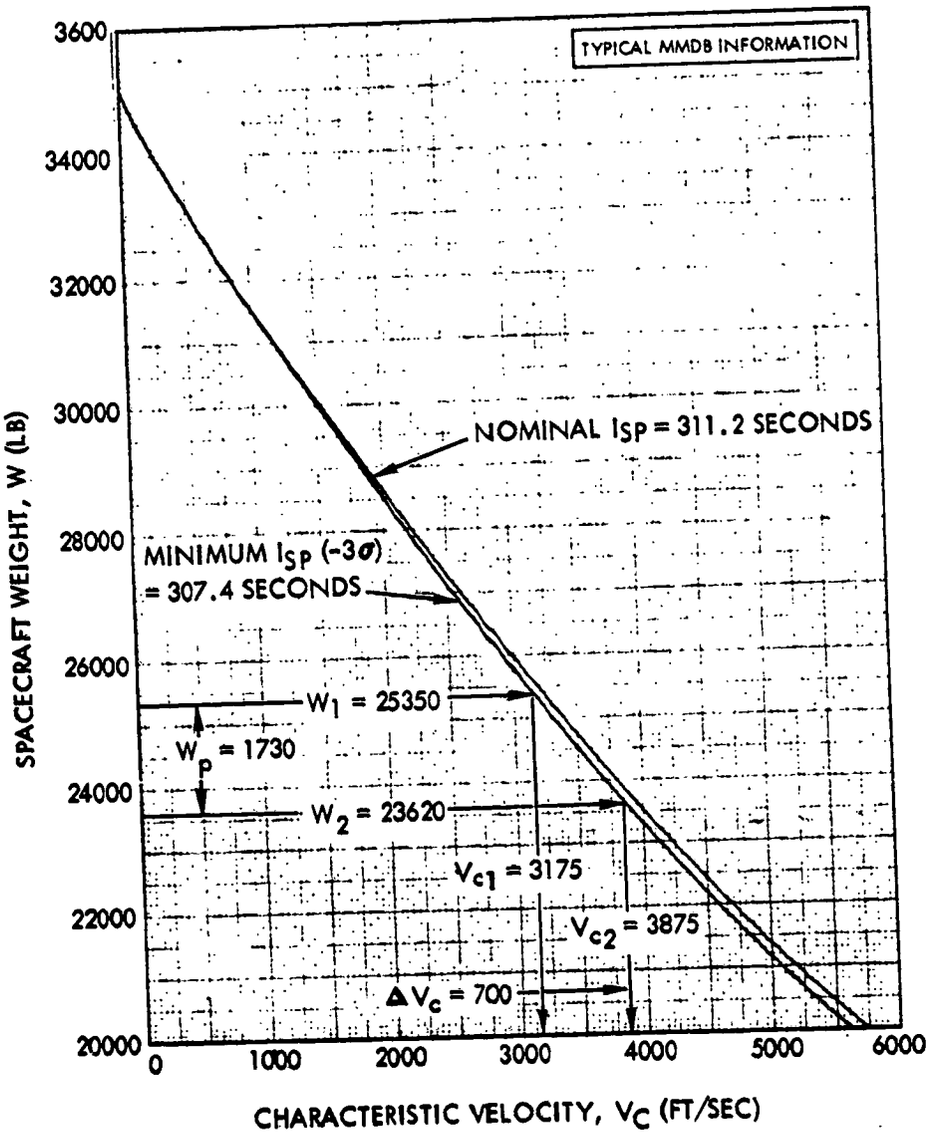
Figure 4-[illegible]. C/M RCS Propellant Consumption Time Histories - Single System



GIVEN: INITIAL SPACECRAFT WEIGHT, W_1
SPECIFIC IMPULSE, I_{SP}
CHARACTERISTIC VELOCITY CHANGE, ΔV_c
$g = 32.174$ FT/SEC^2

PROPELLANT WEIGHT, $W_p = W_1 \left[1 - \frac{1}{e^{\left(\frac{\Delta V_c}{g\, I_{SP}}\right)}}\right]$

SM-2A-1094

Figure 4-20. SPS Propellant Consumption

propellant consumption noted during each firing. (The total propellant requirements are limited to the total usable propellants available to the S/C.)

4.2.. EPS AND ECS CONSUMPTION DATA.

Oxygen and hydrogen reactants (from the cryogenic storage system) are consumed by the EPS fuel cell power plants in the generation of electrical power for the S/C. Water, as a byproduct, is provided for the ECS. Oxygen from the cryogenic storage system is also supplied to the ECS for metabolic consumption by the crewmembers and for pressurization of the crew compartment and the PGA. The cryogenic tanks for oxygen and hydrogen are initially filled to at least 97 percent of full capacity. Nominal values for these consumables are as follows:

Consumables	Storage Tank	Weight per Tank		Flow Rate to System
		Filled (lb)	Usable (lb)	
Hydrogen (H_2) (supercritical gas)	2	29.0	28.0	0.14 lb/hr (min) 0.27 lb/hr (max) (0.75 lb/hr-purge only)
Oxygen (O_2) (supercritical gas)	2	327.0	320.0	1.70 lb/hr (min) 2.58 lb/hr (max) (0.6 lb/hr-purge only)
Nitrogen (N_2) (fuel cell reference pressure)	3	0.44	0.44	N/A

NOTE Both the EPS and ECS utilize oxygen from the same cryogenic storage system (489 pounds of usable O_2 for the EPS and 151 pounds for the ECS).

4.2.... EPS Fuel Cell Reactants Consumption.

The O_2 and H_2 consumption versus electrical output for one, two, or three fuel cell power plants is shown in figure 4-21. Only the H_2 curve is given. (The O_2 consumption rate is eight times the H_2 rate.) Water generated by the fuel cells may be calculated by multiplying the H_2 consumption rate by nine.

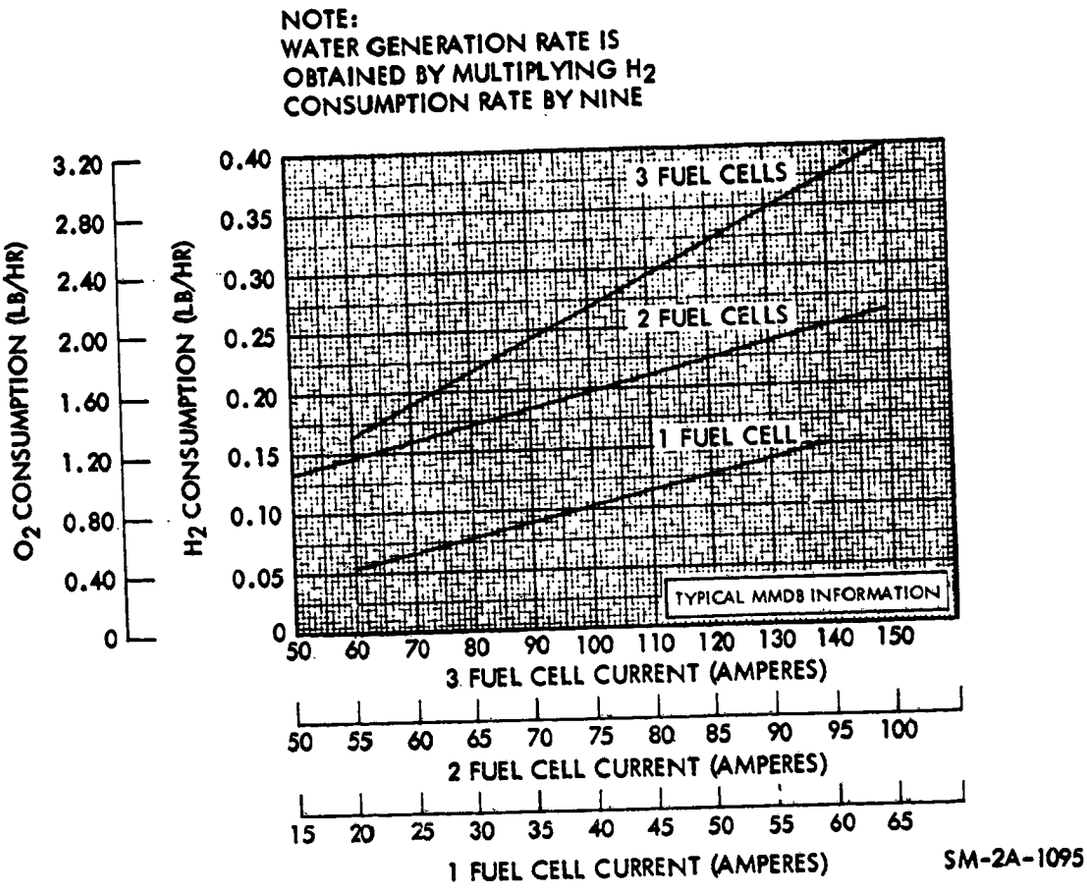


Figure 4-21. Cryogenic Consumption Versus Fuel Cell Current

In order to maintain fuel cell operating efficiency, purging of each power plant is accomplished every 7 hours. The purges will normally be staggered so that a H_2 purge will follow an O_2 purge by 3.5 hours. The present purging cycle of 7 hours is based upon the maximum normal power output of 1420 watts per fuel cell. The time between purges is based upon the ratio of the present maximum of 1420 watts/fuel cell power plant to the actual maximum gross power demand times 7 hours. Thus, if the actual maximum gross power demand is 710 watts/fuel cell module, the nominal purge interval of 7 hours would be increased by 1420/710 or 2. Multiplying 2 times 7 would then provide a purge interval of 14 hours. During purging, the power plant continues to consume reactants in the quantities required to produce the power demanded by S/C electrical loads. The duration of each H_2 purge is 80 seconds and 120 seconds for each O_2 purge.

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4.2.4.2 EPS Electrical Power Output.

During a normal mission, from launch until entry, about 618 kwh of electrical power is supplied to the S/C by three fuel cell power plants operating in parallel. If one power plant should fail, the remaining two will provide for normal power loads. In the event two power plants fail, S/C emergency loads can be accommodated. The three batteries, normally reserved for entry and postlanding phases of the mission, can be utilized to provide for peak loads above operating fuel cell capacities.

NOTE The EPS [illegible] minimum steady-state power level of 2000 watts with three fuel cells operating or 1550 watts with two fuel cells operating during orbit. However, minimum transient power level of 1500 watts for three fuel cells can be reached without causing an overvoltage in the EPS. (Tests are being conducted to determine if a minimum transient power level of 1200 watts for three fuel cells is feasible.)

- By draining the batteries [illegible] power and recharging, an additional 1.0 kwh of energy [illegible] obtained for use during orbital flight.
- The C/M is capable [illegible] sustaining an emergency power load of 1200 watts with two fuel cells operating during orbit.

4.2.4.3 ECS Oxygen and Water Consumption.

Oxygen and water consumables are utilized by the ECS in providing for needs peculiar to the presence of men aboard the spacecraft. Nominal values for the ECS consumables are as follows:

Consumables	Source	Usable Weight (lb)	Remarks
Oxygen (O_2)	Cryogenic storage system tanks (2). NOTE The cryogenic storage system supplies O_2 to both the ECS and EPS (151 pounds for the ECS and 489 pounds for the EPS).	151.0	The basic purpose of the ECS oxygen is for crew metabolic consumption and control of the C/M pressure as follows: a. Metabolic - three men at 0.075 lb/hr/man or 0.225 lb/hr total b. C/M leakage - 0.2 lb/hr

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Consumables	Source	Usable Weight (lb)	Remarks
			c. 2 C/M repressurizations - 11.7 lb (5.85 lb/ea).
	Surge tank	3.7	Initially filled during ground service
	Entry tank	1.0	Initially filled during ground service
Potable water	One C/M potable water supply tank	36.0	Initially filled during ground service; the tank is replenished during flight by the EPS fuel cell power plants at a nominal rate of 0.77 lb per kilowatt. If tank is full, water will overflow into C/M waste water tank.
Waste water	One C/M waste water supply tank	56.0	Initially filled during ground service and then by overflow of water from potable water tank.
	Two S/M water supply tanks	112.0	Additional supply of water is carried in S/M to replenish C/M water tanks, if necessary.
Nitrogen (N_2) (pressurant)	One N_2 supply tank	1.5	Used to pressurize the S/M water supply tanks.

NOTE The ECS potable water will be primarily used for metabolic purposes by the crew and not for cooling purposes in the S/C (unless waste water becomes depleted).

- The ECS radiator inlet temperature is affected by heat transfer from EPS components. As the components become warmer from increased electrical loads, a greater rate of heat transfer will take place. ECS radiator freezing may result if both radiators are exposed to deep space for more than 1 hour and the inlet temperature is below 75°F

with an electrical current level of about 55 amps By rolling or tumbling the S/C, to allow for periodic exposure of the radiators to the sun, the inlet temperature can be 70°F with an electrical current level of about 50 amps before the space radiators start to freeze.

4.3 RCS AND SPS THRUSTING DATA.

4.3.1 RCS TRANSLATION CONTROL.

Spacecraft translation is possible at any time after S-IVB separation and prior to the time when S/M-C/M separation occurs. Translation maneuvers are provided through the S/M RCS engines and are normally initiated manually by the translation control T-handle in the ±X, Y, and Z axes, or by the DIRECT ULLAGE switch in the +X axis. The translation control (manipulated in the counterclockwise position to the abort detent for about 2.5 seconds) also provides for CSM/S-IVB separation. While the control is in the abort detent position, the CSM attitude is not controlled. Upon confirmation of physical separation, the translation control is moved to the +X position and the SCS initiates attitude control to a maximum deadband of 5 degrees. (Refer to section 2 for systems operation.)

NOTE Each S/M RCS engine nominally develops 100 pounds of thrust. If four engines are ignited (as in a ±X translation), the S/C will accelerate at 0.4 to 0.8 ft/sec^2, depending on the S/C weight and control mode. (Only two engines are ignited for ±Y and ±Z translations.)

- The minimum RCS impulse duration, assuming average human response, is on the order of 200 milliseconds. The maximum translation duration is a function of the available propellant.

4.3.2 RCS ROTATION CONTROL.

Automatic or manual rotational control of the S/C is provided in both the G&N and the SCS control modes. (Refer to section 2 for systems operation.)

NOTE The S/C can have a maximum angular acceleration from 1.0 to 1.5 degrees per second^2, depending on the S/C mass configuration and RCS engines fired.)

4.3.2.1 G&N Attitude Control.

During the G&N attitude control mode, the inertial measurement unit (IMU) maintains the primary inertial attitude reference for the S/C. Rotation changes are commanded by either the Apollo guidance computer (AGC) when verb 70 is entered in the S/C display keyboard (DSKY) for manual maneuvers with the rotation control, or by manually dialing the coupling display units (CDU) for maneuvers preprogrammed in the AGC.

NOTE The AGC can be programmed to command a three-axis 60-degree reorientation of the S/C (and is similar in operation to an attitude orientation maneuver for an IMU alignment).

- All preprogrammed AGC maneuvers are executed at an attitude rate of 0.5 degree per second (4.0 degrees per second for abort or entry maneuvers only). In the G&N mode, a ±4.2 degree maximum or a ±0.2 degree minimum attitude error deadband is available The S/C will have a limit cycle rate of less than 0.2 degree per second within these deadbands.

- G&N attitude maneuver rates (used for IMU fine alignments and checks) are limited by the G&N digital program to 0.5 degree per second in pitch, roll, and yaw.

4.3.2.2 SCS Attitude Control.

During the SCS attitude control mode, the body mounted attitude gyros (BMAG) provide an automatic reference for holding the S/C at a specific attitude within a ±4 2 degrees maximum or a ±0.2 degree minimum attitude error deadband. If the S/C is then maneuvered manually by the rotation control, the attitude gyro coupling unit (AGCU) will automatically cage the attitude gyros, correct the attitude hold reference, and present a new display on the FDAI when the maneuver is completed.

4.3.2.3 Manual Attitude Control.

Manual maneuvers for attitude control of the S/C are provided by use of the rotation control for direct and proportional rates, and by the attitude impulse control for low-rotational rates (minimum impulse). The primary

purpose of the manual attitude controls and pertinent data are as follows:

1. Direct rotation control, for emergency and backup conditions, is commanded by use of the rotation control (stick) about the desired axes to its hard stops. Just before engaging the hardstops, a switch closes and applies a direct command to the RCS direct coils. Rate feedback is not used to cancel the stick movement, but the BMAG-AGCU loop is closed and maintains an attitude reference to its limits.

   NOTE The attitude rate, commanded by direct rotation, is limited only by human endurance and the RCS propellant supply. Start and stop transients depend on pilot technique and the attitude reference (FDAI or visual landmark) used to close the outer control loop. The inertial references start to accumulate error (due to gyro slue rate limitations) at a rate of 20 degrees per second about the roll axis and 5.0 degrees per second about the pitch or yaw axis.

2. Proportional rotation control, for attitude corrections, is commanded by displacement of the manual S/C rotation control (stick) into a desired proportional rate (when referring to S/C attitude display on the FDAI).

   NOTE The resulting proportional rate will vary from a minimum of 0.2 degree per second to a maximum of 0.65 degree per second (depending on stick displacement). Attitude error deadbands are ±4.2 degrees maximum and ±0.2 degree minimum.

3. Attitude impulse control, for commanding low-rotational rates about all three axes, is available in either G&N or SCS modes of operation and is used as required during navigational sighting periods. This is accomplished through the attitude impulse control located on panel 105.

   NOTE After the attitude impulse control is enabled and displaced, a switch closure in the control unit will cause one pulse of 18±4 milliseconds, which is applied to the RCS jet selection logic. (One pulse is generated for each attitude impulse switch closure.)

- Attitude impulse control is not a proportional control and does not provide for attitude hold. When this control is enabled, relay action removes all rate attitude error and control inputs from the SCS electronics.

- Use of minimum impulse (for fine adjustment of S/C attitude) excites rates of about 0.01 degree per second minimum to 0.5 degree per second maximum.

4.3.3 SPS ENGINE THRUST PERFORMANCE.

4.3.3.1 SPS Small-Impulse Operation.

The SPS engine is capable of accepting a shutdown signal at any time after receipt of a start signal. A nominal minimum impulse bit of 12,000 pound-seconds is developed when the engine is fired for an open-loop operation period of 0.6 seconds. (See figure 4-22.) The run-to-run minimum impulse-bit tolerance is ±300 pound-seconds (1 sigma). Impulse value as a function of start-to-shutdown signal duration (FS1 to FS2), is estimated from qualification tests generated at AEDC (Arnold Engineering Development Center). (Propellant consumption for small impulse firings including the 14.4-pound propellant loss for each SPS engine start is covered by the equation W_p = (Impulse +4500)/Isp.

4.3.3.2 SPS Engine Start and Shutdown Transients.

The SPS engine start and shutdown transients are presented in figure 4-23. Curves show the percentage of rated thrust as a function of elapsed time from start (FS1) and shutdown (FS2) command signals. Rated thrust is based on nominal inlet condition. All data estimates are from AEDC qualification tests. The start transient total impulse from FS1 to 90-percent rated thrust is limited to the range from 100 pound-seconds (minimum) to 400 pound-seconds (maximum). The run-to-run tolerance on start transient impulse is ±100 pound-seconds (1 sigma). The shutdown impulse from FS2 to 10-percent rated thrust is limited to a range from 8000 pound-seconds (minimum) to 12,000 pound-seconds (maximum). The run-to-run tolerance on the shutdown impulse is ±300 pound-seconds (1 sigma).

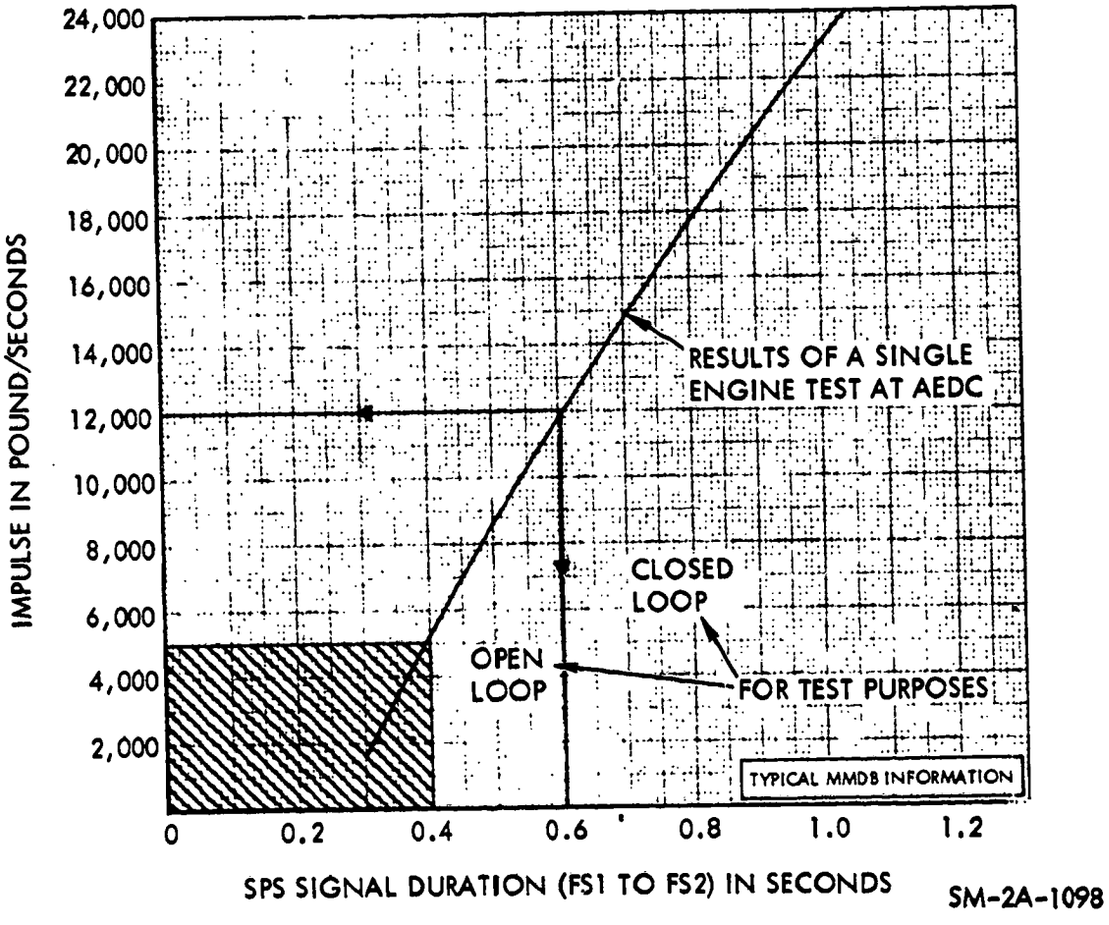

Figure 4-22. SPS Small Impulse Firings for Open-Loop Operations

4.3.3.3 SPS Delta V Capability.

The SPS delta V capability remaining versus SPS propellant remaining is presented in figure 4-24.

4.3.3.4 SPS Engine Gimbal Angle Determinations.

The engine gimbal angle determinations for an SPS firing (thrust vector through center of gravity) can be calculated during

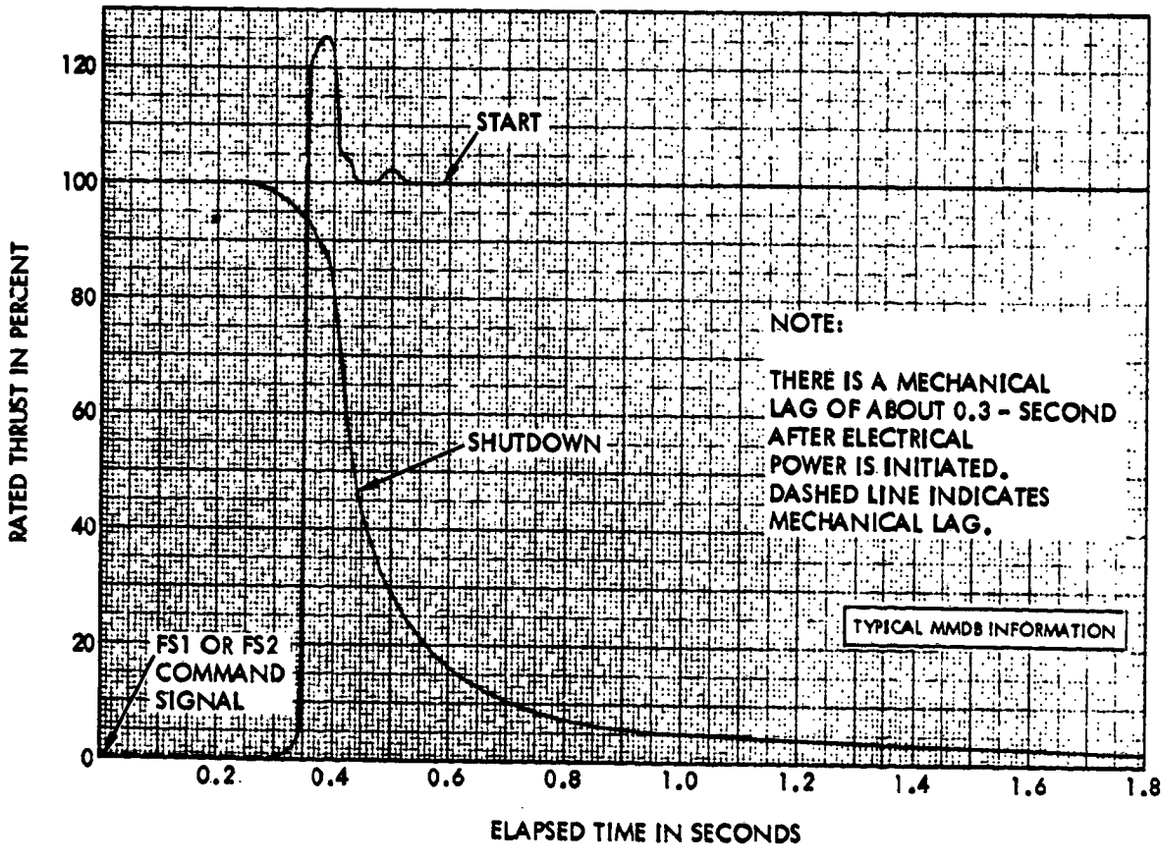

Figure 4-23. SPS Engine Start and Shutdown Transients

flight by the amount of SPS fuel remaining aboard the spacecraft. (See figure 4-25.) The ground controller will determine SPS engine gimbal angles if propellant leaks and/or other than nominal oxidizer to fuel ratios occur.

4.4 S/C OPERATIONAL CONSTRAINTS AND LIMITATIONS.

4.4.1 OPERATIONAL CONSTRAINTS.

Attitude constraints are necessary to prevent excessive exposure of certain spacecraft surface features to solar heating, earth albedo, or deep space. These constraints are required to control temperatures for the ECS radiator inlet, S/M RCS engines, SPS propellant feedlines, and the heat shield.

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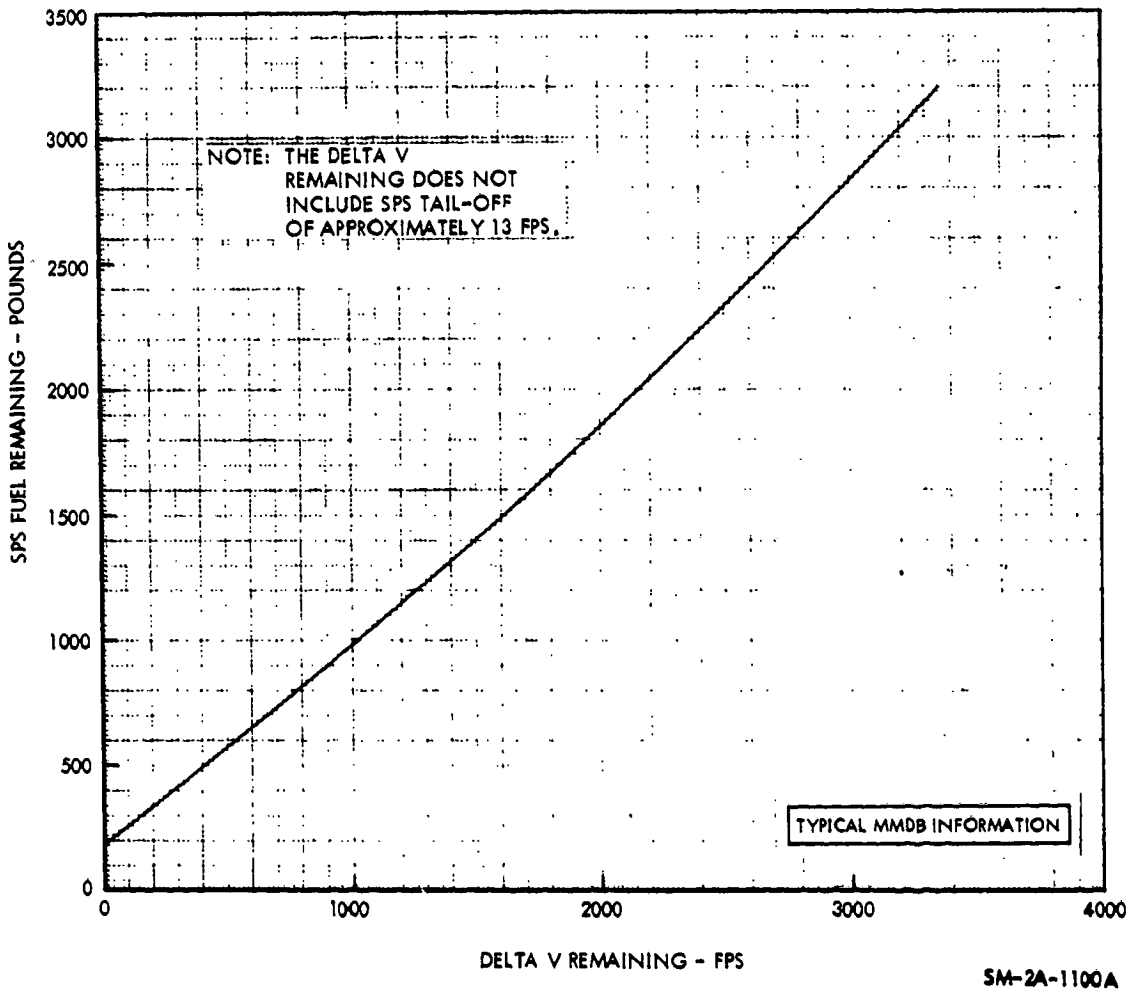

Figure 4-24. SPS Delta V Remaining Versus Propellant Remaining

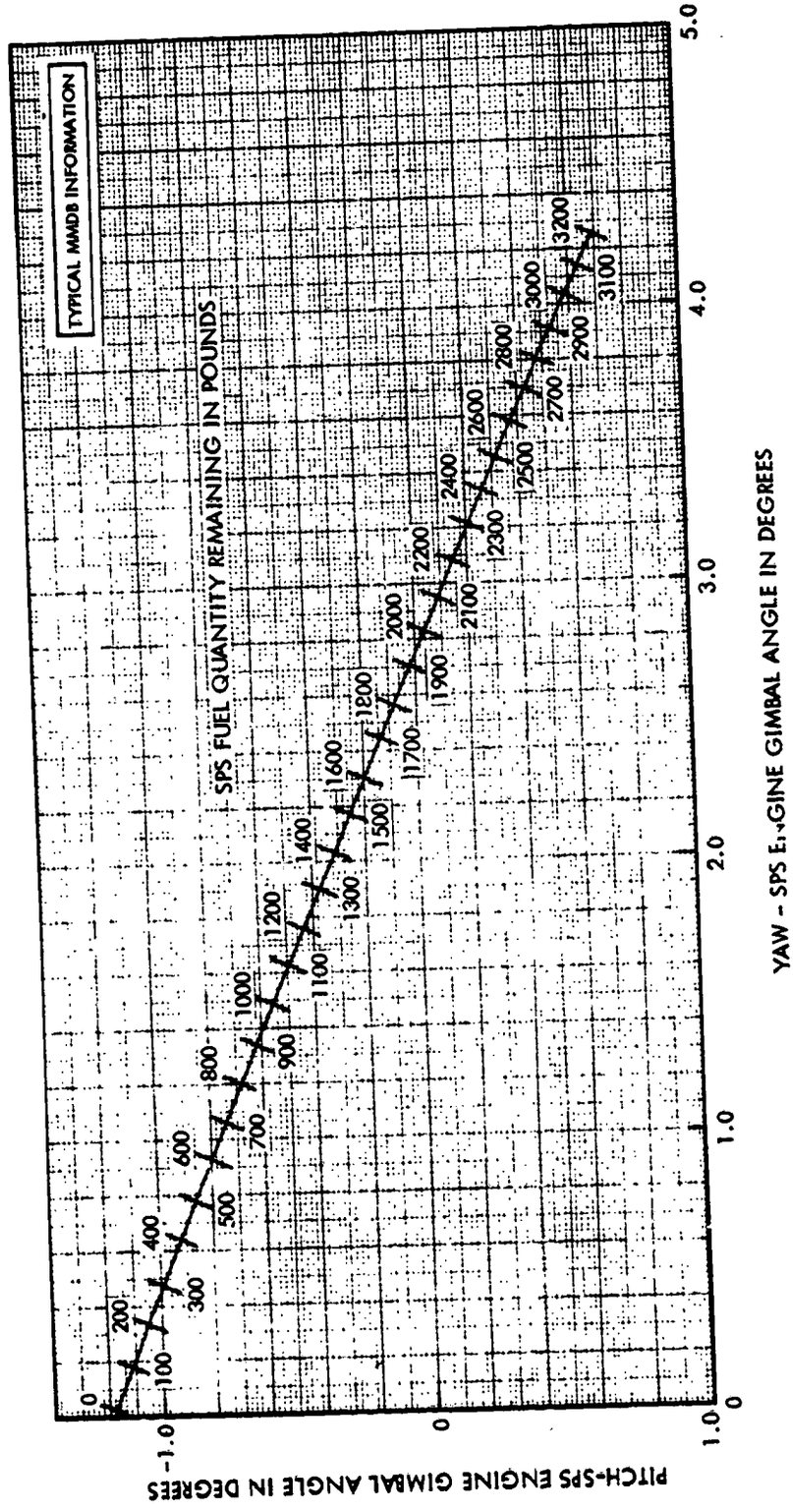

Figure 4-25. SPS Engine Gimbal Angle Settings

4.4.1.1 ECS Radiator Inlet Temperature.

The ECS radiator inlet temperature (obtained from MSFN or the auxiliary DC volts meter on panel 200) should be maintained at 75°F or warmer to prevent against radiator freezing. However, excessive water boiling will result if the radiators are directly exposed to the sun for prolonged periods. S/C orientations exposing the ECS radiator surface to solar incidence angles less than 45 degrees should not be maintained longer than 20 minutes per orbit. Also, the S/C attitude should be constrained inertially or held fixed relative to the earth without roll for a period longer than one orbit, if the solar incidence to the radiator is less than 45 degrees. To prevent excessive water consumption (boiling) the S/C attitude must not be constrained in an inertial or earth-fixed orientation without roll for longer than 3 hours.

CAUTION Extreme radiator sooting can be detected by a rapid depletion of the water supply and high radiator outlet temperature.

- If the radiator outlet temperature averages above 53°F as a result of extreme sooting, high electrical loads, or poor radiator orientation, the water tanks will be depleted at a rate incompatible with the planned mission duration time.

NOTE Observance of ECS radiator constraints will also ensure a satisfactory environment for EPS radiator operation.

4.4.1.2 S/M RCS Engine Temperatures.

The S/M RCS engines are qualified to work within the range of 35° to 175°F, the propellant valve temperature limits. A red warning light on panel 10 will illuminate to indicate when the temperatures exceed this range. Temperatures above 175°F are not expected, except temporarily (possible) during boost. Heaters that cycle automatically are provided on each quad to maintain temperatures above the lower limit. However, if one quad is continuously pointed away from the sun for longer than 10 hours, it is possible for the 40°F lower temperature limit (for the propellant) to be reached at the RCS tank outlet.

NOTE S/C attitude should be monitored during extended periods between RCS firings to ensure that safe temperatures are maintained.

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4.4.1.3 SPS Propellant Feedline Temperatures.

SPS propellant feedlines are normally maintained above 40°F by heaters and insulation. The MSFN should monitor SPS external line temperatures and advise the crew whenever temperatures drop below 50°F. If S/C attitude is maintained so that the SPS is pointed away from the sun for an extended period and heater capacity is insufficient to maintain line temperatures above 40°F, the S/C should be reoriented until acceptable SPS line temperatures are reached.

4.4.1.4 Heat Shield Temperature.

The heat shield ablator lower temperature limit of -150°F can be exceeded and cause surface cracking if the thin (-Z) portion of the ablator is pointed away from the sun for longer than 3 hours. Because of the moderate response time, it is unlikely that a critical cold condition would be approached during the mission.

CAUTION If the heat shield ablator temperature is allowed to rise and remain above 200°F for any aggregate period longer than 2 hours, outgassing will result and cause a corresponding degradation to the ablator stress margin.

4.4.2 OPERATIONAL LIMITATIONS.

The available data in the subsequent paragraphs shows limitations imposed on the S/C and/or crew during ascent, descent or aborts, spaceflight, and entry.

4.4.2.1 Acoustic and Vibration Effects.

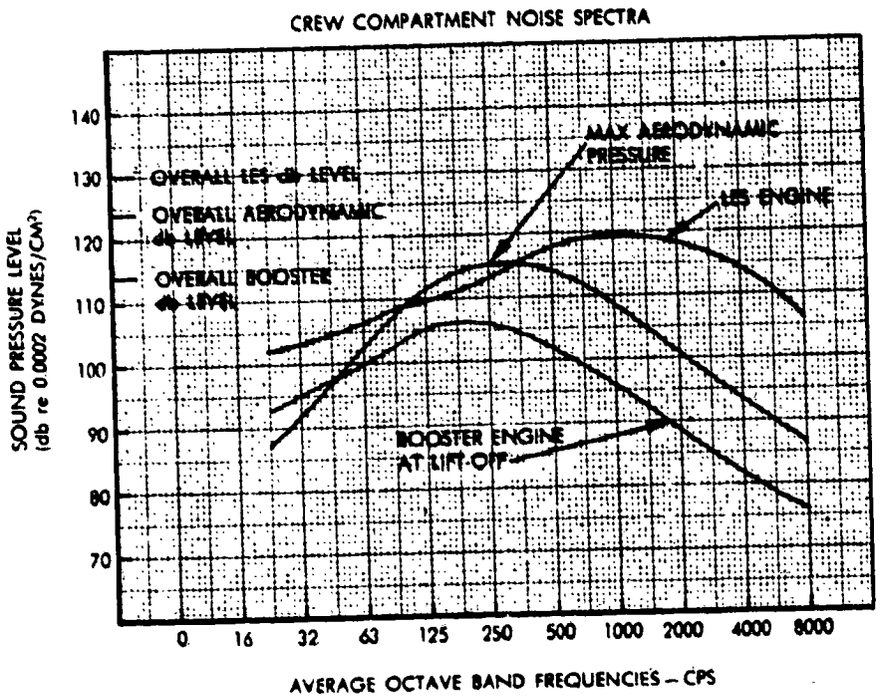
The crew will be exposed to acoustic and vibration effects during ascent (130 seconds), possible LES aborts (10 seconds), and entry (100 seconds). Vibration effects will also be experienced during high-altitude aborts (SPS induced) and spaceflight SPS firings. (See figures 4-26 and 4-27.)

4.4.2.2 Altimeter Error and C/M Base Pressure Effects.

The altimeter (barometric pressure indicator) error resulting from velocity pressures on the command module (below 14,000 feet) is shown in figure 4-28.

4.4.2.3 C/M Lift/Drag Profile and Entry Effects.

Charts showing the C/M lift/drag profile and time histories for normal entries are shown in figures 4-29 through 4-31.



55 db = Sound pressure level (SPL) under average office conditions.
79 db = Maximum SPL inside S/C during space flight with all equipment operating.

NOTES: 1 During space flight, C/M inside noise level is mainly due to equipment operation. SPS and RCS engine firings have little effect on the internal noise level.

2 Each astronaut can reduce the crew compartment noise level about 15 db by utilizing his space suit and closing the helmet visor.

120 db = SPL where discomfort is experienced.
140 db = SPL where pain is encountered
160 db = SPL where the human ear drum can be ruptured.
200 db = SPL equivalent to a 50-pound TNT blast at 10 feet

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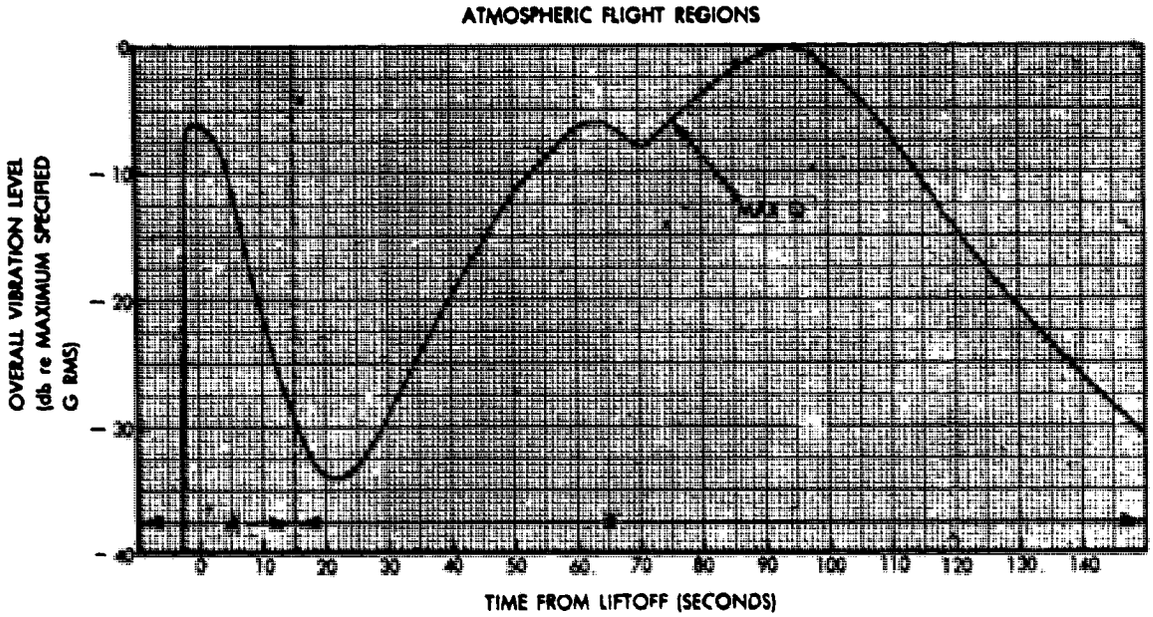
Figure 4-26. C/M Crew Compartment Acoustics



NOTES: 1. Zero on the vertical scale indicates the maximum vibration experienced during flight. The vibration levels are based on boilerplate and spacecraft flight test measurements.

2. Letter "A" indicates vibration time induced by booster engine exhaust (influenced by the flame buckets) and noise reflected from the ground and launch pad.

3. Letter "B" indicates vibration induced by aerodynamic turbulence. As the launch vehicle velocity increases, pressure fluctuations in the turbulent boundary layer (and wake turbulence from the launch escape tower) excite vibration of increasing intensity until a maximum is reached at approximately the time of maximum aerodynamic pressure (MAX Q).

4. SPS engine operation provides the only significant source of C/M vibration during space flight maneuvers. This vibration, transferred mechanically throughout the S/C structure, can generally be expected to decrease with increasing distance from the engine. Since the RCS engines possess a very low thrust capacity, their operation will only produce modest and localized vibration (mostly due to jet impingement)

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Figure 4-27. S/C Relative Vibration Intensity Time History

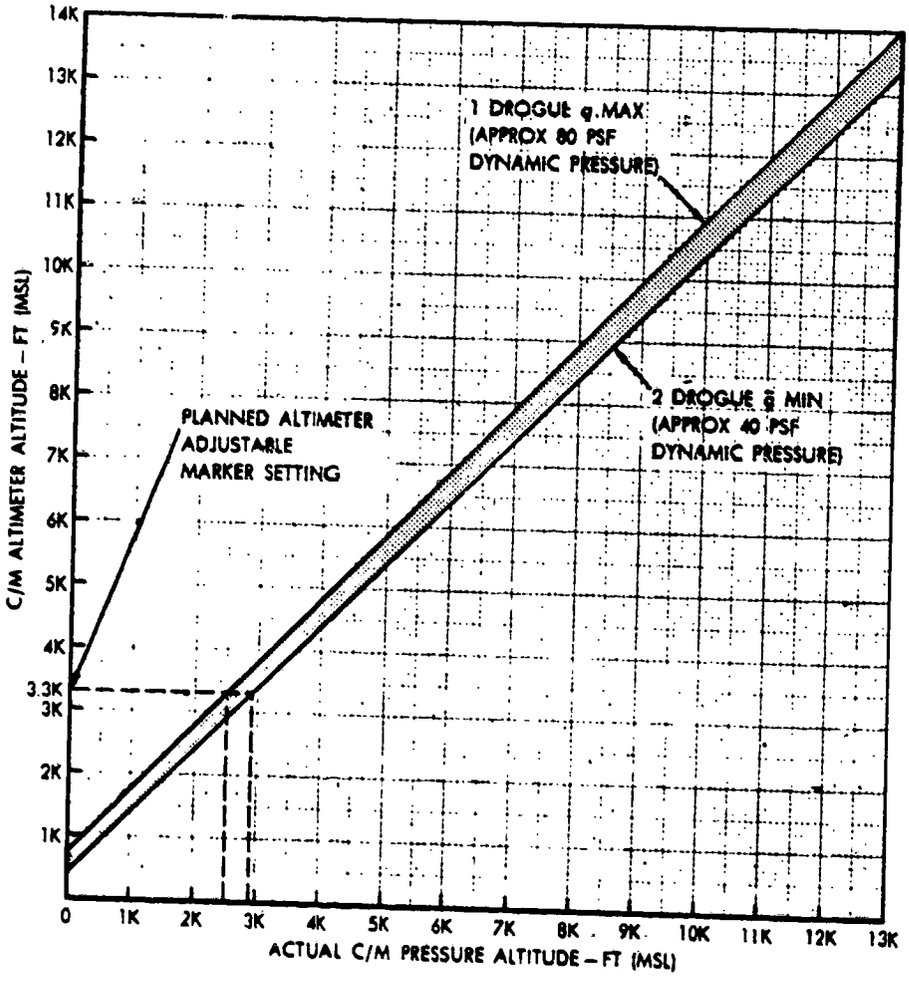

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Figure 4-28. Altimeter Error and C/M Base Pressure Effects

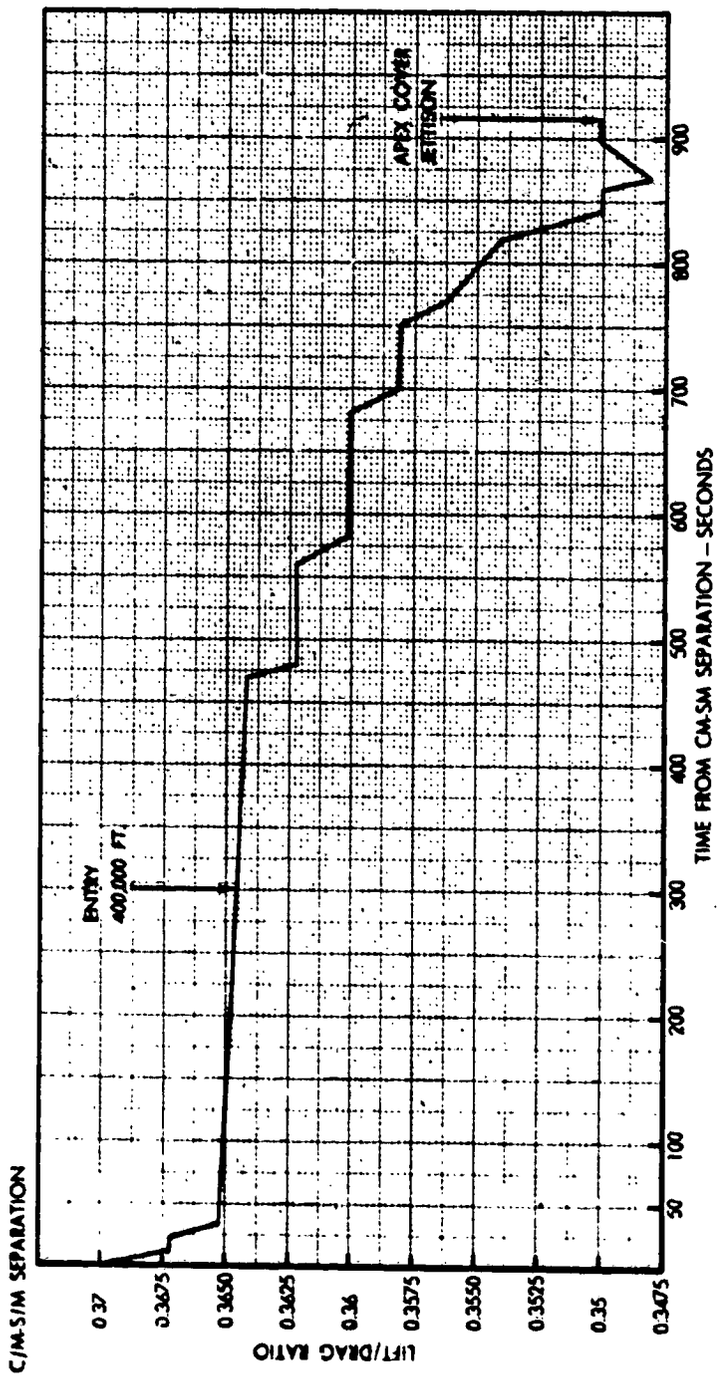

Figure 4-29. C/M Entry - Lift/Drag Profile

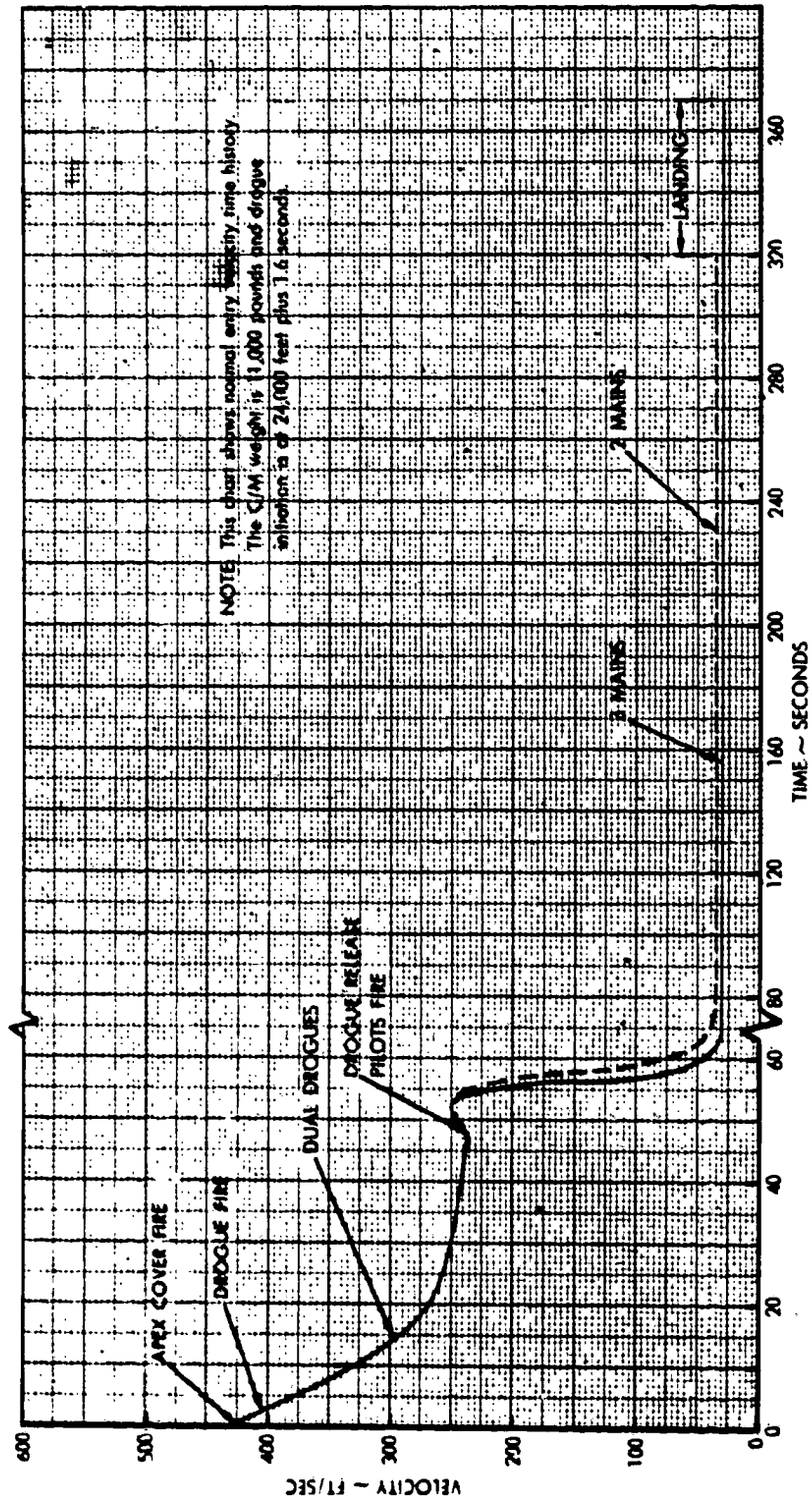

Figure 4-30. Normal Entry - Velocity Time History

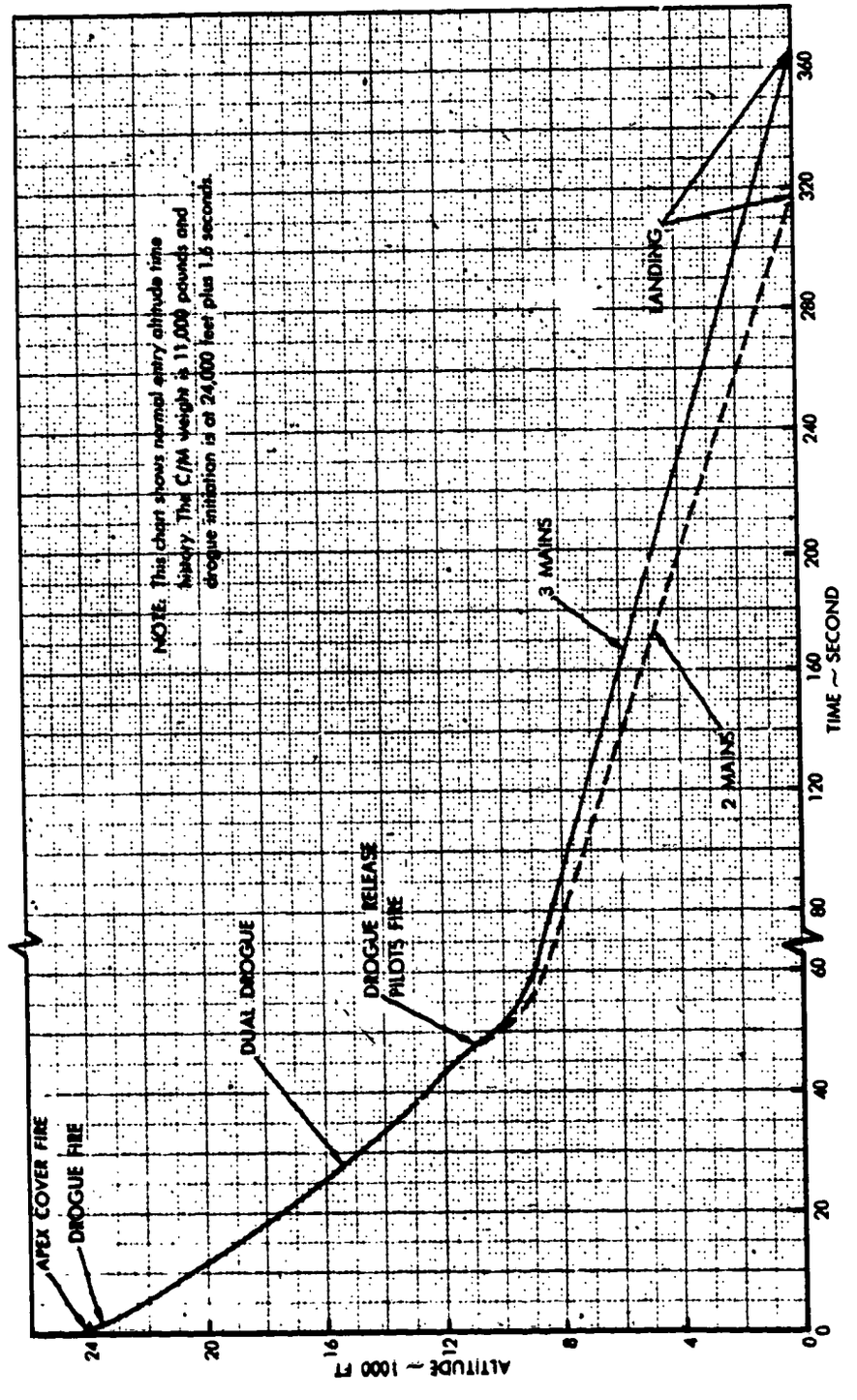

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Figure 4-31. Normal Entry - Altitude Time History

SECTION 5

EXPERIMENTS AND SCIENTIFIC EQUIPMENT DATA

INTRODUCTION

This section presents the objectives of mission 204A experiments and contains a description of associated equipment, stowage areas (figure 5-1), crew participation requirements for data collection, and related scientific equipment data. The in-flight tests are categorized as medical (M-), scientific (S-), and technical (T-) experiments as follows:

- In-Flight Exerciser (M-3A) (M003)
- In-Flight Phonocardiogram (M-4A) (M004)
- Bone Demineralization (M-6A) (M006)
- Human Otolith Function (Vestibular Effects)(M-9A) (M009)
- Cytogenetic Blood Studies (M-11) (M011)
- Cardiovascular Reflex Conditioning (M-48) (M048)
- Synoptic Terrain Photography (S-5A) (S005)
- Synoptic Weather Photography (S-6A) (S006)
- In-Flight Nephelometer (T-3) (T003).

NOTE The Planning and Management Office of the EPO (Experiments Program Office) is the coordinating facility for all of the experiments described in this section.

The experiments stowage areas location will be found in figure 5-1.

5.1 SCIENTIFIC EQUIPMENT.

5.1.1 MEDICAL DATA ACQUISITION SYSTEM (MDAS).

The medical data acquisition system, located in compartment C (figure 5-2), weighs 15.2 pounds and consists of a seven-channel tape recorder, associated signal conditioners, junction box, time code generator, and a front panel with switches and outlets for power and signal cables. This GFE unit uses 28-volt d-c power from compartment A to acquire and permanently record on magnetic tape all required medical (operational and experimental) data. The operational data required consists of electrocardiograph and impedance pneumograph outputs, while the experimental data consists only of phonocardiograph outputs. These medical parameters are routed from sensors and signal conditioners (attached to a crewman) through the PGA or CWG adapter cable, cobra cable, T-adapter, and octopus cable to specified channels in the MDAS. Although 100 watts of electrical power is provided for the MDAS from compartment A via the octopus cable, only about 19 watts are needed to operate the integral tape

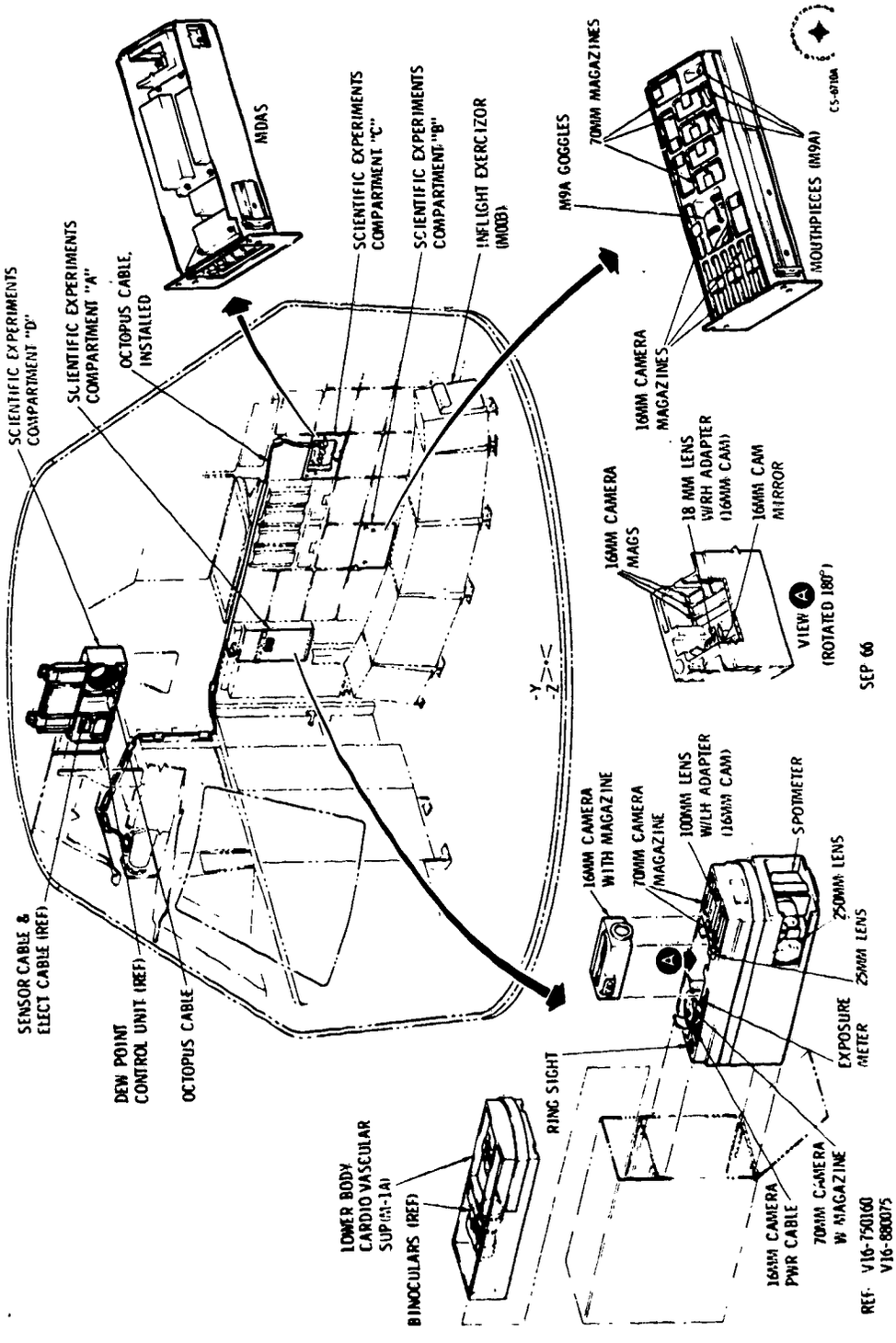


Figure 5-1. S/C 012 Mission Experiments Location, LEB (Sheet 1 of 2)

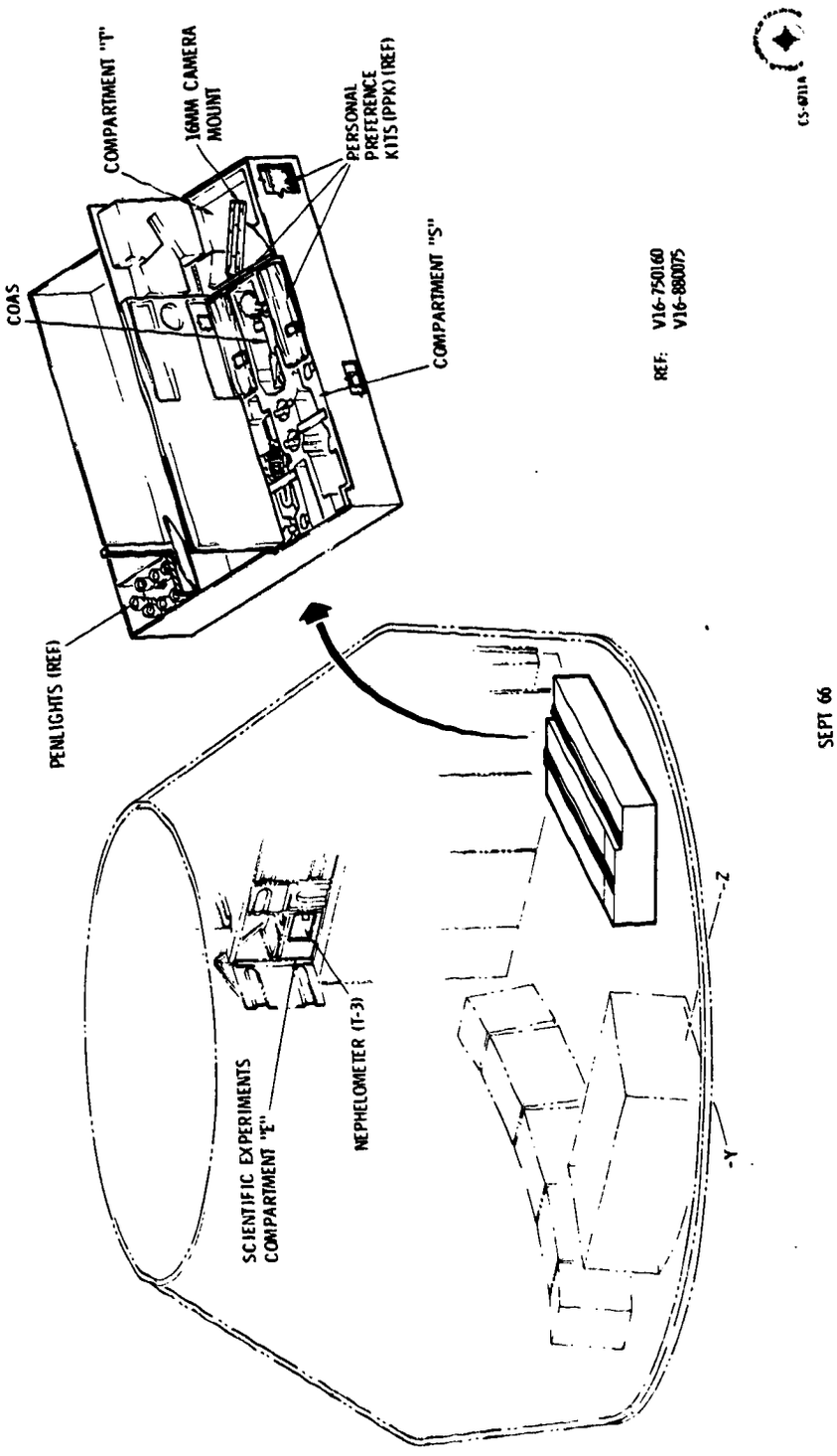


Figure 5-1. S/C 012 Mission Experiments Location, LEB (Sheet 2 of 2)

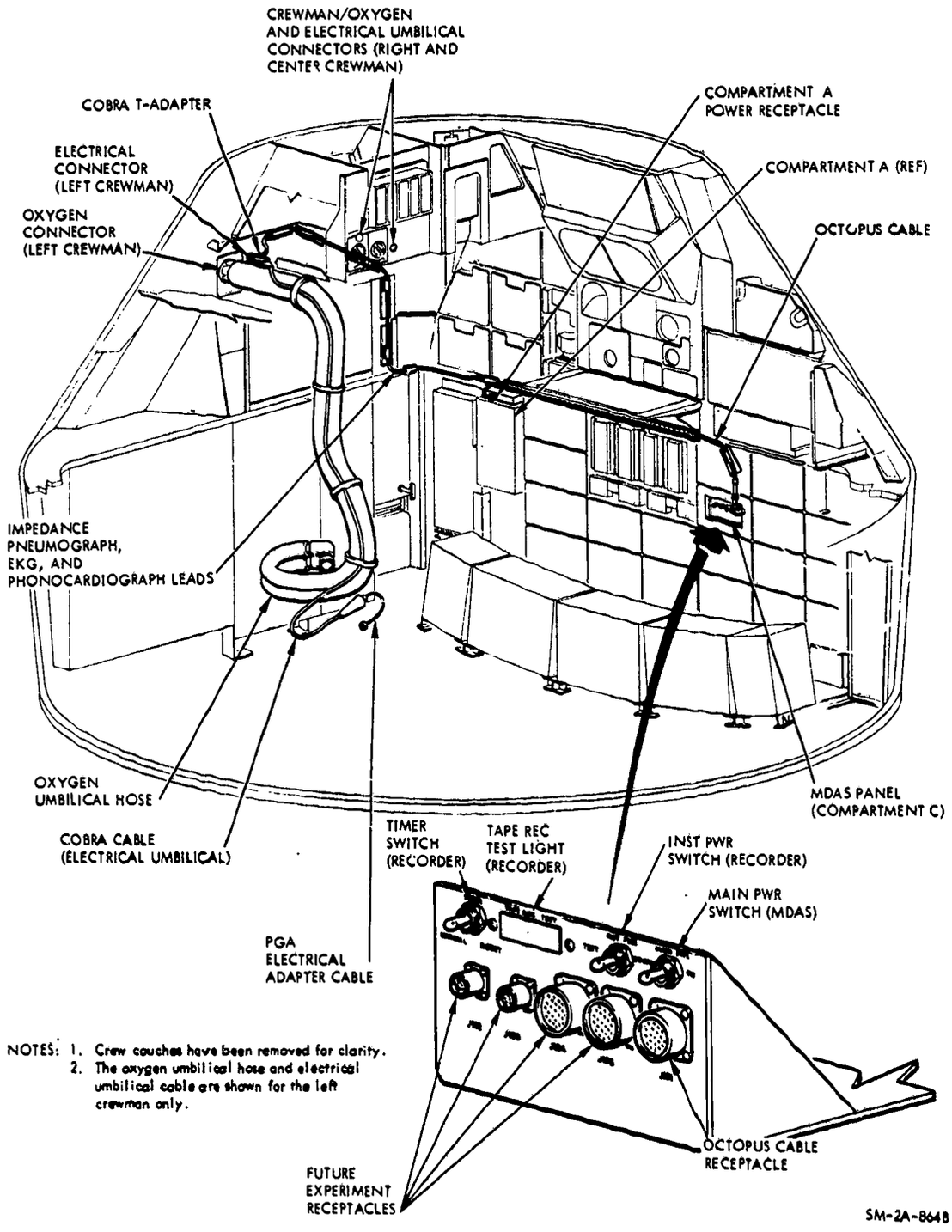


Figure 5-2. Experiments Tape Recorder and Electrical Connectors

recorder. However, electrical outlets on the MDAS front panel are provided for additional or future experiments (via electrical cabling connected directly to the equipment and the MDAS). The MDAS front panel also contains a MAIN PWR switch for controlling power to the unit and unit outlets, an INSTR PWR switch for controlling power to the tape recorder and the recorder test light, and a TIMER switch for correlating mission elapsed time on the tape recorder.

All three crewmembers have the capability of being recorded for their physiological data when electrically connected to the tape recorder. However, only one crewman at a time will have his outputs recorded during flight. (See figure 5-3.) Total recording time for the tape recorder is 100 hours maximum with 880 feet of usable tape. There are seven channels available for collecting data (including the optional channel for recording code signals).

The MDAS tape recorder is removed from the spacecraft immediately after flight, placed in a GFE metal container for protection against strong magnetic fields, and transported to the NASA-MSC (where the magnetic tape is removed from the recorder).

5.1.2 ELECTRICAL CABLES AND ADAPTERS.

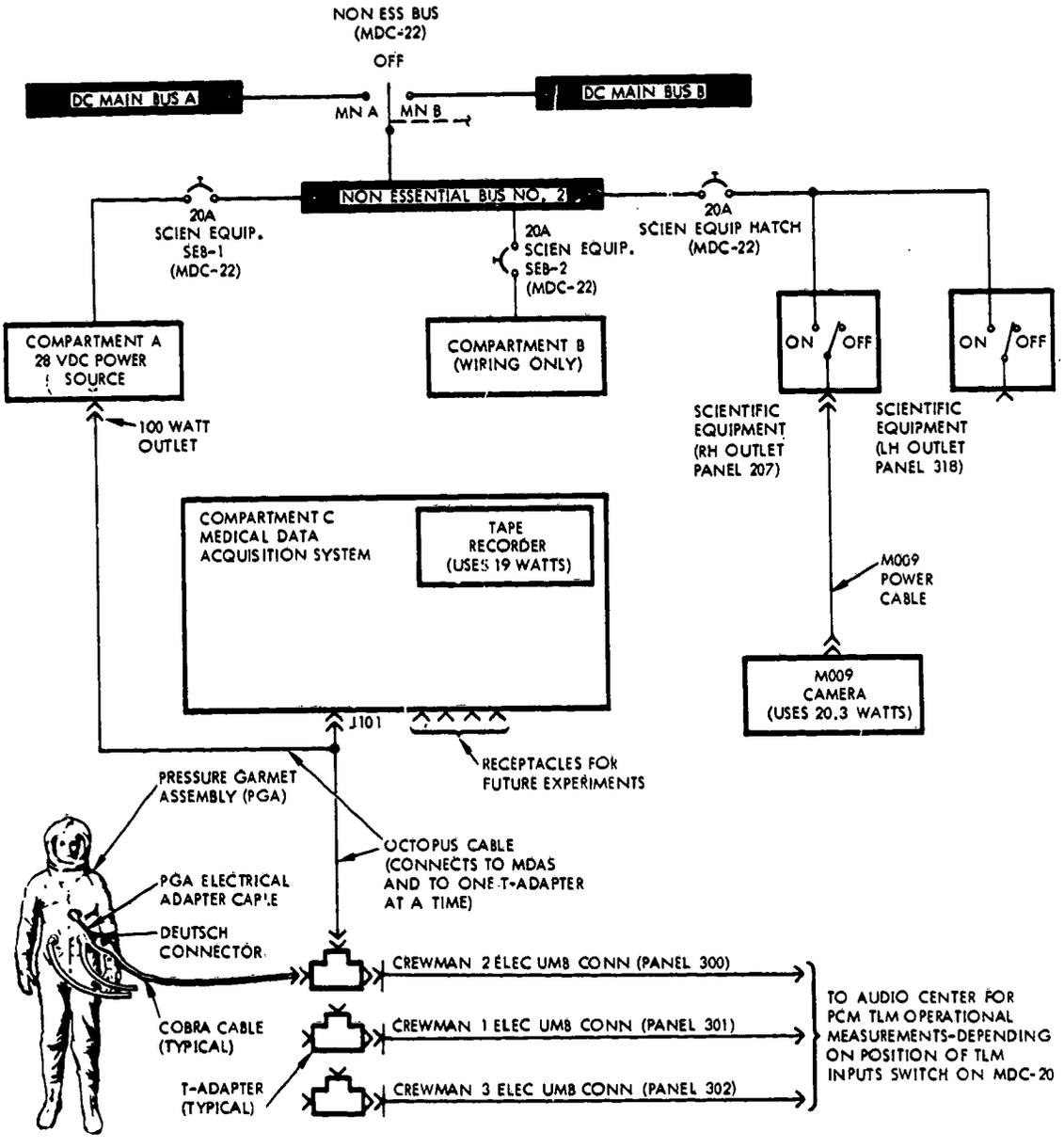
5.1.2.1 Octopus Cable.

The octopus cable (figure 5-2) plugs into the MDAS tape recorder, is protected from electrical arcing by an on-off power switch on the recorder panel, and contains signal and power lines for the following:

- Provides for 28-volt d-c (100 watts) power from compartment A to the MDAS in compartment C
- Provides for biomedical signals from a crewman (attired in the PGA or CWG) to the tape recorder. These signals consist of EKG, phonocardiograph, and impedance pneumograph outputs. This cable weighs 1.5 pounds and is stowed in compartment D of the LHFEB during launch and entry. The cable remains connected to the MDAS and a crewman's T-adapter during orbital flight.

5.1.2.2 Cobra Cable T-Adapter.

The T-adapter (figure 5-2), provided for each crewmember, weighs 1/2 pound and remains attached to the cobra cable at all times. This three-way electrical connector mates the cobra cable to the appropriate crewman electrical umbilical connector (panels 300, 301, or 302) and the octopus cable. A relay incorporated in the T-adapter is controlled by the TLM INPUTS-BIOMED (MDC-20) or the MDAS MAIN PWR switch in compartment C (providing the octopus cable lead is connected to the T-adapter). This relay permits electrical signals, from a crewman's torso, to be transmitted as operational data and recorded in-flight as experimental data.



NOTES:

1. Signal conditioners, sensors, and associated wiring on a crewman's torso (attached to the Microdot connector inside the PGA or on the CWG) provide for PCM TLM operational measurements and scientific experiments data.
2. A T-adapter permits simultaneous transmission of operational measurements (selected for one crewman at a time) and the recording of in-flight experiments data. However, operational measurements can be transmitted from one crewman while another crewman is recording experiments data

SM-2A-902C

Figure 5-3. Scientific Equipment Power Distribution

Operational data from one crewman may also be transmitted while experimental data from another crewman is being taped on the MDAS. However, only one operational transmission and one experimental recording can be taken at the same time.

5.1.2.3 PGA and CWG Electrical Adapter Cables.

The PGA and CWG electrical adapter cables (crew personal equipment) are provided to connect the cobra cable to signal conditioners and communication equipment attached to a crewman's body. (See figure 5-3 and refer to section 6.)

5.1.2.4 Hardware Power and Signal Cables.

Hardware power and signal cables are used for connecting equipment electrically to various outlets in the crew compartment. (See figure 5-3.) Protection from electrical arcing is provided by switches on the equipment or on the outlet panels in the crew cabin. The M-9A camera power cable (figure 5-3) connects to the RH SCIENTIFIC EQUIPMENT outlet on panel 207. A SCIENTIFIC EQUIPMENT outlet on panel 318 (near the LH side window) is reserved for a future experiment but can also be used as a backup outlet for the camera cable. Outlets marked J102 through J105 on the MDAS are reserved for future experiments (See figure 5-2.)

5.2 MEDICAL EXPERIMENTS.

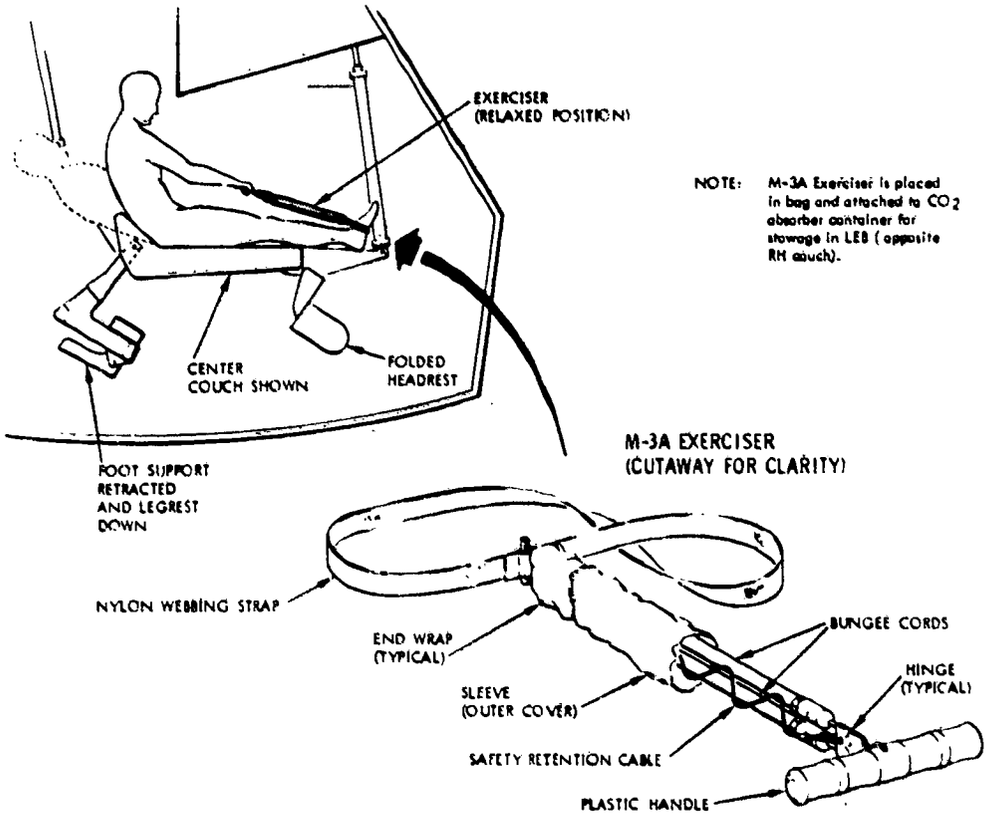
5.2.1 IN-FLIGHT EXERCISER (M-3A) (M003).

The purpose of experiment M-3A is to collect crew data for determining benefits of exercise during space flight. Recumbency (bed rest) studies have shown that exercise work tolerance for an individual is greatly reduced after being relatively immobile and in a horizontal position for a few days. Zero gravity during space flight may further increase the length of a crewman's reconditioning period.

5.2.1.1 Equipment Description.

The exerciser for experiment M-3A (figure 5-4) weighs about 1-1/2 pounds and consists of two rubber elastic (bungee) cords with a retaining cable. A nylon elastic sleeve covers the bungee cords and retaining cable. One end of the exerciser contains a looped strap made of webbing cloth that can be secured around a crewman's feet. The other end of the exerciser has a spherical plastic handle grooved to fit both hands of a crewman. The retaining or safety cable within the elastic sleeve permits the exerciser to be stretched from 9-1/2 to 21-1/2 inches.

A mechanical interface between the equipment and the S/C exists where the exerciser container is attached to the CO_2 absorber container in the LEB (opposite the RH couch). Although all three couches can be used



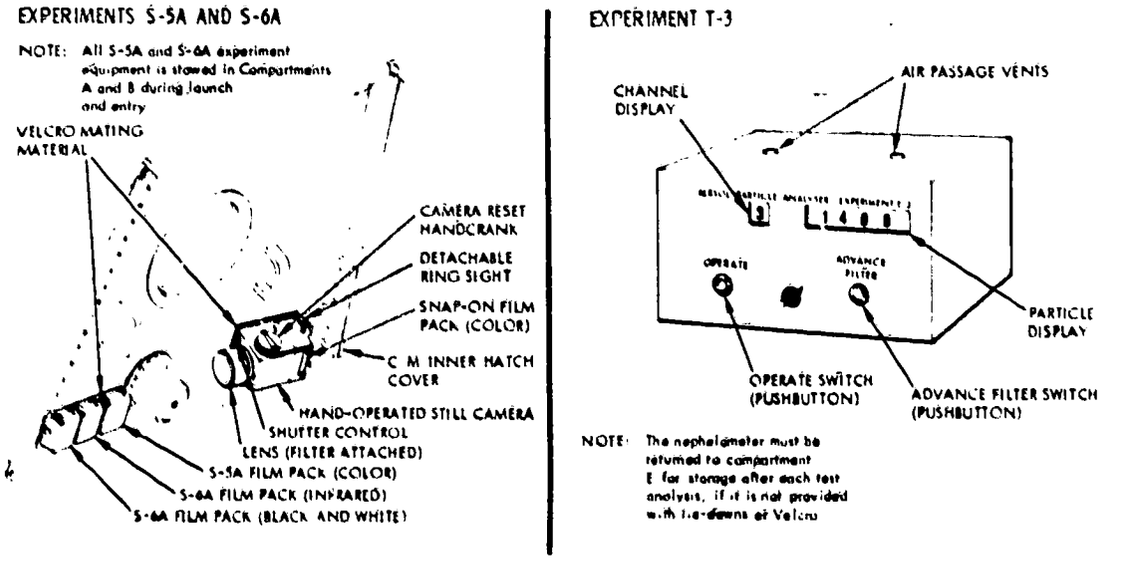


Figure 5-4. Experiments Operational Arrangement (Sheet 1 of 2)

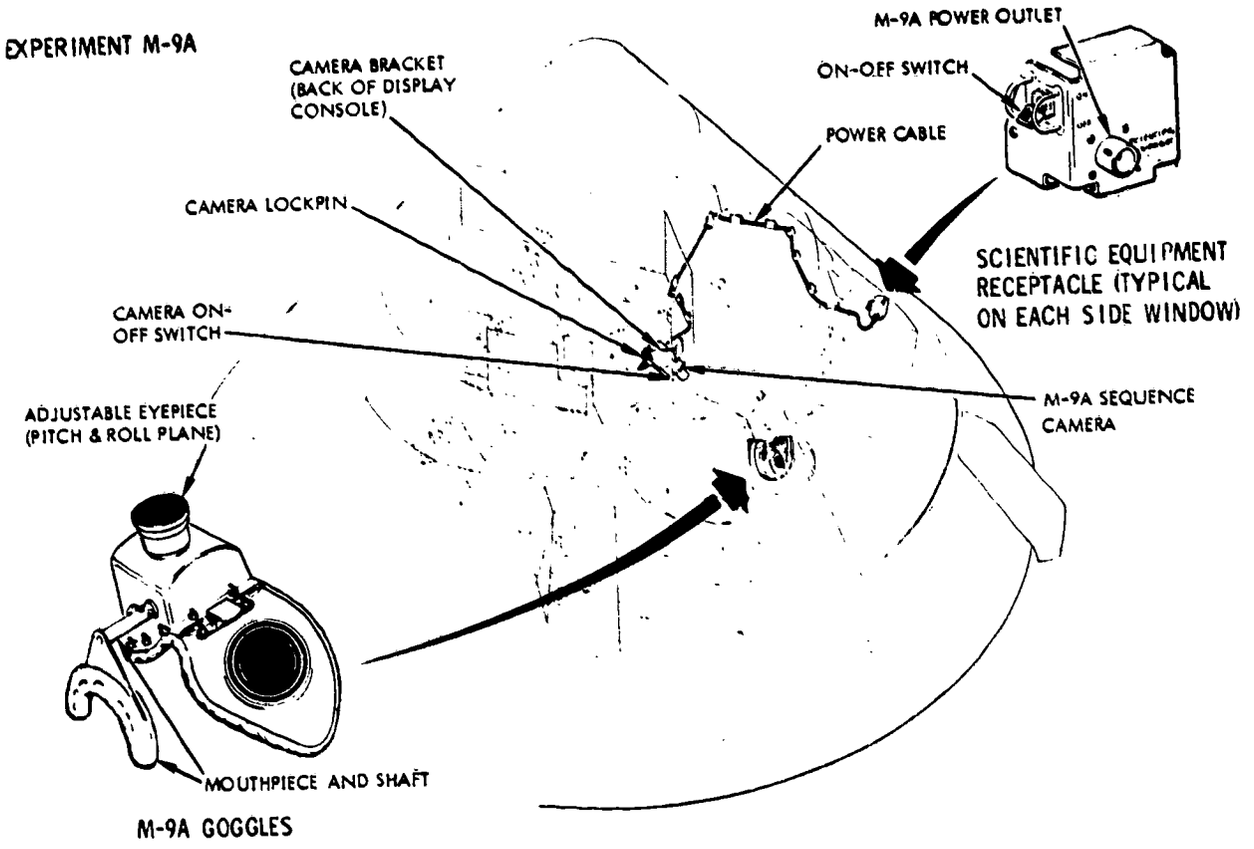


Figure 5-4. Experiments Operational Arrangement (Sheet 2 of 2)

during the M-3A isotonic and isometric exercises, only the center couch provides adequate head room to comfortably perform isotonic exercises when data recording periods are conducted. (Date includes EKG, impedance pneumograph, and phonocardiograph recordings taped on the MDAS recorder.)

5.2.1.2 Experiment Procedures.

All crewmen will exercise in-flight for 10 minutes three times every 24 hours. The base line preflight data will serve as a control for the study. A recording session is required once per day on one crewman before, during, and after an exercise period. Crewmembers will alternate each day for data recordings. (Detailed procedures are provided in section 11.)

5.2.1.3 Crewman Participation.

Requirements for crewman participation in the exercise experiment are as follows:

a. Preflight - Each crewman will be tested for exercise tolerance (physical fitness level) on three separate occasions 8 to 4 weeks prior to flight.

b. In-flight - Each crewman will be required to exercise 3 times daily for 10 minutes each exercise period. Medical data from one crewman will be recorded during one exercise period each day. (It will take 3 days to obtain medical data from all three crewmen.)

c. Postflight - Each crewman will undergo re-evaluation exercises on three separate occasions (12 to 24 hours, 1 week, and 2 weeks after touchdown).

5.2.1.4 Recovery Requirements.

There are no special recovery requirements for experiment equipment because the in-flight exerciser will remain stowed in the S/C during recovery. An exerciser of equivalent design will be available at the site where postflight evaluations are performed and the experiment is completed. The on-site coordinators will be responsible for removal of the magnetic recording tape from the MDAS and delivery of all data to the NASA-MSC.

5.2.2 IN-FLIGHT PHONOCARDIOGRAM (M-4A) (M004).

The purpose of experiment M-4A is to obtain information on the functional cardiac status of two crewman during prolonged space flight. An in-flight recording of the phonocardiographic heart sounds, compared with the highest EKG signal, will be made to determine the delta time interval between electrical activation of the heart muscle (myocardium) and the onset of ventricular systole (heart contraction).

5.2.2.1 Equipment Description.

The equipment worn by the crew commander and navigator in experiment M-4A consists of two phonocardiogram transducers (microphone biosensors), a phonocardiograph signal conditioner package (amplifier) with variable gain, and associated electrical wiring. The biosensors are attached to the crewman's torso (skin) and connected by electrical leads to the signal conditioner (fastened on the CWG) and the Microdot connector on the PGA or CWG. Signal outputs from the crewman's body to the biomedical tape recorder (compartment C) are routed via the PGA or CWG adapter cable, the cobra cable, T-adapter, and the GFE octopus cable. (See figure 5-3 for tape recorder and electrical connectors, and refer to paragraph 5-1 for data on scientific equipment.)

The total S/C electrical power for recording the experiment is approximately 1.4 watts. The octopus cable, for connecting the tape recorder to the PGA, is stowed in compartment D of the LHFEB. (See figure 5-1.)

5.2.2.2 Experiment Procedures.

Installation of phonocardiogram transducers on the chest of the two crewmen and the positioning and hookup of electrical leads, worn outside the CWG, are performed during the preflight suiting procedure. After hookup during flight, recordings are taken on the medical data acquisition system (MDAS). Supporting data such as EKG and impedance pneumograph signals are also recorded during the experiment. (Detailed in-flight procedures are provided in section 11.)

5.2.2.3 Crewman Participation.

Requirements for crewman participation in the phonocardiogram experiment are as follows:

a. Preflight - Sensor application should not exceed one hour. Approximately 5 minutes of recording will be required for collecting baseline data from each crewman.

b. In-flight - No effort will be required by the crewman other than hookup to the MDAS. The one special exception could be time spent in determining optimum placement or repositioning of a microphone biosensor.

c. Postflight - Approximately 5 minutes will be required for post-recovery recording for data comparison

5.2.2.4 Recovery Requirements.

There are no special recovery requirements for the experiment other than removal of the magnetic recording tape from the MDAS. The recorded data will be processed by conventional methods

5.2.3 BONE DEMINERALIZATION (M-6A) (M006)

The purpose of experiment M-6A is to determine the effect of weightlessness and immobilization during space flight on the demineralization of certain bones within the body of each astronaut.

5.2.3.1 Equipment Description.

This experiment does not require any in-flight equipment, S/C power or fuel, or recording equipment. (There are no interface problems between experiment M-6A and the S/C.)

5.2.3.2 Experiment Procedures.

In-flight procedures are not required for this experiment. Prior to flight, crewmen will have X-rays taken of their heel bones and the last joint of the little finger on the right hand. These exposures will be taken before and after flight at Kennedy Space Center X-ray facilities. The hematopietic (i.e., blood forming marrow) areas will not be exposed to the radiation source since the exposure field will be carefully limited

5.2.3.3 Crewman Participation.

Requirements for crewman participation in the bone demineralization experiment are as follows:

a. Preflight - Approximately 45 minutes total time is required per crewman for obtaining X-ray films (three 15-minute sessions at T minus 10 days, T minus 2 days, and T minus 220 minutes).

b. In-flight - None

c. Postflight - Approximately 15 minutes per astronaut are required for obtaining X-ray films after spacecraft recovery. (A follow-on checkup may be required, depending on bone demineralization.)

5.2.3.4 Recovery Requirements.

On-site investigators will develop X-ray films, make bone densitometry measurements, and be responsible for delivery of all data to the NASA-MSC.

5.2.4 HUMAN OTOLITH FUNCTION (VESTIBULAR EFFECTS) (M-9A) (M009).

The purpose of experiment M-9A is to determine the effect of prolonged weightlessness on a crewman's orientation sensation, particularly to the otolith organ (inner ear). All data collected will be used to predict the ability of space crews to orient themselves in a weightless environment, especially when subjected to darkness (eyes covered).

5.2.4.1 Equipment Description.

The equipment used for the experiment consists of the otolith test goggles (a mask with a single eyepiece or monocular scope), a mouthpiece for each crewman to align the goggles with his head, a 16 mm sequence camera (part of the operational equipment), film packs for recording the actual orientation of the subject's head relative to the S/C, and an electrical cable for providing 28-volt d-c power to the camera. (See figures 5-1 and 5-4.)

A bracket, stowed in compartment T on the aft bulkhead, is mounted behind the main display panel in the egress tunnel to secure the camera during the experiment. The experiment goggles and mouthpieces weigh about 5 pounds and are stowed with most of the film packs in compartment B of the LEB. Additional film packs and the power cable are kept in compartment A with the operational camera and lens. The 28-volt d-c power source for the camera is provided by an outlet near the crew cabin RH side window. (See figure 5-4.)

5.2.4.2 Experiment Procedures.

In preparation for the experiment, shades are installed over the windows and all cabin lights are turned on to maximum intensity. The test

subject (in the center couch) operates the camera, covers his eyes with the otolith test goggles, and manually adjusts a self-luminous target line in the monocular scope to what he thinks is straight ahead and parallel to the S/C Y-Y axes. A series of adjustments will be recorded by the camera (for each crewman) during flight and compared to test results obtained during preflight and postflight tests. (Detailed in-flight procedures are provided in section 11.)

5.2.4.3 Crewman Participation.

Requirements for crewman participation during the experiment are as follows:

a. Preflight - A total time of about 3 hours is required for familiarization and training, including collection of base line data (for all three crewmen).

b. In-flight - One test period of 15 minutes per day per crewman is required.

c. Postflight - Each crewman will be subjected to a 5-minute test period as soon as possible after S/C recovery (for a total time of about 15 minutes) to complete the experiment data.

5.2.4.4 Recovery Requirements.

Facilities in the primary recovery area will be used to complete the postflight examination and medical debriefing. The raw data consisting of film is recovered from the S/C along with the goggles and mouthpiece for delivery to the on-site coordinators.

5.2.5 CYTOGENETIC BLOOD STUDIES (M-11) (M011).

The purpose of experiment M-11 is to conduct preflight and postflight analyses to determine if space environment produces cellular changes in the blood of crewmen. These changes, which are important to the medical and scientific point of view, may not be apparent from routine monitoring procedures.

5.2.5.1 Equipment Description.

This experiment does not require any in-flight equipment, S/C power or fuel, or S/C recording equipment. (There is no interface between experiment M-11 and the S/C.)

5.2.5.2 Equipment Procedures.

On two occasions (preflight), approximately one month apart, blood specimens will be obtained from the crewmen for the experiment. The second occasion for drawing blood samples will be scheduled as close to lift-off time as conveniently possible. Blood samples for part A of the experiment (cytogenic studies of human hemic cells) and part B of the

experiment (immunological system) will be drawn at a predetermined hospital site for analyses. Postflight requirements will be essentially the same, except that three such samples will be required over a period of one year. The first postflight blood sample will be drawn shortly after the termination of flight. (In-flight procedures are not required for this experiment.)

5.2.5.3 Crewman Participation.

Requirements for crewman participation in the M-11 experiment are as follows:

a. Preflight - On two occasions prior to flight (T minus 30 days and T minus one day), blood samples (10 cc for part A and 15 to 20 cc for part B of the experiment) will be drawn from each crewman.

b. In-flight - None

c. Postflight - On three occasions after S/C recovery, blood samples (10 cc for part A and 15 to 20 cc for part B of the experiment) will be drawn from the crewmen. It is not essential that blood samples for parts A and B are drawn at the same time.

5.2.5.4 Recovery Requirements.

After mission completion, blood samples must be drawn from the crewmen at a conveniently located, but predetermined, hospital for analyses. Blood determinations made should include immunoelectrophoresis, electrophoresis, electrophoresis on starch gel, measurement of gamma$_2$, gamma a, and gamma M globulin levels, measurement of whole hemolytic complement, titration of blood group antibodies, and measurement of pre-existent antibacterial antibodies.

5.2.6 CARDIOVASCULAR REFLEX CONDITIONING (M-48) (M048).

The purpose of experiment M-48 is to determine the effectiveness of a lower body vascular support garment for preventing physical fatigue, insufficient circulating blood volume to maintain adequate venous return (blood-pooling), and a loss of venomotor reflexes in the legs of a crewman during entry and recovery (when exposed to earth 1-g gravity force).

5.2.6.1 Equipment Description.

The equipment used in experiment M-48 consists of an 8-ounce pair of waist-length tights for supporting veins in the lower portion of a crewman's body. These tights are composed of rubber strands wrapped with cotton and woven into a garment with dacron. When worn, the tights will extend from the crewman's waist to his heel and supply a decreasing pressure from the waist down. The M-48 equipment does not require any S/C electrical power, fuel for attitude maneuvers, or recording equipment. When not in use, the experiment tights are stowed in compartment A of the LEB.

5.2.6.2 Experiment Procedures.

The M-48 vascular support tights are donned by a crewman prior to entry and just before getting into the pressure garment assembly (PGA). This crewmember also wears a two-piece constant wear garment (CWG) to facilitate getting into the tights and replacing the CWG. (Detailed in-flight procedures are provided in section 11.)

5.2.6.3 Crewman Participation.

Requirements for crewman participation in the conditioning experiment are as follows:

a. Preflight - Each crewmember will be given a minimum of three tilt-table checkouts for control data (requiring about 90 minutes per crewman). These checkouts, performed by qualified flight surgeons or experiment medical team, will be conducted within 4 weeks of launch date.

b. In-flight - The in-flight portion of the experiment will consist of one crewmember donning the vascular support garment 1 to 2 hours prior to entry and wearing it until the first postflight tilt-table checkout. A total time of about 3 minutes will be required for in-flight experiment preparations.

c. Postflight - After recovery, a series of tilt-table tests will be given to both the control subjects and the experiment subject. The control subjects will be tested 2 to 4, 8 to 12, 24, and 48 hours after recovery. The experiment subject, wearing the vascular support garment, will be initially tested 2 to 4 hours after recovery. Twenty minutes after his first tilt-table test, the experiment subject will be given a second test without the support garment. The remaining tests will follow the same sequence as described for the control subjects.

NOTE Tilt-table checkouts for the experiment consist of a 5-minute supine tilt, a 15-minute vertical (70-degree head-up position) tilt, and a 5-minute supine recovery tilt. During each tilt phase, performed on a manual tilt table with a saddle support, the crewmember's blood pressure and heart rate will be automatically recorded each minute. Also, changes in the leg blood volume will be measured each minute during the 70-degree and supine recovery tilts.

- Additional data required to complete the experiment such as plasma volume, total blood volume, and red blood cell mass will be obtained during preflight and postflight hematology tests by the experiment medical team.

5.2.6.4 Recovery Requirements.

Tilt table, heart rate, blood pressure, and other medical support equipment for the experiment are required in the recovery area for collection of postflight data (gathered and processed by the experiment medical team).

5.3 SCIENTIFIC EXPERIMENTS.

5.3.1 SYNOPTIC TERRAIN PHOTOGRAPH (S-5A) (S005).

The purpose of experiment S-5A is to obtain photographs of selected areas of the earth from the S/C at orbital altitude. These photographs are required for research in geology, geophysics, geographys, oceanography, and for use in planning photography from a manned orbiting laboratory.

5.3.1.1 Equipment Description

The equipment used in experiment S-5A (figure 5-4) weighs about 5 pounds and consists of a hand-operated Hasselblad 70-mm general purpose camera (single frame) with a detachable ring sight, two color-film packs (55 exposures each), and an exposure dial and spotmeter (operational equipment used with the Hasselblad camera). Except for the film packs in compartments A and B, most of the camera equipment is stowed in compartment A. (See figure 5-1.) This equipment can be retrieved and set up for photography in about 5 minutes.

No special interface problems are anticipated for this experiment. When not in use, the camera may be temporarily secured to the inner hatch cover, or anywhere within the C/M where Velcro mating material is provided.

5.3.1.2 Experiment Procedures.

This experiment will consist of photographing certain areas and features along the S/C flight path. The desired camera angle for taking pictures (with S/C window in shade) will be 90 degrees from S/C level flight over the earth. The crewman will be required to record the time of each photograph, subject, frame number, and film pack number in the experiments log book. (Detailed in-flight procedures are provided in section 11.)

5.3.1.3 Crewman Participation.

Requirements for crewman participation in experiment S-5A (time shared with experiment S-6A) are as follows:

a. Preflight - The crewman-subjects will be provided with a briefing (1 to 3 hours) on the aims, methods, and procedures for in-flight photography of selected terrestrial areas.

b. In-flight - About 45 minutes (total time) will be devoted to photography during 9:00 AM to 3:00 PM local time conditions.

c. Postflight - About one hour will be required for debriefing.

5.3.1.4 Recovery Requirements.

There are no recovery requirements other than removal of the camera and film from the S/C. Personnel performing the postflight debriefing will be responsible for delivering the exposed film to the coordinating facility for processing, analysis, and evaluation.

5.3.2 SYNOPTIC WEATHER PHOTOGRAPHY (S-6A) (S006).

The purpose of experiment S-6A is to obtain selective, high-quality photographs of cloud patterns taken from the spacecraft at orbital altitude. These photographs will be used for studies of weather system structures around the earth.

5.3.2.1 Equipment Description.

The basic equipment used in experiment S-6A (figure 5-4) is the same as that used in experiment S-5A. In addition to the 70-mm general purpose camera and ring sight, the S-6A equipment includes an ultraviolet filter, one color-film pack, and one color-shifted infrared film pack. Except for the film packs in compartments A and B, most of the camera equipment is stowed in compartment A.

No special interface problems are anticipated for this experiment. When not in use, the camera may be temporarily secured to the inner hatch cover or anywhere within the C/M where Velcro mating material is provided.

5.3.2.2 Experiment Procedures.

This experiment will consist of photographing certain weather areas and cloud formations of special interest along the S/C flight path. (Detailed in-flight procedures are provided in section 11.)

5.3.2.3 Crewman Participation.

Requirements for crewman participation (time shared with experiment S-5A) in experiment S-6A are as follows:

a. Preflight - The crewman-subjects will be provided with a briefing (1 to 3 hours) on the aims, methods, and procedures for in-flight photographing of selected cloud formations.

b. In-flight - As required during 9:00 AM to 3:00 PM local time conditions (about 45 minutes total time will be devoted to photography).

c. Postflight - About one hour will be required for debriefing.

5.3.2.4 Recovery Requirements.

There are no recovery requirements other than removal of the camera and film from the S/C. Personnel performing the postflight debriefing will be responsible for delivering the exposed film to the coordinating facility for processing, analysis, and evaluation.

5.4 TECHNICAL EXPERIMENTS.

5.4.1 IN-FLIGHT NEPHELOMETER (T-3) (T003).

The purpose of experiment T-3 (figure 5-4) is to determine and obtain a quantitative evaluation of the size, concentration, and distribution of particles present in the C/M crew compartment. In-flight measurements will be made of particles in the 0.3 to 10 micron size.

5.4.1.1 Equipment Description.

The nephelometer is a portable, self-contained instrument approximately 7.2 by 3.5 by 5.2 inches in size, weighs about 5.5 pounds, contains its own battery power supply, electronics, air pump, and presents a readout display (five channels for particle sizes in five discrete ranges). This equipment provides a collimated light beam that is focused at a point in a moving path of grossly filtered air. The cabin atmosphere, when being evaluated for aerosol particles, is drawn through the particle size detector by the air pump within the analyzer.

There are no interface problems anticipated for this experiment. When not in use, the nephelometer is stowed in compartment E of the LEB. (See figure 5-1.)

5.4.1.2 Experiment Procedures.

Experiment T-3 requires that the nephelometer be initially positioned in a preselected area within the crew compartment for evaluating particles present in the cabin atmosphere. The concentration of aerosol per unit volumes will be determined in each of five ranges (0.3 to 0.6, 0.6 to 1.2, 1.2 to 2.4, 2.4 to 4.8, and above microns). Data will be recorded after each 2-minute test run has been conducted, once every 6 hours. Several different locations may be used for taking particle measurements after the first 2 days of flight. (Detailed in-flight procedures are provided in section 11.)

NOTE To ensure accurate determinations, do not use analyzer if visible particles are floating in cabin; if temperature is above 90°F; or if relative humidity in cabin is over 70 percent.

5.4.1.3 Crewman Participation.

Requirements for crewman participation in experiment T-3 are as follows:

a. Preflight - The crewman-subjects will be provided with sufficient time for equipment familiarization and training.

b. In-flight - Experiment measurements will be conducted once every 6 hours (for a 2-minute test run) until the nephelometer integral battery power is depleted. (The total duration of the experiment is limited by a battery with a 3-hour lifetime.)

c. Postflight - About one hour will be required for debriefing.

5.4.1.4 Recovery Requirements.

The recovery requirements will consist of removing the nephelometer and recorded data from the S/C. Personnel performing the postflight debriefing will be responsible for delivering data to the coordinating facility for analysis and evaluation.

SECTION 6

CREW PERSONAL EQUIPMENT

INTRODUCTION.

This section contains a description of Contractor-furnished crew personal equipment and spacecraft interface data on NASA-furnished crew personal equipment. All major items are identified as Contractor-furnished equipment (CFE), Government-furnished equipment (GFE), or Government-furnished property (GFP).

The following is a list of equipment or subsystems for which coverage is provided.

- Crew Compartment Configuration
- Sighting Systems (GFE)
- Space Suit Assembly (GFP)
  1. Constant Wear Garment (GFP)
     (a) Communication Hat (GFP)
  2. Pressure Garment Assembly (GFP)
- Crew Couches (CFE)
- Restraint Methods (CFE)
- In-flight Data Package (GFE)
- Crewman In-flight Tool Set and Work/Food Shlf (CFE)
- Crew Water (CFE)
- Food (GFP)
- Personal Hygiene (GFP)
- Medical Supplies and Monitoring (GFP)
- Survival Kit (GFP)
- Stowage

6.1 CREW COMPARTMENT CONFIGURATION AND CREW ENVIRONMENT.

The crew compartment is the pressurized compartment within the airtight inner structure (figure 6-1). The total volume within the inner structure is 366 cubic feet. Approximately 121 cubic feet of this pressurized space is occupied by the equipment bays, and control and display consoles surrounding the crew. The couches, astronauts, aft bulkhead equipment, and miscellaneous equipment occupy another 35 cubic feet making a total of 156 cubic feet. There is approximately 210 cubic feet of usable air space. The crew compartment is pressurized to 5±0.2 psi, with 100 percent oxygen atmosphere and approximately 50 percent humidity.

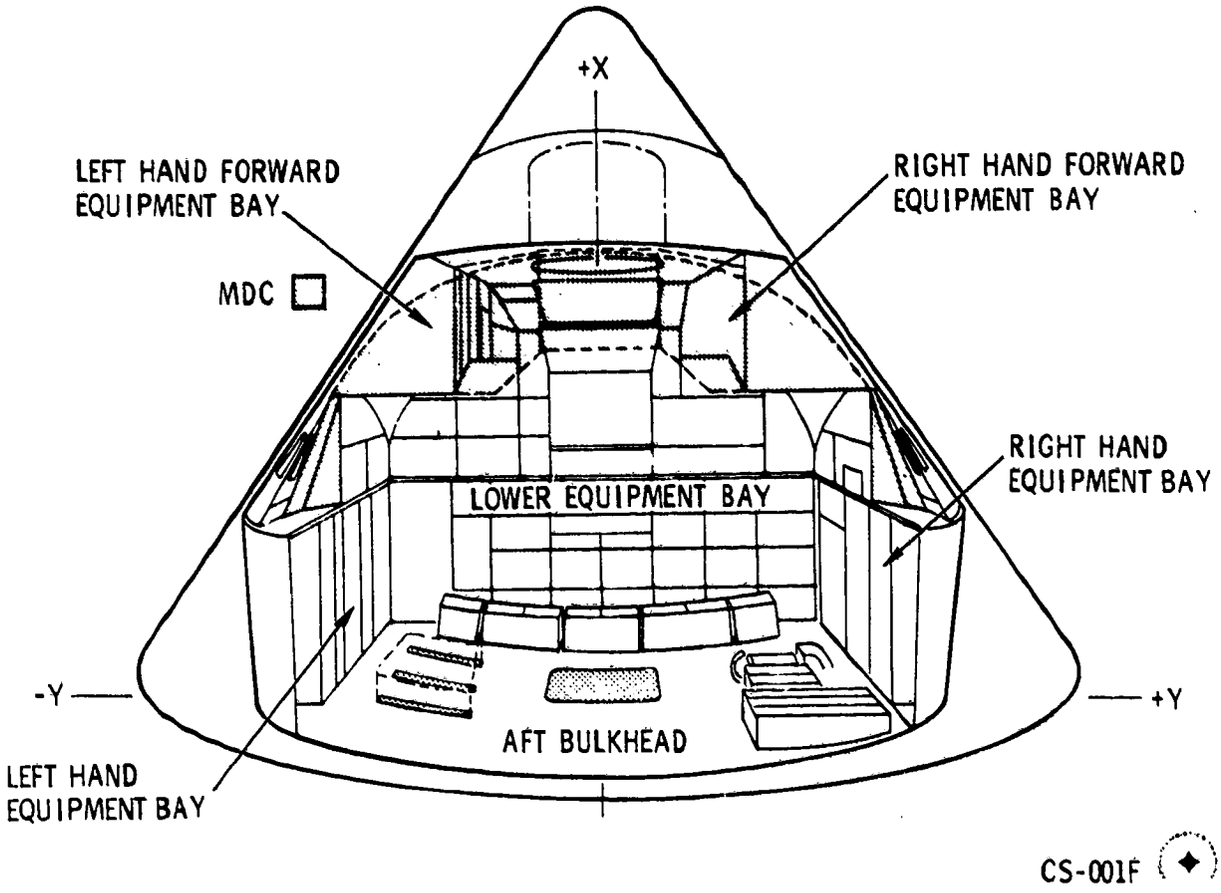


Figure 6-1. Apollo Crew Compartment, Internal View Form -Z-Axis

6.2 MIRRORS.

6.2.1 INTERNAL VIEWING MIRRORS (CFE). (Figure 6-2)

When the astronaut is in the pressure suit, pressurized, and on the couch, his field of vision is very limited. He can see only to the lower edge of the main display console (MDC), thus blanking out his stomach area where his restraint harness buckling and adjustment takes place. The internal viewing mirrors aid the astronaut in buckling and adjustment of the restraint harness and locating couch controls.

There are three mirrors, one for each couch position. The mirrors for the left and right astronaut are mounted on the side of the lighting and audio control console above the side viewing window and fold. The center astronaut's mirror is mounted on the left X-X head attenuator strut.

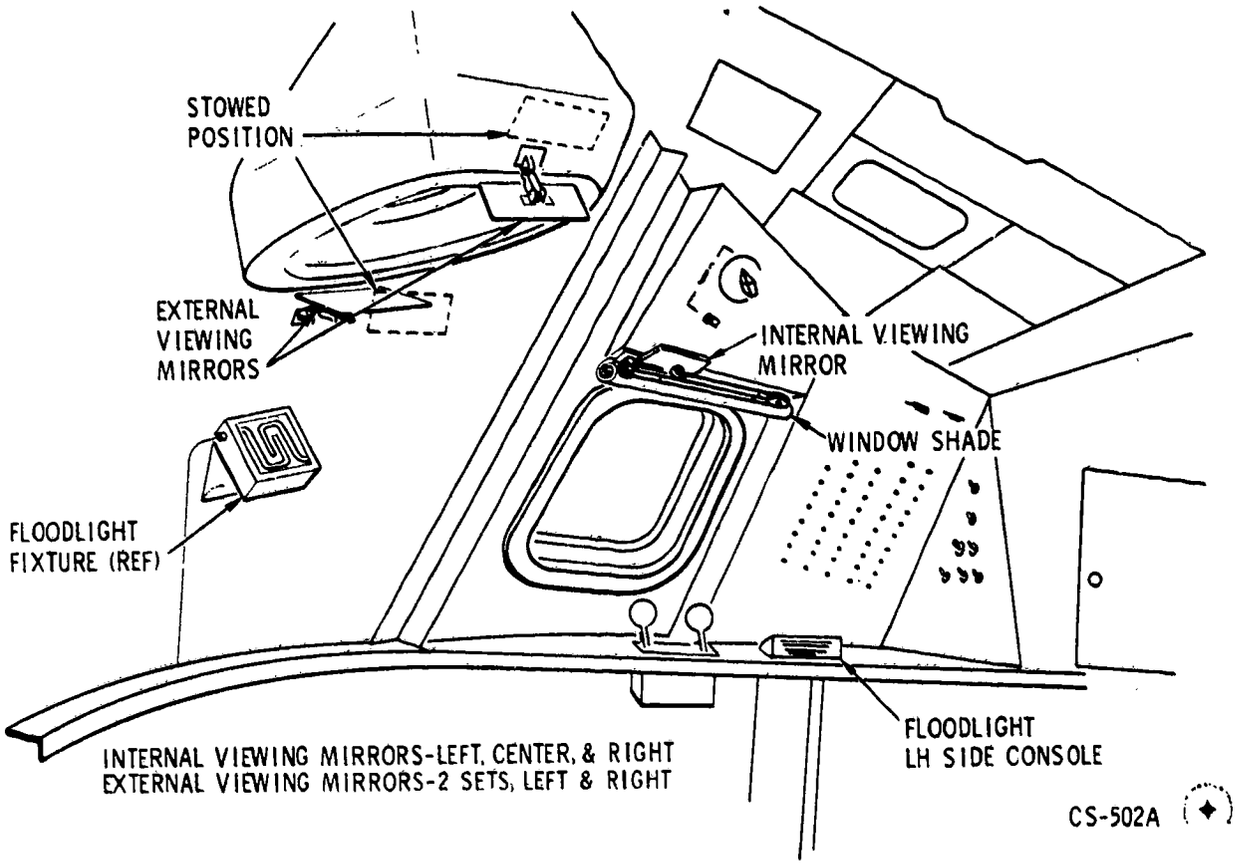


Figure 6-2. CM Mirrors, Block I and II

The mirror assembly consists of a mounting base, a two-segmented arm, and a mirror. The mirror is rectangular (4 by 6 inches), flat, rear surfaced, with a demagnification factor of 1:1. The two-segmented arm allows a reach of approximately 22 inches from the mount. The ends of the arm have swivel joints to position the mirrors in the desired angles. The mirrors are locked in position by a clamp during boost and entry.

6.2.2 EXTERNAL VIEWING MIRRORS (CFE). (Figure 6-2)

With the couches in the 96-degree position, the astronaut's left and right view, through the rendezvous windows, is restricted to +5 degrees to +42 degrees from the X-axis. Therefore, two sets of external viewing mirrors are installed in the CM to permit verification of parachute deployment during entry (figure 6-3). Another function is orientation of the command module in the event of an abort.

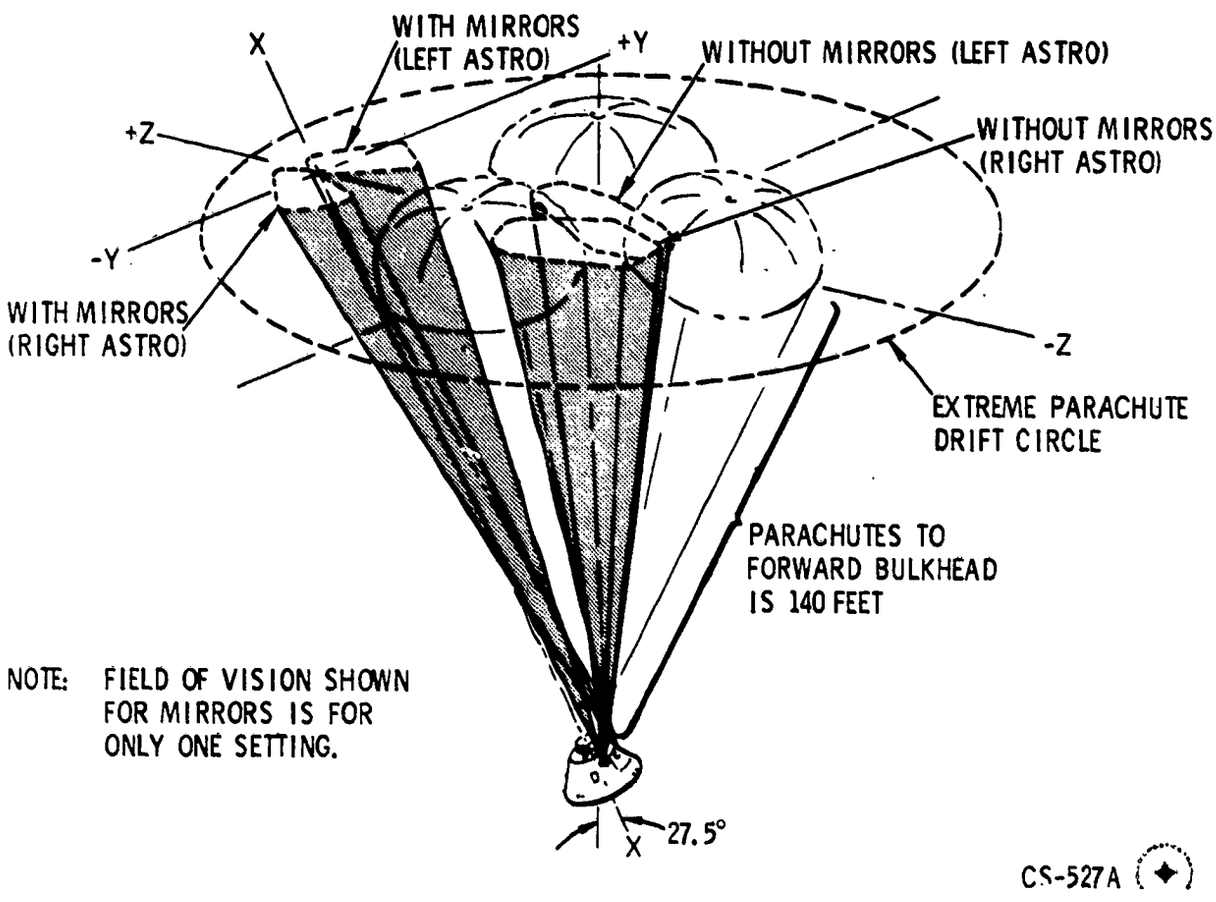


Figure 6-3. Parachute Field of Vision in Couch 96-Degree Position

A set of mirrors consist of an upper mirror assembly and a lower mirror assembly. The upper mirror assembly is mounted on the side wall near the upper rim on the rendezvous window frame. The lower mirror assembly is mounted on the rendezvous window housing near the lower rim of the window frame.

The mirror assembly consists of a mirror and a bracket. The bracket has a short arm with a swivel that allows positioning of the mirror. The short arm has a lock to immobilize the mirror during landing. The mirrors will have a 1:1 magnification factor and are rectangular in shape.

6.3 CREWMAN OPTICAL ALIGNMENT SIGHT (COAS). (Figure 6-4)

The crewman optical alignment sight provides the crewman a fixed line-of-sight attitude reference image which, when viewed through the forward window, appears to be the same distance away as the target. This image is foresighted (by means of a sight mount) parallel to the centerline (X-axis) of the CM and perpendicular to the Y-Z plane.

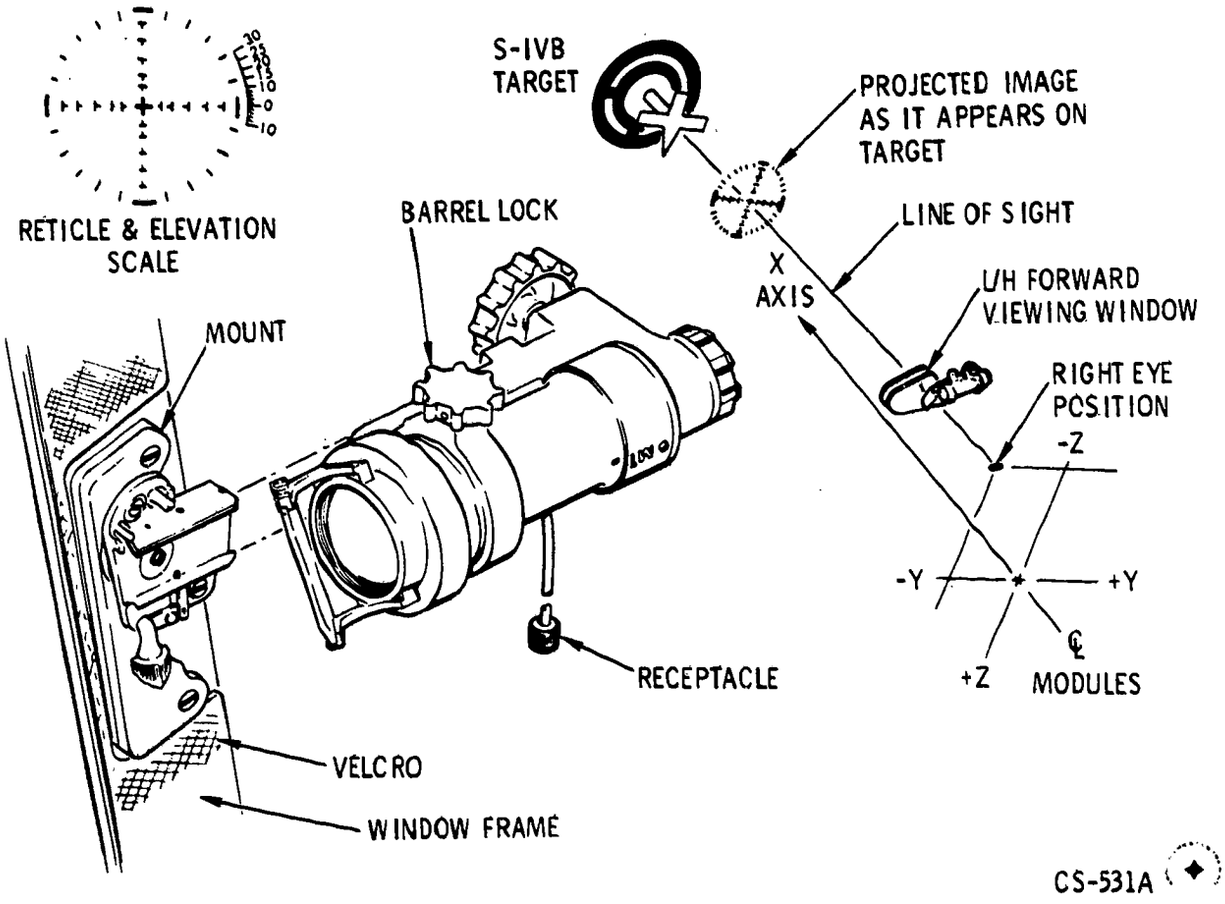


Figure 6-4. Apollo Crewman Alignment Sight System Configuration

The sight is a collimator device, similar to a gunsight. It weighs approximately 1.5 pounds and is 8 inches in length. It has a cord and receptacle and requires a 28-vdc power source. The sight is stowed in compartment T during boost and entry. When operationally required, it is mounted at the left rendezvous window frame. The power receptacle is connected to the SCIENTIFIC EXPERIMENTS receptacle (on the girth shelf).

6.3.1 OPERATIONAL USE.

When photographing activities or scenes outside the spacecraft with the 16 mm sequence camera, the COAS is used to orient the spacecraft and aim the camera. The camera will be mounted on the left sidewall handhold at a 90-degree angle to the X-axis and will be shooting out the left rendezvous window via a mirror assembly.

During rendezvous maneuvers with the S-IVB, the COAS can be used for alignment.

When the TV camera is mounted on the girth shelf for shooting out the right rendezvous window parallel to the X-axis, the COAS will be used for alignment. The COAS can also be used for backup for re-entry alignment and manual thrust vector control.

6.4 SPACE SUIT ASSEMBLY (GFP).

The space suit assembly (SSA) provides crewmembers with protective clothing and atmosphere for spacecraft command module environment. The assembly consists of a constant wear garment (CWG) and pressure garment assembly (PGA). For operational purposes, additional equipment is needed, such as communications and oxygen hoses. The equipment will be described in the two suit conditions: OFF and ON.

6.4.1 SPACE SUIT OFF OR SHIRTSLEEVE ENVIRONMENT.

During earth orbit, normal conditions (nondynamic) will allow the astronauts to remove the pressure garment assembly. The astronauts will wear an undergarment called the constant wear garment (CWG), a part of the space suit assembly. For communications, they will don a personal communications soft hat, connect it to a CWG adapter, and connect the adapter to an electrical umbilical which connects to the audio center.

6.4.1.1 Constant Wear Garment (CWG) (GFP).

The CWG (figure 6-5) is a one-piece, synthetic fabric garment for oxygen compatibility. It will be long sleeved or short sleeved. The short sleeve CWG has sleeve stiffeners. There are also pockets to hold radiation dosimeters. Around the mid-section are pockets for biomed preamplifiers. There are one or two cloth tabs (1 inch) near the chest to attach the cobra cable clip. An opening at the crotch is for urination and the rear opening is for defecation. A zipper up the chest allows easy donning and doffing.

The CWG can be worn for 6 to 7 days; therefore, a change will be needed. Each astronaut will wear a CWG under the pressure garment assembly. Three CWG's will be stowed in the left-hand equipment bay compartment CONSTANT WEAR GARMENT SANDALS. In the same compartment, three flight coveralls, one for each astronaut and three pair of weightless sandals, will be stowed.

6.4.1.2 Flight Coveralls (GFP).

Three flight coveralls will be stowed in the CHEB compartment, marked "CONSTANT WEAR GARMENT," for use while in shirtsleeve environment. The coveralls will be worn over the CWG, and will aid in keeping the CWG clean and the crewman warm.

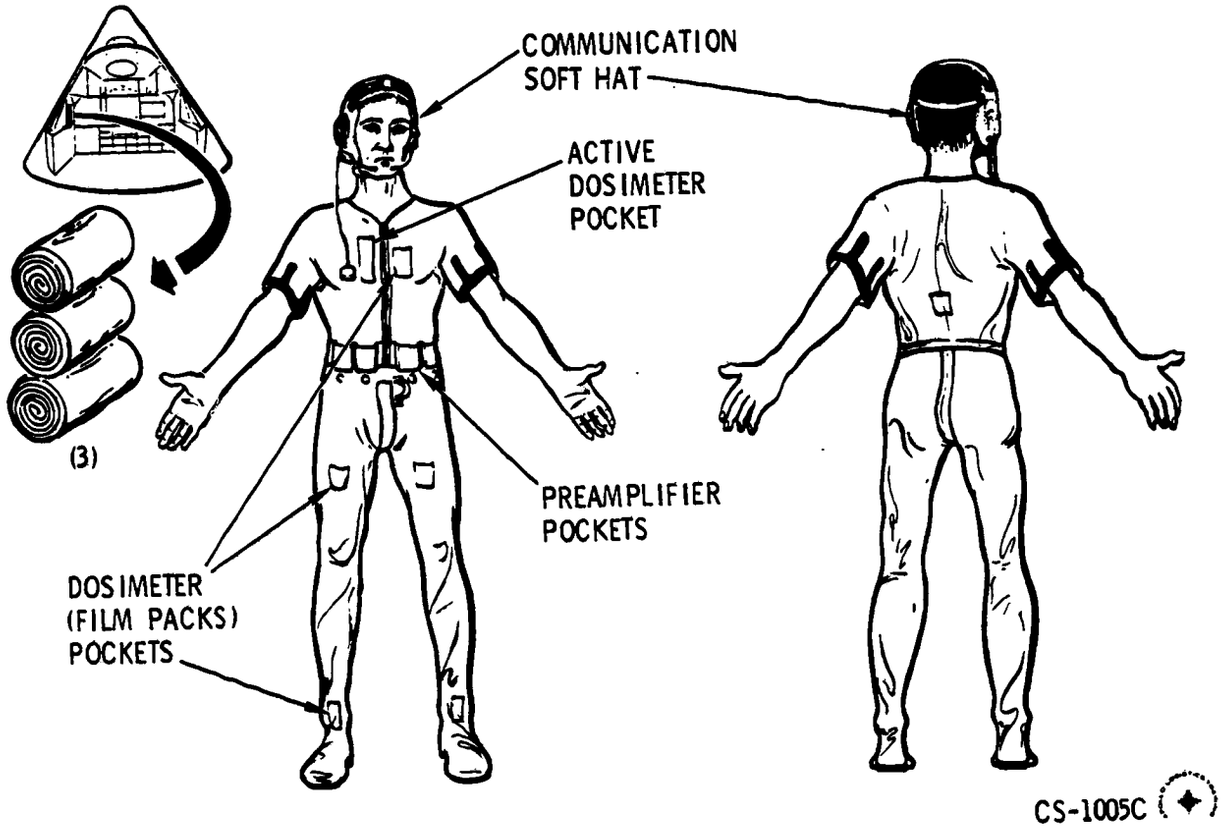


Figure 6-5. Constant Wear Garment (CWG)

6.4.1.3 Communications Soft Hat (GFP).

The personal communications carrier is a soft hat which supports communications equipment: redundant microphone/earphone sets and a connection to the audio center.

The microphones (voice tubes) have two positions: using and stowed. The stowed position is butted toward the forward edge of the helmet. The using position is in front of the mouth. Only one microphone needs to be used. The earphones will be in place over both ears all the time.

Three communications carriers will be stowed at launch and entry in the PGA helmet stowage bags on the aft bulkhead.

Three Lightweight Headsets will be evaluated during the mission and will share the soft hat stowage in the PGA helmet stowage bags.

6.4.1.4 Constant Wear Garment Electrical Adapter (CFE).

The function of the CWG adapter (figure 6-6) is to transmit the communications hat signals and the biomedical harness signals to the electrical umbilical or cobra cable.

The CWG adapter is a 37-pin connector which connects to the 21-socket connector from the communications soft hat. The nine-pin connector mates with the nine-socket connector of the biomedical harness connector.

Three CWG adapters will be required if all astronauts go shirtsleeve simultaneously. The three adapters will be stowed in the RHEB in a compartment marked ELECTRICAL ADAPTERS. The CWG adapter will timeshare the compartment with three PGA adapters.

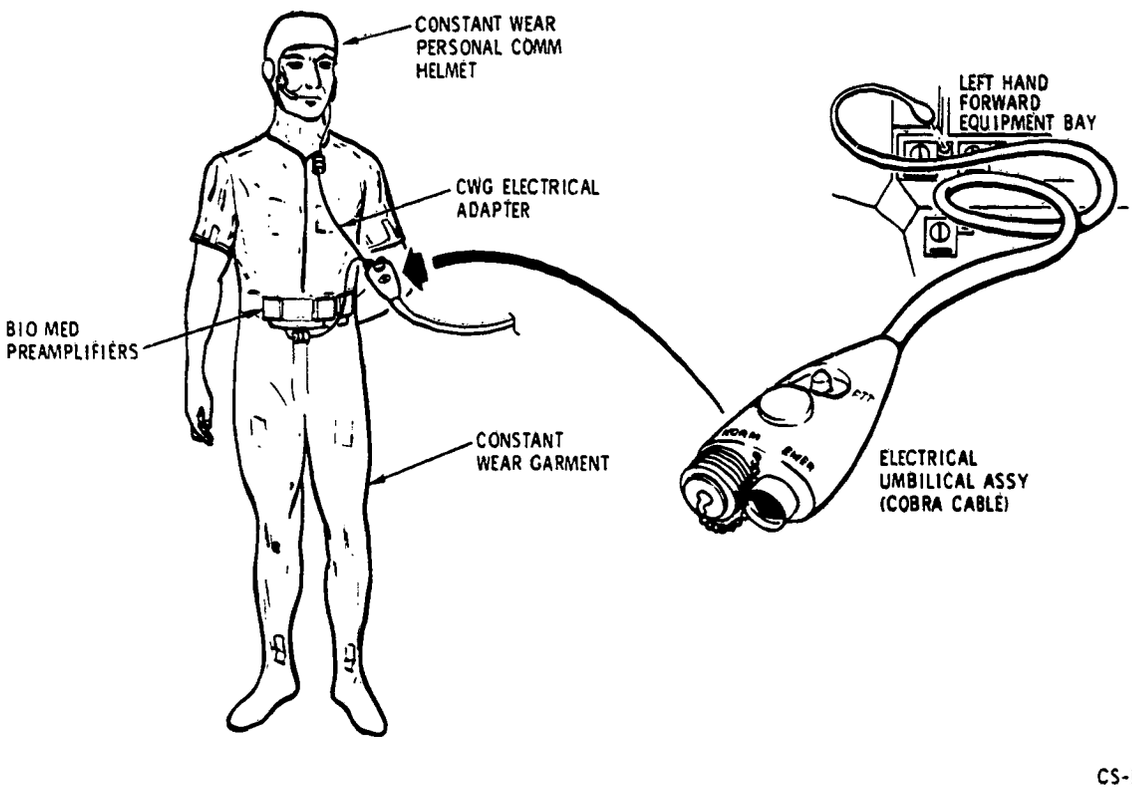


Figure 6-6. Personal Communications Equipment Connection, Block I (CWG)

6.4.1.5 Electrical Umbilical "Sleep" Adapter.

Two electrical umbilical "sleep" adapters will be stowed in the RHEB compartment marked ELECTRICAL ADAPTERS. The purpose of the "sleep" adapters is to eliminate voice communication signals passing through the caution/warning system, thus enabling uninterrupted sleep for two crewmen. The adapter, connected between the cobra cable and the CWG or PGA adapter, will play a pianissimo version of "Brahms Lullaby."

6.4.2 SPACE SUIT ON ENVIRONMENT.

6.4.2.1 PGA Unpressurized or Ventilated.

During launch, boost, entry, descent, and landing phases of the mission, the crew will be required to be suited. The crew will be fully suited but in the unpressurized or ventilated condition. That is, the cabin pressure will be 5 psi and the differential pressure of the suit will be a plus 2 inches of water or 0.072 psi. This is enough differential pressure to hold the suit comfortably away from the body. The oxygen will be flowing from the ECS suit loop, through the oxygen hose into the suit and returning through the return hose to the ECS suit loop. The cabin air is circulated about the cabin by the cabin air fans 1 and 2.

An alternate mode of ventilated usage is with helmet and gloves off, using neck and wrist dams. The gas circulation is the same, except the astronaut breathes cabin oxygen. This mode can only be sustained for 54 man-minutes out of 18 hours (1:20) because the cabin oxygen becomes saturated with water vapor which will condense on the structure. This is not a recommended mode.

6.4.2.2 PGA Pressurized.

The PGA (space suit) will not be pressurized except during an emergency. This condition will exist during a cabin depressurization. If out of the suit, the ECS can maintain 3.5 psi in the cabin for 5 minutes if the hole or leak is less than 1/2 inch in diameter. Therefore, donning the suit must take less than 5 minutes. When the suit is pressurized, the differential pressure will be a plus 3.7 psi in the suit. This condition constrains the body mobility. For this reason, it is normally not desired to be pressurized.

The crew will perform a cabin depressurization to demonstrate confidence in the spacesuit and proper function of the hardware.

6.4.3 PGA DESCRIPTION. (Figure 6-7)

6.4.3.1 PGA Components.

The PGA is a three-piece suit: torso, helmet, and gloves. It is manufactured by Clark Manufacturing Co. of Massachusetts.

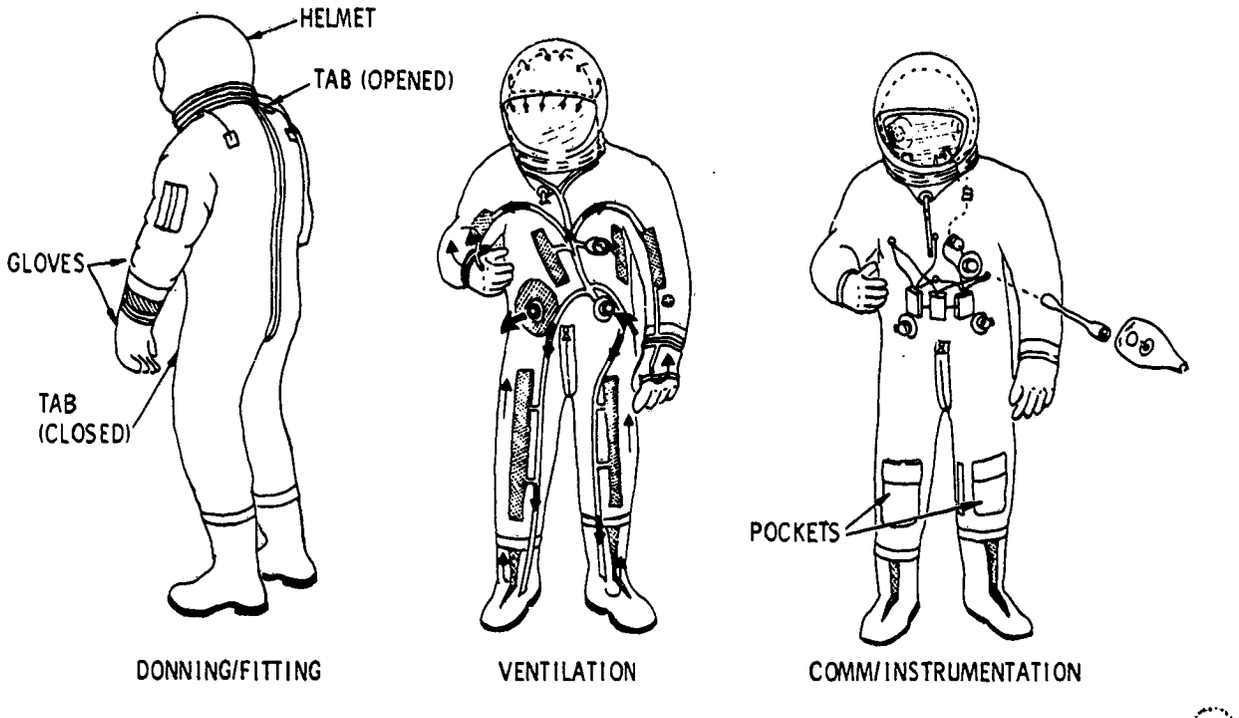


Figure 6-7. Apollo Block I Pressure Garment Assembly

Accessories of the suit are the neck and wrist dams, blood pressure cuffs, and urine collection bag. Operational use of the accessories is optional and will vary in accordance with the mission.

6.4.3.1.1 The Torso and Gloves.

The PGA torso has four layers. From the inside, the first layer is a combination liner and ventilation layer. The ventilation distribution tubes guide incoming oxygen to all extremities. The oxygen also passes through net openings to circulate around the astronaut. The actual cooling takes place as the gas flows from the extremities (higher pressure) to the return (lower pressure) over the CWG. The second layer is a pressure-tight layer, to contain the oxygen or the 3.7-psi operating pressure. The third layer is a restraint layer of strong netting to restrict bulging and enlarging so movement will be unimpared when pressurized. The last, and outside layer is a protective cover. There is a pressure line from the pressure

layer (2nd layer) to a surface pressure gauge to allow the astronaut to monitor the pressure. At the waist is an intake connector valve on the left and a return connector valve on the right.

The outside protective layer has pockets on the arms and legs. The arm pockets contain such articles as neck and wrist dams, handkerchiefs, and pencils. The leg pockets contain scissors.

The neck ring is an aluminum ring, and when mated with the helmet, has O-ring seals. Cables are attached to the neck ring to hold it down when pressurized.

The boots are attached to the legs by laces and are not airtight. A sock from the leg fits into the boot and is airtight. The boots will not be removed during the mission.

The gloves are attached to the arms with a ball race lock and are sealed with O-rings.

A zipper runs from the navel, underneath the crotch, and up the spine to the neck ring. The tab is by the navel when sealed (closed) and by the neck ring when opened. To assist the one-man donning, the tab has a 6- to 10-inch lanyard attached to it. The suit has the capability of one-man donning in less than 5 minutes. It can be donned by having the helmet and gloves attached or attaching them after donning the torso.

The communication and biomedical cables exit through a 61-pin connection at the left breast.

6.4.3.1.2 The Helmet.

The helmet is a plastic shell. It has a liner inside, ear cushions with earphones, and two microphones. On the outside, a visor is pivoted at the ears. A visor protective cover of thin plastic (Cycolac) covers the top of the helmet. A ring seal is at the neck. It will set in the torso neck ring and is held in place by a clamp.

To pressurize the suit, the visor (or faceplate) must be closed. It is rotated down across the face and presses against a seal, and is held in position by a clamp-latch.

6.4.3.1.3 Neck and Wrist Dams.

The primary function of the dams is postlanding sealing of the PGA during water activity.

The dams are wide rubber bands. The neck dam fits over the torso neck ring and around the neck. This keeps the sea water out of the suit. The helmet must be removed. When the gloves are removed, the wrist dams seal the wrists and the crewman will float in the torso.

An optional dam use during the mission would be to cool the body while in the suit with the gloves and helmet off. This is restricted to a short period of time as the crewmans respiration would produce an excessive CO_2 concentration. The comm helmet will be used for communications during this period.

6.4.3.1.4 Urine Collection Device (GFP).

During the standby, hold, launch, and boost phases, the crewman will be suited. A continuous suited period of 3 to 6 hours can be experienced so provisions must be made to urinate within the PGA.

The function of the urine collection bag is to collect and store 1200 cc of urine. There is an external catheter (roll-on) connected to the bag. The bag fits around the crotch and hips and is held into place by Velcro attached to Velcro on the CWG.

When mission operations permit, the suit is unzipped and the urine bag is removed. A valve on the bag will connect to the waste management system, and the urine will be dumped overboard.

6.5 PGA STOWAGE.

6.5.1 TORSO AND GLOVE STOWAGE.

The gloves will be left attached to the torso and stowed together. The PGA helmets will be stowed separately. The suit stowage bag is made of sage green, nylon cloth, 36 inches long, 20 inches wide, and can be expanded from 3 to 12 inches high. It has an aluminum rod frame to maintain the form. A partition separates the bag into two compartments. On the top are flaps held closed with Velcro. Three strips of Velcro loop are on the bottom to anchor the bag on three strips of Velcro hook on the aft bulkhead.

The two-PGA stowage area is beneath the commander's couch (left) on the aft bulkhead. An additional stowage bag is located beneath the head of the pilot on the aft bulkhead near the hatch between the LiOH cartridge stowage boxes and the sidewall. The suit stowage bag is similar to the two-suit bag.

6.5.2 HELMET STOWAGE.

The PGA helmets are stowed only during nondynamic periods, or zero g. Three helmet mid-course stowage bags are provided. The bags (GFP) are located on the aft bulkhead under the center couch.

6.6 PGA CONNECTING EQUIPMENT.

6.6.1 PRESSURE GARMENT ASSEMBLY (PGA) ELECTRICAL ADAPTER (GFP).

The PGA electrical adapter provides interface between the PGA and the cobra cable since the connectors are not compatible.

The PGA adapter is 18 inches in length with a suit interface of a 61-socket connector and the cobra cable interface with a 37-pin connector. There are three adapters.

When the suits are removed and stowed, the PGA adapters will be disconnected from the suit and stowed. They will replace the CWG adapters in the ELECTRICAL ADAPTER stowage compartment in the RHEB.

6.6.2 OXYGEN HOSE (UMBILICAL) (GFP). (Figure 6-8)

The function of the oxygen hose is to interconnect the PGA and the CM ECS.

The oxygen hose is a dual hose, each hose having an inside diameter of 1.25 inches and made of silicon rubber with spiraling steel wire reinforcement.

The ECS end has a double D connector while the suit end splits the hoses about 15 inches from the end. Each hose has an elbow nozzle to connect to the suit.

There are two hoses: one 72 inches long and one 81 inches long. A nylon strap is bonded approximately every 12 inches to restrain the cobra cable to the hose during suit operations.

The double D connector on the ECS end remains connected during the mission. The hose is routed behind the MDC and held in place by tie-down straps. When disconnected from the suits, the ends are routed from the rear of the MDC to the forward bulkhead and strapped. To prevent the incoming oxygen from being sucked into the return side and not into the cabin, the return nozzle will be capped with the oxygen hose return cap, which is attached to the hose with a lanyard.

6.7 CREW COUCHES.

The crew couches support the crew during acceleration and maneuvers up to 30 g's forward, 30 g's aft, 18 g's up and down, and 15 g's laterally.

The spacecraft contains unitized crew couches integrally bolted together in a unit structure.

The couches are designated one of three ways. Structurally, they are left, center, and right. By crew positions, they are 1, 2, or 3 or commander, senior pilot, and pilot (left to right).

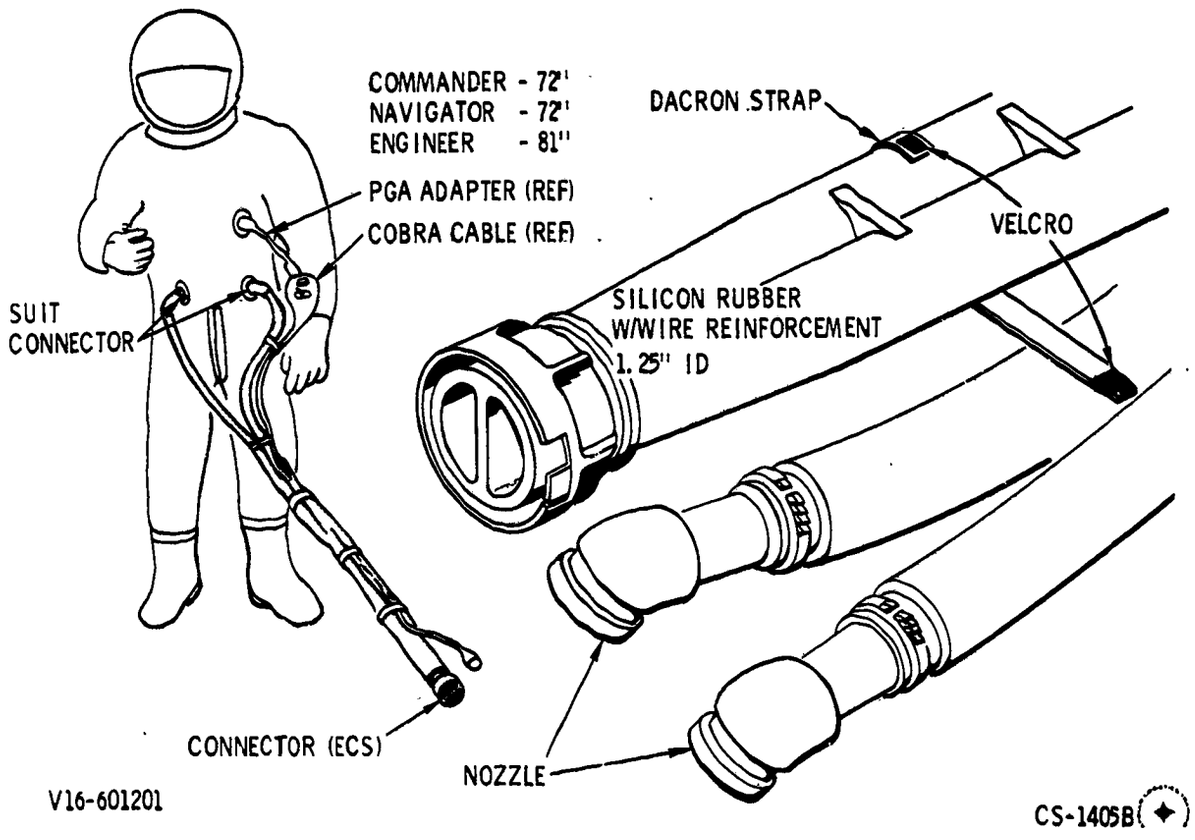


Figure 6-8. O_2 Umbilical Hose Assembly, Block I

6.7.1 CREW COUCH STRUCTURE.

The crew couch structure consists of three crew couches: the left, center, and right (figure 6-9). It is fabricated of aluminum and weighs approximately 400 pounds. The left and right couches are identical. The center couch connects the left and right couch into a single unified structure.

The couch structure, in a one-g environment, is supported by the impact attenuation struts: the four X-X struts from the forward bulkhead, the two Z-Z struts from the aft ring, and the two Y-Y struts in compression against the side panels. The X-X and Z-Z struts connect to the crew couch structure at the left and right couch main side beams...

The left and right couches are capable of the 170-degree position but will not be placed in that position because of equipment interference beneath those couches.

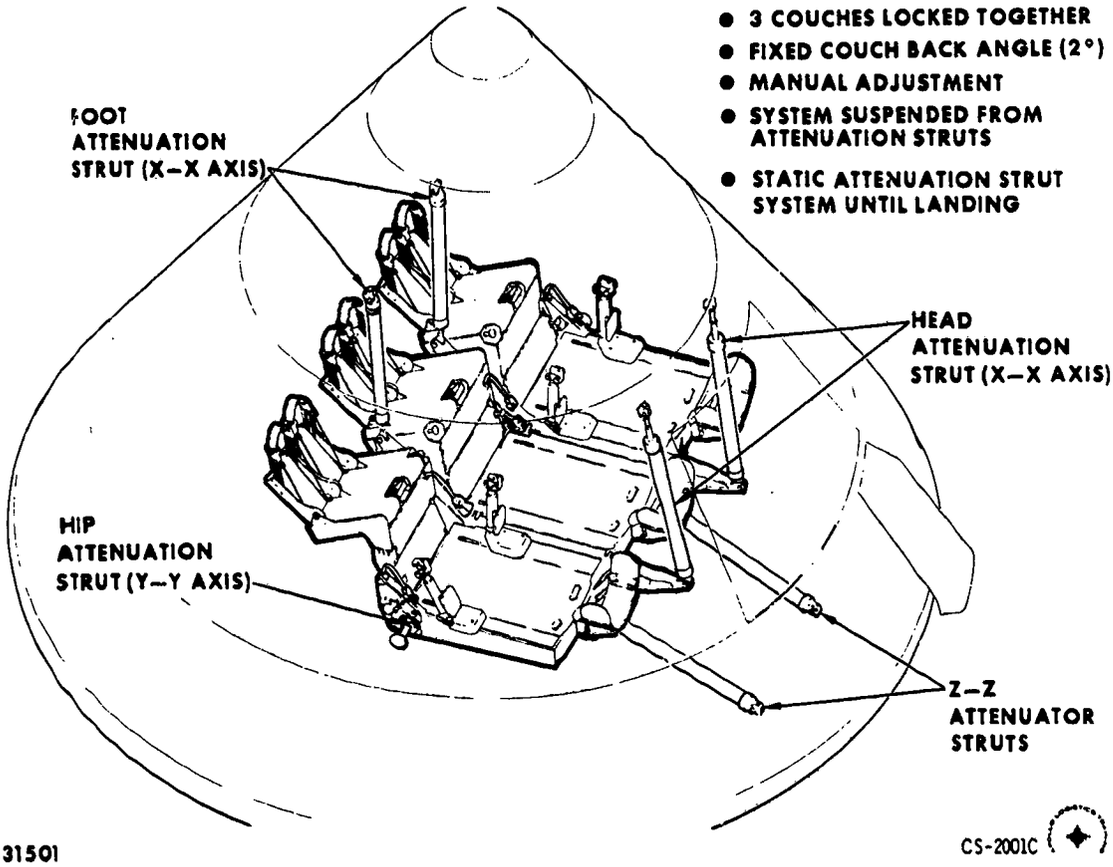


Figure 6-9. Crew Couch Installation

The additional LEB access/docking position will be used during orbit to gain room near the LEB. The seat pan angle remains 96 degrees while the couch structure (all couches) moves 6.5 inches toward the hatch.

6.7.2 CREW COUCH POSITIONS. (Figure 6-10)

6.7.2.1 Occupied Positions.

The most utilized position is the 96-degree position assumed for the launch, orbit, and entry phase. For a 50 percentile crewman, the hip angle is 108 degrees and very easy to assume. It gives maximum support to the body during high g loads.

The 170-degree or flat out position is used primarily for egressing from the center couch. All egressing to the LEB will be from the center couch. For this reason, the lower armrests are removed and stowed,

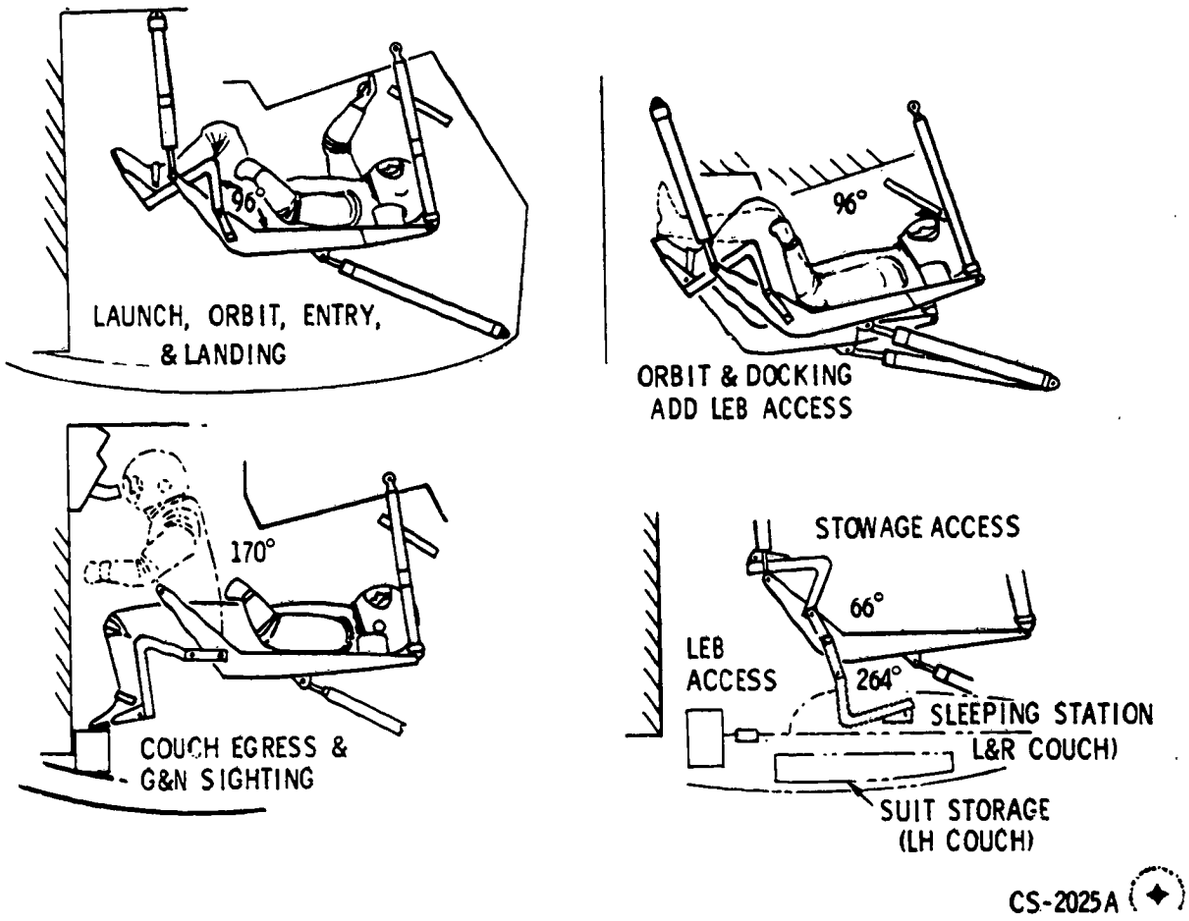


Figure 6-10. Crew Couch Mission Positions and Seat Angles, Block I

making easy egress from right and left couches into the center couch. Another use of the 170-degree position is G&N sighting. The 50 percentile crewman can position himself on the seat pan with his feet in the footrests and sight through the G&N eyepiece.

6.7.2.2 Unoccupied Positions.

The 66-degree seat pan angle position is used primarily for right and left equipment bay stowage access.

The 264-degree position necessitates rotating the seat pan under the backrest. This will clear the LEB area for maintenance activities. Due to restricted clearance beneath the left and right couches, this position is restricted to the center couch only. During use of the fecal canister, this is the desirable seat pan angle.

6.7.3 CREW COUCH COMPONENT DESCRIPTION. (Figure 6-11)

The crew couches are basically the same and the modular components interchangeable. The backrest assemblies differ the most because of the docking position mechanism in the center couch.

6.7.3.1 Headrest.

The headrest is constructed of honeycomb aluminum and has folding tips. It is padded on the inside and both sides of the tips. During maneuvers requiring PGA helmet restraint, the tips are left extended. For orbit and zero g, the tips are folded, affording freedom of movement for nominal visibility.

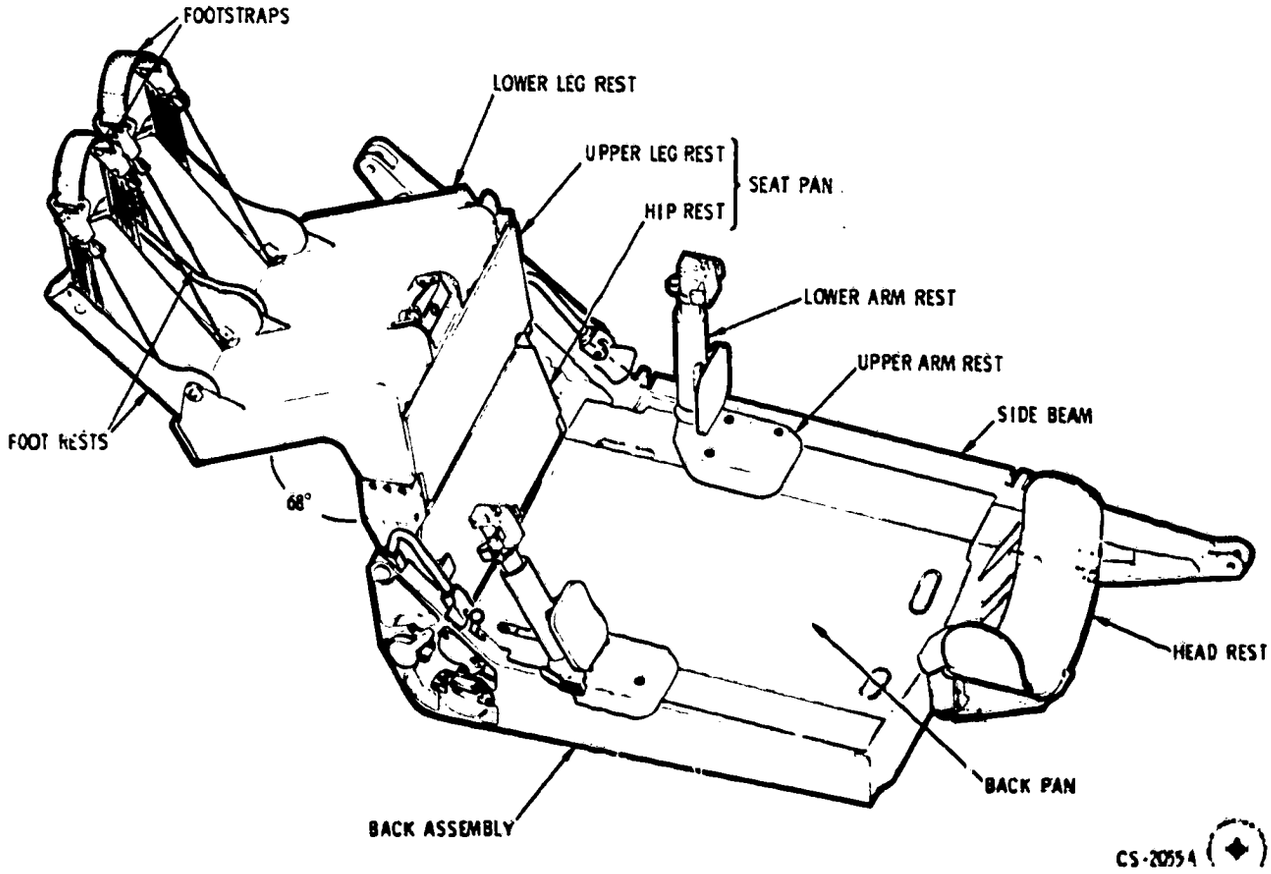


Figure 6-11. Left-Hand Couch Assembly (96-Degree Position)

The headrest has a 3-inch longitudinal movement for adjustment to crewman torso length. The headrest and support will fold under the couch for purposes of accessibility and ingress to the couches.

6.7.3.2 Backrest.

The backrest is constructed of ribs and beams covered with aluminum sheet and is 32 inches long and 22 inches wide. The left and right couch back pans are attached to the integral side beams, the inboard beam of which is 56 inches long and the primary structural member of the couch support.

The backrest assembly is contoured and contains the takeup reel system for the shoulder straps. The back pan is padded in the areas of crewman contact.

6.7.3.3 Armrests.

The armrests attach to the forward surface of the backrest and are adjustable. They consist of an upper and lower armrest. The upper armrest can be adjusted for length of arm and torso.

The lower armrest inserts into and is supported by the upper armrest at an angle of 90 degrees. It is secured by a leverized pin device for quick removal. A tubular shaft extends past the rest pad and contains the mounts for the controls. A major function of the armrests is to mount the SCS controls. The left couch left armrest has an adapter mount for both translation controls T1 and T2, and mounts at an angle of 120 degrees. All other armrests (3) mount at an angle of 90 degrees. The left couch right armrest supports a rotation control (R1). The center couch has no armrests.

On the right couch left armrest is a fitting to which the other rotation control (R2) can be attached for use by the center astronaut. By using an adapter, one translation control (T2) can be mounted for use by the right astronaut.

Normally, the right couch right armrest supports the second rotation control (R2). A third position for the rotation control (R2) is attached to the LEB G&N panel for use during navigational sightings.

6.7.3.4 Seat Pan and Footrest.

The seat pan and footrest has three components: the hiprest, legrest, and footrests.

The hiprest and upper legrest functions as a seat or seat pan. The lower legrest supports the lower legs, and the footrests support and restrain the feet. The hiprest makes an angle of about 170 degrees with the upper legrest, forming the seat pan. There are two pivot points: one at

the aft of the hiprest, and the other where the hiprest and legrest intersect. Part of the mechanism for positioning the seat angles at 96, 170, and 264 degrees is housed in the hiprest.

The lower legrest houses the mechanism for positioning the seat in the 66-degree angle and tightening or loosening of the footstraps. The upper legrest to lower legrest angle is fixed at 68 degrees. The footrests pivot so they can fold parallel to the lower legrest. Footstrap rotation bars are spring-loaded to the release position and are pulled to the restraint position by cables. The cables run to a reel that can be locked or released by a control in the lower legrest.

6.7.3.5 Crew Couch Pads.

The following portions of the couches have pads: headrest, back pan, armrests, and seat pan.

The padding is a triloc material 3/16-inch thick. It is structured of woven dacron wire-like fibers in a low-density pattern giving good ventilation.

The back pan and seat pan pads are composed of three layers of triloc covered with nylon netting, making approximately 1/2 inch of padding.

The armrest and headrest pads are 3/16-inch-thick layers between nylon netting covers.

The pads are attached to the metal surfaces with Velcro strips and can be removed during the mission if the need arises.

6.7.4 MECHANICAL ADJUSTMENTS. (Figure 6-12)

6.7.4.1 Headrest Adjustments.

To adjust the headrest for crewman height, turn the adjustment with the tool set 4-inch CPS driver. It has a 7/32-inch hex drive.

The headrest is folded down by pulling the headrest lock headward. The headrest is spring-loaded to the stowed (down) position so it should be restrained by the hand. To bring it up, pull with the hand; pull headrest lock handle back to clear the hook, position headrest in the normal position, and push the lock handle footward.

6.7.4.2 Armrest Adjustments.

The lower armrests are removed by pulling the armrest lockpin release outward to pull the pin, and then pulling the armrest upward to remove. The left couch right armrest and the right couch left armrest are stowed on the couch side beams by Velcro seats and straps.

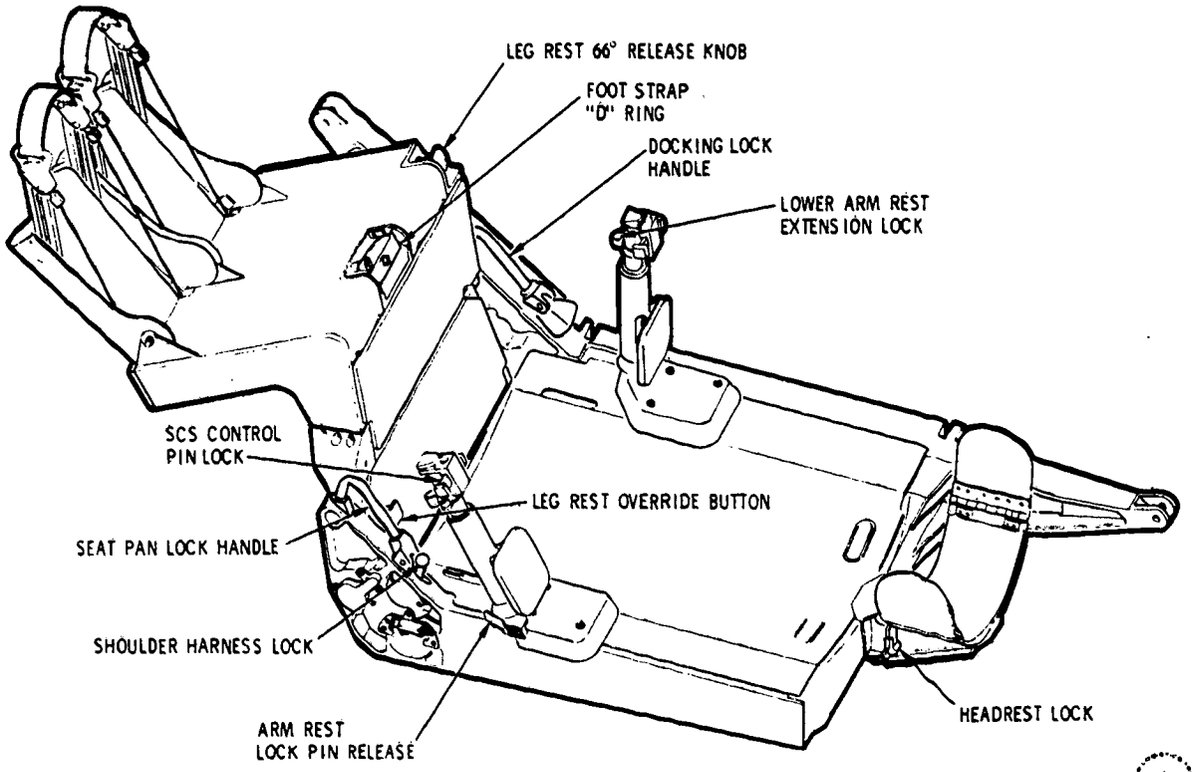


Figure 6-12. LH Crew Couch Operating Mechanisms, Block I

To attach SCS controls, push the SCS control pinlock to the left; slide the control on the dovetail; and push the lock to the right locking a retention pin.

The lower armrest can be extended by rotating the extension lock toward the left, extending the armrest and locking into position by pushing the lock to the right.

6.7.4.3 Seat Pan Adjustment Directions.

SPLH = Seat Pan Lock Handle

LRRK = Legrest Release Knob

LROB = Legrest Override Pushbutton

From (Deg)	To (Deg)	Procedure	Remarks
A 96	170	1. Lift the SPLH and push with feet. 2. Release the SPLM; continue pushing with feet until seat stops at 170°.	1. Key locking the leg pan will disengage. 2. Key on pivot cylinder will engage side beam keyway.
170	96	1. Lift the SPLH and pull with feet. 2. Continue lifting SPLH, pulling with feet until seat stops at 96°, release SPLH.	1. Key on pivot cylinder will disengage. 2. Key on pivot cylinder will engage side beam keyway.
B 96	264	1. Lift SPLH and rotate downward. 2. Continue to lift SPLH passing through 170° position. 3. Release SPLH and continue rotating until seat stops at 264°.	1. Key locking leg pan will disengage. 2. Maintains the leg pan pivot key in disengaged position. 3. Key on pivot cylinder will engage in 264° position slot.
264	96	1. Lift SPLH and rotate seat toward 170°/96° position. 2. Continue to lift SPLH, passing through 170° position. 3. Rotate to 96° position and release SPLH.	1. Leg pan pivot key disengages allowing rotation. 2. Leg pan pivot key maintained in disengaged position. 3. Leg pan point pivot key will engage 96° position slot.
C 96	66	1. Pull up with feet until 66° latch engages the side beam.	1. Disengages seat to hip-rest detent. 66° latch will drop in slot on beams and catch.
66	96	1. Press the LRRK with feet until 96° position is reached.	1. 66° catch disengages. On reaching 96° position, detent will engage.

6.7.4.4 Footrest and Footstrap Adjustments.

The footstraps are controlled by a footstrap D-ring (FSDR) between the astronaut's knees. The D-ring is connected to a cable that runs through a tube to a drum-axle-drum mechanism. By pulling on the D-ring and rotating the drum and axle, cables pull the footstraps to the restrained position. The drums have ratchets that lock the footstraps in position and retain the feet in the footrest. To release the footstraps, the FSDR is pressed, forcing the connecting tube to disengage the ratchet and release the footstraps.

6.7.4.5 D-Ring Handle Extension.

The D-ring handle can be reached easily while the PGA is unpressurized. However, when pressurized, the PGA slightly restricts the 90 percentile crewman from reaching the D-ring, thus making it difficult to lock or free the feet. The D-ring extension has been designed to connect to the D-ring handle. The extension has a 7/16-inch hex shaft to insert into the D-ring handle and control it (paragraph 6.10.10). It has a ball-lock feature to connect to the D-ring. The D-ring extension will be accessible on the right girth shelf.

6.7.4.6 Docking Position Adjustment.

The mechanism that releases the lock which allows the couch structure to slide to the docking position is located in the backrest of the center couch; however, the docking lock handle is on the right side beam of the left couch.

The forward end of the Z-Z struts attaches to the couch by a slide that runs in tracks in the side beams. A lever-lock device (finger latch) locks the slide in two positions: normal and docking. The lever-lock is spring loaded in the lock position. The docking lock handle (DLH) disengages the lever-lock only while the DLH is lifted. The couch structure must be pulled to the docking position by the center astronaut pulling on hand holds located on the side hatch.

When transversing to the docking position, the seats remain in the 96-degree position. The left crewman then lifts the DLH and the center crewman grabs a handhold and pulls the couches toward the side hatch. After movement, the DLH can be released. When the couches have moved approximately 6.5 inches, the lever-locks will drop into slots, locking the couches in place.

To return to the couch normal position, the DLH is lifted and the couches are pushed toward the LEB. The DLH is released and the lever-locks will drop into slots when in position.

6.7.4.7 Shoulder Strap Adjustment.

The shoulder strap takeup reels are on the couch backrest. They allow 10 inches of play and are locked by the shoulder strap lock on the left sides of the couches. A headward pull will unlock the shoulder straps, and a forward and down push will lock the shoulder straps.

6.8 CREWMAN RESTRAINTS.

The crewman restraints provide restraint and physical attachment to the astronauts.

a. In the couches during launch, weightless phases, abort, entry, and landing
b. During weightless periods while performing tasks out of the crew couch
c. While in the sleep position
d. When performing extra vehicular activities

6.8.1 HIGH G-LOAD RESTRAINTS.

6.8.1.1 Crewman Restraint Harness.

There are three restraint harnesses per spacecraft, one for each crewman.

The restraint harness consists of a lap belt and two shoulder straps interfacing the lap belt at the buckle. The harness is permanently attached to the couch and is not removable. The lap belt interfaces straps connected between the seat and back pans. This configuration provides adequate hip support (figure 6-13).

The shoulder straps pass through slots in the upper portion of the back pan and are connected to spring-loaded takeup reels fastened on the underside of the back pan. The takeup reel allows 10 additional inches of strap travel at maximum 10-pound pull. The crewmember can lock or unlock these takeup reels simultaneously by actuating a lever on the side of the couch.

The lap belt buckle is a lever operated, three point release mechanism. By pulling a lever, the shoulder straps and right lap belt strap will be released. The strap ends and buckle are equipped with Velcro patches and may be fastened to mating patches on the couch when not in use. This also prevents the buckle and attachments from floating free during zero g. Each strap can be individually tightened or loosened by the crewman (figure 6-14).

The maximum force on the harness straps will be 3115 pounds at the chests. The straps are dacron, 1-7/8 inches wide, and have a strength of 6000 pounds.

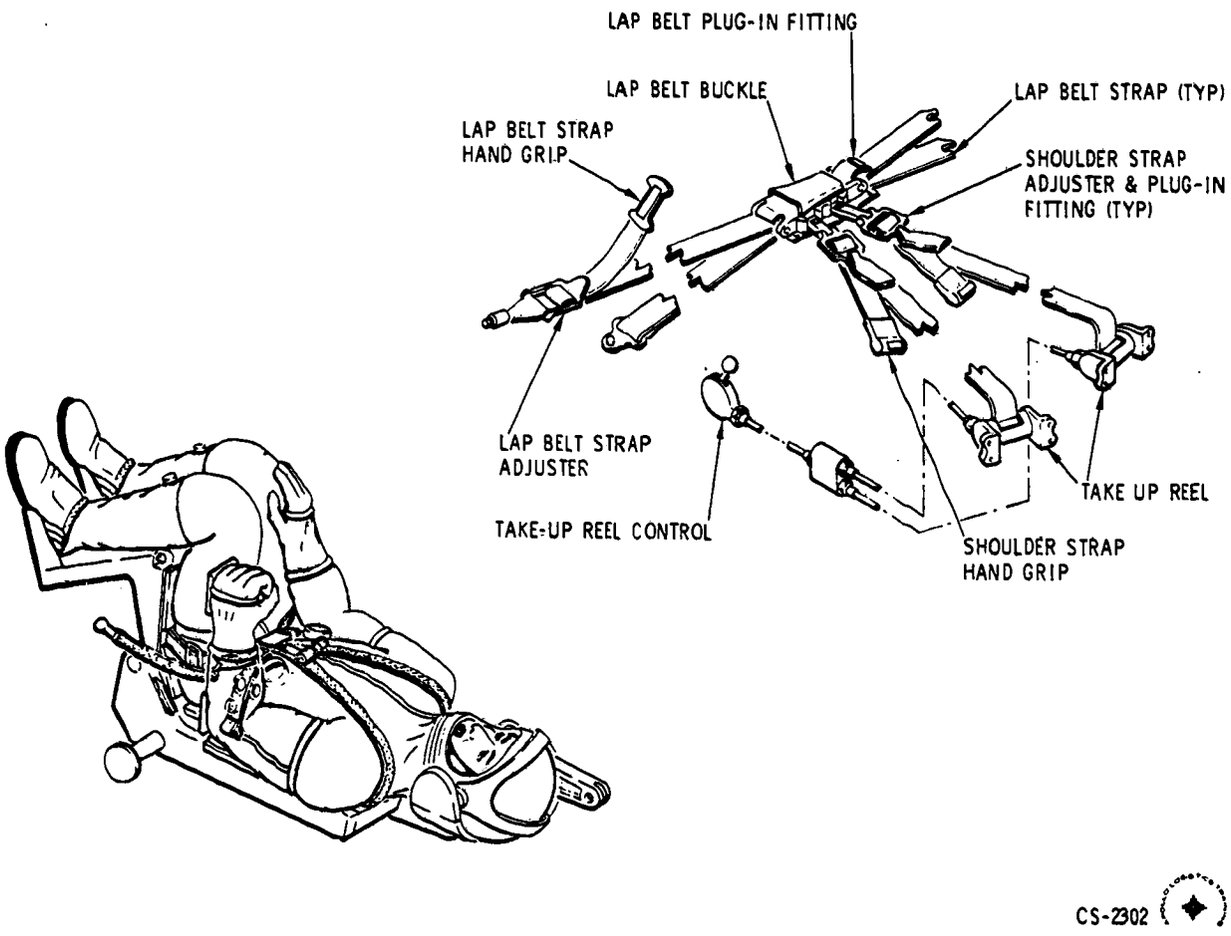


Figure 6-13. Crewman Restraint Harness Components

The harness will be on and locked during all maneuvers when g loads are expected such as launch, delta V, docking, entry, and landing. Securing in the couch prior to impact will include locking of the foot straps in addition to fastening of the harness. The harness can be tightened and loosened readily by the astronaut.

6.8.1.2 Weightless Restraint.

To assist the crew in egressing from the couch, five hand straps are attached behind the MDC (figure 6-15).

When out of the couch, the astronaut will restrain himself with handholds and Velcro foot restraints. Part of the aft bulkhead will be surfaced with Velcro hook material. The astronaut will wear Velcro pile material on the soles and heels of his PGA boots when in the PGA.

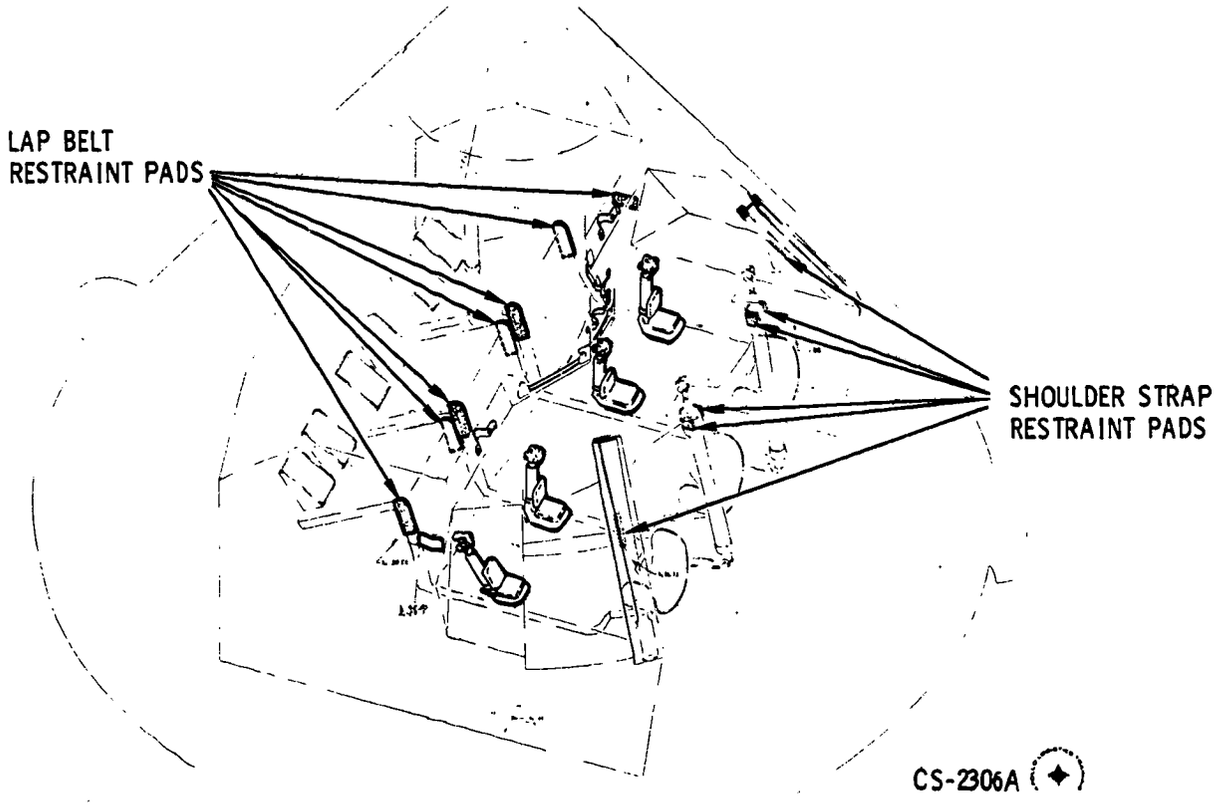


Figure 6-14. Restraint Harness Velcro Restraint Pads

Restraint sandals (figure 6-16) will be worn with the CWG. The sandals are fabricated of a flexible plastic Royalite PR55. Velcro pile material is bonded on the ball and heel of the sole. The sandal is held closed and on the foot by Velcro patches.

There are three pairs of sandals which are stowed in the LHEB with the CWGs and flight coveralls.

6.8.1.3 Guidance and Navigation Station Restraint.

Two positions may be utilized at the G&N station: standing position or center couch G&N position. The astronaut will restrain himself in the standing position by fastening his restraint sandals to the aft bulkhead and using a handhold on the left side of the G&N console.

The astronaut will restrain himself in the center couch at the G&N station by positioning the couch to the 170-degree hip angle and restraining his feet with the couch foot straps.

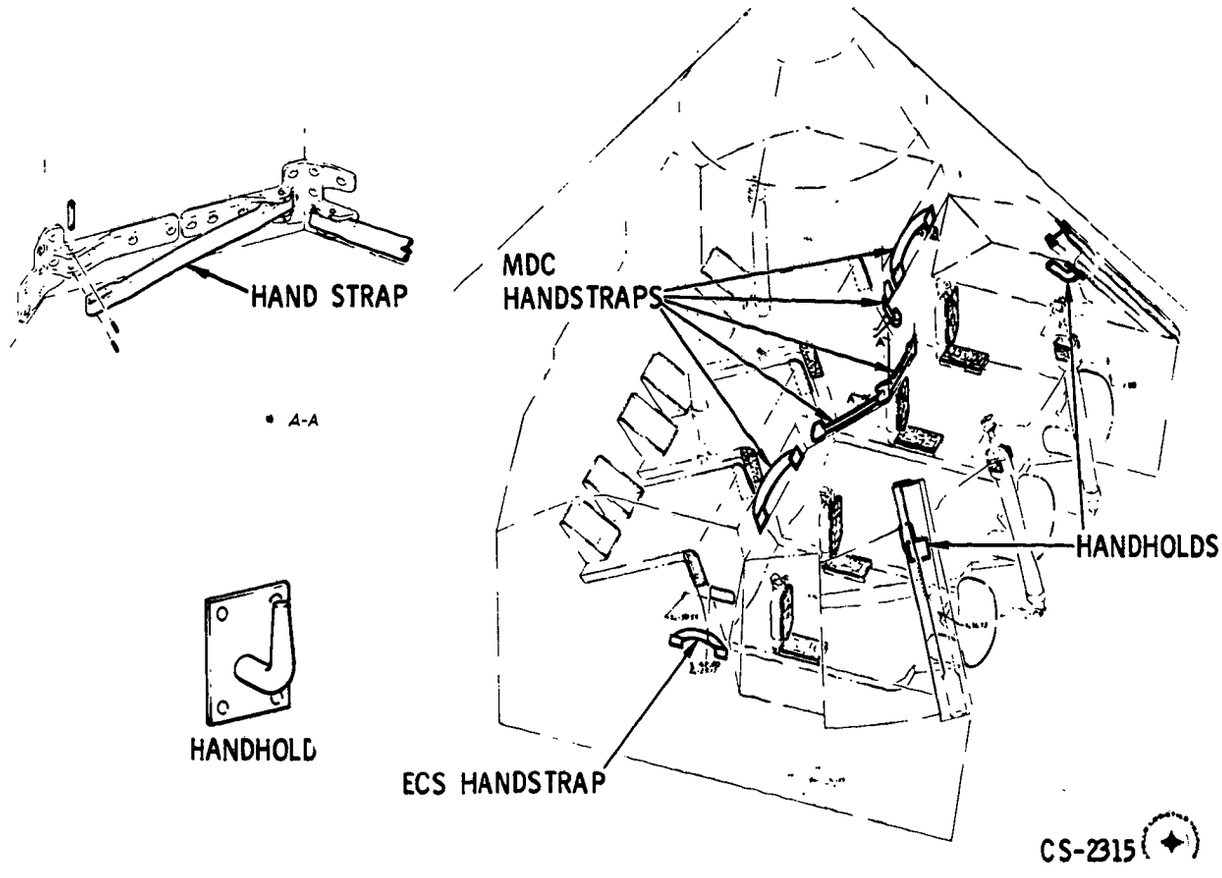


Figure 6-15. CM Interior Handgrips

6.8.1.4 Crewman Sleeping Restraints. (Figure 6-17)

The crewmen sleeping position will be under the left and right couch with the heads toward the hatch. He will be restrained in position by the crewman sleeping restraint.

The restraints (2) are dacron fabric, lightweight, sleeping bags, 64 inches long, with zipper openings for the torso and 7-inch diameter neck openings. They are supported by two longitudinal straps that attach to the LiOH canister storage boxes on one end (LEB) and to the CM inner structure at the other end.

The crewman will occupy the sleeping bag while wearing his CWG and communications soft hat, or lay on top if wearing his PGA. The cobra cable and "sleep" adapter will remain connected. One sleeping restraint will be stowed in each PGA stowage bag during boost and entry.

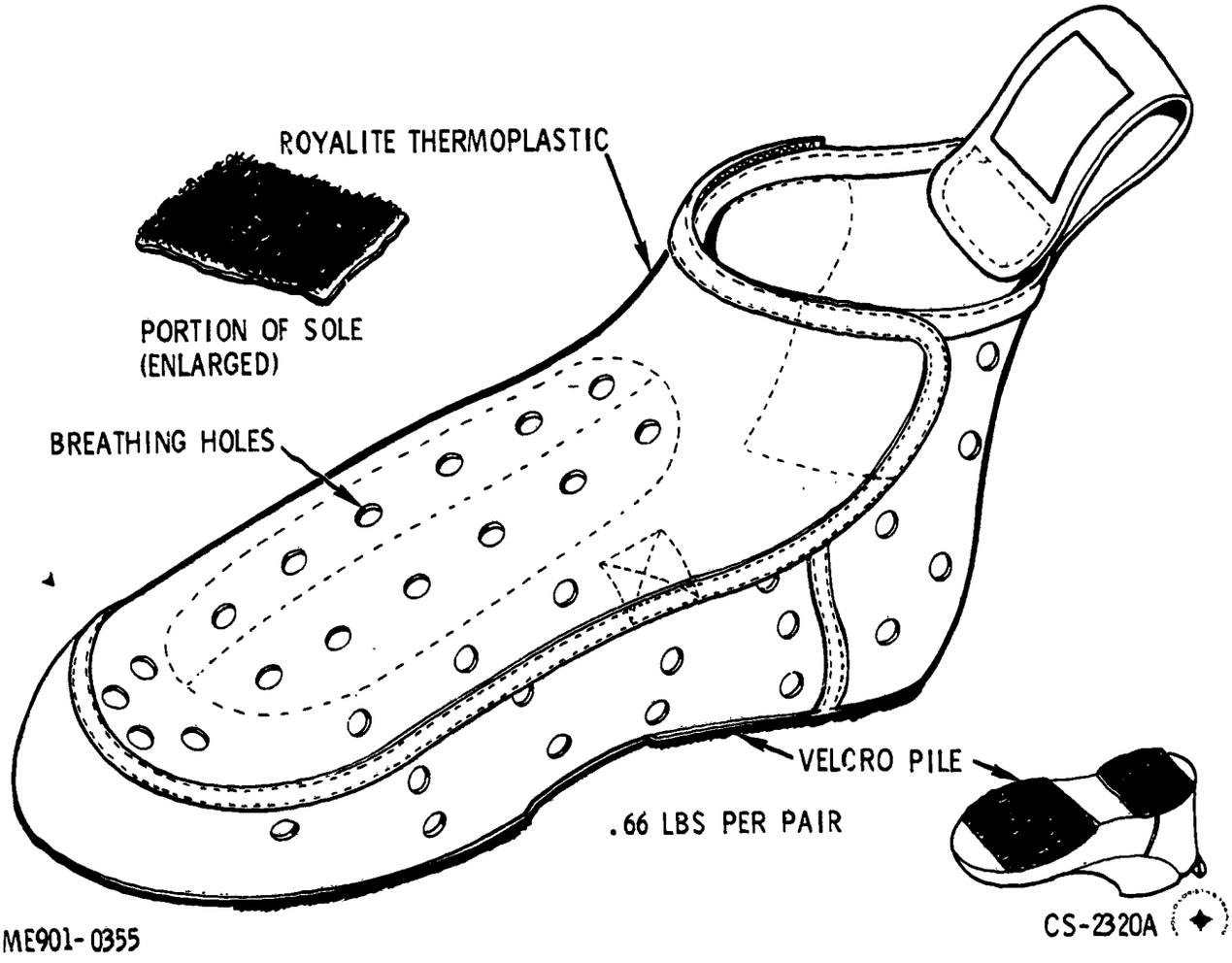


Figure 6-16. Weightless Crewman Restraint Sandal

6.9 FLIGHT DATA FILE (GFP).

The flight data file (figure 6-18) is a mission reference data file that is readily available to the crewman.

The data must be accessible to the commander and pilot in a pressurized suit while constrained in the crew couch. It must be available to the senior pilot at the lower equipment bay.

The flight data file contains checklists, manuals, and charts. The commander's and pilot's data file is stowed in nylon bags and the senior pilot's is stowed in a drawer container.

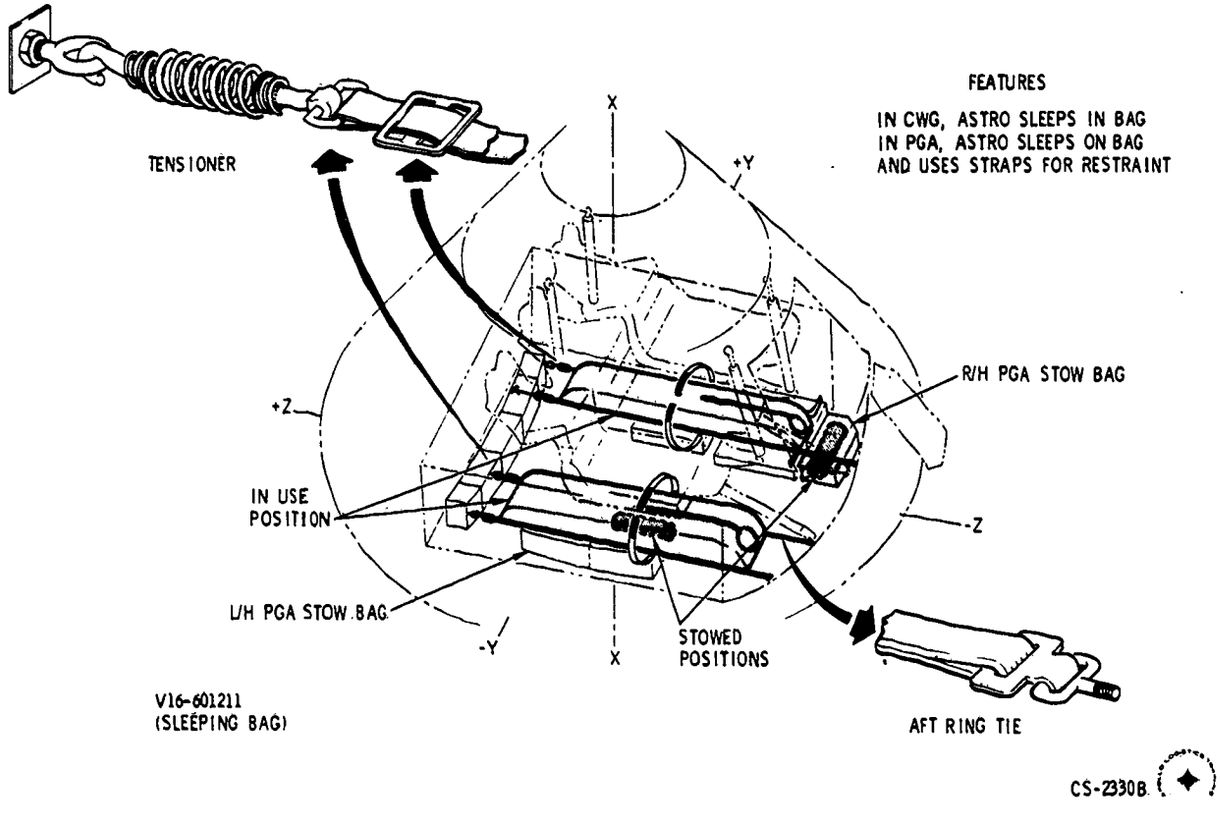


Figure 6-17. Sleeping Position Restraint Configuration

6.9.1 COMMANDER'S FLIGHT DATA FILE.

The commander's flight data file contains a commander's checklist, flight plan, and stowage bag. The stowage bag is nylon cloth material with pouches that close and are retain-closed by Velcro. A flap at the top is lined on the reverse side with Velcro attaching it to its stowage position. It is stowed on the left girth shelf near the commander's left shoulder.

6.9.2 SENIOR PILOT'S FLIGHT DATA FILE.

The senior pilot's data file contains a senior pilot's checklist, mission log and data, and stowage bag. The stowage bag is the same as the commander's except for the nomenclature. It is stowed on the right girth shelf near the senior pilot's left shoulder.

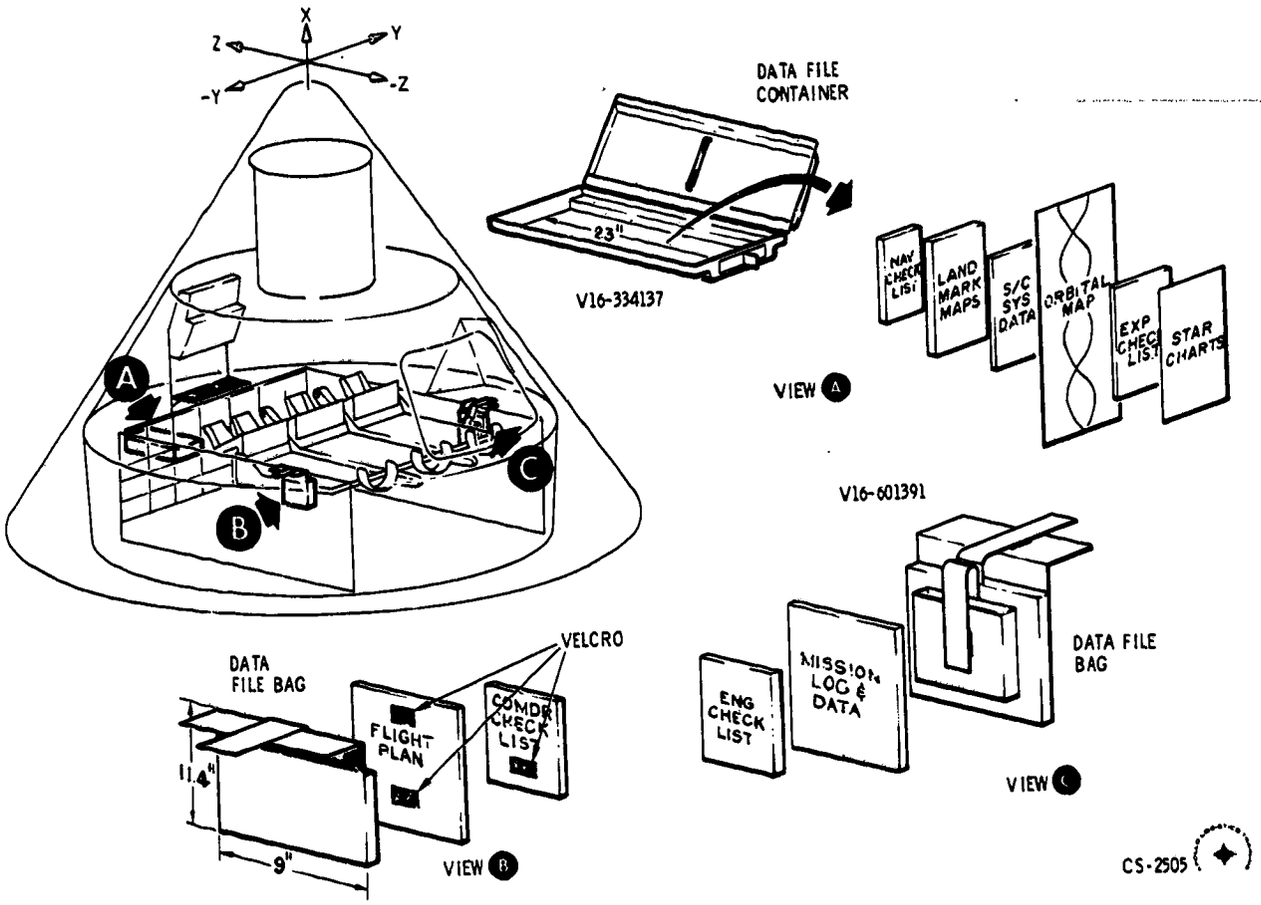


Figure 6-18. Flight Data File Configuration, Block I

6.9.3 PILOT'S FLIGHT DATA FILE.

The pilot's data file contains a pilot's checklist, landmark maps, star charts, S/C systems data, orbital map, and experiments checklist. Stowage is in a fiberglass container 23 inches long, 9.46 inches wide, and 1.75 inches deep. It has a hinged cover to contain the manuals when the container is removed from its stowage compartment in LEB. The container has nylon ribbon tab on each end to aid in pulling it out of the compartment. The compartment has a door with a simple bar latch to restrain the container.

6.10 CREWMAN IN-FLIGHT TOOL SET AND WORKSHELF (GFP).

The crewman in-flight tool set provides multipurpose tools and attachments for Apollo mission activities. The crewman in-flight tool set (figure 6-19) contains the following:

Torque wrench
Adapter handle
10" driver
5/32" short hex driver
7/32" hex driver
4" torque set driver
Emergency wrench
2 T-handles
2 end wrenches
20" tether
D-ring extension handle

Operationally, the tools are designated by a letter (A, B, C, D, etc.).

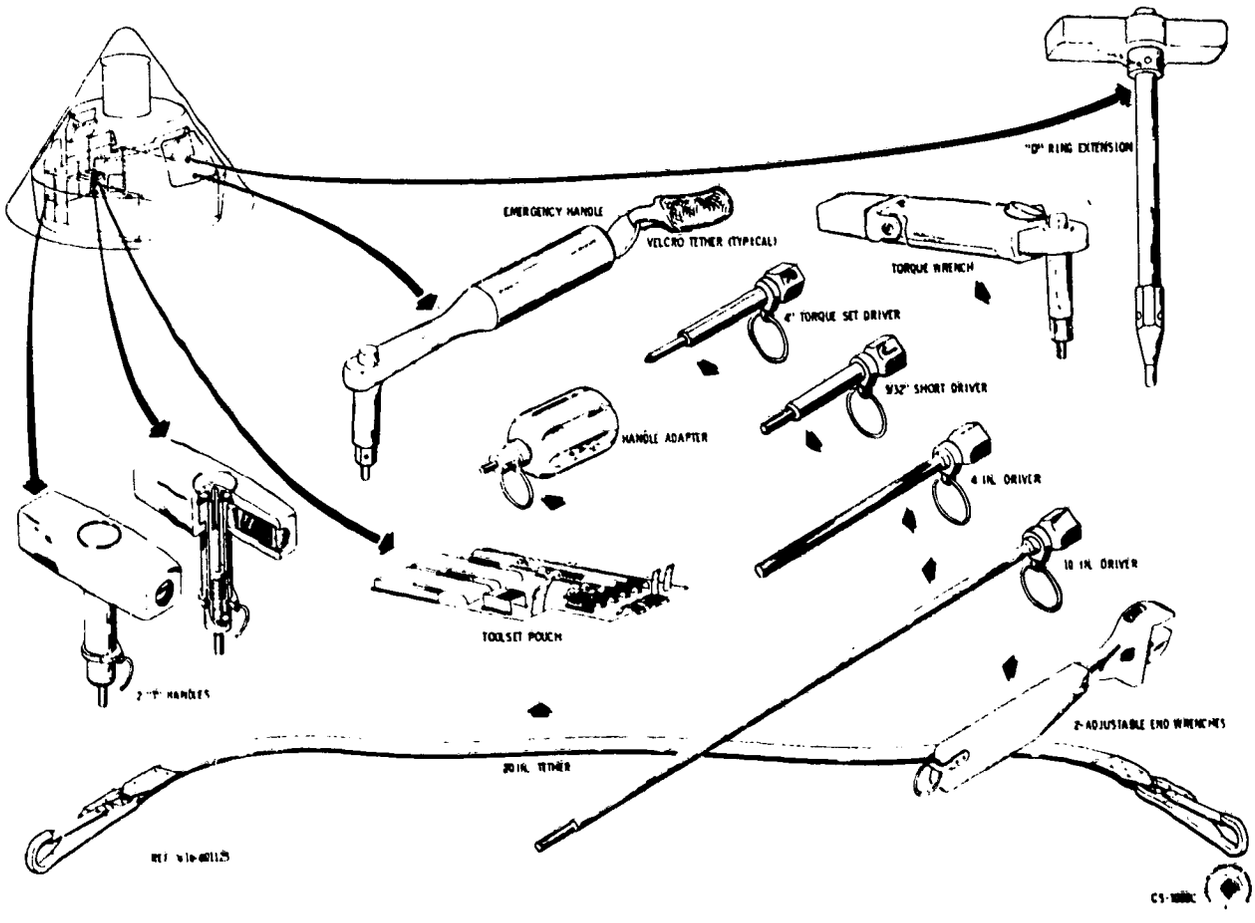


Figure 6-19. Crewman In-Flight Tool Set Configuration, Block I

6.10.1 TORQUE WRENCH (TOOL A).

The torque wrench has a torque limiting capacity of approximately 35 to 200 inch-pounds in the clockwise direction. It has a ratchet capability in the clockwise and counterclockwise direction. The pawl, which indicates operation, has three positions which are marked CW, LOCK, and CCW. The maximum torque capability in the LOCK position is approximately 400 inch-pounds.

The dual driving lug has a 7/16-inch hex male wrench with a ball-lock and a 5/32-inch hex male wrench. The drive lug fits all drivers. The pushbutton on top of the shaft controls the ball-lock which locks the drivers on. The lug reaches 2-1/4 inches beyond the face of the wrench.

Torque settings of 50, 100, 150, and 200 inch-pounds are calibrated and marked. The setting can be set by rotating the knob at the end of the handle and observing the bar in the slot on the underside of the handle. The following symbols indicate the torque values:

- ● = 50 inch-pounds
- + = 100 inch-pounds
- ◣ = 150 inch-pounds
- ■ = 200 inch-pounds.

6.10.2 ADAPTER HANDLE (TOOL E).

The adapter handle is approximately 3.5 inches long and 1.5 inches in diameter. It has a dual driving capability of 7/16- and 5/32-inch hexes and fits all drivers. A ball detent will assist in maintaining contact with the drivers.

6.10.3 10-INCH DRIVER (TOOL H).

All drivers have a 7/16-inch internal hex drive socket. The 10-inch driver is 11.125 inches long with a 10-inch shaft. The shaft end has a 5/32-inch hex drive.

6.10.4 4-INCH DRIVER (TOOL L).

The 4-inch driver is 5.125 inches long with a 4-inch hex shaft of 7/32-inch.

6.10.5 EMERGENCY WRENCH (TOOL B).

The emergency wrench is 6.25 inches long with a 2.5-inch drive shaft. The drive shaft has two hex drives: 7/16- and 5/32-inch. It is capable of applying a torque of 1475 inch-pounds and is a backup for the torque wrench. It has a ball-lock device to lock it in a drive. It is essentially a modified Allen head L-wrench.

6.10.6 T-HANDLE (TOOL C).

There are two T-handles per tool set. The T-handle is 2.75 inches long with an aluminum body. It has a 3/8-inch diameter ball-lock shaft with a 5/32-inch hex wrench. There is a torque break feature, calibrated by an adjustable screw at 35±5 inch-pounds, and then sealed. The ball-lock device is released by a pushbutton on the top of the handle.

6.10.7 END WRENCH (TOOL F) (2).

The adjustable end wrenches are a modified crescent wrench. It is very lightweight, made of aluminum, with an isotactic foam handle. The jaws openings width is from 1/4 inch to 1 inch.

6.10.8 5/32-INCH SHORT DRIVER (TOOL J).

The 5/32-inch short hex driver is 3.62 inches long with a 5/16-inch round shaft and a 5/32-inch hex drive of 0.7 inch.

6.10.9 4-INCH TORQUE SET DRIVER (TOOL R).

The 4-inch torque set driver has a No. 10 torque set on one end and a 5/16-inch driver on the other end.

6.10.10 IN-FLIGHT TOOL SET TETHER.

The tool set tether is a 20-inch strap with snaps at each end. Each tool has a tether ring or band to which the tether snap can be attached.

6.10.11 D-RING EXTENSION HANDLE (TOOL N).

The D-ring extension handle is a rod with a T-handle approximately 7 inches long. The rod end has a guide point tapering to a 7/16-inch hex about an inch long. Every other hex surface has a ball-lock. The T-handle has a pushbutton that controls the balls.

6.10.12 OPERATIONAL USE.

The in-flight tool set tools have multiple uses. Figure 6-20 is a matrix table for tool usage.

In the CM, items operated or adjusted by tools will have a small square placard nearby designating the tool (A through N and R) and the torque setting of the torque wrench. If the torque wrench is not used, just the designating letter (0.19-inch high) will be indicated.

The tool set is designated to be used either in the shirtsleeve environment or the PGA pressurized status.

6.10.13 STOWAGE. (Figure 6-19)

The tool set tools are stowed at various places. For launch and entry, some are stowed in positions ready for an emergency. During orbit, the tools are stowed in a location that affords easy access.

CREW PERSONAL EQUIPMENT

P = Primary Use
B = Backup
E = Emergency

Function (Designator)	Torque Wrench A	10" Driver H	7/32" Hex Driver L	5/32" Hex Sht Drvr J	Emergency Wrench B	Adapter Handle E	"T" Handle (2) C	Crank Handle D	Adj End Wrench (2) F	"D" Ring Ext. Handle N	4" Torque Set Driver R
A. Environmental Control System											
1. Open/close ECS valves on water (315) and O_2 panel (314). (LHEB)	B					B	P				
2. Close water-glycol accumulator isolation valve on panel 312. (LHEB)	P	P				B					
3. Unlatch/latch fasteners of ECU panel (313) over LiOH filter. (LHEB)	B	P				P					
4. Open/close water delivery device valve (304). (LHEB)	B						P				
5. Tighten fluid and gas line connections. (LHEB)									P		
6. Unlatch/latch fasteners of cabin atmosphere recirc. screen. (LHEB)	B	P				P					
7. Unlatch/latch fasteners (3) of access panel to coolant control panel (311). (LHEB)	B					P	P				
B. Guidance, Navigation, and Control System											
1. Unlatch/latch fasteners of "LOOSE PARTS STOWAGE" cover for G&N handles. (LHFEB)	B	P				P					
2. R/R G&N handles (2) on G&N panel. (LEB)	P					B					
3. R/R rotational control adapter on G&N panel (105). (LEB)	B	P				P					
4. R/R optics panel (104) cover. (LEB)	P					B					

Figure 6-20. Crewman In-Flight Tool Set Usage Chart (Sheet 1 of 2)

P = Primary Use B = Backup E = Emergency Function (Designator)	Torque Wrench A	10" Driver H	7/32" Hex Driver L	5/32" Hex Sht Drvr J	Emergency Wrench B	Adapter Handle E	"T" Handle (2) C	Crank Handle D	Adj End Wrench (2) F	"D" Ring Ext. Handle N	4" Torque Set Driver R
5. Adjust scanning telescope shaft and trunnion axis. (LEB)				P		P					
6. Wind/set GMT clock (panel 306). (LHFEB)				P		B					
7. R/R sextant short and long eyepiece from eyepiece.	B	P				P					
8. R/R scanning telescope short and long eyepiece from eyepiece assembly.	B	P				P					
C. Mechanical Systems											
1. Adjust crew couch headrest.	B		P			P					
2. Adjust couch upper armrest.	B		P			P					
3. Stow translational control adapter-center couch legrest.	B		P			P					
4. Open side crew pressure (inner) hatch from C/M.					E						
5. Open side crew heatshield/thermal hatch from C/M (Emer).					B						
6. R/R sea water access tube plug. (LHEB)	P	P				B					
7. Lock/unlock couch footstraps when PGA pressurized.										P	
8. Tighten/loosen mirror U-joints.											P
D. Mission Experiments											
1. Lock/unlock screws (2) of SCIENT EQUIP B drawer.	B	P					P				

Figure 6-20. Crewman In-Flight Tool Set Usage Chart (Sheet 2 of 2)

6.10.13.1 In-Flight Tool Set Stowage Pouch and Tool Set Drawer.

The tool set pouch is located in the tool set drawer on the LEB. The workshelf is stowed in the drawer on top of the tool set. The following tools are stowed in the pouch.

10" Driver
4" Driver
5/32" hex short driver
4" torque set driver
Adapter handle
2 end wrenches
Tether

The pouch is 21.25 inches long and 7.5 inches wide and is made of green nylon cloth. It has a small pouch with a retention strap for each tool and is marked with the tool name and designation. The tool set pouch is held to the drawer bottom by Velcro strips on the underside. The tether will be attached to a driver tether ring and laid in the drawer. The tool set drawer slides in and out on tracks and is held closed by a latch. In a corner of the drawer, a polyurethane block with a cutout for the torque wrench is located.

6.10.13.2 Miscellaneous Stowage.

The T-handles are stowed in the ECS panels at all times when not in use.

The emergency wrench is placed in the inner hatch latch mechanism for the mission. If it is needed, it can be removed and used.

The D-ring extension handle is stowed near the light fixture on the right girth, shelf-accessible to the pilot.

6.10.14 WORKSHELF ASSEMBLY. (Figure 6-21)

The workshelf assembly provides a table for food preparation and map/manual reading.

The workshelf is of aluminum sheet construction approximately 24 by 10.5 inches. At each end, there is a hinged support frame with slide latches. The shelf has two pivots so that it can be folded lengthwise, making storage easier. When stored, it is 24.5 by 6 by 1 inches.

The working top of the shelf is surfaced with Velcro hook material. Items that will be used in conjunction with the shelf will be equipped with Velcro pile material, facilitating zero-g restraint.

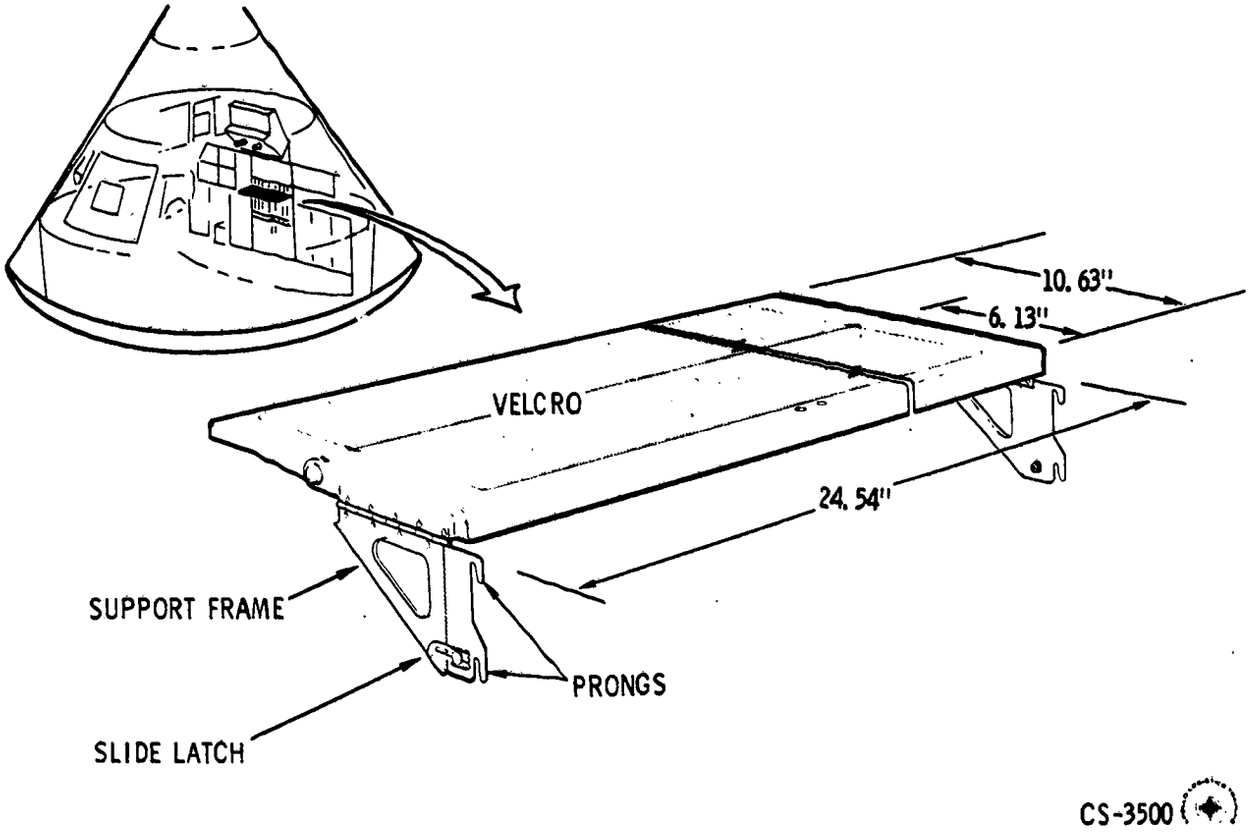


Figure 6-21. Workshelf, Block I

6.10.14.1 Usage.

The workshelf is stored in the lower equipment bay in the tool set drawer next to the flight data file storage. To remove, slide drawer out, lift, and unfold the shelf. Flip the support frames to the extended position and install on the lower bulkhead girth shelf below the G&N equipment by slipping the prongs into the slots. The prongs rest on small pins. Lock the shelf in by actuating the slide latch on each support frame. To remove, reverse the installation process and store.

The food packages and flight data manuals have patches of Velcro pile to interface with the workshelf surface.

6.11 DRINKING WATER SUBSYSTEM. (Figure 6-22)

The source of cold water for drinking is the water chiller. It is the same line that is routed to the cold water tap of the potable water tank. The crewman drinking water line is T'd off, routed through a shut-off valve, to the water dispenser located beneath the main display panel structure. It is handy to the left and center couch positions.

The water dispenser assembly consists of an aluminum mounting bracket, a coiled hose, and a water delivery valve in the form of a push-button actuated pistol. The pistol is GFE. It meters one-half ounce portions of water when the pushbutton is pressed. An accumulative counter is also on the side. It has a safety pushbutton to prevent discharge of water when passing the pistol from one crewman to the other. The uncoiled hose will

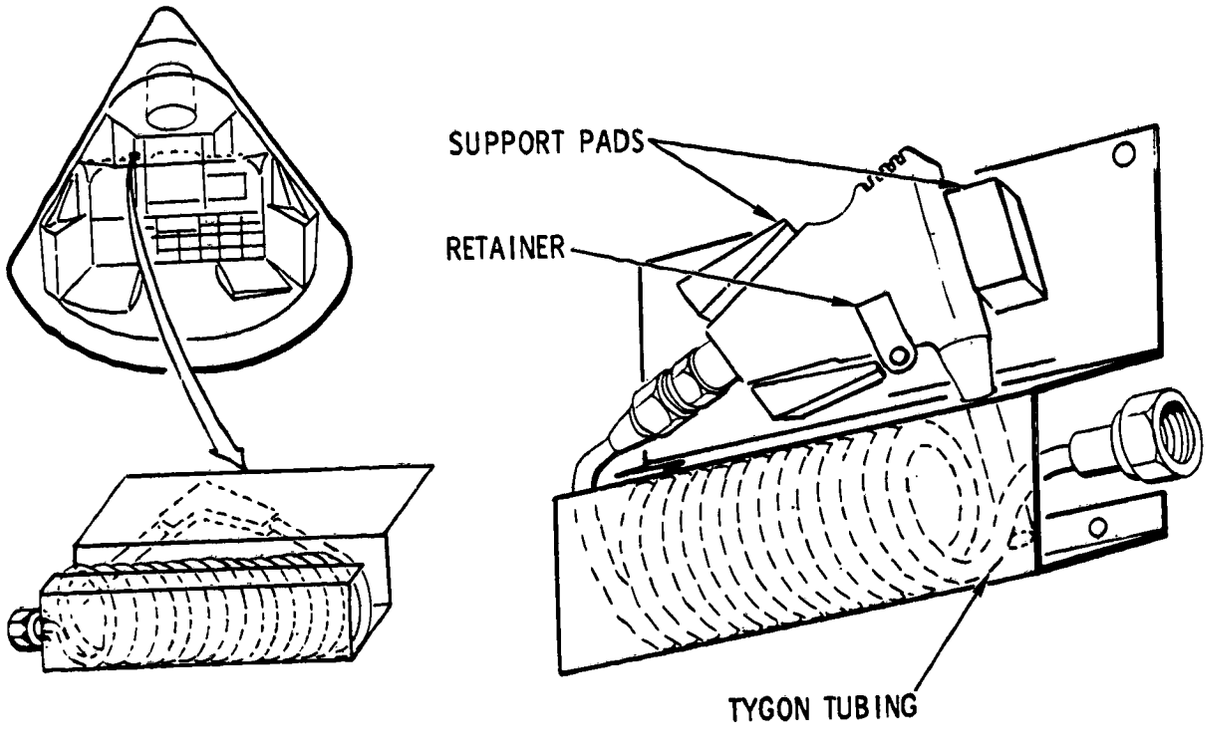


Figure 6-22. Crewman Water Dispenser Assembly

reach 72 inches. When the pistol is returned to the mount, the hose will re-coil into the housing. The pistol is stored in the mounting bracket and is held in place by a retainer.

During orbit, an alternate position is located on the MDC. The pistol is held in place by Velcro tabs.

6.12 FOOD.

The food furnishes a balanced diet of approximately 2650 calories per day to each crewmember. The astronaut's daily requirement for an earth orbital mission is 2650 calories. His daily intake will be 1.2 pounds of food, 6 pounds of water, and 2 pounds of oxygen. He will give off about 2.2 pounds of CO_2.

The food is in many forms such as dehydrated, freeze-dry, and bulk. It consists mainly of a highly nutritious and concentrated food. The food is packaged in plastic bags of a special design to allow food to be vacuum packaged. The food bag has a one-way poppet valve through which the potable water supply nozzle is inserted. The bag has another valve through which the food passes. The food bags are packaged in aluminum foil-backed plastic bags to make one meal for each astronaut. Breakfast, lunch, and snacks will be recycled every 4 days during the mission and the dinner every 8 days. The bags have red, white, and blue dots to identify them for the individual crewman.

6.12.1 USE.

The freeze-dry food is reconstituted by adding hot or cold water through a one-way valve on the food bag neck. It is then kneaded by hand for approximately 3 minutes. When the food is reconstituted, the neck is cut or torn off and placed in the mouth. A squeeze on the bag forces food into the mouth. When finished, a germicide tablet, attached to the bag, is slipped through the mouth piece, an ounce of water added, and the bag shook. The germicide will prevent fermentation and gas. The bag is then rolled as small as possible and returned to the food stowage drawer.

6.12.2 STOWAGE.

Food is stowed in three areas: the food stowage compartment in the lower equipment bay (LEB) on the left hand side, the auxiliary food compartment in the C/U-hand equipment bay (RHEB), and the food stowage compartment in the left-hand equipment bay (LHEB). Combined, they offer approximately 6,006 cubic inches of food storage volume.

6.12.2.1 LEB Food Stowage Compartment.

The food stowage compartment is structurally separate from the CM support structure and contains five bins and five drawers. The combined drawer volume is approximately 3725 cubic inches. The compartment is 23 inches high, 20 inches wide, 23 inches deep, and is constructed as a unit.

The top, bottom, right side, and shelves are 0.25-inch honeycombed aluminum sandwich. The left side is sheet aluminum 0.063-inch thick. The retainer doors are aluminum sheet and hinged at the bottom. The doors are latched at the top with latch bolts that pin into the side support structure.

The food stowage drawers are constructed of 0.020-inch-thick fiberglass: the largest weighs about 26 ounces. The end to be opened has a net closure held in place by Velcro providing easy access when the door is opened.

6.12.2.2 RHEB Auxiliary Food Compartment Drawer.

The auxiliary food compartment drawer is separate from the food stowage compartment and is located on the right-hand equipment bay. The volume is approximately 1000 cubic inches and its dimensions are 29 inches long, 10 inches high, and 10 inches deep.

The auxiliary food compartment drawer is a 3-ply, fiberglass box 0.030 inches thick. The front has a net closure hinged at the bottom and attached at the top by Velcro. It is supported structurally on an aluminum shelf and two sheet aluminum stops in the Z-Z direction. Its rear side fits against the inner structure face sheet. An aluminum door holds the drawer in and gives structural support.

6.12.2.3 LHEB Food Stowage Compartment.

The LHEB food stowage compartment has a volume of 1281 cubic inches. The food stowage drawer is a fiberglass drawer similar in construction to the other food drawers, with a net closure on the front. The drawer rests in the structure and is held in place by a sliding door.

6.13 PERSONAL HYGIENE (GFP). (Figure 6-23)

Personal hygiene items consist of an oral hygiene assembly containing a toothbrush and ingestible gum, wet and dry cleaning cloths, and towels.

6.13.1 CLEANSING OF TEETH - ORAL HYGIENE ASSEMBLY.

An effective method of cleansing teeth is Trident brand chewing gum. It is chewed and then swallowed. One stick is used after each of four meals per day. A stick is approximately 1 by 7/8 inch. To maintain healthy gums, a toothbrush for massaging by brushing is used. The brush also has a rubber prong on the handle for dislodging food particles.

These items are packaged in a one-man module to be used for a 14-day period. The module contains one toothbrush and 28 packs of gum. In each pack, there are two sticks giving a total of 56 sticks per astronaut. The module is stored in the first days food storage drawer to be used for the entire mission.

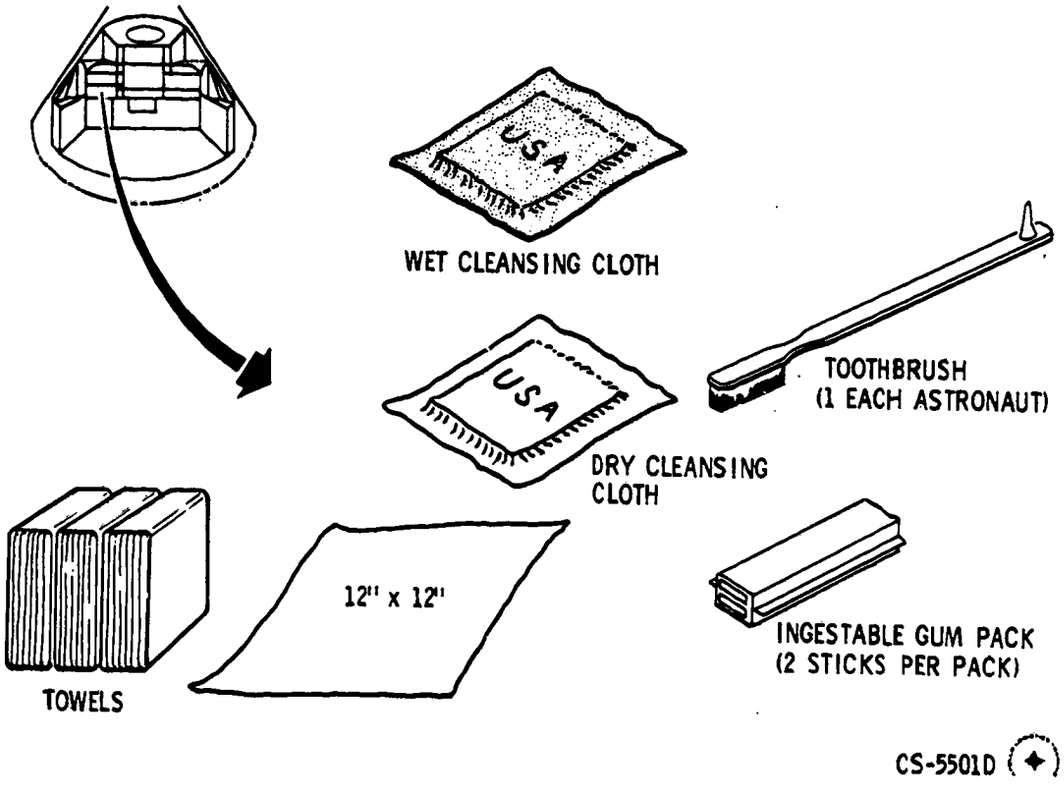


Figure 6-23. Personal Hygiene Items

6.13.2 WET CLEANSING CLOTH.

Wet cleansing cloths will be used for post-meal and post-defecation hygiene. The cloths are 4 by 4 inches folded into a 2-inch square and sealed in plastic. They are saturated with a germicide and water. The cloths for post-meal cleansing are stored, along with the dry cleansing cloth, in the food packages for easy accessibility. The post-defecation cleansing cloths (62 or more) are located in a sanitation supply stowage box.

6.13.3 DRY CLEANING CLOTH.

The dry cleaning cloths will be alternated with the wet cleansing cloths for post-meal cleanup. They are the same size and texture; however, they do not contain water and a germicide. They are also packaged with the food. There are 168 wet and dry cleansing cloths to be placed in the food packages.

6.13.4 TOWELS.

The towels will be used for utility purposes. There are 21, each 12 by 12 inches, and packaged in 3 plastic bags. One bag is stowed on the left couch, and two bags are stowed in the RHEB.

6.13.5 TISSUE DISPENSERS.

The cleansing tissues will also be used for defecation cleanup and utility use. There are nine tissue dispensers, seven are located on the back of the center couch, and two in other areas. They are mounted with Velcro.

6.14 MEDICAL SUPPLIES (GFP).

The medical equipment is used for the following:

- Monitor current physiological condition of the crewmen.
- Furnish medical supplies for treatment of crewman in-flight medical emergencies.

The medical equipment is subdivided into two functional types: monitoring equipment and emergency medical equipment. The monitoring equipment includes the clinical physiological monitoring instrument set, personal biomedical sensors instrument assembly, biomedical preamplifier instrument assembly, and the personal radiation dosimeters. There is also a bioinstrumentation accessories kit for spares. The emergency medical equipment is the emergency medical kit.

6.14.1 MONITORING EQUIPMENT.

6.14.1.1 Clinical Physiological Monitoring Instrument Set.

There is a requirement for periodic measurements of body temperature, blood pressure, heart beat rate, and respiratory rate to be logged by the crewman. This set of instruments will accomplish the measurements. The instruments include the following:

- Individual thermometers for body temperature measurements
- Aneroid sphygmomanometer for measuring blood pressure
- Stethoscope for heart beat measurement.

The physiological monitoring set is stored in the forward medical compartment of the LEB.

6.14.1.2 Personal Biomedical Sensors Instrument Assembly.

Constant monitoring of the heart beat and respiration is required. The sensors assembly automatically and continually senses these functions when the main display panel switch is positioned to the crewman to be monitored. The personal biomedical sensors instrument assembly consists of the following:

- Electrodes (silver silver chloride), 4 or more
- Accessories, such as paste and application tape.

The sensors will be used to gain the following:

- 2 electrocardiographs (ECG)
- Respiration rate.

The sensor assemblies are attached to the body of the astronaut at areas of sparse muscles (to reduce artifact level) by use of paste and tape, and remain throughout the mission.

6.14.1.3 Biomedical Preamplifier Instrument Assembly.

Because of their weak magnitude, the sensor signals have to be amplified before being telemetered. This function is performed by the preamplifiers (or signal conditioners). The preamplifiers are about the size of a cigarette pack and weigh about 100 grams. They operate on a source voltage of 16.8 volts, therefore one dc-dc converter. There are three preamplifiers which are to be used for the following measurements:

- ECG No. 1
- ECG No. 2 or phonocardiograph (uses same preamplifier)
- Respiration rate

The preamplifiers fit into pockets in the constant wear garment, circumferentially around the stomach diaphragm. Wire leads connect to the sensors, which act as electrodes. The sensors act as an electrode for one or more preamplifiers. The difference of resistance between two electrodes is measured. Muscle activity (breathing) changes the skin resistance and this change is measured and sent to the telemetry equipment. One electrode or sensor can be wired to more than one lead for a preamplifier. Each preamplifier will have a lead (to an umbilical) terminating with a connector. The connectors will plug into a larger common umbilical.

6.14.1.4 Bioinstrumentation Accessories Kit.

A kit of spares and possible use for additional scientific experiments will be located in the right-hand equipment bay on the kick ring adjacent to the LEB. The kit will have 35 sensors, 50 micropore discs, 8 wet wipe towels, and 1 tube of electrolyte paste.

6.14.1.5 Personal Radiation Dosimeters.

The crew will wear five passive dosimeters in the form of film packs in the CWG. One crewman will also wear an ionization chamber of the active type in his CWG. Personal dosimeter information will not be telemetered.

6.14.2 MEDICAL KIT (GFP).

The medical supplies are contained in oral drugs, injectable drugs, dressings, topical agents, and an inhaler. The content of the medical kit is as follows:

Oral Drugs

Drug	Use	No. of Tabs
Bismuth subcarbonate	Fever, pain reducer	24
Darvon compound 65	Fever, pain reducer	12
Globaline	Suppresses infection of gastro-intestinal system	50
Tigan, Bonodoxin, or Marezine	Anti-nauseant (6-man day treatment)	24
Dexedrine	Stimulant	12
Acromycin (250 mg)		24
Elective medication		9

Injectable Drugs

Drug	Use	No. of Units
Morphine Sulphate Demerol	Pain killer	3
Tigan, Bonodoxin, or Marezine	Anti-nauseant	3

Drug is contained in an automatic medical injector

Dressings

Item	Qty Reqd
Elastic bandage or compress (3" x 60") Bandaids (1" x 3")	2 12

Topical Agents and Inhaler

Item	Use	Qty Reqd
General purpose ointment, antibiotic	Skin irritations	2 (1/2 oz. tubes)
Benzedrex inhaler	Anti-nasal congestant	1

6.14.2.1 Packaging.

The medical kit is in a single package, accessible at all times during the mission. The package is approximately 4 by 5-1/2 by 4 inches and weighs 2.1 pounds.

6.14.2.2 Storage. (Figure 6-24)

The medical kit will be stowed on the back of the left couch lower leg support.

6.14.2.3 Medical Kit Additional Usage.

In the event the astronauts have to evacuate the command module during the recovery phase, the medical kit will be detached from the couch and carried by an astronaut.

6.15 SURVIVAL KIT (GFP).

There are two survival kits with three packages in each. One package contains three rafts; the other package contains water and miscellaneous survival equipment. They are readily accessible from the right-hand forward equipment bay by the right-hand seat occupant. The kits and containers weigh approximately 70 pounds. In addition to the survival kit, a sea water pump is provided. The pump is used after splashdown if the crew requires water and the onboard supply is exhausted.

6.15.1 STOWAGE.

The kits and the sea water pump are stowed in the right-hand forward equipment bay. They are inserted into the structural framework from the bottom and held in place by a quick-release bar retainer.

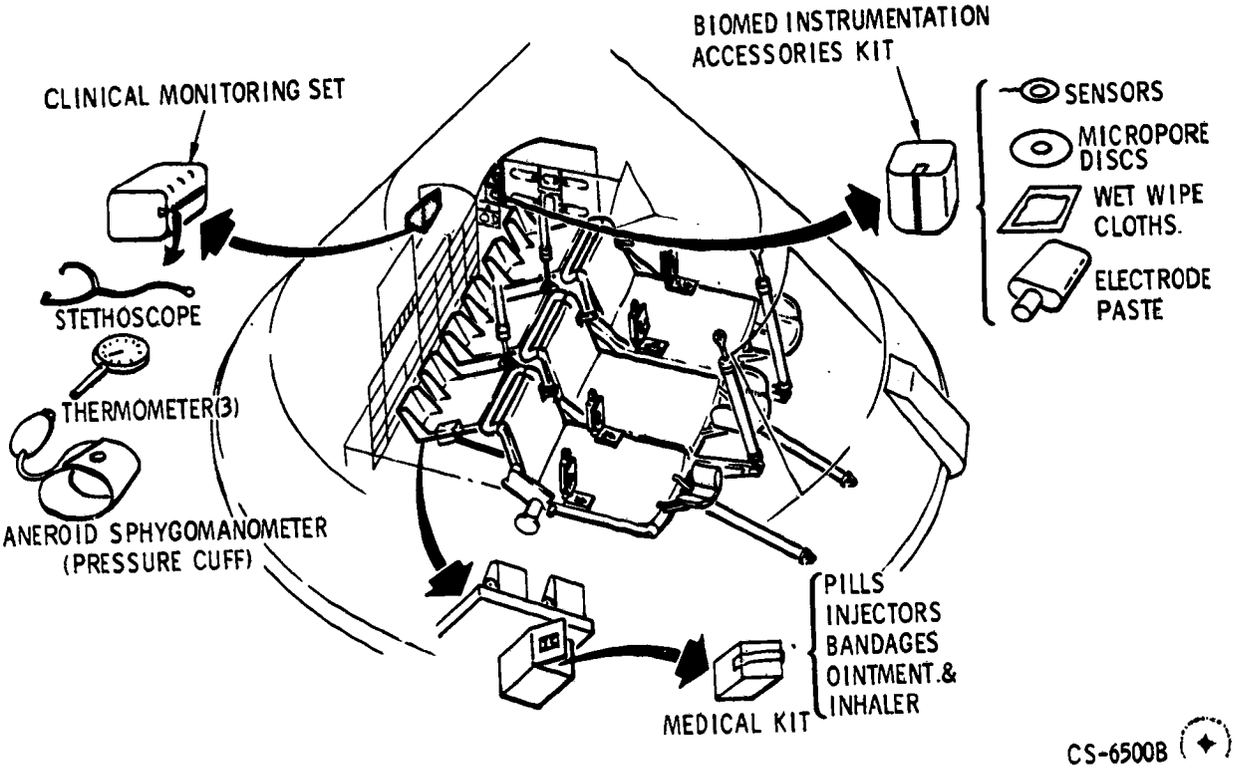


Figure 6-24. Medical Supplies and Equipment C/M Locations

The individual kits are contained in fiberglass boxes called a survival provisions container assembly (hereafter called a container). Thickness varies from 0.040 inch to 0.070 inch, and varies in ply from 4 to 7; a ply being 0.101 inch. One end is a cover and is attached by a breakaway hinge and locked close by a hinge and pin assembly. The cover has Dacron webbing straps that act as a handle. The weight and volumes are as follows:

Container	Weight	Volume
No. 1	5 pounds	0.90 cubic feet
No. 2	4.25 pounds	0.85 cubic feet

6.15.2 SURVIVAL KIT CONTAINER OPERATION.

After impact, and if the CM is damaged or sinking, it has been determined by the crew commander to evacuate, the pilot will release the survival containers by pulling a ring on the bar retainer. He will hand a container to each of the other astronauts. Two astronauts must retrieve the flight data mission logs. The side hatch is removed and the astronauts enter the water. In the water, container top is removed by (1) pulling hinge pin completely out and discarding and (2) rotating top against breakaway hinge until it falls off. Reach inside, pull out contents, activate the one-man raft and climb aboard.

6.15.3 CONTENTS OF THE SURVIVAL KITS. (Figure 6-25)

Container No. 1 contains two cloth pouches. One pouch contains three aluminum containers, each with 5 inches of water. The second pouch contains the following:

Survival radio with battery
Survival radio battery
2 combination survival lights
3 survival glasses
2 survival knives
2 desalting kits with 16 tablets

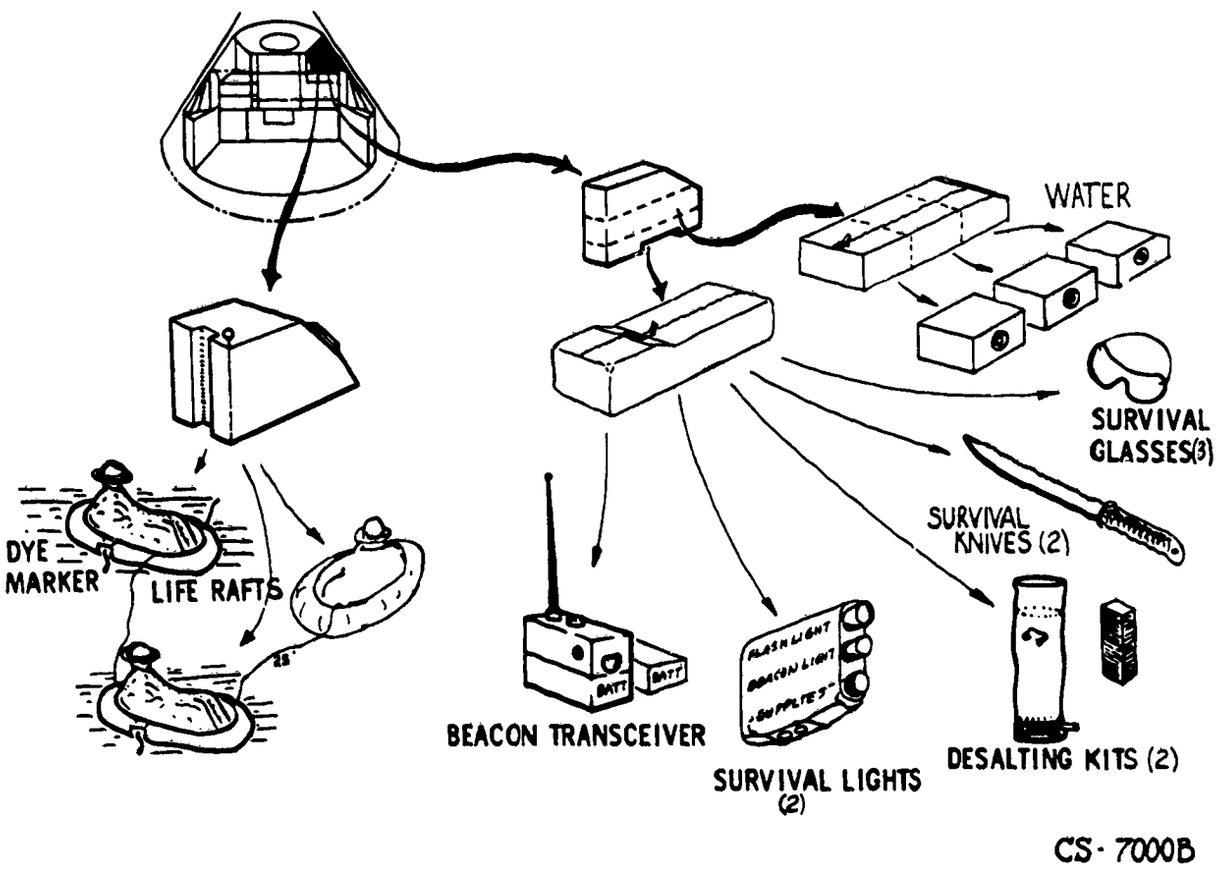


Figure 6-25. Apollo Survival Kit and Components, Block I

Container No. 2 contains one pouch with three one-man liferafts tethered together with 25-foot tethers. The pouches open by use of zippers and have lacings on the bottom to adjust the fit.

6.15.4 DESCRIPTION AND USE OF SURVIVAL KIT COMPONENTS.

6.15.4.1 Liferafts.

The liferafts are of lightweight nylon or mylar and inflated with CO_2. Each has a sea anchor, sponge pad, sun bonnet, tether, and sea dye marker.

6.15.4.2 Beacon/Transceiver.

The UHF beacon/transceiver is a hand-held, battery-powered radio, fixed-tuned to a VHF frequency of 243 mc and manufactured by Sperry Phoenix Company. The radio consists of a receiver-transmitter assembly, a battery pack assembly, and a quarter-wave antenna (figure 6-26). The receiver-transmitter assembly and battery pack assembly mate to form a watertight unit measuring 8 by 4-1/2 by 3 inches. The antenna is an 11-1/2-inch-long tapered, flexible steel tape, terminating in a coaxial RF connector, and is normally stored in a retaining spool and clip on top of the radio unit.

The radio is capable of line-of-sight operation in either of two modes (beacon or voice) through use of either its own antenna or a suitable

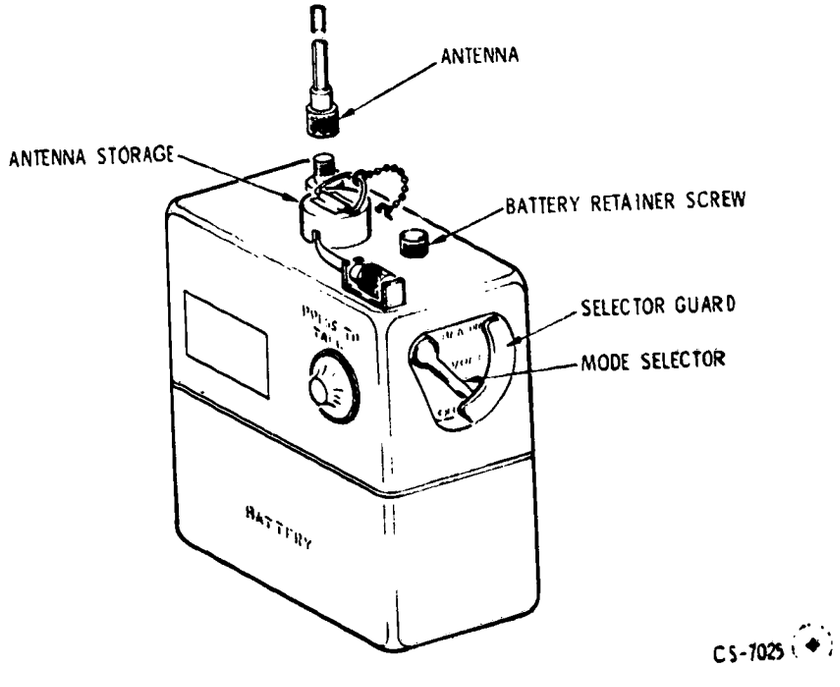


Figure 6-26. Survival Beacon/Transceiver Radio

connected remote antenna. The transmitter output is protected against damage while operating due to accidental shorting of the antenna or submergence of the unit in salt water. In the beacon mode, the transmitter operates unattended, for periods up to 24 hours, to transmit an interrupted 1000 cps tone, amplitude-modulated 25 percent on the 243 mc RF carrier. In the voice mode, the radio provides two-way AM voice communication through use of an integral speaker-microphone and push-to-talk switch. An extra battery is included in the pouch.

The following is a summation of the operating characteristics:

Characteristic	Voice Mode	Beacon Mode
Average power output	1.2 watts into a 50-ohm resistive load	2 watts into a 50-ohm resistive load
Frequency	243 mc carrier. 300 to 3000 cps voice signal	243-mc carrier, 1000-cps signal
Modulation	90-percent maximum	25 percent
Duty cycle	Continuous when PUSH-TO-TALK switch is pressed	2 seconds on 3 seconds off
Receiver sensitivity	10 db signal plus noise-to-noise ratio with 7.5 microvolts signal on antenna	

6.15.4.3 Survival Lights (2).

The survival light is a three units in one device as it contains three compartments. The whole device is waterproof. The controls for the light are on the bottom.

The first unit is a flashlight. The second unit is a strobe light for night signaling. The third unit is a waterproof compartment containing a fish hook and line, a "sparky" kit (striker and pith balls), needle and thread, and whistle. The top of the unit is a compass and on one side is a signal mirror that folds flat to the case.

6.15.4.4 Survival Glasses (3).

For protection of the eyes against the sun and glare, three survival glasses are included. They are a polarized plastic sheet with Sierra Coat III, a gold coating that reflects heat and radio waves.

6.15.4.5 Survival Knives (2).

The survival knives are protected with a cloth sheath. The knives are very thin with razor edges. The back edge is a saw.

6.15.4.6 Water Cans (3).

One pouch contains three aluminum water cans, one for each crewman. The cans have a drinking valve and hold 5 pounds of water.

6.15.4.7 Desalting Kits (2) Plus Tablets (16).

The desalting kits are plastic bags with a filter at the bottom. Approximately one pint of water is put in the bag and one tablet added. The water is desalted after approximately one hour.

6.15.4.8 Emergency Medical Survival Kit.

In the event the medical kit cannot be retrieved before egress, an emergency medical survival kit is in the survival kit. It contains 6 band-aids, 6 injectors, 30 tablets, and one tube of all purpose ointment.

6.15.5 SEA WATER PUMP (CFE). (Figure 6-27)

The pump assembly contains an intake check valve, a discharge check valve, and a 3-inch-diameter bellows, which is operated by means of a fingerhold and extends 1-1/8 inches from a 2/5-inch compressed thickness.

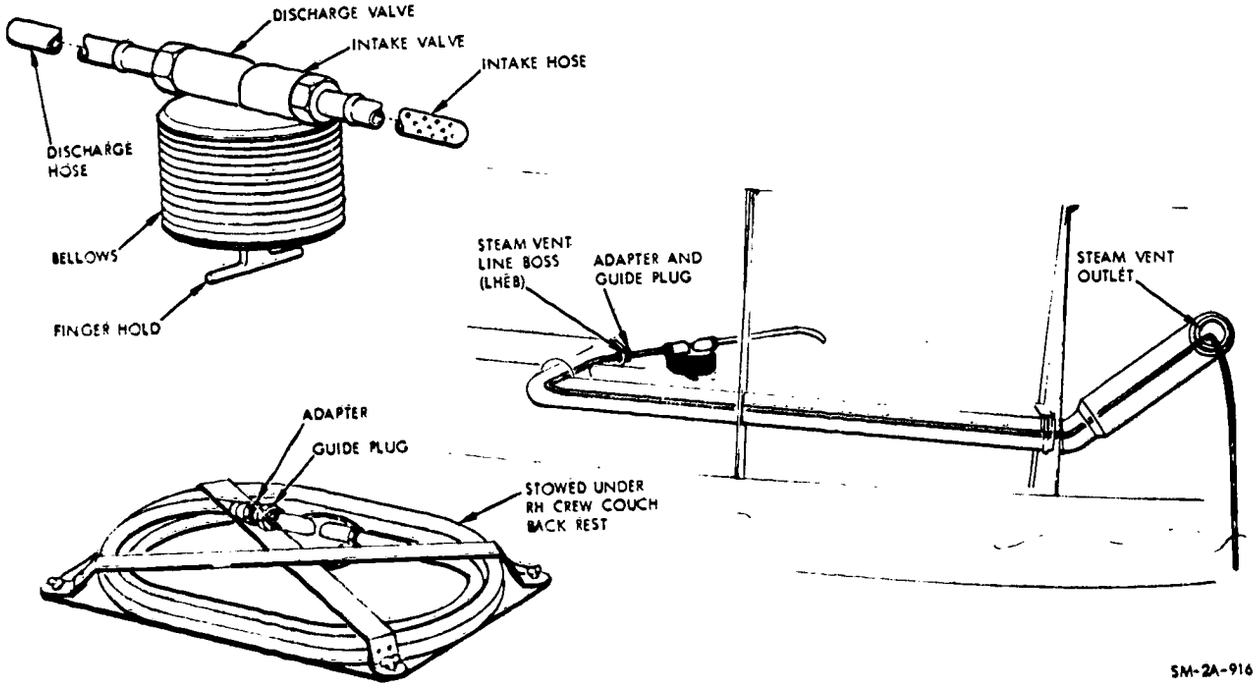


Figure 6-27. Sea Water Pump

A 10-foot-long plastic hose, fitted with a guide plug and an adapter, is attached to the intake valve; a 1-foot-long hose is attached to the discharge valve. To use the pump, the plug is removed from the steam vent hose located just forward of the aft bulkhead in the LHEB; the adapter on the intake hose is threaded into the boss; and the perforated end of the intake hose is fed through the guide plug into the steam vent, along the vent about 5 feet to the vent outlet, and through the outlet into the sea. The guide plug is then tightened into the adapter to form a seal around the hose, and the bellows is extended and compressed to pump water from the short discharge hose into the desalting kit bag. The pump is packaged in a semiflexible plastic container and stowed on the backside of the RH couch position legrest.

6.16 STOWAGE.

The numerous activities of the crew make housekeeping very important. All loose equipment must be stowed during launch and boost. Prior to entry, loose equipment must be stowed for entry and landing. Figure 6-28 defines S/C 012 stowage locations for equipment.

SECTION 7

SYSTEM SCHEMATICS

NOTE This section will contain a brief description of each system, utilizing charts, flow diagrams, and schematics. Information for this section will be provided at a later date by MSC.

Sections 8 through 11 will be submitted at a later date.

APPENDIX A

SYMBOLS AND DEFINITIONS

AB	Aft bulkhead
A/C	Audio center
ACCEL	Accelerometer
ACCUM	Accumulator
ACE	Acceptance checkout equipment
ACK	Acknowledge
ADA	Angular differentiating accelerometer
ADAP	Adapter
ADJ	Adjust
AESB	Aft equipment storage bay
AF	Audio frequency
AF	Atmospheric flight
AGAA	Attitude gyro accelerometer assembly
AGC	Apollo guidance computer
AGC	Automatic gain control
AGCU	Attitude gyro coupling unit
AM	Amplitude modulation
AMPL	Amplifier
AMS	Apollo mission simulator
ANAL	Analyzer
ANLG	Analog
ANT	Antenna
ASD	Apollo standard detonator
ASD	Astrosextant door
ASI	Apollo standard initiator
AS/GPI	Attitude set/gimbal position indicator
ATT	Attenuator
ATT	Attitude
AUTO	Automatic
AUX	Auxiliary
AVC	Automatic volume control
BAT	Battery
BCD	Binary coded decimal
BCN	Beacon
BECO	Booster engine cutoff
BIOMED	Biomedical
BLWR.	Blower
BMAG	Body-mounted attitude gyro
BPC	Boost protective cover
bps	Bits per second
Btu.	British thermal unit
BUR	Backup rate
BURR	Backup rate roll
BURP	Backup rate pitch
BURY	Backup rate yaw
$CA(OH)_2$	Calcium hydroxide
CAUT/WARN	Caution and warning
cb	Circuit breaker
cc	Cubic centimeter
CCW	Counterclockwise
CDU	Coupling display unit
CF	Coasting flight
CFE	Contractor-furnished equipment
cfm	Cubic feet per minute
CG	Center of gravity
CHGR	Charger
CIR & SEP	H_2 circulation, water separation centrifuge, and glycol circulation
C/M	Command module
CMD	Command
C/M RCS	Command module reaction control system
COAS	Crewman optical alignment sight
COMP	Compressor
COMP	Computing
COMPR	Compressor
COND	Condenser
COND	Conditioner
CONT	Control
CO_2	Carbon dioxide
CPC	Coldplate clamp

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cps	Cycles per second
CYRO	Cryogenic
CSM	Command and service module
CSS	Computer subsystem
CTE	Central timing equipment
C/W	Caution and warning
CW	Clockwise
CW	Continuous wave
C&WS	Caution and warning system
db	Decibel
DISP/AGAA/ECA	Display and attitude gyro accelerometer assembly electronic control assembly
DDP	Data distribution panel
DECR	Decrease
DEMOD	Demodulate
DET	Detector
DISCH	Discharge
DPST	Double-pole single-throw
DSE	Data storage equipment
DSIF	Deep space instrumentation facility
DSKY	Display and keyboard
ECA	Electronic control assembly
ECO	Engine cutoff
ECS	Environmental control system
ECU	Environmental control unit
EDS	Emergency detection system
EEG	Electroencephalogram
E_{ig}	Voltage-inner gimbal
EKG	Electrocardiogram
ELS	Earth landing system
ELSC	Earth landing system controller
EMERG	Emergency
E_{mg}	Voltage-middle gimbal
EMS	Entry monitor subsystem
ENC	Encode
ENG	Engine
E_{og}	Voltage-outer gimbal
EPS	Electrical power system
ESS	Essential
EVA	Extravehicular activity
EVAP	Evaporator
EVL	Egocentric visual localization
EXH	Exhaust
F	Fuel
F/C	Fuel cell
FCSD	Flight Crew Support Division (MSC)
FCSM	Flight combustion stability monitor
FDAI	Flight director attitude indicator
FLSC	Flexible linear-shaped charge
FM	Frequency modulation
FOV	Field of view
FQR	Flight qualification recorder
FWD	Forward
g	Gravity
GFAE	Government-furnished airborne equipment
GFE	Government-furnished equipment
GFP	Government-furnished property
GLY	Water-glycol
GMBL	Gimbal
GMT	Greenwich mean time
G&N	Guidance and navigation
GN_2	Gaseous nitrogen
GSE	Ground support equipment
g/v	Gravity vs velocity
HBR	High-bit rate
He	Helium
HEX	Hexagonal
HF	High frequency
HI	High
HT EXCH	Heat exchanger
H_2	Hydrogen
H_2O	Water
HTRS	Heaters
ICDU	Inertial coupling display unit

APPENDIX A

ICS	Intercommunication system
IGN	Ignition
IMU	Inertial measurement unit
INCR	Increase
IND	Indicator
INSTR	Instrumentation
INT	Interphone
INV	Inverter
ips	Inches per second
IRIG	Inertial rate integrating gyroscope
ISOL	Isolation
ISS	Inertial subsystem
I/U	Instrument unit
JETT	Jettison
kbps	Kilobits per second
kc	Kilocycle
kmc	Kilomegacycle
KOH	Potassium hydroxide
lb/hr	Pounds per hour
lb min	Pounds per minute
LBR	Low-bit rate
LCC	Launch control center
LEB	Lower equipment bay
LM	Lunar module
LES	Launch escape system
LET	Launch escape tower
LH	Left-hand
LHEB	LH equipment bay
LHFEB	LH forward equipment bay
LIQ	Liquid
LLOS	Landmark line of sight
LO	Low
LOR	Lunar orbit rendezvous
LOS	Line of sight
LTG	Lighting
LV	Launch vehicle
MA	Master
MAN	Manual
MANF	Manifold
MAX	Maximum
mc	Megacycles
mcs	Megacycles per second
MCT	Memory cycle-time
MDC	Main display console
MED	Medium
MESC	Master events sequence controller
MGMT	Management
MIN	Minimum
MMH	Monomethylhydrazine (fuel)
mmHg	Millimeters of mercury
MN A	Main bus A
MN B	Main bus B
MSC	Manned Spacecraft Center (NASA) (Clear Lake, Texas)
MSD	Monitor selection decoder
MDF	Mile detonating fuse
MSFN	Manned space flight network
MSL	Mean sea level
MSM	Monitor selector matrix
MTRS	Motors
MTVC	Manual thrust vector control
MULTI	Multiplexer
N/A	Not applicable
NB	Navigational base
NCS	Navigator communication station
NON ESS	Nonessential
NRZ	Nonreturn to zero
N_2	Nitrogen
N_2H_4	Hydrazine (fuel)
N_2O_4	Nitrogen tetroxide (oxidizer)
OCDU	Optics coupling display unit
OL	Overload
OMNI	Omnidirectional
OSC	Oscillator
OSS	Optics subsystem
OX	Oxidizer
OXID	Oxidizer
O_2	Oxygen
PA	Power amplifier
PAM	Pulse amplitude modulation

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PART	Partial
PCM	Pulse-code modulation
PCVB	Pyro continuity verification box
PECA	Pitch electronic central assembly
PF	Powered flight
PGA	Pressure garment assembly
PGNS	Primary guidance and navigation system
pH	Alkalinity to acidity content (hydrogen ion concentration)
PIP	Pulsed integrating pendulous (accelerometer)
PIPA	Pulsed integrating pendulous accelerometer
PKG	Package
PL	Postlanding
PLSS	Portable life support system
PLV	Postlanding ventilation
PM	Phase modulation
PMP	Premodulation processor
POT	Potable
PP	Partial pressure
pps	Pulses per second
PRESS	Pressure
PRF	Pulse repetition frequency
PRI, PRIM	Primary
PRN	Pseudo-random noise
PROG	Program
PROP	Propellant
PRR	Pulse repetition rate
PSA	Power and servo assembly
psi	Pounds per square inch
psia	Pounds per square inch absolute
psid	Pounds per square inch differential
psig	Pounds per square inch gauge
PTT	Push-to-talk
PU	Propellant utilization
PUGS	Propellant utilization and gauging subsystem
PWR	Power
PYRO	Pyrotechnic
QTY	Quantity
RAD	Radiator
RBC	Red blood cell
RCS	Reaction control system
RCSC	Reaction control system controller
RCVR	Receiver
REC	Receive
RECA	Roll electronic control assembly
RECT	Rectifier
RECY	Recovery
REG	Regulator
RESVR	Reservoir
REV	Reverse
RF	Radio frequency
RGA	Rate gyro assembly
RH	Right-hand
RHEB	RH equipment bay
RHFEB	RH forward equipment bay
RLSE	Release
RLY	Relay
RMT, RMTE	Remote
RNG	Range
R/R	Remove and replace
RTC	Real-time commands
RUPT	Interrupt
RZ	Return to zero
S-	Saturn stage (prefix)
S/C	Spacecraft
SCE	Signal conditioner equipment
SCIN	Scimitar-notch
SCS	Stabilization and control system
SCT	Scanning telescope
SEC	Secondary
SECS	Sequential events control system
SENSE	Sensing
SEP	Separation
SEP	Space electronic package
SEQ	Sequencer
SHA	Sidereal hour angle
SIG	Signal

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SIG COND	Signal conditioner
SLA	Spacecraft lunar-excursion-module adapter
SLOS	Star line of sight
S/M	Service module
SMJC	Service module jettison controller
S/M RCS	Service module reaction control system
SNSR	Sensor
SOV	Shutoff valve
SPDT	Single-pole double-throw
SPL	Sound pressure level
SPS	Service propulsion system
SPST	Single-pole single-throw
SQG	Sequencer generator
SSB	Single sideband
Sw	Switch
SXT	Sextant
SYNC	Synchronize
SYS	System
TBD	To be determined
T/C	Telecommunications
TC	Transfer control
TEC	Transearth coast
TEMP	Temperature
TFL	Time from launch
TK	Tank
TLC	Translunar coast
TLM, T/M	Telemetry
T/R	Transmit/receive
TTE	Time-to-event
TV	Television
TVC	Thrust vector control
TWR	Tower
UDL	Up-data link
UDMH	Unsymmetrical dimethyl hydrazine (fuel)
UHF	Ultra high frequency
UPTL	Up-link telemetry
USBE	Unified S-band equipment
USBS	Unified S-band system
USM	Service module umbilical
UV	Undervoltage
UVMS	Urine volume measurement system
VAC	Volts ac
VCO	Voltage controlled oscillator
VDC	Volts dc
VHF	Very high frequency
VOX	Voice-operated relay
V/V	Valve
WMS	Waste management system
XDUCER	Transducer
XFMR	Transformer
XMTR	Transmitter
XCVR	Transceiver
XPONDER	Transponder
YECA	Yaw electrical control assembly
Zn	Zinc
ΔP	Change in pressure
ΔV	Change in velocity, differential velocity
ϕ	Phase

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANELS 1 thru 4

REPORT OF PANEL 1
SPACECRAFT AND GROUND SUPPORT EQUIPMENT CONFIGURATION
APPENDIX D-1
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

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SPACECRAFT AND GROUND SUPPORT EQUIPMENT (GSE) CONFIGURATION PANEL

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Spacecraft and Ground Support Equipment (GSE) Configuration Panel 1. The task assigned for accomplishment by Panel 1 was prescribed as follows:

> Establish and document physical configuration of spacecraft and GSE immediately prior to and during fire accident including equipment configuration, switch position, and nonflight items in cockpit. By deviation, document configuration differences with respect to expected launch configuration and configurations used in previous testing, (altitude chamber, for example), as pertinent to this problem. To a lower level of detail, document configurational difference between the spacecraft and other spacecraft as pertinent to this problem.

In response to the task assignment, the Panel Chairman presented for Board approval a Statement of Work which further described the individual elements of the task. The Statement of Work defined the term, "Spacecraft and GSE Configuration", as: "The physical state of the Spacecraft and/or supporting systems, including components, ground equipment, facilities, and their interfaces at a specified point in time."

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Spacecraft and Ground Support Equipment (GSE) Configuration Panel:

Mr. Jesse F. Goree, Jr., Chairman, Manned Spacecraft Center (MSC), NASA
Mr. Charles D. Gay, Kennedy Space Center (KSC), NASA
Mr. Carroll R. Rouse, Kennedy Space Center (KSC), NASA
Mr. Charles R. Haines, Manned Spacecraft Center (MSC), NASA
Mr. Ronald V. Murad, NASA Headquarters, Office of Manned Space Flight
Mr. William F. Edson, North American Aviation, Inc., Kennedy Space Center (KSC)
Mr. Ray F. Larson, North American Aviation, Inc., Kennedy Space Center (KSC)

2. COGNIZANT BOARD MEMBER.

Mr. John J. Williams, Kennedy Space Center (KSC), NASA, Board Member, was assigned to monitor the Spacecraft and Ground Support Equipment (GSE) Configuration Panel.

C. PROCEEDINGS

1. INVESTIGATIVE APPROACH

Enclosures 1-1, 1-2, and 1-3 are general representations of the Spacecraft, Launch Vehicle and Launch Complex, and are provided to aid the discussions contained in this section. This Panel pursued the investigation in terms of exceptions to the required launch configuration. For this purpose, the required launch configuration was defined as that documented by engineering data approved (released) for implementation. Identification of the configuration differences existing at the time of the accident was accomplished through review of work records against released engineering data. These differences were analyzed to identify items pertinent to the accident. This approach did not constitute presumptions as to the adequacy of the documented launch configuration. Rather, these data were considered to represent the engineering effort accomplished during the design of the Spacecraft and provided a baseline for comparative analyses. The Spacecraft and supporting systems were identified according to the major hardware elements to permit discrete consideration of each element relative to the accident. Major hardware elements were

a. Spacecraft (S/C) -

(1) Command Module (C/M) interior

(2) General configuration of the Command Module, Service Module (S/M), and Adapter

b. Spacecraft/Launch Vehicle

(1) Spacecraft/Launch Vehicle

(2) Spacecraft/ground system

c. Ground system -

(1) Spacecraft Ground Support Equipment (GSE)

(2) Supporting facilities

(3) Remote monitoring and control equipment, including Acceptance Checkout Equipment (ACE), the Operational Inter-Communications System (OIS), and other Radio Frequency (RF) command, record, or audio links.

Configurations of the hardware elements were defined as of the time immediately prior to and following the accident on January 27, 1967. The time of the accident is described as occurring during the performance of Operational Checkout Procedure (OCP) FO-K-0021-1, "Space Vehicle Plugs Out Integrated Test", at the condition of a countdown hold ten minutes (T-10) prior to simulated launch. The term, "Plugs Out", refers to disconnection of spacecraft/GSE umbilicals. The C/M interior was pressurized with oxygen to approximately sixteen pounds per square inch absolute, (psia) during the Space Vehicle Plugs Out Integrated Test. Relevant Spacecraft 012 configuration differences existing at the time of the accident were also documented with respect to launch, previous Spacecraft 012 tests, and the test configuration of another Apollo spacecraft. Documentation of the first of these cases was accomplished as an integral part of defining the configuration immediately prior to and following the accident. The following conditions were used as the bases for the latter two cases:

a. Spacecraft 012 configuration during Plugs-In Test at T-10 (hold), January 25, 1967. This test represents the last operation of Spacecraft 012 systems prior to start of the Space Vehicle Plugs Out Integrated Test.

b. Spacecraft 012 configuration during Altitude Chamber Test at T-10 minutes (hold), December 29, 1966. During this test, the spacecraft exterior was exposed to partial vacuum to simulate high altitude operation. The C/M interior was pressurized with oxygen to approximately 16 psia during final preparations for altitude simulation. Following chamber evacuation, the C/M interior pressure was maintained at approximately five and one-half psia. This test was similar to the Space Vehicle Plugs Out Integrated Test in terms of exposure to an oxygen environment.

c. Spacecraft 008 configuration during Altitude Chamber Test No. 3 at the Manned Spacecraft Center, October 26, 1966. This test also involved exposure to an oxygen environment. Differences in test configuration between Spacecraft 012 and Spacecraft 008 were identified to determine possible relevance to the Spacecraft 012 accident.

The scope of this Panel's activities in documenting the configuration of the hardware elements is schematically represented in Enclosure 1-4.

Initial efforts were those of compiling all data to identify configuration differences existing at the time of the accident. While compiling these data, the Panel was called upon to supply specific configuration data to other Apollo 204 Review Board Panels. A total of 34 special reports were prepared in response to these requests. These configuration data are included in this report to the extent pertinent to the accident. After assembling the necessary source information, the data were collated according to hardware elements and conditions depicted in Enclosure 1-4. Data elements organized in this manner permitted comparative analyses from which significant differences could then be identified.

2 PRESENTATION OF DATA.

Data assembled during the course of this investigation are summarized in the following paragraphs according to the specific conditions and hardware elements considered.

a Launch Configuration The required launch configuration of Spacecraft 012 and its supporting systems is identified by basic documentation This documentation is described as follows.

(1) Spacecraft. Released engineering drawings listed in the "Spacecraft 012 Configuration Index", January 29, 1967. The individual component parts are identified, by part number, in "Spacecraft 012 Indentured Parts List", January 28, 1967. Note: Configuration Index and Identured Parts List are computer tabulations for which input data was updated continuously prior to the accident. These data were retrieved on the dates indicated.

(2) Spacecraft Interfaces. Interfaces between the Spacecraft and Launch Vehicle are defined by applicable Interface Control Drawings (ICD's):

(a) "Instrument Unit to Spacecraft Physical Requirements, ICD 18M20408."

(b) "Instrument Unit to Spacecraft Lunar Module Adapter (SLA) Electrical Interface (S/C 012), ICD 40M37508A."

Spacecraft-to-ground system interface connections were specified in the "Launch Complex 34 Checklist, OCP FO-K-10011," and implemented in accordance with the "GSE Functional Integrated System Schematics." Physical provisions for these connections are defined by detailed spacecraft and GSE drawings. The spacecraft-to-launch vehicle and spacecraft-to-ground system interfaces are depicted in Enclosure 1-9, Drawing 1-D-0056-2.

(3) Ground System. The required configuration of the spacecraft GSE is prescribed by the GSE Functional Integrated System Schematics," according to the particular checkout or servicing operation to be performed. "Operational Checkout Procedure, OCP FO-K-0007," prescribes the sequence of launch operations, referring to the "Launch Complex 34 Checklist, OCP FO-K-10011," for detailed GSE connections, operations, and disconnections. The checklist provides only a narrative statement of the operations; therefore, it must be used in conjunction with the "GSE Functional Integrated System Schematics." Basic design interfaces between the spacecraft GSE, supporting facilities, and remote monitoring and control equipment are defined in numerous ICD's (Reference 1-8). Configuration requirements of these ICD's are reflected in released engineering data.

b. Required Test Configuration. Certain of the released engineering orders (EO's) specify that they are to be accomplished prior to a test which follows the Space Vehicle Plugs Out Integrated Test; for example, Flight Readiness Test (FRT) or Countdown. However, explicit definition of total spacecraft configuration requirements for the Space Vehicle Plugs Outs Integrated Test did not exist in the form of released engineering data. The Operational Checkout Procedure for the Space Vehicle Plugs Out Integrated Test, OCP FO-K-0021-1, specified the functional configurations prescribed for the test. These functional configuration requirements include those items required to be different from the launch configuration to permit accomplishment of the simulated launch less the physical event. Both the engineering data and the test documentation leave definition of the required test configuration to inference as opposed to explicit specifications.

The test operation involved a procedure wherein all work not accomplished to meet launch requirements was reviewed to identify those open items which would constrain accomplishment of the test. Therefore, the decision to proceed with the test has been construed by this Panel to mean that all recognized constraints were satisfied. This aspect of configuration requirements was considered in cooperation with Test Procedures Review Panel, 7, and is discussed further in Appendix D-7.

Items required to be different from the launch configuration for reasons of test conditions and procedures are summarized in the following paragraphs.

(1) Spacecraft. Spacecraft configuration differences authorized by OCP FO-K-0021-1 and engineering orders (EO's) for the Space Vehicle Plugs Out Integrated Test were as follows:

(a) Open access panels to permit GSE connections.

(b) Expendables not on board to preclude unnecessary exposure of systems to contamination or hazards to operation.

(c) Fuel cells not activated to preclude partial reduction of useful life.

(d) Electrical circuits to pyrotechnic devices interrupted and shorting plugs installed to prevent actual firing during simulated mission sequence.

(e) Boost Protective Cover installation not completed to permit access to GSE connections.

(f) Circuits from S/M batteries to S/M jettison controller interrupted. This was to prevent

continuous applications of voltage to Reaction Control System (RCS) jet solenoids (simulated by load boxes) following simulated Service Module/Command Module separation.

(g) Installation of test batteries (flight type) to preclude power drain from units assigned (by serial number) for the actual mission.

(h) Those items specifically required to be accomplished as of a planned test subsequent to the Space Vehicle Plugs Out Integrated Test. These items are specified by Engineering Orders which are identified as open EO's (See Reference 1-10).

(2) Spacecraft Interfaces. Differences required for the test operations were:

(a) Facility air supply through C/M access panel to the space between pressure vessel and heat shield to provide humidity control.

(b) Connection of ground-supplied oxygen in absence of on board supplies.

(c) Special umbilical interface for water/glycol circulation to prevent disconnection at time of umbilical separation in planned mission sequence.

(d) Connection of isolated power supply to maintain water/glycol return valve in open position (to continue external conditioning) following planned umbilical separation.

(e) Connections for GSE battery rack to be used as fuel cell substitute following planned simulated transfer to internal power.

(f) Special interfaces for S/C antennas to provide RF link to ground system.

(g) Connection of RCS load boxes (simulators) to permit testing of flight controls, yet preclude exercising RCS jet solenoids.

(h) Installation of fuse boxes in the electrical interface between the spacecraft and the launch vehicle to protect computers in the Instrument Unit from any adverse conditions during the test.

(3) Ground System. The required ground system configuration differences from the launch configuration were those required in support of the interfaces described in paragraph B.3.b(2). The ground system and interface configurations are depicted in the following drawings of Enclosure 1-9.

TITLE	NUMBER
S/C/Range/Launch Vehicle Interfaces, T-10, OCP FO-K-0021-1	1-D-0056-3
S/C/GSE Configuration during T-10 Hold, OCP FO-K-0021-1, Electrical	1-D-0056-4
Launch Complex 34 (LC 34) ECS Airduct	1-D-0056-7
S/C/GSE Configuration during T-10 Hold, OCP FO-K-0021-1, Mechanical	1-D-0056-8

c. Configuration at Time of Accident

Data prescribing the configuration at the time of the accident were obtained from configuration management records as supplied by Panel 6 (Historical Data), witness reports, and special reports submitted by other organizations. Pertinent information contained in special reports prepared after the accident was verified by this Panel. Panel 1 also prepared documentation of configuration elements based upon post-accident inspection in those cases where complete data were not otherwise available. These data are discussed in the following paragraphs.

(1) Spacecraft.

(a) Documentation: Differences between the launch configuration and the configuration at the time of the accident are documented by the following:

1. "Spacecraft 012 Configuration Verification Record (CVR)," January 28, 1967.

This document identifies the work status of all released EO's effective on Spacecraft 012 which were not accomplished at time of receipt at KSC or were released subsequently. The CVR is a computer tabulation of data inputs as of the start of Space Vehicle Plugs Out Integrated Test which was retrieved on the date indicated. Enclosure 1-5 is a graphical representation of cumulative EO releases and work status subsequent to delivery of Spacecraft 012. While verifying this document, Panel 1 identified several EO's partially accomplished at the time of the accident. These EO's are listed in Reference 1-12. Also, twenty-two EO's listed in Reference 1-13, were released subsequent to closeout of the CVR, and were not accomplished as of the time of the accident. A summary listing of all EO's open at the time of the accident was prepared by the Panel and is contained in Reference 1-10. This listing includes those released for incorporation through normal work schedules as well as those constrained for incorporation at a time subsequent to the Space Vehicle Plugs Out Integrated Test.

2. "Spacecraft 012 Test and Acceptance Inspection Report (TAIR)." This document consists of several volumes (or books) with entries for each work item intiated on the Spacecraft. Entries reflect the part affected, authorizing documents, entry date, closeout date, quality control inspection stamps. Entries pertinent to this Panel's investigation are those of "Parts Installation and Removal Records (PIRR's)," and "Temporary Installation Records (TIR's)." "Discrepancy Reports/Material Review (DR/MR)" actions, Type A "Test Preparation Sheets (TPS's)" and OCP requirements authorize work on the Spacecraft. The PIRR is used to record any work against a previously installed and accepted part or the installation of a new part; for example, removal of a part for rework, removal of a part for access, disconnection of mated connectors, etc. The TIR is used to record temporary installations which must be removed to meet requirements of the launch configuration. Entries in either of these records constitute open items until such time as the affected part is returned to the launch configuration and verified by quality control inspection. DR/MR actions result from discrepancy reports which are dispositioned for correction by minor form or fit changes under authority of the Materials Review Board. Type "A" TPS's authorize work to be accomplished on the Spacecraft in conformance with released EO's. PIRR's and TIR's reflect TPS, DR/MR, or OCP authority. PIRR's and TIR's open at the time of the accident were reviewed by the Panel and are listed in Reference 1-10.

3. "Spacecraft 012 Controls Configuration" (switch and valve positions). This document was prepared by Panel 1 and is provided as Reference 1-15. Data presented in this document relative to the controls configuration before the accident were obtained from the accomplished parts of the OCP. The document also contains comparisons of control configurations at other specified times.

4. "Crew Compartment Stowage and Loose Equipment Configuration." Data contained in Enclosure 1-8 were compiled from Reference 1-16, 1-17 and 1-18. This enclosure identifies the stowed equipment and materials that were in the Spacecraft at the time of the accident. This information was used to configure a mockup of the C/M to portray the configuration of Spacecraft 012 immediately prior to the accident. Enclosure 1-6 is a photograph of this mockup, less crew couches. Enclosure 1-7 is a picture of the mockup with couches and umbilicals installed. The mockup was used by Panel 5 (Origin and Propagation of Fire) to study possible fire propagation paths.

(b) Data Synopsis: Review of the data discussed previously reveals that 80 EO's were outstanding at the time of the test. Of these, 20 were specified to be accomplished subsequent to the Space Vehicle Plugs Out Integrated Test and four were of a nature not affecting configuration. A total of 384 PIRR's /TIR's were open, of which 125 were initiated as requirements of the test. The remaining 259 items reflect incomplete status of further work to have been accomplished prior to launch. Open items represented by these figures were identified through reconciliation of configuration records with witness reports and results of post-accident inspection. Procedures for TAIR entries required that removal of a part be documented by PIRR, and that installation of a temporary replacement be entered on a TIR. In some in-

stances, this resulted in two entries against a single change action. Many of the PIRR's/TIR's were not relevant as they affected items such as Service Module access panels or protective covers on external components. Significant items contained in the referenced data are identified in two categories: Significant configuration items, and items which may have relevance to flame propagation. These items are presented below.

1. Significant Configuration Items

a. Investigation of the released engineering and work orders for the installation of new debris traps has shown that this work was only partially complete. Engineering Order No. 582252 released the debris trap modification kit. This modification provides for the replacement of the fish-net type of debris traps with Raschel net debris traps. All old-type debris traps were removed. Eleven (11) of twenty-five (25) new debris traps were installed prior to start of test. This replacement was documented on the authorizing TPS.

b. Flight items installed in other than normal configurations:

(1) Two 16-mm sequence cameras and a camera power cable were stowed loose on the floor of the gas chromatograph installation area. The normal stowage position of these items is one camera with cable in Scientific Compartment "A" and one camera in Scientific Compartment "G."

(2) A Dew Point Hygrometer Sensor, sensor cable, power cable, and control unit, were stowed loose on the floor of the gas chromatograph installation area. The normal stowage position of these items is scientific compartment "D."

(3) The drinking water dispenser was not connected to the hose.

c. The Spacecraft controls configuration which existed at the time of the accident was in accordance with the planned procedure specified in Operational Checkout Procedure FO-K-0021-1 with the following exceptions:

(1) The crewmen's audio center communications controls configuration which existed at the time of the accident differed from the planned procedure due to the troubleshooting of the communications systems during the tests. The exact configuration of these controls at the time of the accident cannot be determined. The configuration as found after the accident would have permitted all three crewmen to have two-way communication both within the Spacecraft and to the ground.

(2) The switch labeled "VHF ANTENNA" (Very High Frequency Antenna Selector Switch) was specified to be in the "UPPER" position, but was changed to "LOWER" per ground personnel request during the communication troubleshooting. This action switched the active VHF antennas.

(3) The switch labeled "S-BAND ANTENNA" (S-Band Antenna Selector Switch) was specified to be in the "UPPER" position, but was changed to "LOWER" per ground personnel request during the communications troubleshooting. This action switched the active S-Band antennas.

(4) The switch labeled "H_2O ACCUM AUTO/MAN/AUTO" (Water Accumulator Mode Selector Switch) was specified to be in the "MAN" (Manual) position, but was changed to "AUTO" (Automatic) during the test per flight crew request. In the "AUTO" position, the cyclic accumulator is actuated automatically every ten minutes to remove moisture from the suit loop gases. In the "MAN" position, the cyclic accumulators must be cycled by the crew using the switch labeled "H_2O ACCUM/ON/OFF/ON" (Manual On-Off Switch) as required.

(5) The switch labeled "AC INVERTER 2 MNB/OFF" (Inverter Number 2 Power Switch) was specified to be in the "OFF" position, but was changed to "MNB" (Main Bus B) by recorded deviation to the OCP during the test. "MNB" is the correct position, supplying the Main Bus B power to Inverter No. 2.

d. Earth Landing System sequence cover panel assembly in right-hand equipment

bay removed on January 23, 1967. Removed per OCP FO-K- 10011 deviation No. 25 for purpose of connecting Acceptance Checkout Equipment (ACE) connectors. (ACE removed prior to Space Vehicle Plugs Out Integrated Test).

e. Cover on connector on Guidance and Navigation (G&N) computer removed to facilitate installation of 100 series test connector cover which was installed for testing purposes and would be removed before flight.

f. Ten connector caps on Power Servo Assembly (PSA) trays were removed on December 30, 1966.

g. Translation Controller ME901-0171-0204, S/N EAC 1024, installed on left-hand couch, left-hand side on January 24, 1967. Authorization for installation was per Test Preparation Sheet S/C 566 Step No. 3. Controller was installed to support OCP FO-K- 0006 (Plugs In Test) and OCP FO-K-0021-1.

h. Rotational Controller, ME901-0172-0204, S/N DAK 1034, installed in left-hand couch, right-hand side on January 24, 1967. Authorization for installation was per Test Preparation Sheet S/C 566 Step No. 4. Controller was installed to support OCP FO-K-0006 and OCP FO-K-0021-1.

i. Carbon dioxide absorber elements ME901-0218-0001, S/N 24172 and 24171, installed on January 27, 1967, as specified in OCP FO-K-10011 deviation No. 140. Absorber elements are a different configuration than the flight articles (ME901-0218-0001 as compared with -0021-1). Elements installed for Space Vehicle Plugs Out Integrated Test did not have by pass provisions and were enclosed in a glass fiber shell as opposed to aluminum.

j. Pyro Panel (No. 150) was temporarily installed prior to the Plugs In Test, (OCP FO-K-0006). Panel was not fully installed and was recorded as a temporary installation. The panel was out approximately 5 to 6 inches from lower equipment bay panel line and was located on aft bulkhead.

k. Engineering Order (EO 507283) released the requirements for replacing the electrical bonding straps for couches with a strap that is less susceptible to damage. Two of four existing straps were removed on Parts Installation Removal Records. New electrical bond straps (P/N MS 25083-3BB8 and MS 25083-2BB8) were to be installed by TPS-SC 012-SC-535, which was not accomplished prior to the Space Vehicle Plugs Out Integrated Test.

l. Gas Chromatograph (P/N R534845-2-A, Serial Number 5) was removed on December 30, 1966. Replacement of gas chromatograph was not a constraint to the conduct of Space Vehicle Plugs Out Integrated Test or Plugs In Test. The power and sensor connector for the chromatograph had voltage present, and was placed on the shelf of the gas chromatograph compartment. (See Appendix B, Witness Statement No. 44).

m. The Data Storage Electronic Assembly (DSEA) Recorder (P/N LSC-360-12, Serial Number 104) was temporarily installed January 27, 1967. Installation was made in accordance with Test Preparation Sheet (TPS SC 012 583, Step 1P). The temporary installation of the DSEA Recorder was accomplished to provide a flight configuration for the Space Vehicle Plugs Out Integrated Test. The power connector to the DSEA was energized during the test. Post-test investigation revealed that the power connector was not hooked up.

2. Items Which May have Relevance to Flame Propagation

a. Engineering Order, (EO 226756) released at the Contractor's Downey facility on January 20, 1967, provided direction to inspect the polyurethane foam (Specification MB0130-039) in specified areas and coat with silicone rubber, (Type II, Specification MB0130-019) to meet flammability requirements. This direction was not recorded in the CVR as of start of Space Vehicle Plugs Out Integrated Test (issued at Contractor's Florida Facility on January 27, 1967,) and was not accomplished on S/C 012. This item is of possible significance in terms of fuel for the fire and as a medium for flame propagation.

b. Polyethylene bags were used to cover the hose fitting for the drinking water dispenser and the battery instrumentation cable and connectors (2) and transducer, which were placed on the aft bulkhead near the batteries. These bags are nonflight materials.

c. Two Polyurethane pads, approximately 20 x 24 x 2 inches, covered with Velostat, were stowed over the Z-Z couch struts. The pads were placed in the Spacecraft to protect the struts, wiring, and aft bulkhead during the planned emergency egress at the end of the test. (See Appendix B, Witness Statement Number 3). These items were nonflight materials and were not documented by quality inspection records.

d. Three packages of switching checklists from Operational Checkout Procedure FO K-0021-1 (multilith process) and one package of system malfunction procedures (Xerox and Bruning processes), in a manila folder were stowed on the crew couches and on the girth shelf. These items were on unqualified paper. While required for the test, these items were not documented by quality inspection records.

e. Nylon protective sleeves were covering all three crewmen's oxygen umbilicals. These were nonflight items.

f. Three GSE window covers were temporarily installed. Covers were installed to protect the windows and are nonflight items that were in the Command Module (C/M) at the time of the accident. Another such cover for the side hatch window was removed by the crew and stowed inside the C/M. Covers are nylon fabric where the flight covers are made of aluminized Mylar.

g. Velcro pile MFL-F-21840A installed to protect Velcro hook on C/M floor. Would have been removed before flight.

h. "Remove before flight" streamers installed in C/M interior. Represents additional nonflight items in C/M.

i. Polyethylene zipper tubing installed to protect hand controller cables. Polyethylene tubing cover is a nonflight item and represents additional material in the C/M.

(2) Spacecraft Interfaces

(a) Documentation: Configuration of Spacecraft interfaces at the time of the accident is defined by the documentation described below:

1. Spacecraft/Launch Vehicle (SC/LV) interfaces are depicted in Enclosure 1-9, Draw-1-D-0056-3. Also, details of the SC/LV electrical interface functions are defined in Reference 1-19. These data are based upon review of ICD's 40M137508A, 13M120408, changes thereto, and visual inspection to the extent possible.

2. Spacecraft/Ground System interfaces are represented schematically in Enclosure 1-9, Drawings 1-D-0056-3, -4, -7, and -8. Also electrical cable connections and interface functions are identified in Reference 1-19.

(b) Data Synopsis:

Significant interface differences from the required launch configuration were as follows:

1. The fuel cell battery rack assembly (C14-395) was electrically mated to the connectors from which fuel cells 1 and 3 would (in flight) supply direct current (DC) power to the S/C busses. This was accomplished per Checklist FO-K-1011 and was required due to the fact that the fuel cells were not operating in this test. Power was being supplied through the flyaway umbilical from a ground power source. At T-0 minutes, the umbilical would have been dropped to satisfy test requirements. At T-10 minutes, per the Test Procedure, OCP FO-K-0021-1, bus power would have been transferred from external GSE power to C14-395 battery power (Enclosure 1-9, Drawing 1-D-0056-4).

2. The Y00-085 cable and a power supply were connected to the S/C water glycol drain and vent shutoff valve S23LV1 (Reference 1-D-0056-8). This valve must be held open by a 28 VDC source in order to maintain water glycol circulation during ground testing. During this test, the flyaway umbilical which normally carries the 28 VDC power is disconnected at T-0 minutes and, the valve would close if not separately powered.

3. The ground oxygen (O_2) source was connected to the S/C. Oxygen to the Space-

craft was supplied (Reference Schematic 1-D-0056-8) from a bottle source through the O_2 Test Set to the O_2 valve box in the S/C. This particular configuration was being used for the first time at LC 34.

4. A thermocouple was taped to the oxidizer "A" isolation valve and was connected to a GSE meter. During this test, the propellant isolation valves were to be energized for a period of approximately 15 minutes. A technician was to monitor the valve temperature during the actuation time in the test.

5. Seven C/M RCS simulator cables were connected from the simulator boxes to the S/C. These cables were connected from the simulator boxes to the RCS Control Boxes through C/M access panels. Each of these cables ran beneath the Boost Protective Cover (BPC) sections that had been installed surrounding the S/C hatch. Post-test observation indicates that the cable interference with the BPC bulged the installed sections of BPC such that the hatch section of the BPC could not be installed properly.

(3) Ground System

(a) Documentation: The configuration of the ground system at the time of the accident is described by the following:

1. Spacecraft GSE configurations existing at the time of the accident or used earlier in the test are depicted in Enclosure 1-9, Drawings 1-D-0056-1, -4, -5, -7, -8, and -9. These drawings were prepared for Panel 1 based upon visual inspection and reference to GSE Functional Integrated Schematics for internal detail. The individual GSE models used during the test and change actions not accomplished are tabulated in Reference 1-19.

2. Configuration of supporting facilities was documented by a report prepared by the KSC Launch Facilities Division in support of this Panel's investigation. This report is provided as Reference 1-20. Reference 1-21 is an inventory listing of miscellaneous items found on the service structure platforms after the accident.

3. Configuration of remote monitoring and control equipments are briefly described in Reference 1-20. Reference 1-22, prepared by this Panel, contains further data regarding details of the configuration of the Acceptance Checkout Equipment (ACE), Operations Intercommunications System (OIS), and the Mission Control Center, Houston. The overall configuration of remote monitoring and control equipment at the time of the accident is depicted in Enclosure 1-9, Drawing 1-D-0056-3. The configuration of ACE is shown in Enclosure 1-9, Drawing 1-D-0060. OIS configuration is shown in Drawing 1-D-0062.

(b) Data Synopsis: Significance of the ground system configuration is summarized as follows:

1. No further significance is attached to the Spacecraft GSE configuration beyond that previously discussed under the heading "Spacecraft/Ground System Interfaces."

2. The configuration of supporting facilities within the scope of this Panel's investigation is not represented as pertinent to the accident. The safety aspects of the facility configuration were deferred to Panel 13 (Ground Emergency Provisions Review).

3. The remote monitoring and control equipment were configured according to published requirements and operational procedures. Analyses of difficulties experienced in the communications equipments, as mentioned in Reference 1-22, were referred to Panel 9 (Design Reviews).

d. Post-Accident Configuration

The damage caused by the fire in the Spacecraft is documented by the Apollo 204 Review Board Photographic Files and by the work records of the disassembly accomplished by Panel 4 (Disassembly activities). Panel 1 considered those aspects of the post-accident configuration necessary to verify certain elements of the configuration existing at the time of the accident and to identify changes in control configuration accomplished during the fire. The scope of these considerations was limited to configuration change actions accomplished during and immediately following the fire. Considerations were based upon photographs and visual inspection by members of this Panel. The significant post-accident configuration differences are summarized as follows:

(1) The rotary switch labeled "BMAG POWER" (Body-mounted attitude gyro power switch) was found in the "OFF" position, whereas it should have been in the "AC2 MNB" (Alternating Current Number 2 and Main Bus B) position. A silhouette pointing to the "AC2 MNB" position

indicates the switch was moved to the "OFF" position after sooting occurred.

(2) Thirty-three circuit breakers which were closed prior to the accident were found "OPEN." The shafts exposed by the circuit breakers opening vary from sooted to clean, giving some gross determination of the relative times at which the different breakers opened (Reference 1-15).

(3) Two switches labeled "MAIN BUS TIE-BAT A & C and BAT B & C" (Battery A and C tie to Main Bus A and Battery B and C tie to Main Bus B) apparently were changed from the "AUTO" to the "ON" positions by the crew after the fire was reported. This action placed Spacecraft batteries A and C in parallel onto Main Bus A and batteries B and C in parallel onto Main Bus B; in addition to the ground power being supplied. This action was not a planned procedure in event of rapid or emergency egress. It could have been taken in an attempt to maintain communication or lighting since emergency procedures called for GSE power off.

(4) The Pad Emergency Egress Procedure specified in the Apollo Crew Abbreviated Checklist, page 15-2 (including planned changes), called for: (a) Turning off the switches labeled "MASTER EVENT SEQ CONT PYRO ARM 1 and -2," (Master Event Sequence Controller Pyrotechnic Arming Switches); (b) "SM RCS PROPELLANT A, B, C, AND D," (Service Module Reaction Control System Propellant Switches for Quads A, B, C and D); (c) Placing the CABIN RELIEF VALVE TO "DUMP"; (d) Opening the four circuit breakers labeled "MASTER EVENT SEQ CONT ARM A BAT A, ARM B BAT B, LOGIC A BAT A, and LOGIC B BAT B," (Master Event Sequence Controller Pyrotechnic and Logic Arming Circuit Breakers). One of the circuit breakers, "MASTER EVENT SEQ CONT ARM B BAT B" was found open. All the other controls listed above are in the pre-accident configurations.

(5) The switch labeled "RCS INDICATORS" (Reaction Control System Indicators) was specified to be in the "SM D" position (Service Module Reaction Control System Quad D), but was found in the "SM A" position. OCP FO-K-0021-1 did not specify the normal step of returning this switch to the "SM A" position after use (as specified in the Apollo Crew Abbreviated Checklist and in previous Operational Checkout Procedures). The crew apparently did this in accordance with the abbreviated checklist. This switch selects the inputs to the time-shared RCS displays on Panel 12.

(6) The switch labeled "TAPE RECORDER RECORD/PLAY" was found after the accident to be in the "OFF" position (OCP FO-K-0021-1 specified "RECORD"). There is no record of the crew deviating from the OCP FO-K-0021-1 specified position. The Apollo Crew Abbreviated Checklist specified "OFF" for this switch until immediately prior to launch. The switch might have been set to "OFF" per that procedure (without ground coordination) or knocked off inadvertently. The Tape Recorder (DSE) would not operate in either switch position until enabled by setting the switch labeled "TAPE RECORDER FWD/REV" (Tape Recorder Forward/Reverse Selector Switch) to the forward or reverse position (planned just prior to launch).

(7) The gas chromatograph power sensor connector was found on the aft bulkhead. This connector was placed on the shelf of the chromatograph compartment at time of crew ingress.

e. Plugs-In Test Configuration

The Spacecraft 012 Plugs-In Test, OCP FO-K 0006, was initiated at 4:00 a.m. EST, January 25, 1967, and was completed at 2:54 a.m. EST, January 26, 1967. Aside from test set-up, few configuration changes were accomplished between completion of Plugs-In Test and start of the Space Vehicle Plugs Out Integrated Test at 7:00 a.m. EST, on January 27, 1967. Configuration changes were identified from Parts Installation and Removal Records, Temporary Installation Records, and Discrepancy Report Material Review dispositions. The configuration at the time of the Plugs-In Test relative to the Space Vehicle Plugs Out Integrated Test is summarized as follows:

(1) Spacecraft

Difference in the configuration of the Spacecraft at the time of the Plugs-In Test with respect to the Space Vehicle Plugs Out Integrated Test are listed in Reference 1-10. Significant differences were as follows:

(a) Boost Protective Cover (BPC) and splice plate (10 pieces) installed for Space Vehicle Plugs Out Integrated Test. The BPC was partially installed to accommodate the hatch BPC which was necessary for the planned emergency egress exercise.

(b) Main "A," Main "B," and the post-landing test batteries were not installed (used)

during the Plugs-In Test. Jettison controller batteries were used for each test, but were of a different serial number.

(c) Eleven protective dust caps installed on pyrotechnic connectors in the C/M subsequent to Plugs-In Test. Caps placed on non-mated connectors to provide protection and prevent shorting.

(d) The Inertial Measurement Unit (IMU) heater shorting plug was temporarily installed in tray 7 for the Space Vehicle Plugs Out Integrated Test. This provides heater power from the S/C bus rather than from an external source. The installation of this shorting plug represents a configuration difference from the Plugs-In Test; however, this plug had been used previously during the Altitude Chamber Test (OCP FO-K-0034A). The "Launch" configuration also requires that this plug be installed.

(e) Carbon dioxide absorber elements, P/N ME 901-0128-0001, were installed for the Space Vehicle Plugs Out Integrated Test. These absorber elements were not flight configuration.

(f) The same three crewmen umbilical electrical cables (cobra cables) were used in the Plugs-In Test as were used in Space Vehicle Plugs Out Integrated Test. However, two additional cobra cables were stowed on board for this test, one of which was used by the Command Pilot during part of the test.

(g) Noise-limiter adapters were attached to the cobra cables for the Space Vehicle Plugs Out Integrated Test, but not used for Plugs-In. They were check out in the Spacecraft between the times of the two tests.

(h) An "octopus cable," (Medical Data Acquisition System cable) was installed for the Space Vehicle Plugs Out Integrated Test, but not used for Plugs-In Test.

(i) Flight crew equipment was not stowed for the Plugs-In Test.

(2) Spacecraft Interfaces

Differences in the Spacecraft interface configurations between the Plugs In and Space Vehicle Plugs Out Integrated Tests are identified in Reference 1-19. The significant differences were:

(a) Pyrotechnic Substitute Units were utilized during the Plugs In Test and were disconnected during the Space Vehicle Plugs Out Integrated Test in an attempt to provide better S/C ground isolation.

(b) Fuel Cell Battery Substitute Unit was utilized during the Space Vehicle Plugs Out Integrated Test. This unit is used to supply S/C bus internal power in the absence of fuel cell operation after the flyaway umbilical has been dropped.

(c) Protective Pressurization Unit was utilized to maintain a pad pressure on the Service Propulsion System (SPS) tanks. This unit was disconnected during the Space Vehicle Plugs Out Integrated Test in an attempt to maintain better ground isolation.

(d) Battery Substitute Unit was used during the Plugs In Test. This unit was utilized in lieu of the S/C entry and post-landing batteries during that test.

(e) Water/glycol shutoff valve control cable and associated power supply was utilized during the Space Vehicle Plugs Out Integrated Test. This requirement exists in order to hold the water/glycol return shutoff valve open after flyaway umbilical ejection, such that continuous water-glycol circulation may be maintained.

(f) Conditioned air was supplied through the access arm White Room and the open Spacecraft hatch for the Plugs-In Test, therefore not requiring external oxygen supply. An oxygen test set was utilized during the Space Vehicle Plugs Out Integrated Test. Oxygen was supplied from two K bottles through this unit to a facility valve box and then to the Spacecraft.

(g) GSE access connectors were connected to the Service Module (S/M) during the Plugs-In Test to monitor fluid system parameters. They were not required for the Space Vehicle Plugs Out Integrated Test.

(h) The ACE carry-on test equipment was utilized during the Plugs-In Test. This equipment is located on Level A8 outside the C/M and is connected to the Spacecraft systems through cables which run through the hatch and connect to the individual Spacecraft systems. This equipment was not required for the Space Vehicle Plugs Out Integrated Test.

(3) Ground System

The Spacecraft GSE configuration differences between the Plugs In and Space Vehicle

Plugs Out Integrated Test are given in Reference 1-19. No significant differences were identified beyond those discussed above under the heading, "Spacecraft Interfaces." Data presented in Reference 1-22 reflect that no differences existed in the configurations of the ACE and OIS equipment relevant to the accident.

f. Configuration for Altitude Chamber Test

The final run of the Spacecraft 012 Altitude Chamber Test, OCP FO-K-0034A-1, began at 6:00 a.m. EST., on December 29, 1966, in the East Altitude Chamber in the Manned Spacecraft Operations Building (MSOB). The test was completed at 3:30 a.m. EST, December 30, 1966. At the time of the Altitude Chamber Test, configuration records reveal that sixty (60) released EO's had not been accomplished. Test Acceptance Inspection Records reflect that three-hundred-eight (308) work items were open. These records were reviewed to determine configuration actions accomplished or closed out between the completion of the Altitude Chamber Test and the Space Vehicle Plugs Out Integrated Test. Discrepancy Report/Material Review dispositions were screened to identify corrective actions that altered configuration and were accomplished in this time period. Configuration differences are summarized as follows:

(1) Spacecraft

Differences in the spacecraft configuration between the Altitude Chamber Test and the Space Vehicle Plugs Out Integrated Test are presented in Reference 1-10. Enclosure 1-8 reflects differences in crew equipment and loose items stowed in C/M. Significant differences were as follows:

(a) Only the inner hatch was installed for the Altitude Chamber Test. Both inner and outer hatches were installed and latched, and BPC hatch was in place but not latched for Space Vehicle Plugs Out Integrated Test.

(b) Pyrotechnic panel (no. 150) was temporarily installed for Altitude Chamber Test. This panel was removed December 30, 1966, and was temporarily installed prior to the Plugs In Test (OCP FO-K-0006). The panel was not fully installed, being out approximately 5 to 6 inches from the lower equipment bay panel line and located on the C/M aft bulkhead.

(c) Carbon dioxide absorber elements of the correct flight configuration (ME 901-0218-0021) were installed for the Altitude Chamber Test, instead of the non-flight configuration for the Space Vehicle Plugs Out Integrated Test.

(d) Command Module interior panel, P/N V16-441802, covering J-box in left-hand lower equipment bay was removed for DR MR disposition to relieve interference with wire bundle. The panel was replaced prior to the Space Vehicle Plugs Out Integrated Test.

(e) Spacecraft oxygen tanks were serviced for the Altitude Chamber Test.

(f) Hydrogen tanks were pressurized with nitrogen during the Altitude Chamber Test.

(g) Fuel cell battery substitute unit was not connected for Altitude Chamber Test. Spacecraft was powered by external GSE facility power.

(h) DC power bus voltage monitor recorder was installed for Altitude Chamber Test.

(i) Additional Velcro was installed after completion of Altitude Chamber Test.

(j) Noise limiters were not installed on cobra cables for Altitude Chamber Test.

(k) The gas chromatograph was installed for the Altitude Chamber Test.

(l) The Data Storage Electronics Assemblies (DSEA's) were installed in flight configuration for Altitude Chamber Test.

(m) The Spacecraft TV camera was on during the Altitude Chamber Test, but not for Space Vehicle Plugs Out Integrated Test (after crew ingress).

(n) Translation and rotation controllers were installed to flight configuration for Altitude Chamber Test.

(o) Floodlight installation was modified subsequent to Altitude Chamber Test.

(p) Crew equipment stowage was approximately flight configuration for Altitude Chamber Test. See Enclosure 1-8 for detailed differences.

(q) Debris traps were modified subsequent to Altitude Chamber Test.

(r) All crew couch ground straps were installed for Altitude Chamber Test

(2) Spacecraft Interfaces

The Spacecraft ground system interfaces existing during the Altitude Chamber Test are

depicted in Enclosure 1-9, Drawing 1-D-0056-6. Significant interface differences relative to Space Vehicle Plugs Out Integrated Test were:

(a) During the Altitude Chamber Test, the A-14-062 Launch Vehicle Substitute Unit was installed. During Space Vehicle Plugs Out Integrated Test, the Command and Service Module/Spacecraft to Lunar Module Adapter (CSM SLA) configuration was mechanically and electrically mated to the LV. The electrical connection to the Instrumentation Unit (IU) was through a separation device.

(b) RCS engine simulators were used for both tests. The X00-075 units were used during the Altitude Chamber run and the A14-275 units were used for the Space Vehicle Plugs Out Integrated Test.

(c) The external Digital Test Command System (DTCSC 14-231) is utilized at LC 34 and is not required in the Altitude Chamber.

(d) The Fuel Cell Battery Substitute Unit (C14-395) was utilized during the Space Vehicle Plugs Out Integrated Test. This unit is used to supply S/C bus internal power after the flyaway umbilical has been dropped.

(e) The Mobile Data Recorder was utilized to record S/C DC bus voltages during the Altitude Chamber Test. It was not utilized during the Space Vehicle Plugs Out Integrated Test.

(f) The water glycol shutoff valve control cable and associated power supply was utilized during the Space Vehicle Plugs Out Integrated Test. This requirement exists in order to hold the glycol shutoff valve open after flyaway umbilical eject, such that continuous water-glycol circulation may be maintained.

(g) The oxygen test set (Z00-025-401) was used during the Space Vehicle Plugs Out Integrated Test. Oxygen was supplied from one "K" bottles through this unit to a facility valve box and then to the Spacecraft. During the Altitude Chamber Test, oxygen was supplied from the on board tanks, each of which had been loaded with liquid oxygen (LOX). Oxygen, hydrogen, and nitrogen fill, vent, pressurization, and relief lines were connected to the S/C during Altitude Chamber operation.

(h) The Protective Pressurization Unit (S14-099) was used to maintain a pad pressure on the SPS tanks. This unit was disconnected during the Space Vehicle Plugs Out Integrated Test to maintain better ground isolation.

(i) During the Space Vehicle Plugs Out Integrated Test, the Launch Escape System (LES) tower was installed and electrically connected. During the Altitude Chamber Test, neither the LES tower nor the pyrotechnic substitute boxes were installed.

(j) GSE access connectors were connected to the S/M during the Altitude Chamber Test and were not connected during the Space Vehicle Plugs Out Integrated Test.

(k) The access Arm White Room was mated to the S/C during the Space Vehicle Plugs Out Integrated Test. This configuration does not exist in the Altitude Chamber.

(l) Air was being supplied to a C/M access port to maintain a low humidity condition in the space between the C/M pressure vessel and heat shield during the Space Vehicle Plugs Out Integrated Test.

(3) Ground System

Configuration of the Spacecraft GSE at the time of the Altitude Chamber Test is defined in Reference 1-19. Configurations of the supporting facilities together with the GSE are shown schematically in Enclosure 1-9, Drawing 1-D-0056-6. Remote monitoring and control equipment configurations are described in Reference 1-22. Significant differences in the ground system configuration relate directly to the interface differences discussed previously; therefore, further discussions are not provided.

g. Spacecraft 008 Test Configuration

The Spacecraft 008 Thermal Vacuum Test No. 3 was conducted at the Space Environmental Simulation Laboratory (SESL), MSC, from October 26, 1966 through November 1, 1966. The configuration for this test was selected for comparison with the configuration of S/C 012 at the time of the accident. A special computer tabulation was obtained to compare the configuration verification records of the two Spacecraft. Copies of the S/C 008 test reports and supporting data were

obtained. These data were reviewed and a summary report was prepared (Reference 1-24). Significant extracts from the summary report are:

(1) Spacecraft 008 wire harnesses did not have the modification kit (Teflon wrapping) installed which provides additional protection to crew compartment wiring. A special pad protected the wiring on the aft bulkhead during the S/C 008 test.

(2) Spacecraft 008 had additional wiring that was not in S/C 012 to implement limited remote control during unmanned altitude chamber tests. Additional wiring for test instrumentation was installed in S/C 008. The right-hand C/M window of S/C 008 was utilized for an umbilical pressure bulkhead penetration to bring out the additional control circuits and instrumentation.

(3) Command Module floodlights of improved configuration were employed on S/C 012. S/C 008 utilized the basic configuration for all thermal vacuum testing. The provisions for portable floodlights were established as a requirement from the S/C 008 tests and installed on S/C 012, but the portable lights were not aboard for Space Vehicle Plugs Out Integrated Test.

(4) Noise filter adapters for the crewman umbilical electrical cables were not utilized on S/C 008, but were used on S/C 012.

(5) Spacecraft 008 instrumentation and signal conditioners for test monitoring were not flight qualified instruments in all cases, but had been tested to the actual test environment. Flight instrumentation was installed on S/C 012.

(6) Design modifications were incorporated in the Environmental Control Unit (ECU) on the S/C 012 unit as compared to the S/C 008 ECU.

(7) A production prototype mission events sequencer was used on S/C 008. S/C 012 had production sequencers that were flight qualified.

(8) Crew couches were modified for the long duration of thermal vacuum test on S/C 008. Crew compartment stowage and special Teflon covered Sarfoam pads on the aft bulkhead were used on S/C 008, differing from the S/C 012 flight configuration. The crew compartment hatch on S/C 008 thermal vacuum test run No. 3 had the airlock incorporated for scientific experiments.

(9) Beta cloth over Teflon covering was used extensively on the aft bulkhead (covering the special Sarfoam pad) and couches during the Spacecraft 008 test. This is a fire-resistant material. Also, fire extinguishers were available inside the crew compartment during the S/C 008 test.

(10) A large number of differences existed in the GSE and supporting facilities. These differences were not significant to the Spacecraft 012 accident.

D. FINDINGS AND DETERMINATIONS

Review of data presented in this report results in summary findings and determinations as follows:

1. FINDING

One hundred and sixty-four (164) Engineering Orders (EO's) were not accomplished at the time Spacecraft 012 was received at KSC. Six hundred and twenty-three (623) EO's were released subsequent to receipt at KSC. Of these, twenty-two (22) were recent releases which were not recorded in configuration records at KSC at the time of the accident.

DETERMINATION

Continuing engineering changes indicate progressive development of the Spacecraft configuration through the time of the Space Vehicle Plugs Out Integrated Test. At the time of the test, the configuration could not have been complete with respect to the launch configurations.

2. FINDING

The required Space Vehicle Plugs Out Integrated Test configuration was not explicitly defined by design engineering or test documentation. Definition of required test configuration was limited to test set-up and controls configurations specified in OCP FO-K 0021-1.

DETERMINATION

The absence of explicit definition of Spacecraft test configuration requirements relegated such definition to the test organization. Further, it is the opinion of this Panel that the lack of timely and

explicit design definition of the required test configuration precluded complete assessment of adverse configuration aspects as constraints to the test.

3. FINDING

Eighty (80) EO's effective on S/C 012 were not accomplished at the time of the accident. Of these, twenty (20) were specified to be accomplished subsequent to the Space Vehicle Plugs Out Integrated Test. Four (4) of the open EO's were of a nature not affecting configuration. Three hundred and eighty-four (384) Parts Installation and Removal Records (PIRR's) and Temporary Installation Records (TIR's) were open, of which one hundred and twenty-five (125) were in compliance with requirements of the test documentation.

DETERMINATION

It is concluded that test requirements had no defined relationship to the open status of fifty-six (56) EO's and two hundred and fifty-nine (259) PIRR's/TIR's. It is the opinion of this Panel that all work items and EO's were not closed because of late receipt of changes or further work scheduled to be accomplished prior to launch.

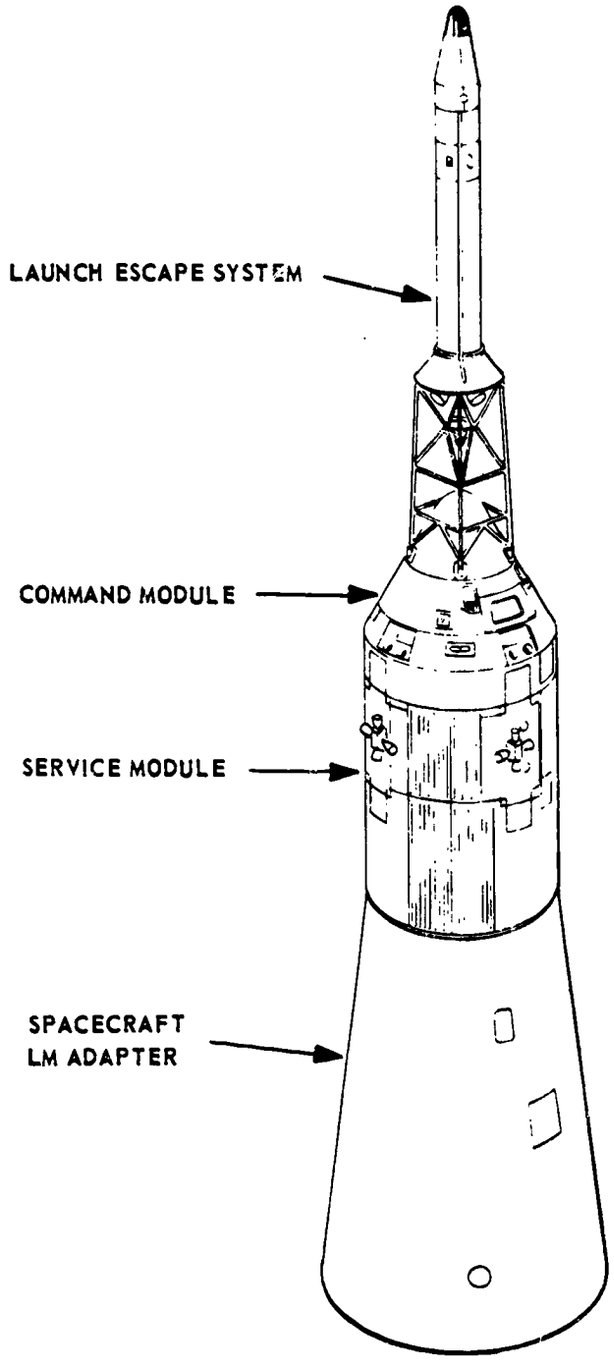
4. FINDING

Items were placed on board the Spacecraft during preparation for the Space Vehicle Plugs Out Integrated Test which were not documented by quality inspection records.

DETERMINATION

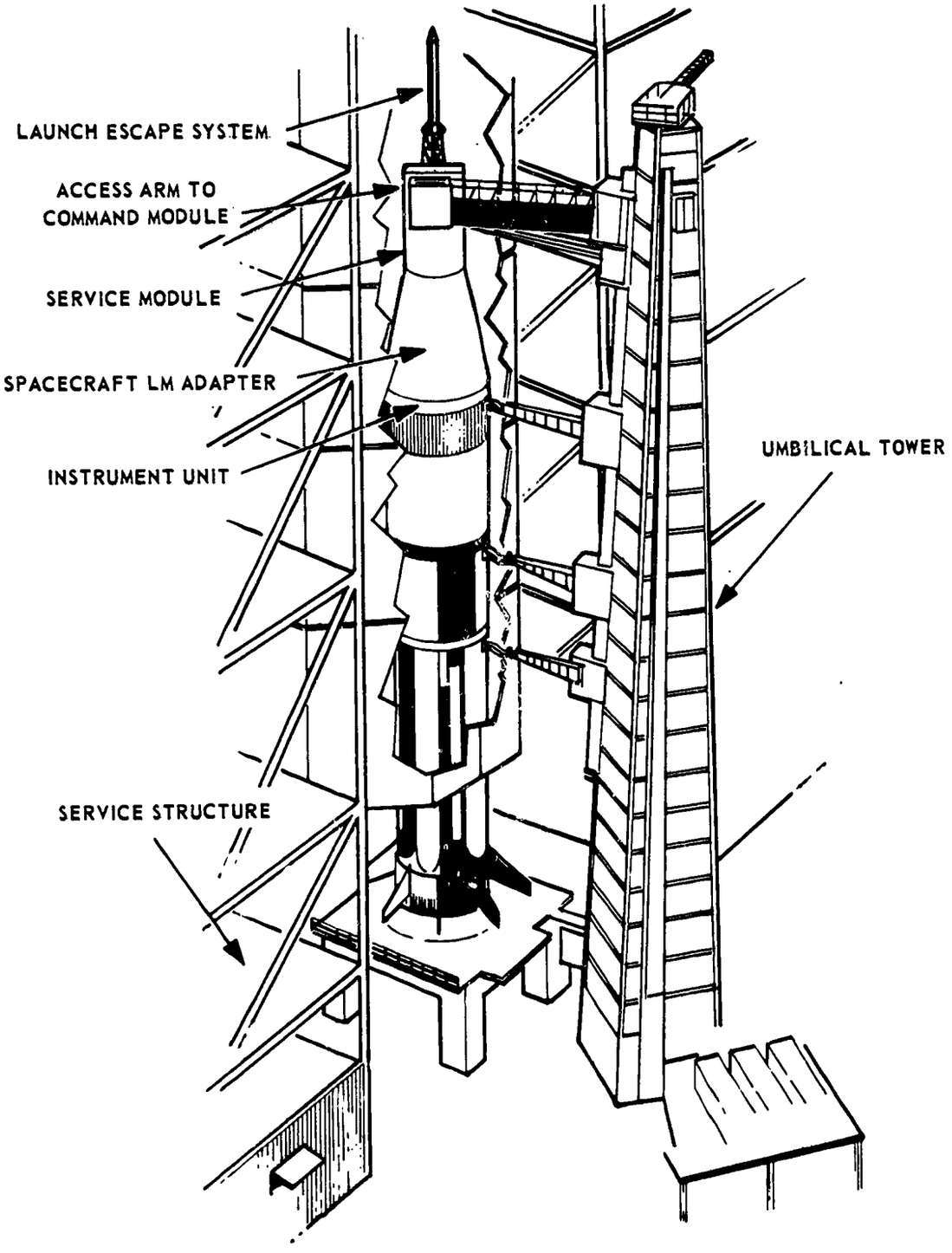
Procedures for controlling entry of items into the Spacecraft were not strictly enforced.

SPACECRAFT CONFIGURATION



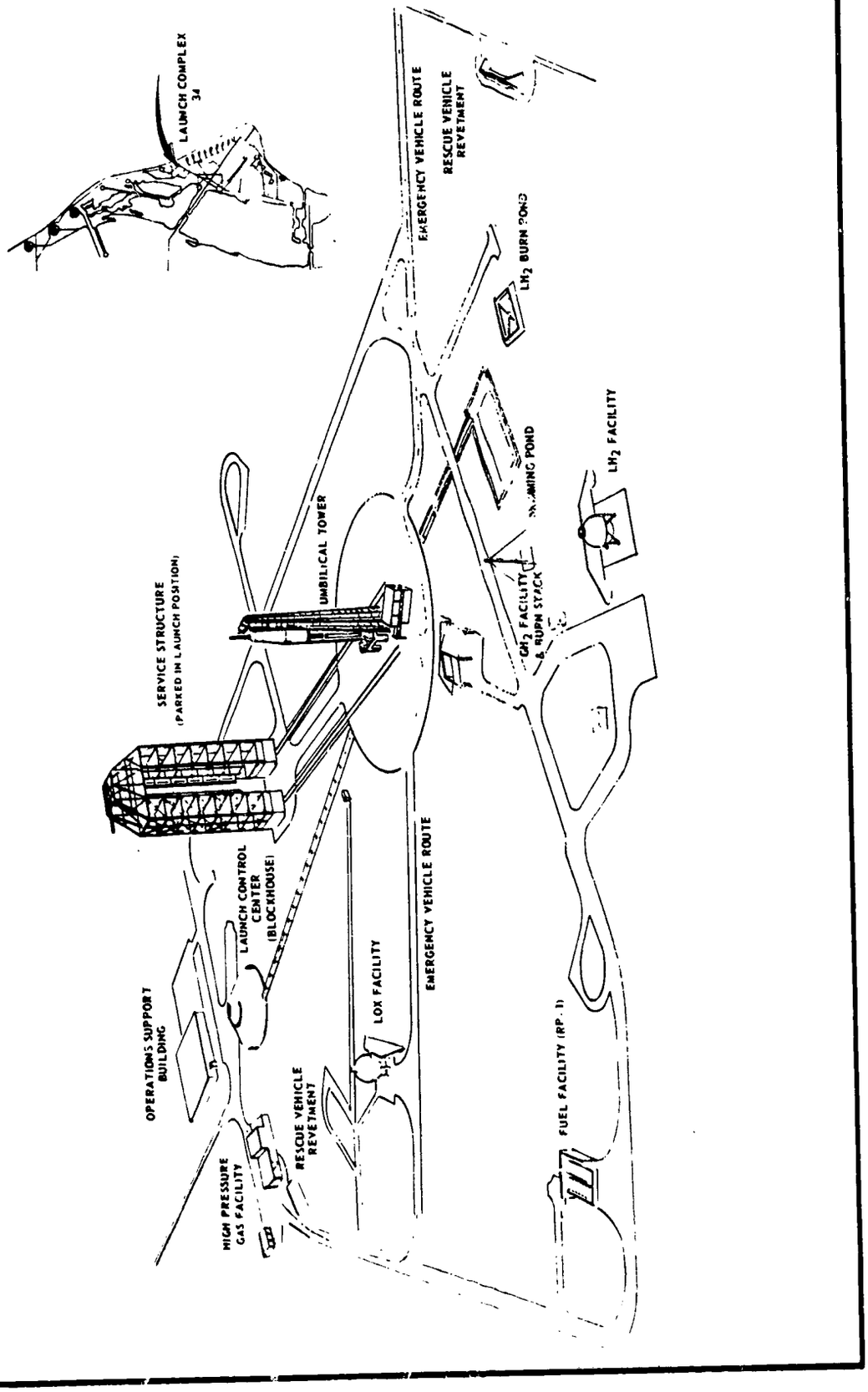
ENCLOSURE 1-1

VIEW OF SPACECRAFT LAUNCH VEHICLE IN SERVICE STRUCTURE
WITH ACCESS ARMS EXTENDED

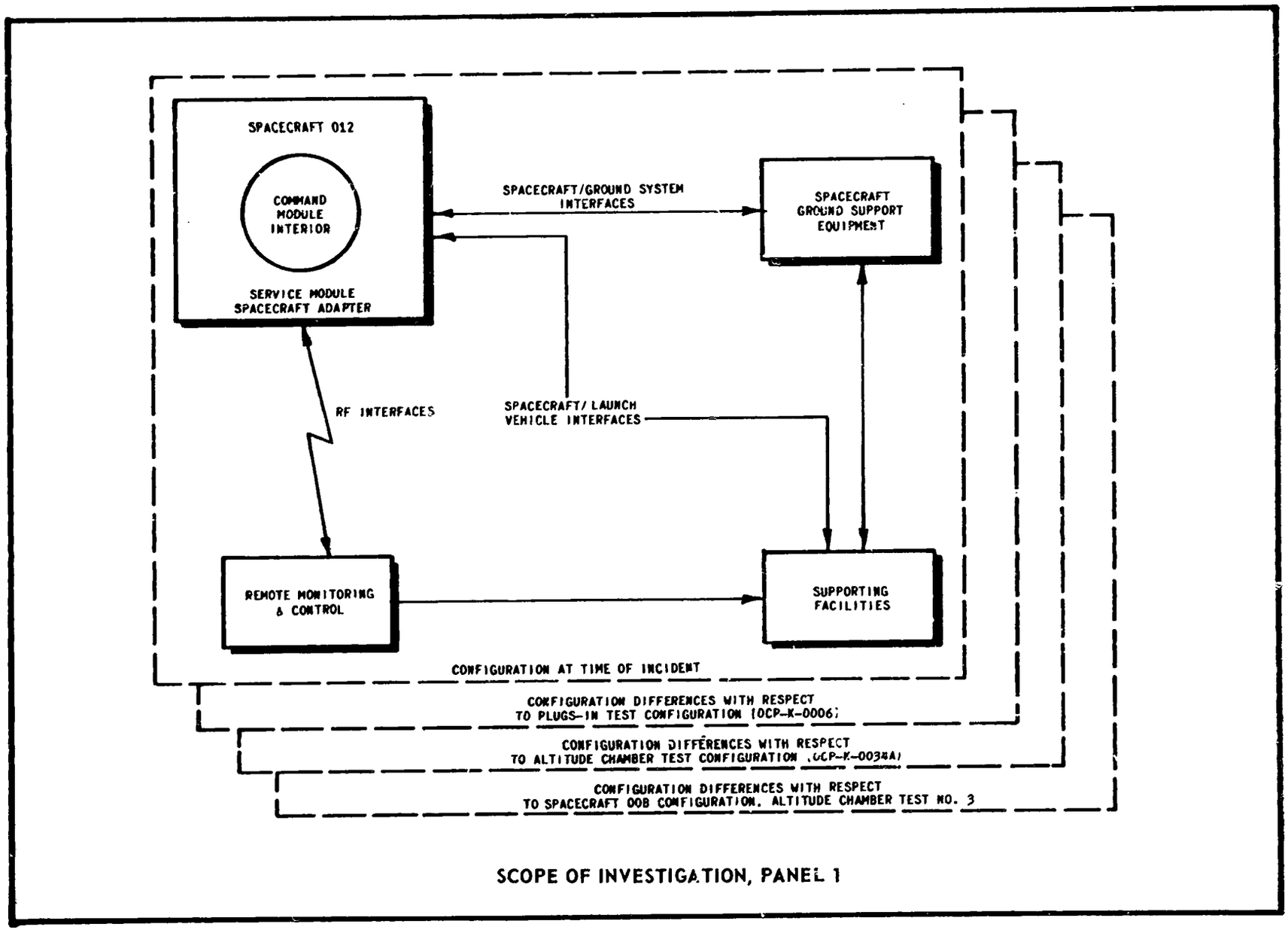


ENCLOSURE 1-2

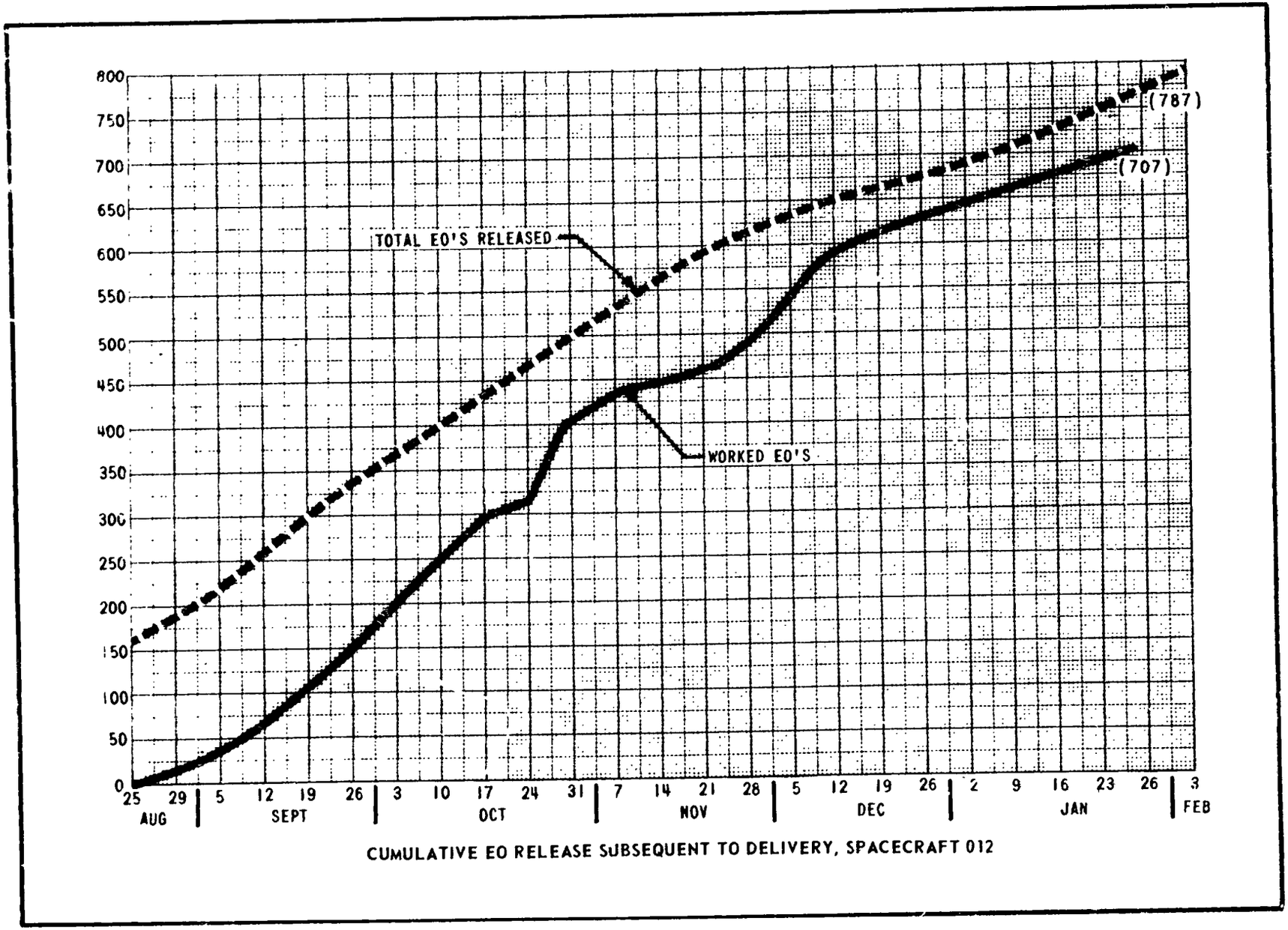
AERIAL DRAWING OF LAUNCH COMPLEX 34



ENCLOSURE 1-3



SCOPE OF INVESTIGATION, PANEL 1



CUMULATIVE EO RELEASE SUBSEQUENT TO DELIVERY, SPACECRAFT 012

ENCLOSURE 1-5

SPACECRAFT 012 CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

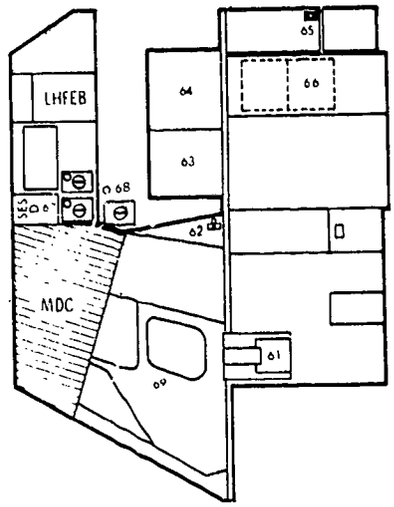
The attached table lists by area the configuration of stowage items and other loose equipment for the Spacecraft 012 Crew Compartment. This information is given for the planned launch, Operational Checkout Procedure (OCP) K-0034A-1-Manned Altitude Chamber Test, and OCP K-0021-1-Plugs-Out Test.

The data for planned launch was taken from the Spacecraft 012 Operational and Experimemtal GFE/CFG Stowage List. Data for OCP's K-0034A-1 and K-0021-1 were derived from the applicable Test Preparation Sheets, Part Installation or Removal Records, Temporary Installation Records, Stowage OCP's and interviews of ground and flight crew support personnel. In the case of OCP K-0021-1 some data was also derived from physical inspections of the spacecraft after the incident.

The data includes all items loose in the crew campartment, installed in stowage containers, carried on the flight crew's persons, or items subject to removal displacement by the flight crew. It further includes all non-flight materials known to be on board the spacecraft. All items are listed under their normal launch stowage locations, except that non-flight items are listed where actually stowed for the test. Items stowed in other than normal launch locations or in other than normal launch conditions are identified by notes in the "REMARKS" column.

The "STOWAGE ITEM NUMBER" is a cross index to the Spacecraft 012 Operational and Experimental GFE CFE Stowage List.

LEFT HAND EQUIPMENT BAY

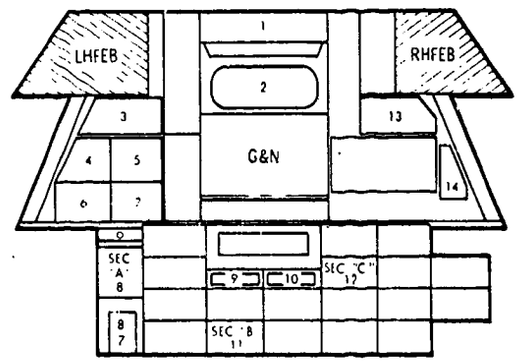


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC Form 1125 (MAR 67)(OT)

STOWAGE AREA	QUANTITY: PLANNED LAUNCH	QUANTITY: OCF K-0034A-1	QUANTITY: OCF K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
67	-	1	-	V16-55[illegible]0-41	Scientific Container "D"	873	
67	-	1	1	EC[illegible]0034-1	Dew Pt Hygrometer Sensor	038	-Stowed on floor of area 67 in LEB for OCF-1
67	-	1	1	EC3[illegible]004	Sensor Cable	039	-(same as above)
67	-	1	1	EC[illegible]400	Control Unit	040	-(same as above)
67	-	1	1	SEB111000[illegible]	Control Pwr Cable	041	-(same as above)
67	1	1	1	SDC18300001	Octopus Cable	043	-Installed across LEB
6[illegible]	1	1	1	V16-601140-11	Tee Handle	805C	
6[illegible]	-	-	-	TA44-	Roll Tape	077	
6[illegible]	-	-	-	V16-601[illegible]0	Container (Food Strg Supp)	812	
6[illegible]	-	-	-	14-011[illegible]	Food Set	0[illegible]6	-1 man-month food stowed in special container on 0034A-1
6[illegible]	-	-	-	SEB[illegible]10007[illegible]-70	Plastic Bag	066	
6[illegible]	-	-	-	A1[illegible]-000	LCG	070	
6[illegible]	-	2	-	A. 007-000	In Flt Coveralls (jacket)	071	
6[illegible]	-	2	-	A. 006-000	In Flt Coveralls (pants)	072	
6[illegible]	-	-		ME901-03[illegible]	Sandals (3 pr)	805	
[illegible]	-	-	-	ME901-03[illegible]5-00[illegible]	Sandals (2 pr)	805	
6[illegible]	-	-	-	ME[illegible]01-03[illegible]-00[illegible]	Sandals (2 pr)	805	
6[illegible]	-	1	-	ME901-03[illegible]-00[illegible]	Sandals (3 pr)	805	
[illegible]	1	1	1	ME901-03[illegible]-0040	Sandals	806	
6[illegible]	-	-	-	SEB[illegible]10007[illegible]-70	Plastic Bag	061	
[illegible]	1	1	-	SDB[illegible]10030	Commanders Checklist	011A	
6[illegible]	1	1	-	SDB[illegible]10040	Flight Plan	011B	
68	1	1	-	V16-[illegible]0391	Container Flt Data File	840	
6[illegible]	1	1	-	V16-601140-11	Tee Handle	805C	
68	-	-	3	V16-601[illegible]-7	Noise Limiter Adapter Cables		
68	Ten	-	3	V16-601201-71,-81, -91	Umbilical Assy	877	
68	3	3	3	[illegible]-5	O2 Hose Inlet Nozzle	408	- On umbilicals
68	3	3	3	[illegible]36	O2 Hose Exhaust Nozzle	410	- On umbilicals
68	-	-	2	V16-601263-41	Cobra Cable	878	
68	1	1	1	V16-601263-[illegible]	Cobra Cable	878	
68	-	2	-	V16-601[illegible]0E	T-Adapter Elect	1000	- Center Crewman cobra cable ONLY on OCF-1
68	-			ME[illegible]-[illegible]-[illegible]	LiOH Cartridges	868	- Dash numbers -0001 installed for OCF-1. Non-flight data number
6[illegible]	-	-	-	None Flight	OCF Cover		- On all 3 umbilicals. Made of nylon. Each had "Remove before flight" streamer

LOWER EQUIPMENT BAY

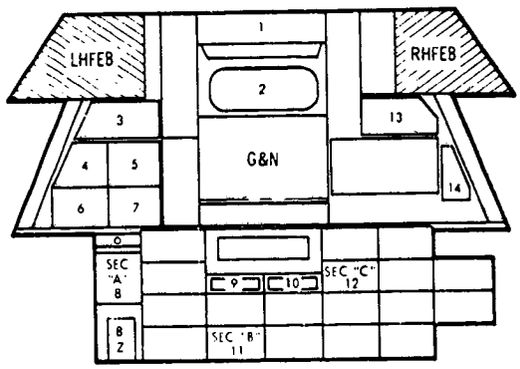


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 1725 (MAR 67)(01)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	QUANTITY OCP K-0034A-1	QUANTITY OCP K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
1	1	1	1	2012691	G&N Long Eyepiece SCT	019	
[illegible]	1	1	1	2012719	G&N SCT Eyepiece	016	
[illegible]	1	1	1	1013010	SCT Prism Housing	016A	
1	1	1	1	2012700	G&N SXT Eyepiece	017	
[illegible]	[illegible]	[illegible]	1	2012699	SXT Mirror Housing	017A	
2A	1	1	1	SEB33100065-201	G&N Optics Cover SXT	054	
2B	1	1	1	SEB33100071-201	G&N Optics Cover SCT	055	-Found on aft bulkhead after 0021-1
[illegible]	[illegible]	-	-	V16-601018	Food Container "A"	814	
[illegible]	[illegible]	-	-	V16-601016	Food Container "B"	816	
[illegible]	[illegible]	-	-	V16-601017	Food Container "C"	815	
6	[illegible]	-	-	V16-601014	Food Container "D"	818	
7	[illegible]	-	-	V16-601015	Food Container "E"	817	
8	1	1	-	SEB33100031-201	Ring Sight	008	
8A	[illegible]	1	1	SEB331000[illegible]-207/-208	16 MM Seq Cam with Film	001	-Stowed on floor of area 82, LEB for 0021-1
8B	1	1	1	SEB33100026-201	16 MM Power Cable	005	-Stowed on floor of area 82, LEB
8C	1	1	-	SEB331000[illegible]-201	18MM Lens	003	
8D	[illegible]	1	-	SEB331000[illegible]-201	[illegible] MM Lens	202	
8E	1	1	-	SEB331000[illegible]-201	100 MM Lens	004	
8F	[illegible]	1	-	SEB331000[illegible]-201	Mirror Mtg Bracket	037	
8G	[illegible]	1	-	SEB331000[illegible]-206	16 MM Magazine	002	-1 stowed in area 40, crew couch, on 0034A-1
8H	[illegible]	1	-	SEB331000[illegible]-201	10 MM Camera	006	
8I	[illegible]	1	-	SEB331000[illegible]-201	250 MM Lens	009	
8J	[illegible]	-	-	SEB331000[illegible]-201, -202, -203	70 MM Magazine	212	
8K	[illegible]	1	-	SEB331000[illegible]-201	Exp Dial	011	
8L	1	1	-	SEB33100028-201	Spotmeter	010	
8M	1	1	-	EC-0135	Vascular Support	215	
8N	1	1	-	SEB12100037-201	Binoculars	036	
8N	1	1	-	V16-752031	Foam Cushion	1015	
8N	1	1	-	V16-752058-41	Foam Cushion	1016	
8N	1	1	-	V16-753110	Foam Separator	1016A	
8N	1	1	-	SEB33100050-201	Filter (on camera)	053	
8Z	-	-	1	Non-flight	Plastic Dust Cap		-On gas chronatograph pyro connector
8.	1	1	-		Gas Chromatograph		-Not installed on 0021-1
9	1	1	-	V16-334137	Crew Flt Data File Cont.	839	

LOWER EQUIPMENT BAY (CONT.)

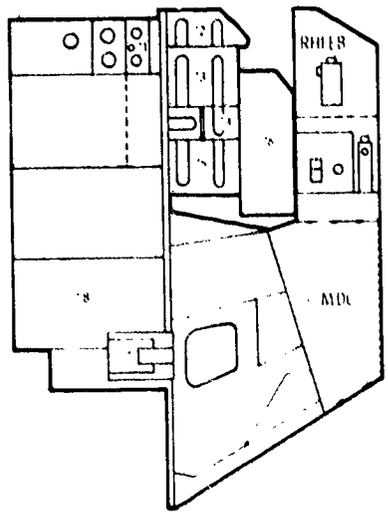


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 3725 (MAR 67)(OT)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	QUANTITY OCP K-0034A-1	QUANTITY OCP K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
9	1	1	-	SDB33100044	Landmark Maps	012F	
9	1	1	2	SDB33100048	S/C Sys Data	012G	•One document found on center couch, on on RH girth shelf, area 9E after 0021-1
9	1	1	-	SDB33100047	Exper Checklist	012H	
9	1	1	-	SDB33100045	Star Chart	012I	
9	1	1	-	SDB33100046	Orbital Map	012J	
9	1	1	-	SDB33100043	Navigation Checklist	012B	
10	1	1	-	V16-601125	Tool Workshelf Dwr	803	
10	1	1	-	V16-601145-21	Tool "A"	803A	
10	1	1	-	V16-601480	Tool "E"	803E	
10	1	1	-	V16-601510-21	Tool "F"	803F	
10	1	1	-	V16-601134-11	Tool "H"	803H	
10	1	1	-	V16-601481-11	Tool "J"	803J	
10	1	1	-	V16-601133-11	Tool "L"	803K	
10	1	1	-	V16-601400	Tether	803M	
10	1	1	-	V16-601241-11	Dwr Assy with Workshelf	819	
10	1	1	-	V16-601406	Work/Food Shelf	820	
10	1	1	-	SEB12100049-201	Inspection Mirror	068	
11	1	-	-	EX75036	Goggles	204	
11	1	-	-	EX75037	Mouthpiece	205	
11	8		-	SEB33100080-201, -202 or -203	70 MM Magazine	006	
11	7	7	-	SEB33100022-201	16 MM Magazine	002	
12	1	1	1	SD511076	MDAS	600	
13	1	1	-	SEB42100004-201	Physiological Monitoring Kit	024	
13	1	1	-	14-149	UCD Clamp	029	
13	1	1	-	14-0107	Urine Receptacle	035	
13	1	1	-	14-0109	Urine Filter Assy	034	
13	1	1	-	V16-601421-101	Receptacle Assy Relief Tube	861	
13	1	1	-	V16-601526-11	Wrapper Assy Relief Tube	876	
14	1	1	-	14-0112	Towels (Dry Utility)	031	
15	-	-	1	Non-flight	Mounting Hardware for Panel 150		•In plastic bag taped to panel
Several LEB Panels	-	-	-	Non-flight	White Room Tape		•Over open ACE connectors on 14 panels & over entry battery terminals

RIGHT HAND EQUIPMENT BAY



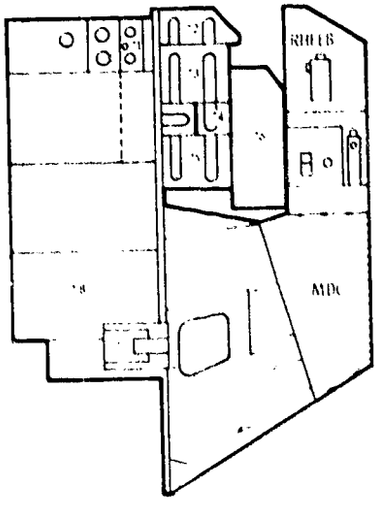
CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 3215 (MAR 87)(EG)

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	OCP K-0084A-1	OCP K-0021-1				
[illegible]	[illegible]	[illegible]	-	V10-6011-50	Vacuum Cleaner Compartment Vacuum Clnr Ref Stow Bag Assy	850	
[illegible]	[illegible]	[illegible]	-	ME10[illegible]-0001-0001	Vacuum Clnr Debris Bag	846A	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Fecal Outer Bag	846B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Vacuum Clnr Germicide Pouch	846C	
[illegible]	[illegible]	[illegible]	-	MF[illegible]-0001-0001	Tie Band	846D	
[illegible]	[illegible]	[illegible]	-	MF[illegible]	Medical Accessories Kit Compt		
[illegible]	[illegible]	[illegible]	-	10[illegible]	Bio Instrumentation Acc Kit	0[illegible]	
[illegible]	[illegible]	[illegible]	-	SEB4-10001-[illegible]-01	Electrodes	0[illegible]A	
[illegible]	[illegible]	[illegible]	-	SEB4-10001-[illegible]-01	Micropore Disk	0[illegible]B	
[illegible]	[illegible]	[illegible]	-	[illegible]-0[illegible]	Wet Wipe Towels	0[illegible]C	
[illegible]	[illegible]	[illegible]	-	SEB4-10001-[illegible]-01	Paste	0[illegible]D	
[illegible]	[illegible]	[illegible]	-	SEB4-10001-[illegible]-01	Stoma Seal Disk	0[illegible]E	
[illegible]	[illegible]	[illegible]	-	SEB4-10001-[illegible]-01	Bio Instr Stowage Bag	0[illegible]F	
[illegible]	[illegible]	[illegible]	-	V10-6011-51	Vacuum Cleaner Nozzle	843A	
[illegible]	[illegible]	[illegible]	-	EA[illegible]-0008-1	Nephelometer(Aerosol Particle)	101	
[illegible]	[illegible]	[illegible]	-	V10-6014-[illegible]-101	Sanitation Supply Assy	811	
[illegible]	[illegible]	[illegible]	-	V10-6014[illegible]-11	Inner Fecal Bag	811A	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Germicide Pouch	811B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Outer Fecal Bag	811C	
[illegible]	[illegible]	[illegible]	-	V10-6014-[illegible]	Outer Tie Band	811D	
[illegible]	[illegible]	[illegible]	-	[illegible]-0[illegible]	Dry Utility Towels	031	
[illegible]	[illegible]	[illegible]	-	V10-6011-48	Vacuum Cln Ref Stow Bag Assy	850	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Vacuum Clnr Debris Bag	846A	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Fecal Outer Bag	846B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Vacuum Clnr Germicide Pouch	846C	
[illegible]	[illegible]	[illegible]	-	MF[illegible]-0001-0001	Tie Band	846D	
[illegible]	[illegible]	[illegible]	-	MF[illegible]	Elect Adapters, Sleep	887	
[illegible]	[illegible]	[illegible]	-	V10-6014-[illegible]	Adapter-CWG-Elect	871	
[illegible]	[illegible]	[illegible]	-	V10-6014-[illegible]	Cobra Cable	878	- On 0021-1, both spares removed from stowage by crew, both found on couch
[illegible]	[illegible]	[illegible]	-	V[illegible]-6014-[illegible]			
[illegible]					Sanitation Supplies Compt.		
[illegible]	[illegible]	[illegible]	-	V10-6011-[illegible]-101	Box San Sup Storage A	806	
[illegible]	[illegible]	[illegible]	-	V10-6011-[illegible]-101	Box San Sup Storage B	808	
[illegible]	[illegible]	[illegible]	-	V10-6011-[illegible]-101	Box San Sup Storage C	809	
[illegible]	[illegible]	[illegible]	-	V10-6014[illegible]-11	Sanitation Supply Assy	811	
[illegible]	[illegible]	[illegible]	-	V10-6014[illegible]-11	Inner Fecal Bag	811A	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Germicide Pouch	811B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Outer Fecal Bag	811C	

ENCLOSURE 1-8c

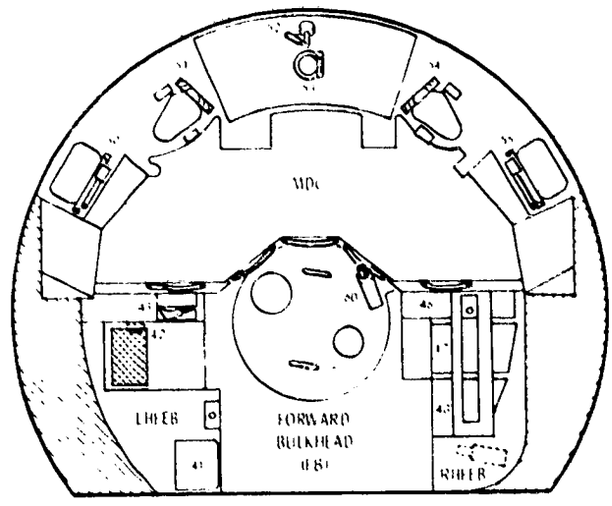
RIGHT HAND EQUIPMENT BAY (CON'T)



CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

STOWAGE AREA	QUANTITY PLANNED CAL. CM	QUANTITY OCF K-0021-1	QUANTITY OCF K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE LIPM NUMBER	REMARKS
76	62	62	-	V10-6021-19-1	Outer Tie Band	811D	
76	2	2	-	V10-6011-50-51	Cover	810	
76	1	1	-	V10-6011-50-61	Cover	809	
76	1	-	-	V10-6016-19	Aux Food Comp RHFB	811	
76							
77	1	1	-	V10-6016-91	Crew Flt Data File Container	812	
77A	1	1	-	SDB3410-3041	Sys Eng Checklist	01-3C	
77B	1	1	2	SDB3410-3042	Mission Log & Data	01-3E	-Found on LH and center couches after 0021-1. -Installed in alternate position - Primary installation position taped with "Boat Tape" on 0021-1.
78A	2	2	1	LSC-340-1-5	DSEA (Voice Recorder)		
78A	1	1	1		DSEA Adaptor Cable		-Not connected on 0021-1
78	-	-	8	Non-Critical	Plastic Dust Caps		-On pyro and circuit interrupter connectors

FORWARD BULKHEAD, SIDEWALL AND HATCH

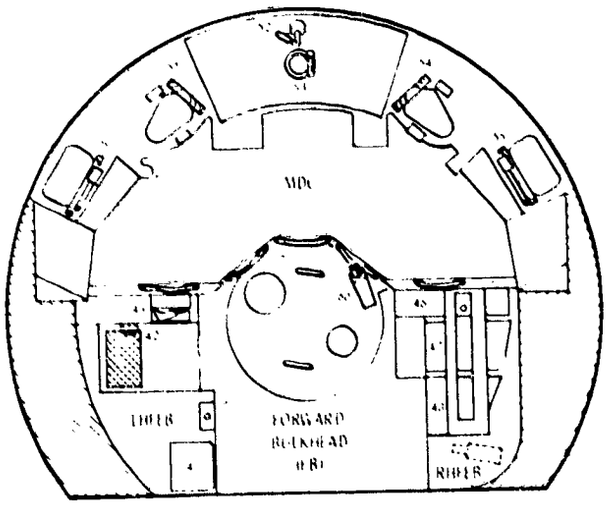


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 3129 (MAR 87)(COE)

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	OCP K-0084A-1	OCP K-0021-1				
41					LHEB--Loose Parts Compart.		
41A	1	1	1	2014264-011	Short Handhold	014	
41F	1	1	1	2014264-021	Long Handhold	014	
41G	1	1	1	V16-334100	IFM Rot Cont Mount	831	
41P	1	1	1	1011785-1	T/E Long Eyerelief Eyepiece Kit	015	
42	1	1	1	14-0104-02	Metering Water Dispenser	400	Not connected to hose or 0021-1. Hose fitting covered by plastic bag
44					RHEB--Stow. Area - Survival Kits		
44	1	1		V16-601371-101	Container Survival Kit A	84	
44	1	1		SEP401000011-201	Rucksack No. 1	085A	
44A	1	1		SEP401000010-201	Rucksack	085A	
44B	2	2		20548	Confirmator Survival Assy	085A	
44C	10	10		SEP401000021-001	Desalter Kit Tablets	085A	
44D	2	2		SEP401000021-002	Desalter Kit Process Ba.	085A	
44F	2	2		SEP401000021-003	Sponge Kit	085A	
44F	3	3		SEP401000020-201	Sunglasses	085A	
44G	1	1		2588218	Radio/Beacon Assy	085A	
44H	1	1		2588054	Radio/Beacon Spare Battery	085A	
44I	1	1		2555852	Radio/Beacon Cable Assy	085A	
44J	2	2		SEP401000004-201	Mirror	085A	
44K	2	2		SEP401000001-201	Mirror Area	085A	
44	1	1		SEP401000013-201	Rucksack No. 2	085B	
44A	1	1		SEP401000012-201	Rucksack	085B	
44B	2	2		SEP401000022-201	Water Container	085B	
44C	1	1		SEP401000052-201	Water Container	085B	
44D	12	12			Water	085B	
44E	3	3		SEP401000048-201	Water Container Stoppers	085B	
44F	1	1		SEP401000058-201	Medical Kit	085B	
44G	1	1		2815GAR	Filler Material	085B	
45	1	1		ME281-0023-0001	Gas Water Pump	848	
45	1	1		V16-601372-101	Container Survival Kit B	818	
45	1	1		SEP401000013-201	Rucksack No. 3	085C	
45A	1	1		SEP401000014-201	Rucksack	085C	

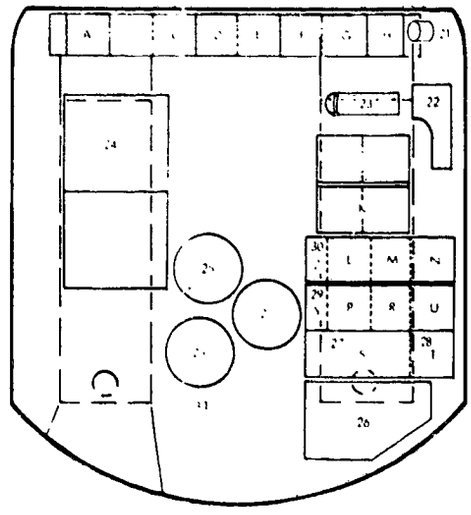
FORWARD BULKHEAD, SIDEWALL AND HATCH (CONT.)



CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	ON-ORBIT ADD	ON-ORBIT DEL				
[illegible]	1	1		SFHA01000031-001	Life Raft Kit - 4 Man	025	
[illegible]	1	1		SFHA01000030-001	Life Raft Inflation Assy	025	
[illegible]	3	3		SFHA01000033-001	Sea Anchor	025	
[illegible]	3	3		SFHA01000005-001	Sea Dye Marker	025	
[illegible]	3	3		SFHA01000032-001	Air Raft	025	
[illegible]	3	3		SFHA01000034-001	Lanyard	025	
[illegible]	3	3		SFHA01000035-001	Mooring Assembly	025	
[illegible]	1	1		SFHA01000036-001	Pad	025	
[illegible]	3	3		SFHA01000037-001	Strap Assy	025	
[illegible]	3	3		SFHA01000038-001	Strap Assy	025	
[illegible]	3	3		SFHA01000039-001	Strap Assy	025	
48	1	1		VIC-C013-3-101	Container Survival Kit C	869	
50	1	1		VIC-C1439-21	Left Side View Window Shade	84	-03E Nylon covers installed in lieu of aluminized mylar flight window covers on windows in areas 50, 51, 53, and 56. Each window cover (83) removed by crew after ingress and stowed somewhere in the spacecraft.
51	1	1		VIC-C1441-11	Shade-LH Rendezvous	845	
53	1	1		VIC-C1440-21	Shade-Center	844	
56	1	1		VIC-C1439-21	RH Side View Window Shade	84	
[illegible]	1			VIC-C0136	Tool "T" Wrench Assy	803	
[illegible]	1	1		VIC-C1441-11	Shade-RH Rendezvous	845	
[illegible]	1			99001-0000-0003	70 MM Camera	849	
[illegible]	1	1		SFHA01000031-001	4 Man Life Raft		
[illegible]	10	10		SFHA01000015-001	Urine Storage Bag		
[illegible]	1	1		P/O 01085-1	Urine Receiver		
[illegible]	3	3		SFHA01000001-001	Stiff Stowage Bag		
68	68	68		P/O 0000-	Roll-on Cuff		
MDC			1	Not-Flight	FDAI Cover		Removed from FDAI 1; stowed Item 803 and placed on aft bulkhead after crew ingress.

AFT BULKHEAD

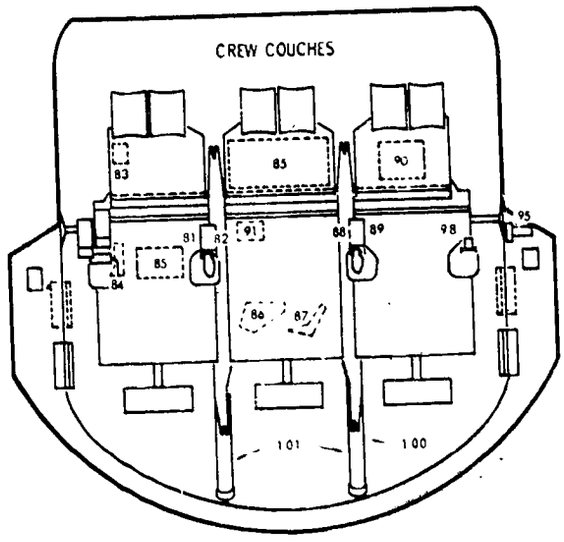


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 3129 (MAR 67)(CD)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	QUANTITY OFF K-00.84A-1	QUANTITY OFF K-00.1-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
[illegible]							
[illegible]	1	1	-	EC[illegible]	Inflight Exerciser	[illegible]7	
[illegible]	1	1	-	SEB[illegible]	Inflight Exerciser Pouch	[illegible]8	
[illegible]							
[illegible]	1	1	1	ME[illegible]	TV Optics Container	8.7	
[illegible]	1	1	1	ME[illegible]	TV Zoom Lens	8.8	
[illegible]	1	1	-	V[illegible]	Fecal Canister	8.0	
[illegible]			-	V[illegible]	PGA Stowage Bag	8.1	
[illegible]	[illegible]	[illegible]	-	V[illegible]	Crew Waste Basket	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	V[illegible]	Crew Restraint	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	V[illegible]	Pad Fecal Canister	8.[illegible]	
A	[illegible]	[illegible]	[illegible]	A[illegible]	Skull Cap Assy	8.[illegible]	
B	[illegible]	[illegible]	[illegible]	A[illegible]	Skull Cap Assy	8.[illegible]	
C	[illegible]	[illegible]	[illegible]	A[illegible]	Skull Cap Assy	8.[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	A[illegible]	Head Set	8.[illegible]	
[illegible]	[illegible]	[illegible]		A[illegible]	Helmet Stowage Container	8.[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	V[illegible]	Sleep Restraint	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	V[illegible]	PGA Stowage Bag	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	70 MM Film Pack	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	70 MM Camera	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	Ring Sight	8.[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	ME[illegible]	COAS	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	70 MM Magazine	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	16 MM Magazine	8.[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	COAS Bolt	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	V[illegible]	16 MM Camera Bracket	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	FC[illegible]	Pen Lights	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	Tool Kit	8.[illegible]	
[illegible]	[illegible]	[illegible]	-	SE[illegible]	PFK	8.[illegible]	
	[illegible]	[illegible]	IN	Non-flight	Velcro pile covering velcro hook over large portion of aft bulkhead		*Installed to protect velcro hook.
A-[illegible]	[illegible]	[illegible]	-	ME[illegible]	LiOH Cartridges	8.[illegible]	*Stowage canister, not installed on 30.1-1
J,K	[illegible]	[illegible]	-	ME[illegible]	LiOH Cartridge	8.[illegible]	
L,M,N	[illegible]	[illegible]	-	ME[illegible]	LiOH Cartridge	8.[illegible]	
P,R,[illegible]	[illegible]	[illegible]	-	ME[illegible]	LiOH Cartridges	8.[illegible]	
AA-[illegible]	[illegible]	[illegible]	-	ME[illegible]	LiOH Cartridges	8.[illegible]	
[illegible]-F	[illegible]	[illegible]	[illegible]	Non-flight	Battery Instrumentation Cable & Translator		*Stowed in pan tie [illegible] on aft bulkhead

CREW COUCHES GIRTH SHELF

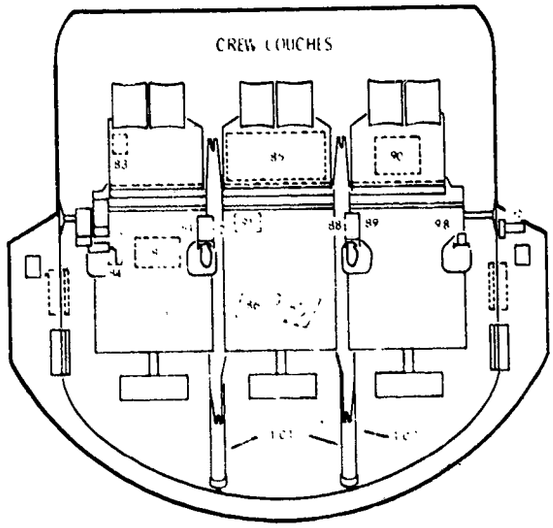


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 1225 (MAR 87)(OI)

STOWAGE AREA	QUANTITY: PLANNED LAUNCH	QUANTITY: OCP K-0036A-1	QUANTITY: OCP K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
Crew Couches	2	1	1	V16-601472-151	Couch Pad Assy	879	
	2	2	2	V16-601472-161	Couch Pad Assy	879	
	1	1	1	V16-601472-171	Couch Pad Assy	879	
	2	2	2	V16-601472-181	Couch Pad Assy	879	
	1	1	1	V16-601472-191	Couch Pad Assy	879	
	3	1	1	V16-601472-201	Couch Pad Assy	879	
	3	1	1	V16-601472-211	Couch Pad Assy	879	
	3	3	3	V16-601472-221	Couch Pad Assy	879	
	3	1	1	V16-601472-231	Couch Pad Assy	879	
	1	1	1	V16-601494	Wire Run Cover	880	
	2	2	2	V16-601495	Wire Run Cover	880	
	1	1	1	V16-601496-1	Wire Run Cover	880	
	1	1	1	V16-601496-2	Wire Run Cover	880	
	1	1	1	ME901-0257-0007	Restraint Assy	881	
	1	1	1	ME901-0257-0009	Restraint Assy	881	
	1	1	1	ME901-0257-0011	Restraint Assy	881	
	-	-	1	Non-flight	OCP K-0021-1 Checklist		- Found on LH couch after 0021-1 - Multilith Process Paper
	-	-	1	Non-flight	OCP K-0021-1 Checklist		- Multilith process paper
	-	-	1	Non-flight	Malfunction Procedures Document		- Multilith process paper - Zerox and Bruning process paper in manila folder.
81	1	1	1	V16-731750-1	Arm Rest, crew couch	871	
81	-	-	1	Non-flight	Tubular Cover		- On rotational hand controller harness
81	1	1	1		Rotational Controller		
83	1	1	-	RMK-100A	Emergency Medical Kit	022	- Container only stowed on 0021-1
84	1	1	1	V16-880207-21	Translation Cont. Mtg Bkt	869	
84	1	1	-	V16-880207-11	Translation Cont. Adapter	830	
84	2	2	1		Translation Controller	870	
85A	6	6	-	EC33203	Tissue Dispenser	030	
85B	1	1	-	EC33203	Tissue Dispenser	030	
86	1	1	-	V16-331128	TV Camera Mtg Bkt	853A	
87	1	1	-	V16-331160	16MM Camera Mtg Bkt	853	
89	1	1	1	V16-531750-1	Arm Rest, Crew Couch	870	
90							
90	1	1	1	SEB33100021-207/208	16 MM Seq Camera	001	- Stowed on floor of area B6 in LEF for 0021-1, stowed w/ loaded magazine for 0036A-1

CREW COUCHES GIRTH SHELF (CON'T)



CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

NSC FORM 8125 (MAR 87)(OT)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	QUANTITY OCF K-0034A-1	QUANTITY OCF K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
80	1	1	-	SEB331000[illegible]-301	70 MM Super Wide Angle Cam	048	
80	1	1	-	SEB331000[illegible]-301	[illegible] MM Lens, 16MM Camera	045	
80	[illegible]	-	-	SEB331000[illegible]-301, -302 or -303	70 MM Film Magazine	212	
80	[illegible]	-	-	SEB331000[illegible]-309	Interference Filter	249	
80	1	-	-	SEB331000[illegible]-3	Filter	230	
80	1	1	-	V16-7[illegible]	Vol "G" Foam Cushion	888	
80	[illegible]	[illegible]	-	SEB331000[illegible]-301	Haze Filter (on camera)	[illegible]	
80	[illegible]	[illegible]	-	EL[illegible]0170	Goggles Assy	241	
81	1	1	-	ME[illegible]80-0008-0003	Sensor Unit-Temp Evaporator	884	
95	1	1	-	V16-601501-[illegible]	Tool "F" Handle Ext.	803F	
96	1	-	-	V16-771[illegible]8	Floodlight		-Stowage cap [illegible] stowed for 0021-1
96	1	-	-	V16-[illegible]0346	Floodlight Cable		
97	1	-	-	V16-75[illegible]080	Camera Brkt (0051)		
98	1	1	1	V16-5317[illegible]-[illegible]	Arm Rest, Crew Couch Rotational Controller	871	
99	1	1	-				
100	-	-	1	Non-flight	Dust Cap		-Plastic - on SCS function box connector
101	-	-	[illegible]	Non-flight	Foam Rubber Pads		-Covered with velostat, clean room tape, laid over Z-2 struts

CARRIED ON CREWMEN

CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

STOWAGE ALTS	STOWED IN			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLATFORM [illegible]	OCP K-00[illegible]-1	OCP K-00[illegible]-1				
	3	3	3	A 1936-000	Pressure Garment Assembly	400	1 per crewman
	3	3	3	A 1912-003	Constant Wear Garment	401	1 per crewman
	15	15	15	RFB-OP-4-3-002	Passive Dosimeter	402	5 per crewman
	3	3	3	EC 30115	Penlights	403	1 per crewman
	3	3	3	SEB12100033-201	Sunglasses	404	1 per crewman
	3	3	3	SEB12100034-201	Sunglass Puch	404A	1 per crewman
	3	3	3	SEB40100095-201	Life Vest	405	1 per crewman
	3	3	3	14-0105	Urine Collection Device	406	1 per crewman
	1	1	1	RFB-OP-4-3-003	Pocket Dosimeter	414	On Senior Pilot
	3	3	3	SEB12100029-001	Chronograph	415	1 per crewman
	3	3	3	SEB12100030-201	Watchband	416	1 per crewman
	6	6	6	SEB12100031-001	Marking Pen	417	2 per crewman
	6	6	6	SEB12100032-202	Mechanical Pencil	418	2 per crewman
	1	1	1	CSD 20542	Scissors	421	On Command Pilot
	2	2	2	EC 30190	Scissors	419	On Senior Pilot and Pilot
	3 pr	3 pr	3 pr		Glove Inserts		1 pair per crewman
	3 pr	3 pr	3 pr		Wrist Dams		1 pair per crewman
	3	3	3		Neck Vent Dams		1 per crewman
	3	3	3		Neck Dams		1 per crewman
	3 pr	3 pr	3 pr	A-1901-001	Heel Plates		1 pair per crewman
	3 pr	3 pr	3 pr	A-1902-001	Sole Plates		1 pair per crewman
	1	1	1	EC 30045	Shroud Cutters	422	On Senior Pilot
	3	3	3		Combination Knife		1 per crewman
	-	-	1	Non-flight	Ratchet Wrench		On Command Pilot
	-	3	3	Non-flight	Personal Watchband		1 per crewman
	3	3	3		Bioinstrumentation System	407	1 per crewman

SPACECRAFT GSE INTERFACE DRAWINGS

ATTACHMENTS:

Drawing No.	Title
1-D-0056-1	SC GSE Status During T-10 Hold - 0021
1-D-0056-2	SC GSE Configuration During T-10 Hold - 0007
1-D-0056-3	SC Range Launch Vehicle Interfaces T-10 - 0021 (2 sheets)
1-D-0056-4	SC GSE Configuration During T-10 Hold - 0021 Electrical
1-D-0056-5	LC-34 EPS GSE Electrical (General)
1-D-0056-6	Altitude Chamber SC GSE Configuration - 0034A
1-D-0056-7	LC-34 ECS Airduct
1-D-0056-8	SC GSE Configuration During T-10 Hold - 0021 Mechanical
1-D-0056-9	LC-34 ECS Water Glycol/Oxygen GSE
1-D-0060	ACE-S C Uplink (Command) Configuration T-10 Minutes OCP-K-0021 (Sheet 1 of 2)
	ACE-S C Downlink (Monitor) Configuration T-10 Minutes OCP-K-0021 (Sheet 2 of 2)
1-D-0062	AS-204 Astro Comm Circuits

SPACECRAFT AND GROUND SUPPORT EQUIPMENT

CONFIGURATION DURING T-10 HOLD

ELECTRICAL POWER STATUS

MAIN BUSS POWER	EXTERNAL
BATTERY BUSSES	ENTRY BATTERIES
BATTERY RELAY BUSS	EXTERNAL
PYROTECHNIC BUSSES	ARMED
LOGIC BUSSES	ARMED
EMERGENCY DETECTION SYSTEM BUSSES	ARMED
SERVICE MODULE JETTISON CONTROLLERS	OPEN CIRCUIT TO SM BATTERIES

NON-FLIGHT CONDITIONS

CONDITIONED AIR WAS BEING BLOWN INTO COMMAND MODULE BASE AREA

CRYOGENIC TANKS EMPTY

NO PROPELLANTS, HELIUM, OR NITROGEN ON BOARD

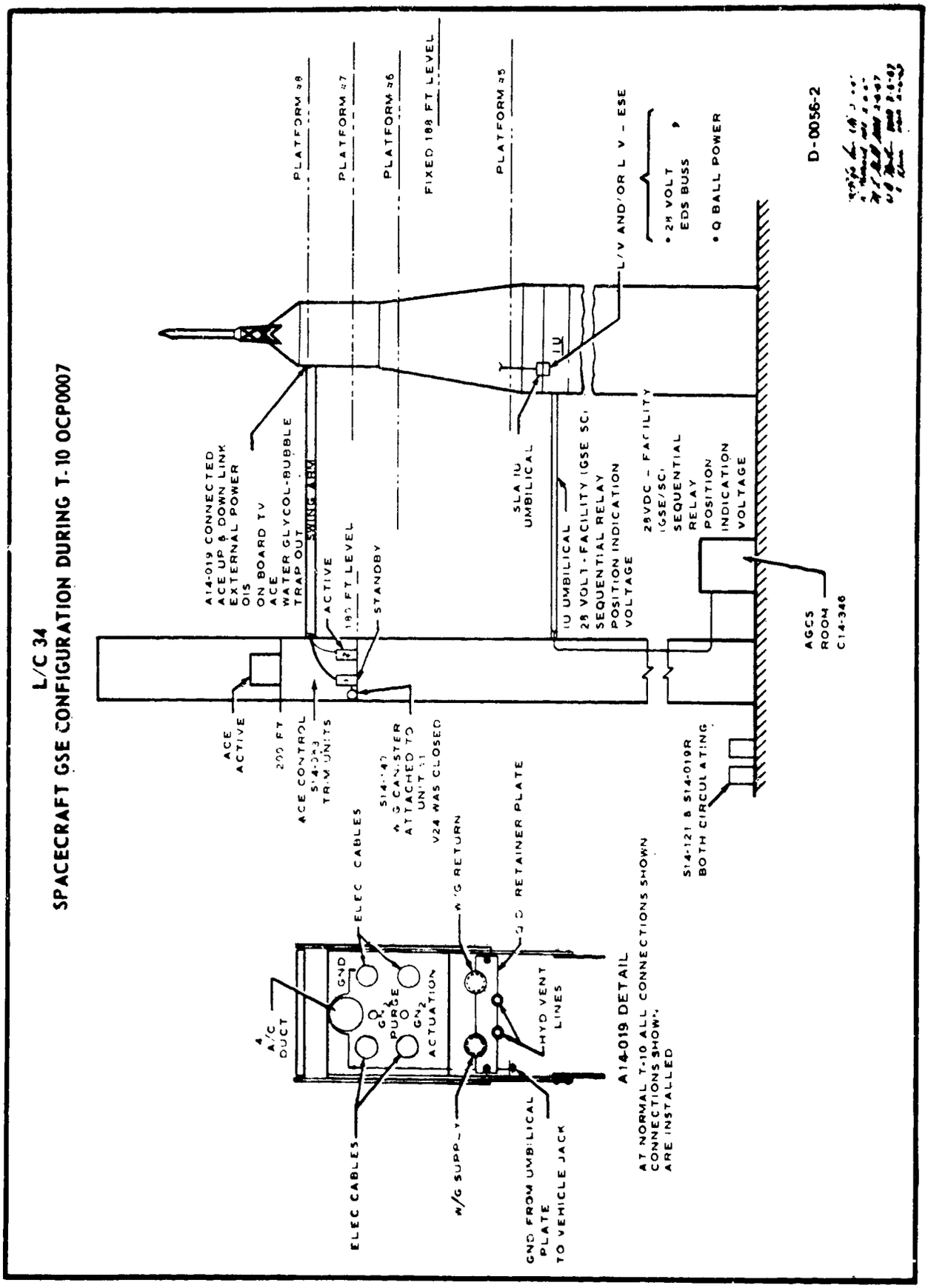
WATER GLYCOL RETURN SHUT OFF VALVE (SM) HELD OPEN BY EXTERNAL POWER

PYROS SHORTED, CONNECTORS TIED BACK

COMMAND MODULE OXYGEN SUPPLIED THROUGH ONE UMBILICAL LINE

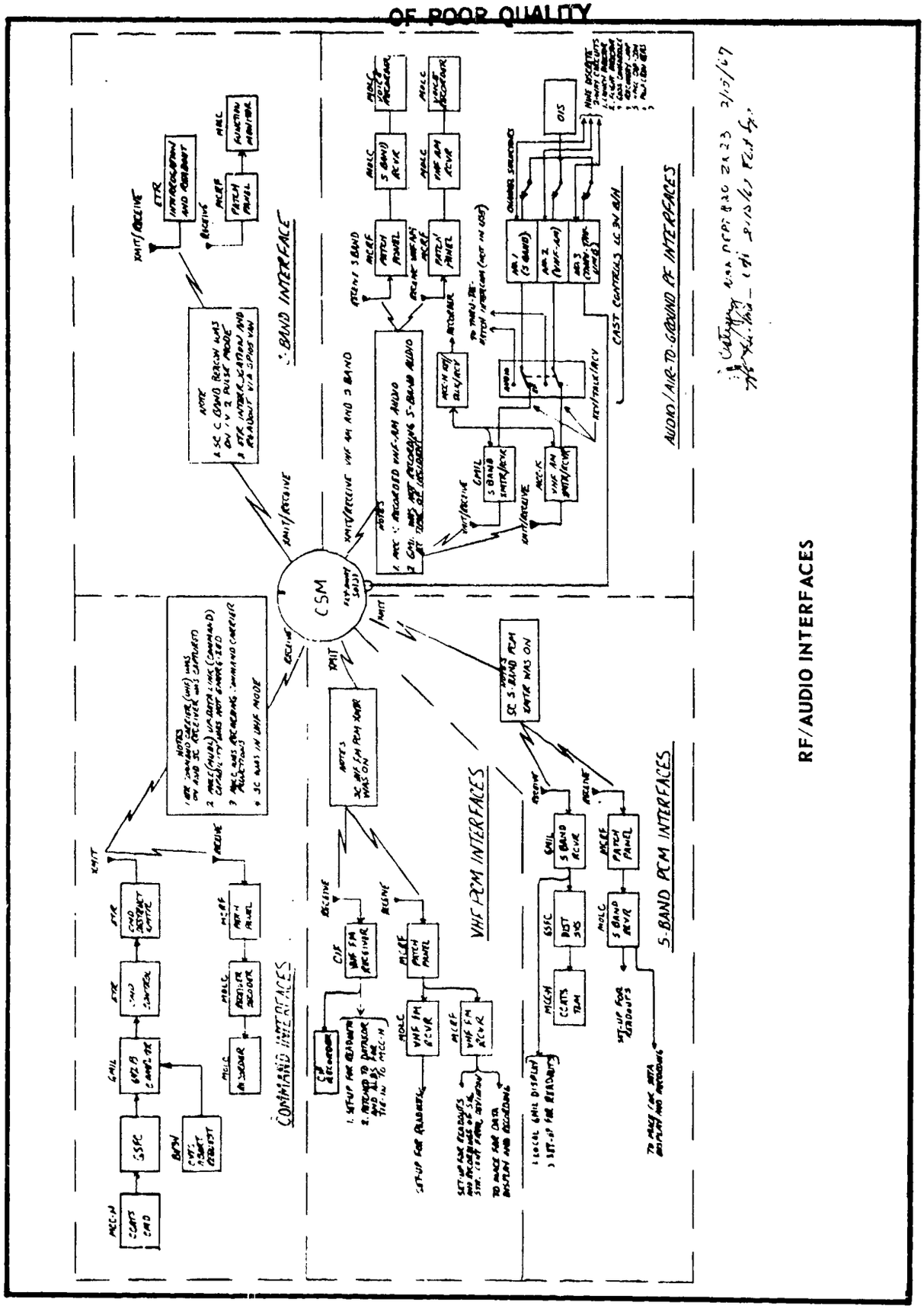
1-D-0056-I

ENCLOSURE 1-9a

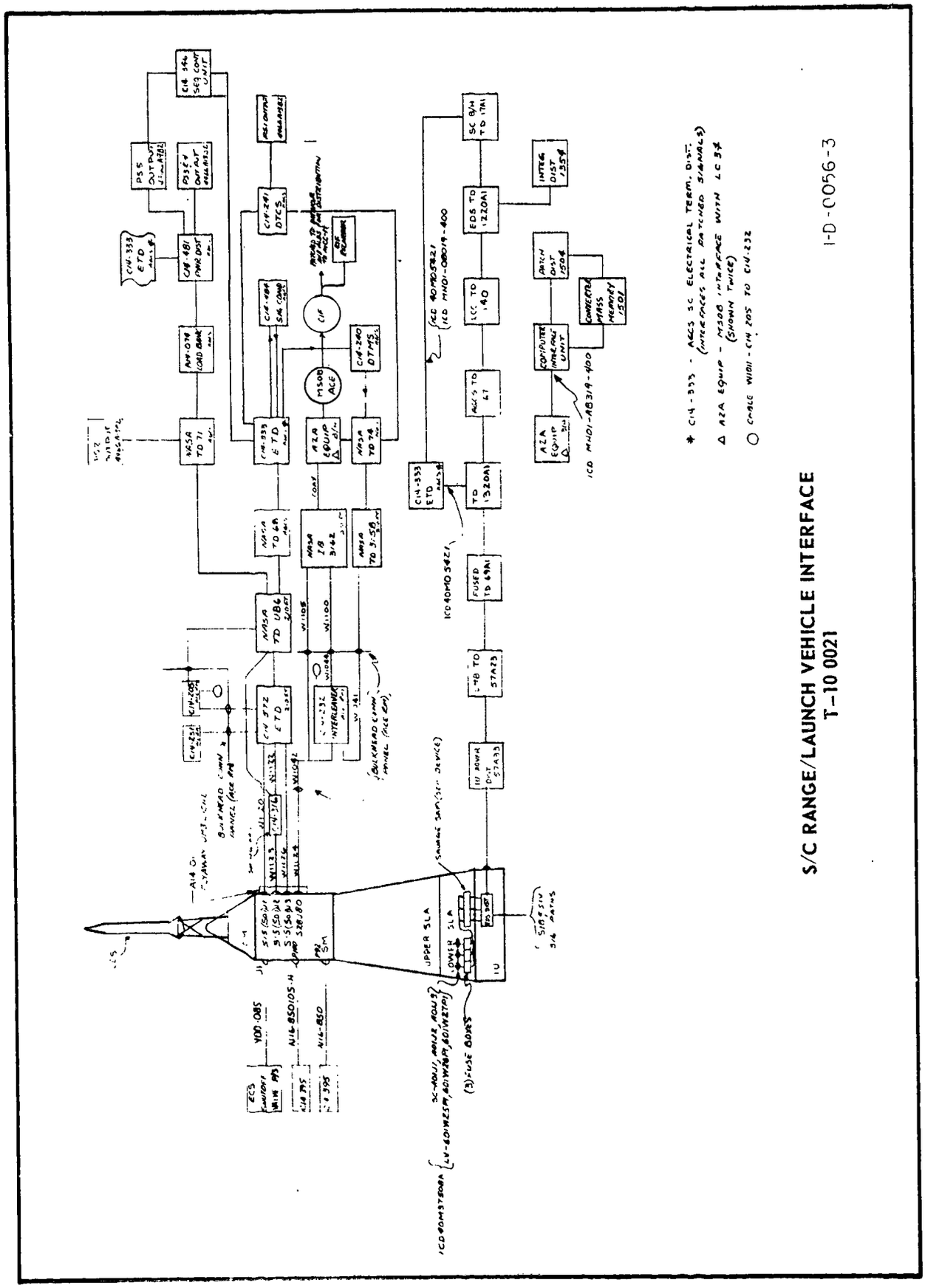


ENCLOSURE 1-9a

ORIGINAL PAGE IS
OF POOR QUALITY

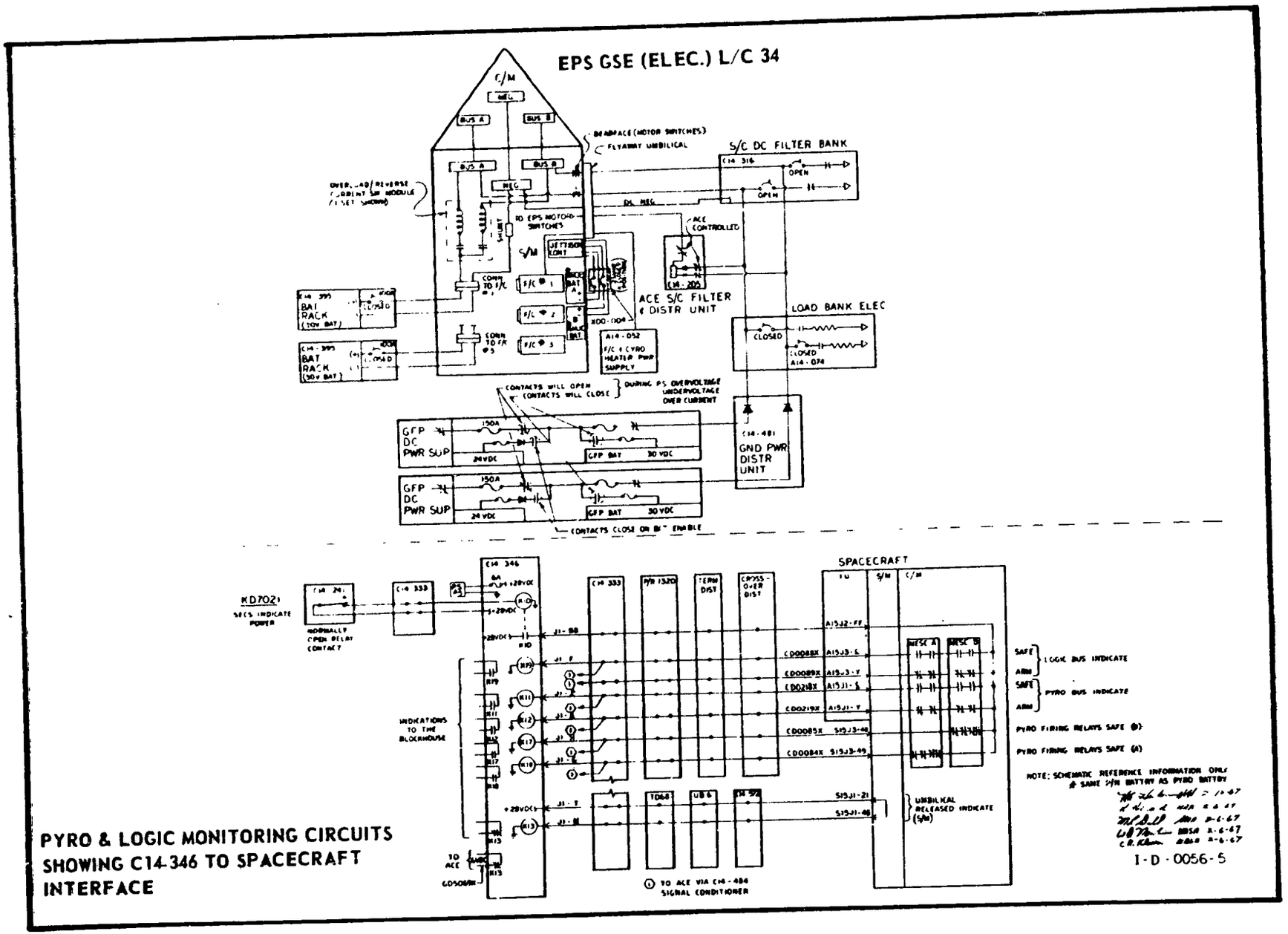


ENCLOSURE 1-96


S/C RANGE/LAUNCH VEHICLE INTERFACE
T-10 0021
1-D-0056-3
* C14-333 - AGCS SC ELECTRICAL TERM. DIST.
(INTERFACES ALL DATA/HRD SIGNALS)
Δ AZA EQUIP - M500 INTERFACE WITH LC 39A
(SHOWN TWICE)
○ CABLE W1081 - CW 205 TO C14-232
ICD M401-AB319-400
ICD 40M03821
ICD 40M03822
ICD 40M03823
ICD 40M03824
ICD 40M03825
ICD 40M03826
ICD 40M03827
ICD 40M03828
ICD 40M03829
ICD 40M03830
ICD 40M03831
ICD 40M03832
ICD 40M03833
ICD 40M03834
ICD 40M03835
ICD 40M03836
ICD 40M03837
ICD 40M03838
ICD 40M03839
ICD 40M03840
ICD

ENCLOSURE 1.9d

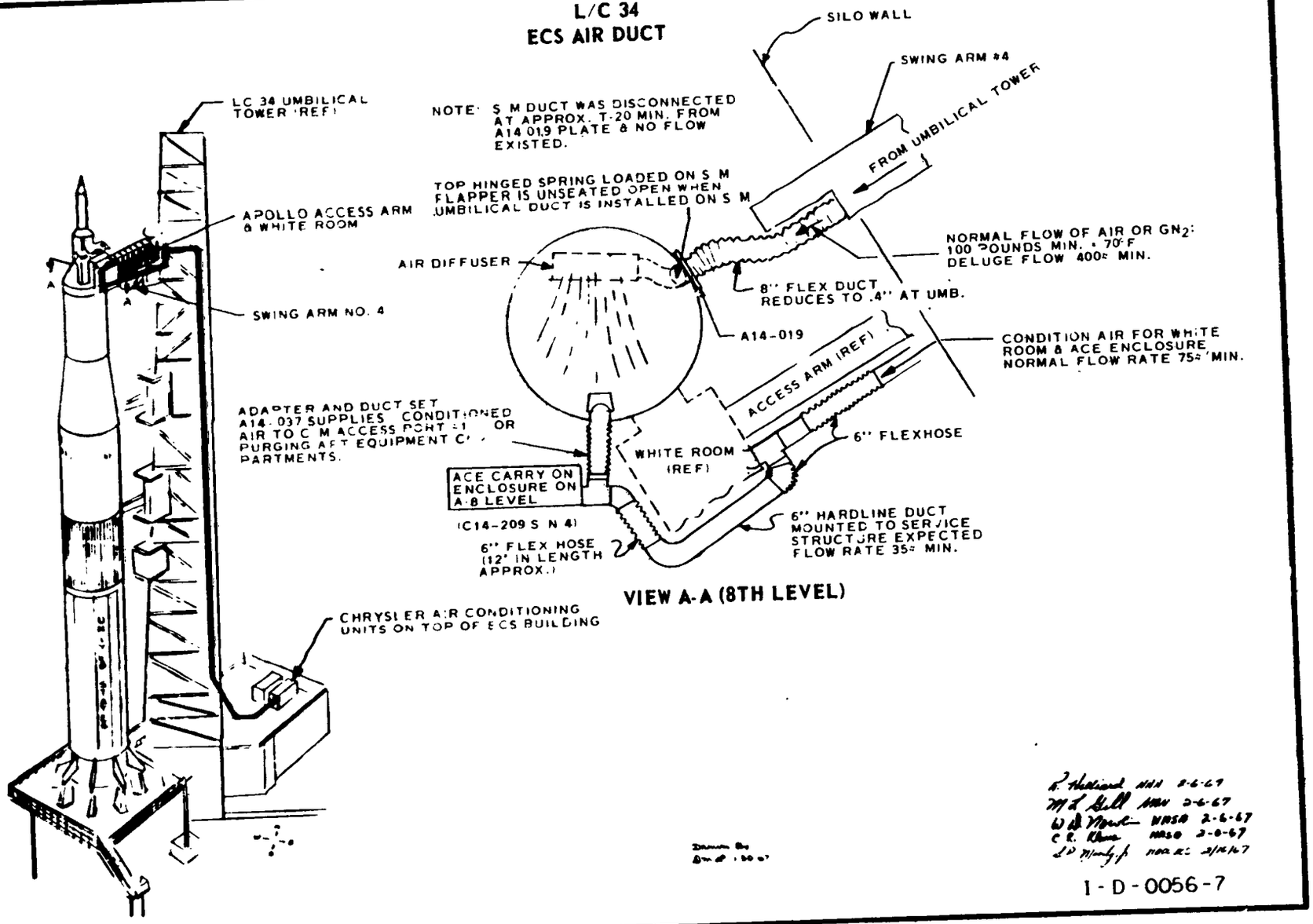
D-1-54A



ENCLOSURE 1-91

D-1-57

L/C 34
ECS AIR DUCT



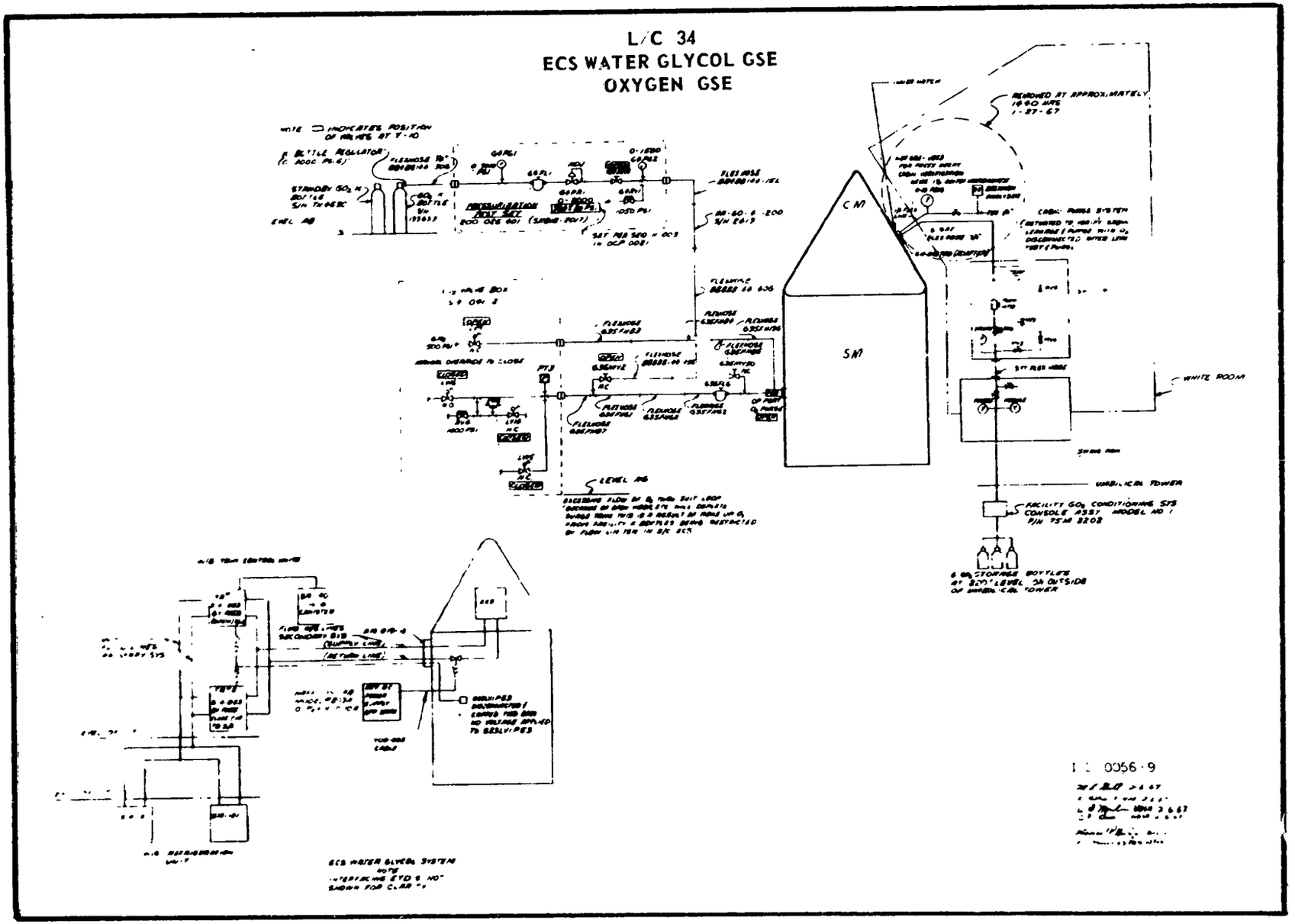
VIEW A-A (8TH LEVEL)

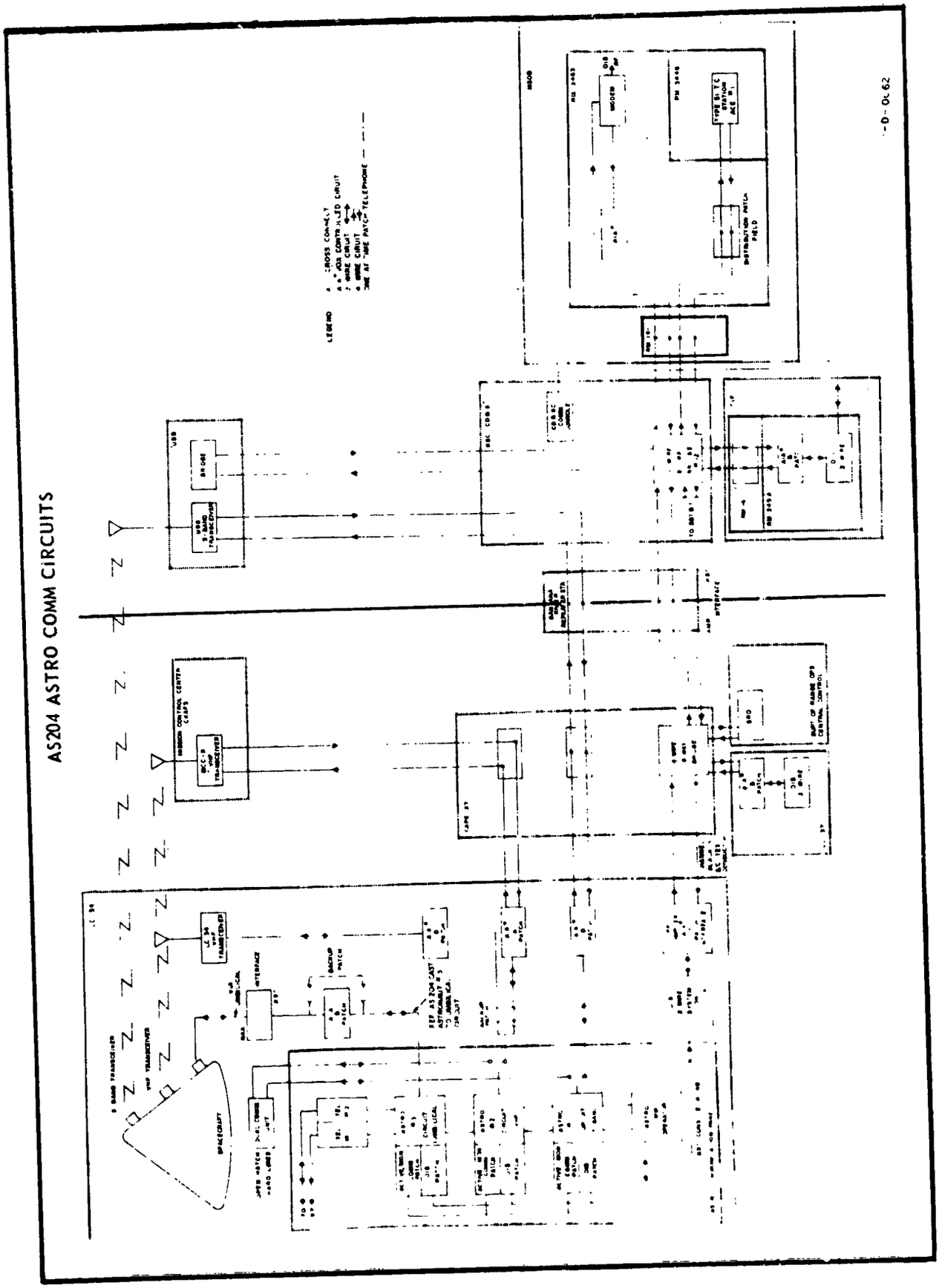
Drawn By

R. Hubbard NAA 2-6-67
M L Gill NAA 2-6-67
W B Mock NASA 2-6-67
C R Chase NASA 2-6-67
L D Manly Jr NAA 2-6-67

1-D-0056-7

ENCLOSURE 1-9h
D-1-61





ENCLOSURE 1-9i

E. SUPPORTING DATA

LIST OF REFERENCES

The following documents are referenced in this report and are available from the Apollo 204 Review Board, General File.

Number	Reference
1-1	"Spacecraft 012 Configuration Index", Jan. 29, 1967, North American Aviation, Inc. Process Data Report No. U487-16; Panel 1 Reference No. 1-D-0006
1-2	"Spacecraft 012 Indentured Parts List", Jan. 28, 1967, North American Aviation, Inc. Process Data Report No. U487-14; Panel 1 Reference No. 1-D-0007.
1-3	"Apollo Interface Document, Instrument Unit to Spacecraft Physical Requirements", Saturn Apollo Mechanical Integration Panel, ICD 13 M 20108. Panel 1 Reference No. 1-D-0097.
1-4	"Interface Control Document Definition of Saturn SA-204, and Apollo S C 012 Electrical Interface", Apollo Saturn Electrical Panel, ICD 40 M 37508A; Panel 1 Reference No. 1-D-0096.
1-5	"Launch Complex 34 Checklist, FO K 1001", Oct. 25, 1966, North American Aviation, Inc., (Panel 7 Data).
1-6	"GSE Functional Integrated System Schematics, Spacecraft 012 & 014, ETR LC34", North American Aviation, Inc. Document No. G14-900912; Panel 1 Reference No. 1-D-0094.
1-7	"Launch Countdown, Preliminary Review Document, FO-K-0007", Jan. 17, 1967, North American Aviation, Inc.; Panel 1 Reference No. 1 D-0100.
1-8	"Inter-Center Interface Control Document Log", Monthly Publication, Marshall Space Flight Center, NASA; Panel 1 Reference No. 1 D-0102.
1-9	"Space Vehicle Plugs Out Integrated Test, FO-K-0021 1", Jan. 25, 1967, North American Aviation, Inc.; (Panel 7 Data)
1-10	"Summary of Spacecraft Configuration Differences", Apollo 204 Review Board, Spacecraft and GSE Configuration, Panel 1 Reference No. 1-D-0098.
1-11	"Spacecraft 012 Configuration Verification Record (CVR)", January 28, 1967, North American Aviation, Inc., Florida; Facility CVR, Panel 1 Reference No. 1-D-002.
1-12	"List of EO's Partially Accomplished Spacecraft 012 at Time of Accident", Panel 1 Reference No. 1 D-0020
1-13	"EO's Outstanding Against S C 012 Not in Florida Facility CVR Tab Run", Panel 1 Reference No. 1 D-0024
1-14	"Spacecraft 012 Test and Acceptance Inspection Report (TAIR)", (Panel 6 Data)

1-15 "Spacecraft 012 Controls Configuration", Panel 1 Reference No. 1-D-0058.

1-16 "Comparison of S/C 012 Operational and Experimental GFE/CFE Stowed Equipment for K-0034A-1 and K-0021-1, Letter from CF22/Team Leader, Apollo 204, to Chairman, Panel 1, February 21, 1967. Panel 1 Reference No. 1-D-0099.

1-17 "Items on Crew at Ingress", R. A. Mitchell, February 6, 1967, Panel 1. Reference No. 1-D-011.

1-18 "Initial Report on S/C Configuration", February 1, 1967, by W. F. Edson and C. D. Gay; Panel 1 Reference No. 1-D-0003.

1-19 "S/C/GSE Configuration Comparison", Panel 1 Reference No. 1-D-0093.

1-20 "Support Operations Investigation, AS-204 Incident, Panel No. 1 GSE and Spacecraft Configuration", submitted by Chief, Launch Facilities Division, KSC, Panel 1 Reference No. 1-D-0095.

1-21 "Inventory of Levels A-6, A-7, A-8 (LC 34 Service Structure)", February 23, 1967, Panel 1 Reference No. 1-D-0101.

1-22 "Report - Test Configurations of Remote Test Monitoring and Control Equipments", Panel 1, March 9, 1967; Panel 1 Reference No. 1-D-0091.

1-23 "Crew Abbreviated Checklist - Mission AS-204", January 23, 1967, NASA Manned Spacecraft Center; (Panel 7 Data).

1-24 "Summary Comparison, S/C 008 Thermal Vacuum Test No. 3 and S/C 012 Plugs Out Test (OCP-K-0021)", March 10, 1967, Panel 1; Panel 1 Reference No. 1-D-0092.

REPORT OF PANEL 2
TEST ENVIRONMENTS
APPENDIX D-2
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

TEST ENVIRONMENTS PANEL

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Test Environments Panel, 2. The task assigned for accomplishment by Panel 2 was prescribed as follows:

> Provide history of all test environments encountered by this Spacecraft on a major assembly-total assembly basis which are germain to validation of systems from fire hazard standpoint. Include appropriate qualification testing of systems and subsystems. Particular emphasis should be placed on qualification tests in pure oxygen with regard to pressures, temperature, time of exposure, and simulation of equipment malfunction. Indicate any deficiencies in this test program related to the subject problem. Also, include comparison with previous tests of appropriate flight, house, or boilerplate spacecraft. Any problems encountered related to fire hazard shall be documented.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Test Environments Panel:

Mr. W. F. Hoyler, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. B. J. McCarty, Manned Spacecraft Center (MSC), NASA
Mr. C. F. Key, Marshall Space Flight Center (MSFC), NASA
Mr. C. O. Baker, North American Aviation, Inc. (NAA)
Mr. A. E. Toelken, North American Aviation, Inc. (NAA)
Mr. H. J. Dunham, General Electric Company (GE)
Mr. C. M. Nolen, General Electric Company (GE)

2. COGNIZANT BOARD MEMBER

Mr. G. C. White, Jr., NASA Headquarters, was assigned to monitor the Test Environments Panel.

C. PROCEEDINGS

1. GENERAL PROCEEDINGS

This Panel planned and implemented a review of all tests for histories pertinent to the investigation. Attention was focused primarily upon oxygen test histories of the crew compartment systems, and arcing and shorting problems experienced during those tests. However, all environments were reviewed for rationale used in original derivation, substantiation by ground and flight vehicle tests, and margins imposed when implemented into component level tests. The other environments were examined as possibly being germain to the cause of the accident from an indirect standpoint. These reviews included the vibration, heating, and humidity environments.

The qualification tests were reviewed at MSC and involved examination of more than 1000 documents. The vehicle level tests were reviewed at NAA, Downey, California, and included a review of another 500 or more related documents. Summaries of these efforts were reviewed by the Panel at Kennedy Space Center (KSC) to seek out any test program deficiencies.

Other related oxygen fires which have occurred in and out of the Apollo Program were investigated to determine areas of similarity.

The difference in qualification, or component level tests, and flight vehicle tests should be pointed out before the discussion of testing which follows. In the qualification tests, the component is subjected to design limit conditions sequentially and/or simultaneously, is essentially worn out by the end of its test program, and is never flown. In vehicle level tests, a considerable amount of functional testing is

performed, but always under nominal conditions, rather than design limit conditions.

2. OXYGEN TEST HISTORY

Summaries of oxygen test history are given by Enclosure 2-1, for Spacecraft (S/C) 008, 009, 011, and 012, and by Enclosure 2-2 for component level tests. Details of these histories (References 2-4 and 2-5) are in the Apollo 204 Review Board General File.

The Certification Test Specification (CTS), SID 65-1210, recognized that ground operations would involve short duration high pressure oxygen exposure. It specified 14.7 pounds per square inch absolute (psia) pressure of 95 per cent oxygen for four hours, and 21 psia with 14.7 psia partial pressure oxygen for two hours. Although few subsystems experienced this requirement in the component level tests (Enclosure 2-2), most cabin subsystems were exposed to this environment in the S/C 008 tests (Enclosure 2-1). About half of the components of the Environmental Control System were tested to the MIL-STD 810 exposure proof test, which is a somewhat more positive test against fire hazards than is oxygen explosure per se.

The original CCOH ((combined contaminant, oxygen, and humidity) test was established in early 1965. It was unrealistic, being based upon MIL-STD 810 which is established as an accelerated test of the atmospheric conditions an aircraft would experience under years of service in sea coastal regions. The Apollo S/C is maintained in a controlled atmosphere during manufacture and at KSC. Because of this, early in 1966, the test was established as being 8 hours of salt spray, 50 hours of dry oxygen exposure at 5 psia, and 120 hours of humid oxygen exposure. Cold-plate mounted equipment was temperature cycled during the humid oxygen exposure.

Nearly all of the cabin electrical equipment was subjected to the CCOH test, or to the MIL-STD 810 explosion proof test. Some were not actually tested, but were qualified by being similar in design to another tested component.

3. VEHICLE TEST COMPARISON

During S/C 008 testing, the cabin equipment was exposed to approximately 18 hours of oxygen exposure (6.5 hours unmanned, 11.5 hours manned) at concentrations of 90 per cent or higher and pressure of one atmosphere or greater. S/C 012 experienced 8 hours and 30 minutes of manned testing under similar oxygen concentrations and pressures. Neither S/C 009 nor 011 were subjected to oxygen concentrations above 75 percent during either ground testing or flight.

4. ETHYLENE GLYCOL LEAKS IN COMMAND MODULE 012

Command Module (C/M) 012 experienced water/ethylene glycol leaks and spillages. This is reported in detail by Panel 8. Panel 2, concerned that the connectors had been broken open during the cleaning process, recommended test requirements to Panel 16 to verify the effectiveness of the cleaning techniques.

5. ARCING AND SHORTING PROBLEMS

The evaluation of anomalies considered relevant to possible causes of, or contributors to, a fire was focused on C/M 012 checkout and test experience, and the certification test program. All discrepancy and failure records at NAA and KSC were reviewed to identify arcing and shorting anomalies. The review included both resolved and unresolved anomalies so that the corrective action planned or taken could be reassessed. The significant anomalies were then classified as either likely or remotely possible candidates relative to possible bearing on a spacecraft fire.

Although many hundreds of records were reviewed in the course of this anomaly investigation, only those considered most significant are included in this report. Enclosures 2-4 and 2-5 summarize these anomalies encountered during certification testing and C/M 012 testing, respectively.

6. EQUIPMENT USED FOR TEST ONLY

C/M 012 was configured with some equipment which was installed for test only. This equipment,

necessary to monitor test parameters or permit system operation, etc., during ground tests, would be replaced with flight hardware or removed prior to launch. However, investigation disclosed some equipment of this nature remained in the crew compartment during manned ground tests. Equipment falling in this category was reviewed for aspects of test history and failures which might reflect a possible cause of the accident. Two of the items of this type which were on C/M 012 and perhaps relevant to the accident were the Elapsed Time Indicators and the Lithium Hydroxide (LiOH) canisters.

Elapsed Time Indicators (ETI) required to measure the total operating time of selected subsystems were installed on 15 units of cabin equipment. By virtue of their requirement to record total operating time on limited life equipment, they remain installed at all times until just prior to flight. Test history of the ETI's indicated that in one case a fire hazard existed. An ETI on the Caution and Warning System had failed by shorting and was found distorted and cracked due to excessive heat. Subsequent examination of C/M 012 absolved the ETI as an area of concern.

LiOH canisters installed in the Environmental Control System (ECS) were being utilized for test only. This type canister had previously failed certification tests due to powdering of LiOH pellets under vibration.

Equipment which was not required to be on-board during flight did not receive the intense and repeated scrutiny imposed on flight hardware. This was recognized by restricting the use of non-flight hardware.

7. OTHER OXYGEN FIRES

Data and documentation on four non-Apollo manned experiments in which there were fires were accumulated and reviewed. Failure and trouble reports on two Apollo ECS explosions and one Apollo ECS fire were reviewed. This review was summarized (Enclosure 2-6) and forwarded to Panel 5.

8. ENVIRONMENTAL REQUIREMENTS

Environments, other than oxygen exposure, were reviewed to seek out any possible deficiency that may have contributed indirectly to the accident.

a. Temperatures

Temperature requirements were derived from wind tunnel data and heat transfer analyses, then later substantiated and/or modified by ground vehicle test data (S/C 008), and flight data. Flight data from S/C 009 and 011 boost conditions indicate Service Module (S/M) shell temperatures of about 200°F which is within the 400°F design temperature.

The S/C 008 vehicle was tested in a vacuum chamber, with solar heat generators and cold walls, to verify orbital temperature distribution. These tests confirmed that the equipment in the C/M will experience temperatures in the +30°F to +90°F range. The equipment is qualified to temperatures from +5°F to +145°F.

b. Acceleration

Acceleration test levels were defined on the basis of maximum conditions expected during boost, entry, and abort. The peak acceleration during ascent occurs just prior to first stage separation and is 4.9 g along the x axis; lateral accelerations are much lower (1.85 g maximum at lift-off). The peak acceleration for the mission occurs during abort or entry, and is expected to be 10 g. Test conditions are typically 6 g along each of 3 mutually perpendicular axes for S/M equipment and 20 g for C/M equipment. Acceleration levels experienced during the S/M 011 flight were well within expected limits.

c. Vibration

In this area of testing for the effect of repeated stresses there are trade-offs between the level of stress introduced by vibration and the number of times stresses of a given level are repeated. Thus, a given level for a given time may be a proper simulation of a higher level for a shorter time period and may give a more useful answer than the latter. These facts are reflected in the qualification test program for the 012 Spacecraft components.

(1) Apollo Program Testing

The vibration levels for qualification testing of components were originally established on the basis of data from other programs. These data were used to define a spectrum of flight vibration levels which would be expected along each axis of the Spacecraft throughout the frequency range of 20 to 2000 cycles per second. The components were qualified by subjecting them to a random vibration throughout this frequency range at the expected flight level. The length of these tests, which was 15 minutes along each axis, was several times the expected duration of vibratory excitation during atmospheric flight. Some component vibration tests were conducted using electromagnetic shakers and the remaining components were tested with acoustic excitation.

Ground test Service Module 006 and Service Module and Command Module 007 were acoustically excited in a reverberation chamber at a level which corresponded to the estimated external vibration levels which would be applied to the complete Spacecraft in actual flight. These tests showed that the interior vibration levels which were experienced by the components were higher than the originally established criteria. New criteria, corresponding to the levels obtained in these ground tests on 006 and 007, were established and all components were requalified to this higher expected flight level. The duration of the new component qualification tests was decreased to one-third, that is, from 16 minutes per axis to 5-1/3 minutes per axis. The 5-1/3 minutes duration is still three times the amount of time the Spacecraft will experience significant vibration levels during the ascent flight out of the atmosphere.

The flight test data from Spacecraft 002, 009, and 011 verified the flight vibration level criteria used in the ground tests of 006 and 007.

Components used in flight spacecraft are given flight acceptance vibration testing which is like the qualification testing except that the vibraton level is 25 per cent of the expected flight level and the duration is only about one (1) minute.

No complete flight spacecraft, including 012, was given flight acceptance vibration tests.

(2) Vibration Test Philosophy

There are two basic philosophies regarding flight acceptance vibration testing. Some believe that flight acceptance vibration tests are an essential tool in verifying that a component or system of proven design (proven in qualification testing) does not have workmanship defects. Others believe that flight acceptance vibration tests of actual flight hardware may degrade the equipment and produce incipient failure. This possibility of potential degradation of flight equipment is very real. A dilemma is presented, therefore, in deciding how to best insure reliability of flight hardware and to balance the risk of having undetected defective hardware against the risk of creating an incipient failure in the acceptance test. This dilemma is particularly acute in manned flight programs.

At the component level, this risk was balanced on the Gemini program by acceptance testing at 75% of the expected flight level and on Apollo by acceptance testing at 25% of the flight level. Both programs tested the components for a duration of one (1) minute in each axis. The reduced levels and durations of the tests were such that defective items would likely be noted but the risk of creating incipient failure was minimized. In Gemini one complete flight spacecraft (No. 2) and the first manned flight spacecraft (No. 3) were subjected to 75% flight level vibration testing. This testing revealed no design or workmanship deficiencies. At that time, it was decided to eliminate testing of the follow-on Gemini Spacecraft. In Apollo, no complete spacecraft intended for flight has been given vibration acceptance tests.

d. Shock

Shock levels for the C/M and S/M were determined analytically and then modified by flight and landing impact test vehicles. There are no significant flight shock levels for the S/M and the Service Module/Lunar Module Adapter (SLA). The C/M equipment is tested to shock levels of 78 g's. The maximum shock level measured was 75.8 g's on the main display console during drop number 104 on S/C 2S-1, which represented a "worst-case" water drop.

e. Test Levels on Two ECS Components

As typical examples, the following are some of the specific environmental test levels imposed on two Environmental Control System components during the qualification test program:

	Service Module (Nitrogen Regulator Used as Typical Component	Command Module (Oxygen Flow Restricter Utilized as Typical Component)
Temperature	0 – 200° F.	Fluid flow governed temperature extremes on this item, rather than the cabin atmospheric temperature
Vibration	0.1 g^2/cps 90 – 250 cps, decreasing to 0.012 at 2000 cps	0.06 g^2/cps, 80 – 400 cps, decreasing 3 db-oct. to 2000 cps
Acceleration	7 g's along the longitudinal axis	20 g's, 5 minutes per axis
Shock	Not applicable	78 g's (ECS equipment also receives tumbling abort shock test)

f. Results of Environmental Review

In reviewing the environments, and the manner in which they were implemented into tests, it appears there is a fundamental difference in philosophy in the way Apollo and Gemini programs treated the vibration environment.

There are two prevailing philosophies concerning acceptance vibration. Some feel that vibration is a very effective acceptance "tool" for exposing defective workmanship. They feel that flight hardware should be acceptance tested at expected flight level vibration for a short period, but only if the equipment is qualified to flight levels for long periods. Others feel that if the flight equipment is vibrated at flight levels for acceptance, it will be degraded.

In the Gemini program the former philosophy prevailed. Equipment was qualified to greater than flight level vibration for 15 minutes per axis, which permitted several one minute acceptance vibration tests. The Apollo program qualifies equipment to vibration for only 320 seconds per axis, which permits only limited high level vibration acceptance tests.

High level vibration acceptance tests expose amplitude sensitive faults in wiring connectors, such as cold solder joints. These faults, if not exposed and corrected, can eventually be manifested as failures by subtle combinations of other environments, such as pressure-temperature.

D. FINDINGS AND DETERMINATIONS

1. FINDING

All crew compartment equipment was not tested to be explosion proof.

DETERMINATION

There was insufficient testing of possible ignition sources.

2. FINDING

Crew compartment equipment of C/M 012 was exposed to water ethylene glycol contamination. Untested cleaning techniques were employed for that equipment discovered to be wet.

3. FINDING

Some of the C/M cabin equipment exhibited arcing or shorting during either certification or S/C 012 testing. There is no positive way to determine from the records reviewed whether S/C anomalies (possibly caused by a short or an arc) are reviewed by systems engineers and the test conductor prior to a test.

DETERMINATION

Review of possible ignition sources prior to manned testing was inadequate.

4. FINDING

Not all equipment installed in C/M 012 at the time of the accident was intended to be flown. Some components were installed for test purposes only.

DETERMINATION

The suitability of this equipment in the C/M for this test was not established.

5. FINDING

Non-certified equipment was installed in the C/M at the time of the accident. The "cobra cable" P/N V16-601263 and "T" adapter P/N V16-601396 are examples.

DETERMINATION

The suitability of this equipment in the C/M for this test was not established.

6. FINDING

The design required the mating and demating of "hot" electrical connectors as normal crew procedure. Changing to a spare "cobra cable" is an example.

DETERMINATION

The practice of breaking "hot" electrical circuits introduces fire initiation hazards.

E. SUPPORTING DATA

This section contains the following Enclosures to which Section C refers:

Enclosure

2-1	Vehicle Test Summary
2-2	Summary of oxygen test history of component level tests
2-3	Not Used
2-4	Summary of significant certification test anomalies involving possible ignition sources
2-5	Summary of significant C/M 012 anomalies involving possible ignition sources
2-6	Summaries of other oxygen fires
2-7	Glossary of terms
2-8	List of References

VEHICLE TEST SUMMARY
(Oxygen Experience)

Space-craft	Test Name	Test No.	Oxygen Concentration in Cabin, Percent	Cabin Pressure (psia)	Cabin Temperature Degrees	Test Duration, (hr)	Systems Operating
008	SID66-475	1 (Unmanned)	90 or greater	14.7 or above	95+	Approx. 6.5	Comm. (up link) Elec-trical Power Environmental Control
				Between 5 and 14.7	64 to 89	72	Comm, Elect. Pwr., Env. Control
		2 (Manned)	90 or greater	14.7 or above	64 to 89	Approx. 4	ECS, EPS, D&C, Comm, G&N & SCS
			90 or greater	Between 5 and 14.7	64 to 89	152	ECS, EPS, D&C, Comm, G&N & SCS
		3 (Manned)	90 or greater	14.7 or above	61 to 81	Approx. 7.5	ECS, EPS, D&C, Comm, G&N & SCS
			90 or greater	Between 5 and 14.7	61 to 81	137.5	ECS, EPS, D&C Comm, G&N & SCS

ENCLOSURE 2-1
D-2-10

VEHICLE TEST SUMMARY
(Oxygen Experience)

Space-craft	Test Name	Test No.	Oxygen Concentration in Cabin, percent	Cabin Pressure, (psia)	Cabin Temperature Degrees F	Test Duration, (hr)	Systems Operating
009	(No 0_2 was used in cabin during CDDT or Pre-launch Test)						
011	Countdown Dem. Test (CDDT)	OCP FO-K-0033	75	15.3	76	6 hrs.	ECP EPS D&C
	Launch Countdown	OCP FO-K-0007	75	15.3	76	6 hrs.	SEQ COMM
012	Mission Run Plugs Out	OCP FO-K-0021	93	16	73	2 hrs. 13 min.	
	CSM Alt. Chamber Test No. 1	OCP FO-K-0034 a) Unmanned Alt. Run (220.000')	Approx 100 75	App. sea lev. 6.2	75	1.2 hrs. 28 hrs.	
		b) Manned Alt. Run (220,000')	Approx 100 95	App. sea lev. 5.5	75 - 77	1 hr. 11 hrs.	ECS EPS D&C SEQ
	CSM Alt. Chamber Test No. 2	OCP FO-K-0034A-1 a) Unmanned Alt. Run (220,000')	Approx 100 75	App. sea lev. 6.2	77	1.5 hrs. 6 hrs.	
		b) Manned Alt. Run (220,000')	Approx 100 95	App. sea lev. 5.5	75 - 77	1.5 hrs. 11 hrs.	COMM

SUMMARY OF OXYGEN TEST HISTORY OF COMPONENT LEVEL TESTS

Total Equipments in Cabin by Subsystem which Use, Control or Distribute Electricity

SUBSYSTEM	NUMBER	NUMBER RECEIVING EXPLOSION TEST
Pyro Devices	2	0
Sequence Systems	6	0
Environmental Control System (ECS)	68	32 Received MIL-STD 810 Explosion Proof Test 16 Qualified by Similarity
Crew Equipment	3	0
Stabilization & Control System (SCS)	12	11 Received O_2 Test at 14.7 psia
Guidance & Navigation (G&N)	19	18 Received O_2 Test at 14.7 psia
Instrumentation	12	0
Communications	32	14 Received O_2 Test at 14.7 psia
Electrical	47	0
Displays and Cont.	14	0
Subtotal	215	
GFE	15	3 Received MIL-STD 810 Explosion Proof Test 1 Received O_2 Test at 14.7 psia
TOTALS	230	96

35 Equipments received MIL-STD 810 Explosion Proof Test

44 Equipments received Oxygen Tests at 14.7 psia.
G&N Oxygen Test duration was 22 hours. All other Oxygen Tests were 4 hours duration.

Remaining equipments received oxygen tests at 5 psia pressure, with duration varying from one hour to 640 hours. Most of the ECS components were tested for 640 hours.

SUBSYSTEM DISPLAYS AND CONTROLS				
Part Name	Part No.	CTR No.	Certification Test Problem	Problem Disposition
Floodlights	ME434-0045-XXXX	01226316	During both Qualification and S/C Systems Tests, failures occurred involving transient susceptibility of solid state components.	Vendor instituted a redesign and retest.

SUBSYSTEM - EPS DISTRIBUTION EQUIPMENT				
Part Name	Part No.	CTR No.	Certification Test Problem	Problem Disposition
Static Inverter	ME495-0001-0004	01122702 01222302	Reference Failure Report WE000537. During phase unbalance tests per CTR 01222302, the inverter input shorted. Two pairs of 65 ampere booster transistors were shorted, caused by shorting of a Zener diode in the DC link.	Corrective action was to provide added surge tests for Zener diodes and high current density tested molyblock transistors for the inverter. The added surge tests and high current density tests have been concluded to be effective. However, sufficient test history has not been accumulated to preclude consideration of this failure as suspect.

SUBSYSTEM - ENVIRONMENTAL CONTROL				
Part Name	Part No.	CTR No.	Certification Test Problem	Problem Disposition
Waste Manager Blower	Item 10.1 ME901-0030-0001 Vendor #12A1306	01111339 01211314 01211729	(A) Failure Report GL000229 Motor shorted out during Dielectric test due to damaged wire insulation. (Pre-Qual Functional Test)	(A) The stator molding fixture was modified to allow easier insertion and removal of the stator. Also, in-process dielectric check of the stator assembly immediately after molding was changed from 1000 VAC to 1250 VAC for one minute. New Part No. ME901-0030-0002
			(B) Failure Report GL000241 Motor failed to operate due to a short in an electrical connector. Short was caused by the accumulation of water around the connector terminal pins. (Qualification Mission Life Test - Oct. 22, 1965)	(B) Blower Connector was redesigned by eliminating sleeving insulation and substituting the use of plotting compound to insulate connector terminals. New Part No. ME901-0030-0003
			(C) Failure Report MA024568 Motor stopped and drew excessive power. Failure was caused by a migration and build up of bearing lubricant between the rotor and stator causing the motor to freeze. (Qualification Mission Life Test - April 29, 1966)	(C) Motor bearing was redesigned using a Barden Bar-Temp dry lubricant bearing. New Part No. ME901-0030-0004

SUBSYSTEM - ENVIRONMENTAL CONTROL (CONTD)				
Part Name	Part No.	DTR No.	Certification Test Problem	Problem Disposition
Waste Management Blower (contd)	Item 40.1 ME901-0030-0004 19A1306	01111339 01211314 01211729	(G) Failure Report MA024562 Blower developed an internal short during oxidation testing. Failure was caused by moisture contamination in the rotor-stator area. (Oxidation Qual. Test) April 14, 1966	(G) No corrective action has been implemented for the following reasons: This failure occurred with the blower installed in the old Waste Management System configuration where moisture contamination was possible. The Waste Management System has been redesigned per CCA 827 to provide a direct urine to space dump capability. This change deletes the requirement for blower performance during urine and fecal modes of operation. Therefore, the blower is now needed only for vacuum cleaner operation and under this design the blower should not be subjected to moisture contamination.
			(H) Failure Report M165617. During second spacecraft 008 manned test, blower apparently shorted out and failed to operate.	(H) Analysis indicated failure was due to urine contamination resulting from a previous test. Blower motor did overheat when operated for 3 1/2 hours under deadheaded (no flow) conditions prior to the subject failure. No corrective action was implemented due to the system design change described in Paragraph G.

SUBSYSTEM - SEQUENTIAL EVENTS CONTROL				
Part Name	Part No.	CTR No.	Certification Test Problem	Problem Disposition
Master Events Sequence Controller	ME901-0567-0008	00909302	An improperly located splice shorted to cover of unit.	Instruction wasgiven to Manufacturing and Inspection by the Failure Review Board to check clearance around wire bundle in accordance with the existing specifications (AA0113-005, AA1113-017 and AAD1130921). The instruction was given by IL 696-704-110-65-300.

SUBSYSTEM - TELECOMMUNICATIONS				
Part Name	Part No.	CTR No.	Certification Test Problem	Problem Disposition
PCM Telemetry	ME901-0083-0002 and ME901-0083-0102	012 21 308 011 21 303 009 21 306	After salt spray test and prior to post-salt spray functional test, 400 Hz line fuse blew. Collins FR 100971 and NAA APS 303-AN apply. After repair of the test article, it was resubmitted to salt spray test, and 400 Hz power was applied this time, whereas it had not been applied during the 48 hr. salt spray test referred to above. Another failure was incurred almost immediately. Collins FR 101187 and NAA APS 304-AN apply.	The "fix" assigned for the first post-salt spray failure (FR 100971) was immediately rendered invalid by the second failure (FR 101187), which occurred during the first salt spray retest. A second, more extensive, corrective action involving potting the capacitor bank with RTV 1538 was evolved. This afforded a better seal for capacitor bank. It also gave better protection to the 400 Hz power-input wiring against workmanship error by lessening the likelihood of pinched or mashed insulation. The test article was potted according to requirements of the second corrective action and was retested again with satisfactory results. There has been no recurrence of this problem to date.

ENCLOSURE 2-5
D-2-21

SUMMARY OF SIGNIFICANT S/C 012 ANOMALIES INVOLVING POSSIBLE IGNITION SOURCES			
Part Name	Part No.	Anomaly	Disposition
Caution and Warning System		During OCP K-0034-A, a master alarm occurred when switch S-5 on panel 13 and switch S-5 on panel 23 were placed in the push-to-talk position. (Ref. interim discrepancy report I.D.R. No. 003)	Trouble shooting failed to identify cause of anomaly. This discrepancy was still open at the time of the last test.
Connector	ME0114-0265-5550	Connector J-288 was identified as "deteriorating" at pins 80-81-82. This is a connector attached to the yaw ECA. (Ref. D. R. 0293).	Material review action determined that the unit was acceptable for flight, with the proviso that it be reexamined each time it was demated. The next demating took place on Oct. 27, 1966, when the yaw ECA was removed. The connector was judged acceptable by inspection.
"T" Adapter	V16-601396	During OCP K-0034A-1, it was noted that when either crewman pushed the push-to-talk, parameter CJ0002 (respiration rate) modulated approximately 20% full scale. (Ref. I.D.R. -029)	After extensive trouble shooting (89 steps) failed to disclose the cause of this anomaly, it was decided that RF conditions in the altitude chamber were probably responsible. The DR was held open until after satisfactory completion of sequence 12 of OCP K-0021.

ENCLOSURE 2-5
D-2-22

SUMMARY OF SIGNIFICANT S/C 012 ANOMALIES INVOLVING POSSIBLE IGNITION SOURCES

Part Name	Part No.	Anomaly	Disposition
DC to DC Conferter	130110	S/N 035 causes intermittent noisy operation of the signal conditioners.	Troubleshooting failed to determine the cause. Item considered acceptable for OCP FO-K-0021-1 (Ref. DR AK-037) .
Harness Assy.	V16-420312	Potting was split at end away from pins on connector E01W1J5. (Reference D.R. 0518)	Dispositioned OK for flight because the damaged area was at the end of the potting installation.
Cobra Cable	V16-601263	Insulator chipped out between pins 13 and 14 on "normal'' side of connector on Command Pilot's cable.	Accepted for flight after Material Review Board evaluation.
Guidance and Control System		During OCP 6504 a high frequency oscillation was observed on the middle gimbal angle indicator. (Reference NAA P.A.R. MA 019060 and ACED AFR 13432, 13428 and 13429.	Analysis revealed a burned hole and charring on external potting on tray 2 and tray 3. Failure closeout stated cause to be human error in installing trays.

SUMMARIES OF OTHER OXYGEN FIRES

A review of one unmanned and four manned experiments in which there were fires shows that the exact ignition source in four of the fires was undetermined. They were believed to be electrical in nature. The only fatalities occurred in the two accidents in which there was a flash fire. In all five fires, inadequate safety precautions had been taken to either prevent or extinguish the fire or to protect the occupants.

BROOKS AIR FORCE BASE, SEPTEMBER 9, 1962

A fire occurred in the Space Cabin Simulator at Brooks Air Force Base on September 9, 1962. Test conditions were 5 psia 100 percent oxygen and the test had been in progress fourteen days at the time of the fire. The odor removal system used activated charcoal and the Carbon Dioxide (CO_2) removal system had an aluminum cover and consisted of a 500-pound bed of a mixture of 80-percent calcium hydroxide and 20-percent barium hydroxide. The Environmental Control System circulated cabin air progressively through the hydroxide, the charcoal, through the temperature controller (electric heater and refrigerant evaporator coil), then through an aluminum duct to the circulation fan. From the fan, ducts distributed air over the area behind the electronic test panel (cyclomotor). The air then leaked through openings in the panel back into the cabin. Both occupants wore pressure suits and one was asleep. Immediately upon noticing a glow behind the cyclomotor, one occupant awoke the other, grabbed a CO_2 extinguisher, and fought the fire until he collapsed from smoke inhalation. The awakened occupant immediately opened his face plate with the apparent intention of donning an oxygen mask, but he collapsed from smoke inhalation before he could get a mask or assist in extinguishing the fire. Both occupants were treated for smoke inhalation and neither received burns. There was no flash fire and damage was confined to the end of the chamber in the vicinity of the cyclomotor. Photographs of the aluminum duct immediately downstream of the temperature controller show definite signs of an implosion-explosion in the duct with a three-inch to four-inch diameter hole burned through one duct wall at the center of the imploded area. This was never fully clarified during the investigation and testimony revealed insufficient fuel had been consumed (burned) in the vicinity of the hole to melt the aluminum. Testimony also revealed that a small explosion could have occurred in the duct without being heard by either of the helmeted occupants. The investigating board concluded that the most likely source of ignition was a short or arc in an undetermined electronic component behind the cyclomotor panel.

BROOKS AIR FORCE BASE, JANUARY 31, 1967

A second fire occurred on January 31, 1967, in the same Brooks Air Force Base facility described in the first accident. Test conditions were 7.2 psia 100-percent oxygen. The test was in the first day of a planned 67-day test to study hematology of 16 rabbits. Two men had been in the simulator 12 minutes at the time of the fire, which was fatal to both. Both men suffered second and third degree burns over 90 percent of their bodies. An outside observer witnessed a flash fire which engulfed the chamber. A final report by the investigating board is at present unavailable and details of the facility design, and its differences with the design at the time of the 1962 fire, are therefore also unavailable. However, progress reports of the investigating board have provided the following information. Examination of the blower motor after the fire showed that the impeller was binding against the motor case and application of power to the motor resulted in blowing the fuses. Relationship of the motor malfunction to start of the fire has not yet been determined. The motor was downstream of the CO_2 absorbent bed. A short has been positively identified in an unspecified electrical fixture. The unanimous opinion of the investigating board and its observers-advisors and consultants is that the most probable cause of the fire was the existence of a combustible atmosphere within the chamber. The combustible atmosphere is believed (by the board) to be primarily hydrogen and possibly included hydrocarbons as a result of the animal experiment. Experiments conducted on-site have conclusively shown that the CO_2 absorbent reacted with water and aluminum and generated hydrogen. The ducting and the CO_2 absorber materials are the same as at the time of the 1962 fire; i.e., 80 percent calcium hydroxide and 20 percent barium hydroxide in aluminum ducting. There is evidence of intense heat in the CO_2 absorbent bed and intense exothermic chemical reactions were present in the air conditioning duct. This

can be explained by an additional reaction which would have resulted from aluminum and iron oxide being reacted in the presence of a hydrogen-oxygen flame which can cause fusing of metals such as stainless steel, chromium, and other metals. This is known as a "thermite reaction" and the AF Materials Laboratory has determined that it can be initiated at 2352°F, the reactants being stainless steel and oxygen. The reaction is self-sustaining and reaches a temperature of 2550 to 2650°F. The reaction is suppressed in the presence of steam or about 35 percent CO_2. A possible source of the initiating temperature is the burning tape which was around the top of the CO_2 absorber filters. This tape can initiate the oxygen/stainless steel reaction in three seconds in 14.7 psia oxygen, but its burning temperature is as yet unknown in 7 psia oxygen. The CO_2 fire extinguishers were not removed from their holders and examination of the three oxygen regulators show no indication of malfunction. Ignition sources were considered by the investigation board to include an arc from an electrical short, an electrostatic spark, a friction spark, spontaneous oxidation, heated surfaces (particularly those which might have been in the CO_2 absorbent bed), heated surfaces from friction or hot wire, the electrical motor downstream of the CO_2 absorbent bed, clothing which might have ignited on contact with a heated surface or as a result of spontaneous oxidation, or ignition of a sponge, chair cushion, or rabbit fur from either an electrostatic discharge or spontaneous oxidation. A short in a lighting fixture wire was determined to be the most probable source of ignition.

NAVY EXPERIMENTAL DIVING UNIT, FEBRUARY 16, 1965

A fire occurred in the decompression chamber of the Navy's Experimental Diving Unit (EDU) at Washington, D.C. on February 16, 1965. Conditions at the time of the fire were 28-percent oxygen 36-percent nitrogen, and 36-percent helium at a total pressure of 55.6 psia (92 feet depth) or an oxygen partial pressure of 15.6 psia. About eleven minutes after entering the chamber (via a lock) from an adjacent chamber at 126 psia (250-foot depth) one of the divers reported the fire. Two observers at a viewing port observed a fire four inches in diameter and two feet high coming from the CO_2 scrubber immediately prior to a flash fire which engulfed the entire chamber. During the next minute, chamber pressure rose to 130 psia (260-foot depth). Attempts to rescue were unsuccessful and both occupants died. The CO_2 scrubber was portable and was designed for use as an emergency device for submarine atmosphere control and consisted of a tub containing six cylindrical tubes. The center tube contained the fan motor and outer tubes contained four CO_2 absorbent canisters and one filter element. Flow of chamber air through the scrubber was down through the four absorber canisters and up and out through the filter unit. The absorber elements consisted of a cylindrical metal can with metal screens on each end. The metal cylinder and screen materials are unidentified. The absorber chemical was the same as that in use at the time of both Brooks' fires; i.e., 80 percent calcium hydroxide and 20-percent barium hydroxide. The "tub" which housed the entire scrubber assembly was made of an unidentified metal. The filter element was made of convoluted paper (probably Kraft) cylinders supported on the inside by a perforated metal (iron) cylinder and at the ends with stamped aluminum covers cemented to cardboard rings which are in turn cemented to the convoluted paper. Each unused unit weighs 2.1 pounds of which paper and cemented end rings comprise 1 pound. Investigation determined that primary use for this filter was in hydraulic systems and in the fuel systems of jet aircraft, and that common practice is to test every single filter element by immersion in an organic liquid and, while submerged, blow air through the filter to see if flaws existed at the seals of the paper. Tests were performed on two unused filter elements identical in design to the accident-involved filter. An acetone extraction on one showed that it probably contained about 0.3 to 0.4 pounds of kerosene-like liquid. This is consistent with the filter specification which lists maximum dry unit weight at 1.8 pounds. This also shows that the dry weight of the paper and end rings is 0.7 pound, arrived at by subtracting total wieght of metal (2.1-1.0=1.1) from the 1.8 pounds total dry weight. A second filter was placed in a CO_2 scrubber, without CO_2 absorbent installed and operated for 2 hours. From this test, it was determined that the volatile liquids would be removed from the filter in 5 to 10 hours depending upon temperature and flow rate through the unit. The accident-involved filter was one of two supplied with the scrubber which had 1-1/2 to 2 years of intermittent use and the time logged on each filter is unknown. The used filter not involved in the accident had no "hydrocarbon" odor and an acetone extraction of the paper revealed a weight loss of only 10.2 percent compared to 36 percent loss on an unused filter. Samples from the used filter and an unused filter were subjected to high-frequency

discharge (Tesla coil) in a stream of oxygen. The unused filter ignited easily and the flame spread rapidly whereas the used filter required 5 to 7 seconds of continuous discharge, ignited at the edge of the paper, and did not burn readily. From these tests, it was concluded that most or all of the easily ignitable material (hydrocarbon) had been removed from the filter by use prior to the EDU fire and that a rather strong ignition source would have been required to ignite it. A bench test of the scrubber motor after the fire showed that it ran at a reduced speed and rapidly overheated, the condition being caused by faulty operation of the centrifugal throw-out switch which resulted in the motor running on starting windings. The EDU had no provisions for odor removal (such as activated charcoal). The fire caused extensive damage including complete consumption of untreated cotton terry-cloth bath robes and about twelve feet of flexible air conditioning duct made of fabric-covered spiral wire. Untreated cotton mattresses with flame-proof covers were partially consumed. About five feet of the rubber on the unarmored electric cord to the portable scrubber was consumed as was rubber of armor-covered cables directly above the CO_2 scrubber. A simplified calculation by Naval Research Laboratory personnel showed that the pressure rise experienced during the fire would have caused a 761°F temperature rise and that the temperature rise would require the burning of only about 1.1 pounds of cellulosic material, i.e., cotton or perhaps wood-based paper in the filter. The investigation concluded that the most probable cause of the fire was the overheated scrubber motor causing spontaneous ignition of the filter element in a high-oxygen atmosphere. Fire extinguishing equipment consisted of a bucket of sand and a bucket of water, neither of which was used.

NAVY AIR CREW EQUIPMENT LABORATORY, NOVEMBER 17, 1962

A fire occurred in the Navy's Air Crew Equipment Laboratory (ACEL) on November 17, 1962. Test conditions were 100 percent oxygen at 5 psia and the fire occurred on the 17th day of the test. The fire started on the insulation of the ground wire to a light fixture. The ground wire was loose and an arc ignited the insulation. One of the four occupants tried to smother the fire with a towel which also ignited. Further attempts with an asbestos blanket resulted in ignition of the blanket and clothing worn by occupants. Subsequent attempts by all four to extinguish fire on the clothing of others resulted in the ignition of the clothing of all four, generally on the sleeves and pants legs. One occupant's hand caught on fire. All occupants escaped in about 40 seconds after first report of the fire and all were treated for first and second degree burns over 15 to 20 percent of their bodies. Immediately after exit of the occupants the door was closed, the chamber taken to 80,000 feet and purged for 20 minutes with CO_2 to extinguish the fire. There was no flash fire and there were no extinguishers in the chamber.

APOLLO ECS FIRE AT AIRESEARCH TORRANCE FACILITY, APRIL 28, 1966

A fire occurred in an unmanned qualification test of the Apollo Environmental Control System at Torrance, California, on April 28, 1966. Test conditions at, and 23.5 hours prior to the fire, were 100 percent oxygen at 5 psia. Prior to bringing the test up to 5 psia, the test had included 2456 hours at 10^{-4} millimeters of mercury (Torr). The investigating board concluded that the most probable cause of the fire was failure of a commercial quality strip heater used to add heat to the steam duct. The strip heater used polyvinyl chloride (PVC) insulation and the manufacturer's temperature rating was 167°F continuous, 190°F maximum in air. There was a sharp bend in the heater strip bearing against an ECU power lead splice at the heater strip entry into asbestos tape wrapped over the steam duct in the test set-up. Under high temperature conditions, the heater tape wire was demonstrated to extrude through the PVC insulation and a fire was initiated under simulated test conditions. Three other ignition causes were considered as possibilities. Strip heaters of the same type as above, but covered with aluminum foil, were on the potable water and dew point line sensor. Deterioration of insulation could have caused a short between one of the wires and the aluminum foil. Dew point measurements within the cabin showed that some metal surface temperatures were such that water could have condensed on them causing arcing on open terminal strips, unpotted connectors, or the 400-cycle unit, igniting adjacent materials. One of the ECU high pressure oxygen check valves, which use an elastomeric (DPR) seal, was severly damaged and it was theorized that high pressure "impact" of the 900 psia oxygen could have ignited the EPR. AiResearch ran a series of 3000 psi impact tests without ignition, and although the test results were not absolutely conclusive, it was concluded that this was the least probable of the possible

causes presented. Other damage caused by the fire included excessively burned insulation of the test set-up wiring, fusing and burning of ECU wire harness, and burned polyurethane foam insulation on the oxygen and water-glycol lines. The investigating board concluded that, although 16 components had malfunctioned prior to and during the test and 18 had failed due to damage by the fire, the ECS qualification unit was not the direct cause of the fire. Also, test equipment and materials were improper for the environment, there was no fire detection or extinguishing equipment, and there were no emergency procedures. The board also concluded that improvement in the selection of some materials used in the ECS and the Apollo Command Module (C/M) could be made to control fire. Also, the C/M electrical circuits and wiring have potential hazards from arcing or direct short circuits. Also concluded was the fact that AiResearch procedures and documentation were inadequate, that quality control (QC) personnel were provided inadequate direction and that a NASA Test Readiness Review might have precluded the incident. The board recommended that all action necessary be taken to preclude initiation of a fire in the C/M with special emphasis on adequacies of wire bundle derating, circuit breaker/wire compatibility, and elimination of all possible nonmetallic materials in contact with wire bundles. The board also recommended the imposition of nonmetallic materials specification requirements on all contractors and other suppliers of flight equipment, and to strengthen the materials selection and application program.

APOLLO ECS EXPLOSION AT AIRESEARCH, APRIL 13, 1965

An explosion occurred in an unmanned qualification test of the Apollo ECS at AiResearch on April 13, 1965. The explosion occurred after 127 hours of a planned 141-hour test. Conditions were corrosive contaminants, oxygen, and humidity (CCOH) per qualification test procedure SS-1224-R, paragraph 6.8. Failure reports were prepared for four components; a sensor (P/N 820110-1), a fan (P/N 826310-2-1), a valve (P/N 850028-1-1), and an absolute pressure transducer (P/N 837044-1-1). The explosion was determined to be the result of polyurethane foam swelling underneath a water tank causing a suspended electrical immersion heater to touch the bottom of the tank. Sufficient localized heat was generated to ignite the oxygen-saturated foam. Electrical connections did not indicate evidence of shorting and it was noted that all units were operable after the test was aborted. Corrective action included use of Teflon sheets in place of polyurethane foam and neoprene to isolate the units electrically, connection of the unit mounting frame and tank to a common ground, potting of heater leads, installation of a commercial submersion heater in the water tank by welding a boss.

APOLLO ECS EXPLOSION AT AIRESEARCH, JULY 1, 1964

An explosion occurred in unmanned qualification test in the explosion proof chamber at AiResearch on or about July 1, 1964. The test had been in progress 30 minutes and test conditions were in accordance with explosion proof test SS-1218-R, paragraph 6.9.2. A cabin air temperature sensor, P/N 820100-1, was damaged to the extent that the glass bead around the thermistor was bubbled and pitted from the heat. Conclusion as to the cause of the explosion was that the insulation around the heater coil broke down from heat inside the explosion chamber while the explosion proof test was in progress. Corrective action was to retest the sensor for temperature versus resistance per SS-1113-R, revision 1, paragraph 4.2. The sensor was retested, witnessed by NAA and Air Force QC, and released for future testing on July 1, 1964

GLOSSARY OF TERMS

APS	Apollo Problem Summary
AFB	Air Force Base
AS	Apollo/Saturn
BTU	British Thermal Unit
CC	Cubic Centimeter
C/M	Command Module
Cm^2	Square Centimeter
CO_2	Carbon Dioxide
cps	Cycles Per Second
CTN	Certification Test Network
CTR	Certification Test Requirement
DR	Discrepancy Report
db	Decibel
ECS	Environmental Control System
EPS	Electrical Power System
ECU	Environmental Control Unit
ECA	Electronic Control Assemblies
FR	Failure Report
°F	Degrees Fahrenheit
g	Acceleration Due to Gravity
g^2 /CPS	Vibration Power Spectral Density
GSE	Ground Support Equipment
GT	Ground Test Titan
H_2O	Water
HZ	Frequency In Cycles per Second

GLOSSARY OF TERMS (Continued)

IMU	Inertial Measurement Unit
LB	Pound
LiOH	Lithium Hydroxide
LM	Lunar Module
MA	Mercury/Atlas
MEK	Methel Ethyl Ketone
MIL STD	Military Standard
MSC	Manned Spacecraft Center
MSOB	Manned Spacecraft Operations Building
NA	Not Applicable
N_2	Nitrogen
OCP	Operational Checkout Procedure
O_2	Oxygen
P/N	Part Number
PSIA	Pounds Per Square Inch Absolute
QD	Quick Disconnect
S/C	Spacecraft
SLA	Spacecraft/Lunar Module Adapter
S/M	Service Module
S/N	Serial Number
TORR	Millimeters of Mercury Vacuum
VAC	Volts Alternating Current
VDC	Volts Direct Current
W/G	Water Glycol

LIST OF REFERENCES

2-1 Memorandums generated by Panel 2.

2-2 Response from MSC concerning:
a. Unqualified equipment on S/C 012.
b. Significant arcing and shorting anomalies.
c. Explosion proof testing.

2-3 Discrepancy reports supporting Enclosure 2-7.

2-4 Oxygen exposure and failure data of vehicle level tests.

2-5 Oxygen exposure history of component level tests.

2-6 Discrepancy reports and failure reports regarding water/glycol leaks in the ECS.

2-7 Elapsed Time Indicators qualification data.

2-8 Failure survey for possible or highly probable fire initiators.

2-9 Environmental Control System qualification requirements.

2-10 Acceptance Test Procedure AiResearch Rpt. SS-110-R, Rev. 1 dated 10-2-64.
Interim Change Notice A to above dtd. 12-2-64.

2-11 Acceptance Test Procedure AiResearch Rpt. SS-1720 P. dtd. 9-20-65.
Interim Change Notice E to above dtd. 5-11-66.

2-12 Group 1 Qualification Test Procedure AiResearch Rpt. SS-1274-R, Rev. 2 dtd. 10-1-65.

2-13 Group 1 Qualification Test Report AiResearch Rpt. SS-1474-R, dtd. 3-21-66.
Errata to above dtd. 9-7-66.

2-14 Group 111 Qualification Test Procedure AiResearch Rpt. SS-1507-R, Rev. 1 dtd. 8-30-65.

2-15 Group 111 Qualification Test Report AiResearch Rpt. SS-1807-R dtd. 4-12-66.
Errata to above dtd. 9-29-66.

2-16 Environmental Control System Procurement Specification NAA No. MC901-0215, Rev. G, dtd. 8-31-66.

2-17 Goodyear Aerospace Rpt. GER-12246 dtd. 8-21-65.

2-18 U.S. Naval Research Laboratory Rpt. 6090 dtd. 7-28-64.

2-19 U.S. Naval Research Laboratory Ltr. 6130-56 dtd 3-23-65.

2-20 U.S. Naval Research Laboratory Ltr. 6130-41 dtd. 2-25-65.

2-21 U.S. Naval Research Laboratory Ltr. 6180-39, dtd. 2-25-65.

2-22 Fire at High Pressure by J.V. Harter, dtd, 3-24-65.

2-23 Preliminary Report AiResearch Fire dtd 4-28-65.

2-24 Final Report AiResearch Fire dtd 4-28-66.

2-25 Report of Fire at Naval Air Crew Equipment Laboratory undated.

2-26 Report of Fire at Air Force Aerospace Medical Division dtd 10-9-62.

2-27 13 Photographs of fire at A.F. Aerospace Medical Division undated.

2-28 Group of TWX's regarding fire at Brooks AFB on 1-31-67 Progress Rpt. No.'s 5, 6, 7, and 8.

2-29 NAA Failure Notification AR-TR-64-242 dtd 2-2-65.

2-30 AiResearch Trouble Rpt. 4769 dtd 1-28-65.

2-31 Notebook of 40 photographs of S/C 012 in and around LiOH canisters.

REPORT OF PANEL 3
SEQUENCE OF EVENTS
APPENDIX D-3
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

SEQUENCE OF EVENTS

A. TASK ASSIGNMENT

Analyze data obtained immediately prior to and during the fire incident including digital, analog, voice communications, photography, etc. Data should display significant events as they occurred with precise time tag. Time histories of all continuous or semi-continuous recorded parameters, correlation of parameter variations and events shall be recorded as well as interpretation of the results of said analysis. Where pertinent, normal expected variations shall be compared with those actually obtained.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Sequence of Events Panel:

Mr. D. D. Arabian, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. H. Creighton, Kennedy Space Center (KSC), NASA.
Mr. W. Jewel, Kennedy Space Center (KSC), NASA
Mr. W. Eckmeier, North American Aviation (NAA), Kennedy Space Center
Mr. A. Tischler, North American Aviation (NAA), Downey

2. COGNIZANT BOARD MEMBER:

Dr. M. Faget, Manned Spacecraft Center (MSC), NASA, Board Member, was assigned to monitor the Sequence of Events Panel.

3. PANEL CONSOLIDATION:

Panel 3 served as a separate Panel from January 31, 1967 through February 23, 1967. The Panel was dissolved on February 23, 1967 and merged with Panel 18. This merger was accomplished to better support the Apollo 204 Review.

C. PROCEEDINGS

1. GENERAL DESCRIPTION OF THE DATA SYSTEM

a. The engineering data used in the determination of the sequence of events was obtained from the spacecraft instrumentation system and is presented in Enclosure 3-1. This system consists of the following main elements:

(1) The instruments in the Command Module which measured about 400 items such as voltages, temperatures and pressures.

(2) A signal processing system in the Command Module which converts the physical parameters measured into a form suitable for transmission.

(3) The hard-line and radio transmission links which carry the converted data to the ground.

(4) The ground system which provides permanent tape records of the data obtained and also provides the various kinds of real-time displays of the data required to conduct the test.

(5) The instruments in other parts of the Space Vehicle and Ground Support Equipment systems. These instruments provide data to the ground recording stations in a similar manner as for the Command Module.

(6) A communications network for voice transmission between the various groups associated with the tests including the Command Module crew.

Enclosure 3-2 is a simplified schematic of the data system in use in Spacecraft (S/C) 012 and on the ground during the Plugs Out Test and shows the general elements within the Spacecraft and the radio and hard-line links to the main ground stations at John F. Kennedy Space Center (KSC). Data were also transmitted from the KSC ground stations to other sites such as the Air Force Eastern Test Range (AFETR) and to the Manned Spacecraft Center (MSC) in Houston

b. Because of the large number of measurements which are made in the Command Module, and in the other systems in the Spacecraft, it is impossible within the present state-of-the-art to provide continuous information on each measurement made. This is true for both ground tests and space flight operations. A system is used, therefore, which provides periodic sampling of each measurement. The sampling system used is the Pulse Code Modulation (PCM) system. This system takes samples of each measurement a predetermined number of times each second. The sampling rate varies from 200 per second on parameters which are expected to vary rapidly sometime during test or flight operations to one per second for parameters not expected to vary rapidly. The final record, therefore, provides samples of data from each measurement permitting a near continuous record to be constructed. This may not be possible if rapid variations in the measured quantity occur. Rapid variations between sampling times are not recorded. However, a change may be detected when the parameter is sampled even though the actual initial variation of the parameter, or the precise time the variation occurred, cannot be determined. This condition may provide clues to the nature of events that are not fully recorded.

c. The signal processing equipment in the Command Module converts the sampled data into a binary code. This code consists of "words" each of which are eight "bits" long. The Command Module PCM system transmits 6400 "words" per second and, therefore, 51,200 "bits" per second.

Each "word" corresponds to a particular value of the parameter being measured. Such a "word" is also called a "count." The full scale range of each measuring instrument is divided into 254 "counts." A change, however, in a "count" (or "word"), does not necessarily correspond to a real change in the parameter being measured. This effect is obtained because "noise" is inherent in information transmission and processing system. The "noise" can cause changes in "counts." Careful examination of records is required to distinguish between real changes in magnitude of the parameters being measured and apparent magnitude changes which are due to "noise." This result is particularly true when the "noise" produces a one "count" change between two adjacent measurement levels. In general, a one "count" change does not reflect a real change in level of the measured parameter, particularly if one "count" fluctuations have occurred for an extended period.

2. SEQUENCE OF EVENTS

a. On the morning of January 27, 1967, a test of S/C 012 commenced. The purpose of the test was to verify systems operation in a simulated launch and to exercise countdown procedures in preparation for actual launch. The test was identified as a Space Vehicle Plugs Out Integrated Test OCP-FO-K-0021-1 in which the spacecraft would be electrically disconnected from the Ground Support Equipment (GSE) by removing the umbilical connectors normally disconnected at the time of launch.

b. Spacecraft power buses were energized at 12:55 GMT(7:55 a.m. EST) and subsystems were activated and checked in preparation for crew ingress which occurred about five hours later at 18:00 GMT. At the time the Spacecraft Commander changed from the closed-loop ventilator to the Environmental Control System (ECS), he stated there was an odor like "sour milk" in the suit circuit loop. Ingress of the Pilot and Senior Pilot continued and at 18:20 GMT, the countdown was held for Bendix support personnel to obtain a gas sample from the suit circuit loop for later analysis of the odor. The countdown then continued at 19:42 GMT with the normal suit circuit checks, cabin switch checklists, hatch installations, and cabin purge with oxygen followed by the leak check of the sealed cabin. During the cabin leak checks, the Emergency Detection System (EDS) which monitors critical functions within the launch vehicle and indicates to the crew when an emergency situation exists, was checked. By 21:50 GMT, the EDS and the cabin purge and leak checks were finally completed. The boost protective cover which provides thermal protection to the spacecraft outer surface during launch could not be properly latched in place; however, the test continued until 22:30 GMT when a hold of the countdown was called for a communications problem. The crew became aware of the problem, a "live mike" condition, at 22:26:48 GMT, and a series of trouble-shooting exercises was conducted, such as interchanging the communications cables (Cobra Cables) that connect the astronauts' microphones and earphones to the communications equipment within the Spacecraft, and checking the effect of various communication

mode selection of the communications system. The "live mike" condition continued to exist after the troubleshooting exercises and the cause for this condition had not been determined by the time of first voice indication of fire. Another communication problem appeared after troubleshooting; it was in the ground station and involved the distribution of the various voice links. Shortly after the troubleshooting period, decision was made to proceed with the simulated static firing of the Reaction Control System (RCS) thrusters while communications were still possible. By 23:04 GMT the ground station worked around their problem by patching Spacecraft communications to Black 5, a specific communications loop. All test personnel were switched to this loop. By around 23:13 GMT the static firing exercise was completed. Voice check was made between the crew and the ground. The communications from the crew to the ground were somewhat garbled. At 23:22:27 GMT, the ECS engineers noted an appreciable depletion of the oxygen purge tank. The Command Pilot had his face plate open which accounted for the change and by about 23:23 GMT the face plate was closed. Still plagued by poor communication, Astro Communication Console CAST suggested the crew switch to S-band voice link; a communication check with each of the crew was acceptable. However, some undefined difficulty with the communications between the Spacecraft and the ground still existed.

c. At 23:28:00 GMT the count was holding at T-10 minutes and resumption of the count was anticipated momentarily. All the systems being monitored through the PCM system by systems engineers showed normal operation (particularly the electrical and ECS) at this time. Sixteen personnel were standing by at the various floor levels of the gantry to provide technical support as required. Those with specific functions to be performed at T-0 were positioned in the vicinity of assigned stations. Movement was reportedly negligible and no work was being performed on the flight or ground support hardware. Seven persons were positioned within the Saturn S-IV-B aft interstage monitoring assigned communication channels or otherwise engaged in support coordination. The only known anomaly within the Spacecraft was the "live microphone" which was picking up the rhythmic cadence of the Command Pilot's breathing sounds representative of a man at rest. In addition, the Senior Pilot's biomedical parameters showed normal resting levels. During this period, voice transmissions from the Spacecraft confirmed this impression of a relaxed situation. The termination of the last relaxed conversational transcript from the Spacecraft occurred at 23:30:02 GMT.

d. At 23:31:04.7 GMT, the crew call of fire was received over the voice loop. The series of events during the minute preceding the fire call was extracted from an after-the-fact review of the data and observation by personnel involved with the test.

At about 23:30:40 GMT, random sounds other than the normal breathing from the Command Pilot were evident on the "live mike." The sounds were similar to those obtained by tapping or brushing a microphone. The frequency of the noise occurrences was much greater than noted earlier in the test when the mike was "live." The noises subsided several seconds before the crew call of fire. Throughout the one-minute period before the crew call of fire, the oxygen flow to the suit circuits continually increased and reached the upper flow limit of the measuring system at about 23:30:59 GMT. During this period the torquing signals to the Inertial Measuring Unit showed fluctuations which were an indication of movement of the Spacecraft. In addition, biomedical data indicates a slight increase of activity by the Senior Pilot. This indication subsided within the one-minute time period. An assessment of the noises on the voice loop, increasing oxygen flow to the suit circuits, torquing signal variations to the Inertial Measuring Unit and Senior Pilot slight increase in activity between about 23:30:40 GMT and 23:30:59 GMT show that crew activity within the Spacecraft occurred. During the period when the crew was active, the open channel of the gas chromatograph showed fluctuations commencing at about 23:30:50 GMT. This fluctuation may have also indicated crew activity because of the antenna characteristics of the disconnected cable. At about 23:30:55 GMT a momentary dropout of the data being transmitted from the Spacecraft occurred. The C-band beacon also showed an interruption at this time. The AC voltages on the three phases of inverter Number 2 showed a transient, as did one of the phases which supplied power to the hand controller.

e. About six seconds before the call of fire by the crew, all systems appeared to be at a steady or quiescent state, except for the high oxygen flow to the suit circuits The crew call of fire occurred at 23:31:04.7 GMT.

There were two voice transmissions from the Spacecraft. The first transmission, believed to be that of the Command Pilot, at 23:31:04.7 GMT reported "a fire in the cockpit." This transmission ended at 23:31:10 GMT. The second and last transmission, believed to be the Pilot's, started at 23:31:16.8 GMT and ended at 23:31:21.8 GMT. This transmission reported "a bad fire" followed by two garbled phrases. Coincident with the call of fire, immediate and marked increase in the biomedical measurements from the Senior Pilot occurred. The magnitude of these readings continued to increase until loss of data from the Spacecraft. Those systems sensitive to the Spacecraft movement, including the launch vehicle accelerometers, showed increasing indications of Spacecraft movement. These indications continued until loss of data, which occurred at 23:31:22.40 GMT (6:31:22.40 p.m. EST).

The witnesses on station to support the test heard the call of fire. A muffled explosion was heard next, followed by two loud whooshes of escaping gas as the Spacecraft cabin ruptured from the internal pressure increase caused by the fire. Flames shot from open access panels. Astronaut helmet, arm and back movements were observed through the cabin window. The light intensity from within the cabin increased, and flames filled the view through the window.

f. Ground power was switched from the Spacecraft at 23:32:46.4 GMT. However, internal batteries had been switched on the main buses by the crew at about 23:31:13 GMT so that removal of ground power did not deenergize the electrical systems within the Spacecraft. Between 23:31:15 GMT and 23:33:00 GMT repeated attempts were made by the pad crew to enter the smoke-filled White Room to rescue the astronauts from the Spacecraft. The fires external to the Spacecraft continued to burn as hatch removal progressed. At about 23:36 GMT the hatch was removed and at approximately 23:43:00 GMT, three physicians arrived from the blockhouse.

g. Detailed events from about one minute prior to the fire to the time when ground power was switched from the Spacecraft, are shown in Enclosure 3-3. (Ground power was removed from the Spacecraft after loss of all data transmission from the Spacecraft.) The recorded data from the onboard instrumentation, the ground instrumentation, and the voice transcripts were used to establish the events of the enclosure.

3. DATA INDICATION

Some of the more significant data obtained just prior to the crew call of fire is shown in Enclosure 3-4. These data cover a period of one minute before the call of fire until loss of the data signals. The data shown include various parameters indicating Spacecraft motion, the "live mike" audio noises on the Command Pilot's S-band, oxygen flow rate into the suit loop, biomedical indications from the Senior Pilot, AC bus 2 transient and associated effects on the C-band operation and VHF telemetry carrier and the gas chromatograph signal monitor. Each of these subjects is discussed in the Report of Panel 18.

D. FINDING AND DETERMINATIONS

1. FINDING:

The data recorded from the Spacecraft and ground instrumentation system during the Spacecraft Plugs Out Test were found to be valid except for three brief dropouts which occurred around 23:31:17.4 GMT, 23:31:21.0 GMT and 23:31:21.4 GMT. All onboard data transmission ended at about 23:31:22.40 GMT.

2. DETERMINATION:

The onboard instrumentation system functioned normally prior to and during the initial phases of the fire. There were no indicated malfunctions in any of the instrumentation sensors during this period.

E. SUPPORTING DATA

1. Enclosure 3-1 Sequence of Events, Final Summary Report

2. Enclosure 3-2 Flow of Data Information from S/C and Ground Support Equipment

3. Enclosure 3-3 Sequence of Events

4. Enclosure 3-4 Data Indications

ENCLOSURE 3-1

1. INTRODUCTION

This report contains the sequence of events from about one minute prior to the crew call of fire to loss of data. The basic data pertinent to the sequence of events are presented in direct-write recorder form. Abrief discussion of the data indications for each system is given. The analysis of these data indications are presented in the final report of Panel 18 where additional data is presented to support the discussion.

CR	Cathode Ray
AC	Alternating Current
DC	Direct Current
ECS	Environmental Control System .
TVC	Thrust Vector Control
PCM	Pulse Code Modulation
VHF/FM	Very High Frequency/Frequency Modulation
MTVC	Manual Thrust Vector Control
W/G	Water-Glycol
S/C	Spacecraft
IMU	Inertial Measurement Unit
OAT	Over-All Testing
GSE	Ground Support Equipment
SRP	Senior Pilot
EDS	Emergency Detection System
HFLT	Houston Flight
BPC	Boost Protective Cover
CMD	Command Pilot
SM-RCS	Service Module-Reaction Control System
ACE S/C	Acceptance Checkout Equipment Spacecraft
ACE	Acceptance Checkout Equipment
LOS	Loss of Signal
KSC	Kennedy Space Center
ECA	Electronic Control Assembly
ECU	Environmental Control Unit
SPS	Service Propulsion System
F/C	Fuel Cell
G&N	Guidance and Navigation
PIPA	Pulse Integrating Pendulous Accelerometer
LEB	Left Equipment Bay
FHS	Forward Heat Shield
CSM SLA	Command Service Module Saturn LM Adapter
LES	Launch Escape System
DSEA	Data Storage Electronic Assembly
MCCH	Mission Control Center Houston
GMT	Greenwich Mean Time

PSIG	Pounds Per Square Inch Gauge
PSIA	Pounds Per Square Inch Absolute
S/V	Space Vehicle
NRZ PCM	Non-Return to Zero Pulse Code Modulation
TPS	Test Planning Sheet
EPS	Electrical Power System
EDU	Coupling Display Unit
ADA	Angular Differentiating Accelerometer
CW	Continuous Wave
MSOB	Manned Spacecraft Operations Building
MOLC	ACE Open Loop Communication Station
CAST	Astro Communicator Console
PLT	Pilot
MSTC	Manned Spacecraft Operations Building Spacecraft Test Conductor
CGSS	Cryogenic Gas Storage System
PUGS	Propellant Utilization Gaging System
SM-A	Service Module Quad A
SM-D	Service Module Quad D
SM	Service Module
MDAS	Medical Data Acquisition System
VDC	Voltage Direct Current
CG	Gas Chromatograph
C &W	Caution and Warning
PTT	Press to Talk
VHF/AM	Very High Frequency Amplitude Modulation
CCW	Counterclockwise
RFI	Radio Frequency Interference
CSM	Command Service Module
T/R	Transmit Receive

2. SIGNIFICANT EVENTS PRIOR TO THE START OF THE FINAL TEST

a. SC ARRIVAL TO START OF PLUGS OUT TEST

August 26, 1966	- Command Module arrival at KSC.
September 14	- Start of combined systems test (OCP-FO-0035).
Semptember 17	- Spacecraft (S/C) power-down for troubleshooting.
September 19	- S/C power-up for OCP-FO-K0035.
September 23	- S/C power-down for OCP-FO-K-0035 troubleshooting.
September 27	- OCP-FO-K0035 ECS leak checks.
September-29	- Remove electronic control assemblies (ECA) because of water glycol (W/G) leak.
September 30	- Reinstall ECA's. Environmental control system water glycol leak corrected.

October 1	- S/C power-up and completed OCP-FO-K-0035.
October 7	- W/G spill during transducer change. Remove all ECA's because of W/G wetting.
October 8	- Install new ECA's.
October 10	- Manned sea level run of flight crew altitude chamber test, OCP-FO-K-0034 started.
October 11	- Manned sea level run discontinued due to bent pins in CM-SM umbilical. PCM replaced due to suspected bad transistors.
October 12-13	- Manned seq level run performed.
October 14-15	- Unmanned altitude run performed.
October 18	- First manned (flight crew) altitude run aborted at 13,000 feet due to inverter no. 1 failure. Inverter replaced. Shorted input transistor. (Had not gone through the screening process.) Replacement was of modified and screened type.
October 19	- First manned (flight crew) altitude run completed.
October 21	- Second manned 9back-up crew) altitude run initiated but scrubbed due to O_2 regulator failure.
October 27	- Decision received to change ECU. Inverters no. 2 and no. 3 removal started. (These two were of the unmodified type.)
October 28	- ECA's removed for water glycol drain.
October 29	- Demate CSM to pressure test service propulsion system (SPS) tanks. Installed Yaw Axis ECA. C/M moved to integrated no. 1 stand.
October 31	- ECU removed.
November 1	- SPS tank removal from S/M started.
November 3	- Install roll and pitch ECA's. New inverter installed complete.
November 4	- Fuel cell (F/C) no. 2 W/G pump replaced due to leak.
November 5	- Start SPS tank pressure testing at Pad 16.
November 6	- O_2 panel with new O_2 regulator installed.
November 8	- Installation of ECU initiated. Installation of SPS tanks initiated. Drain of fuel cell water-glycol completed.
November 9	- F/C W/G fill initiated. New SPS fuel tanks received.
November 11	- Leak check of ECU completed. Installation of SPS tanks completed.
November 12	- Power-up S/C to support ECS checks.
November 13	- Move S/M to Pad 16 for SPS installed tank pressure checks. G&N computer , S/N 123, removal in work to install flight program memory.
November 14	- ECS W/G servicing started.
November 15	- Install S/M in altitude chamber. ECS W/G servicing complete.

November 16	-	G&N computer installed temporarily to perform PIPA test. Corrosion noted on pins. Must be removed.
November 17	-	G&N PIPA test complete.
		Computer S/N 123 removed. Will install new computer S/N 124 due to corrosion on pins of S/N 123.
November 19	-	CSM mate started.
November 20	-	Installation of new G&N computer S/N 124. Held up by broken bolt.
		CSM mate complete.
November 21	-	Air in ECS W?G system. Must be re-serviced.
November 22	-	ECS W/G drain started.
		Broken bolt in computer removed. Computer removed. Computer removed.
		Computer bolts found to be too soft.
November 25	-	O2 panel removed and -5 O2 regulator installed.
November 26	-	G&N computer S/N 124 installed.
November 27	-	ECS W/G reservice complete.
		W/G leak in lower equipment bay (LEB) repaired.
November 29	-	S/C power-up and conduct OCP-FO-K-0034.
November 30	-	Test scrubbed due to W/G leak in ECU.
December 1	-	Decision made to remove ECU.
December 2	-	Drain W/G system. Repair W/G leak in LEB.
December 3	-	Removed ECU and shipped to AiResearch (A, R).
December 14	-	Started ECU installation.
December 16	-	Completed installation of forward heat shield (FHS).
December 19	-	Completed ECU installation.
		Started W/G servicing per OCP-FO-K-5518.
December 21	-	Completed W/G servicing.
December 27	-	Initiated manned (back-up crew) sea level run OCP-FO-K-0034A.
December 28	-	Manned sea level run completed.
		Unmanned altitude run completed.
December 29	-	Started manned (back-up crew) altitude run.
December 30	-	Manned altitude run completed.
January 3, 1967	-	Remove CSM from altitude chamber for SPS nozzle installation and SLA mate.
January 4	-	Start CSM/SLA mate
January 6	-	New quads "A" and "D" installed due to minor damage in original quad engine nozzle.
		Moved to LC-34 and mated to launch vehicle.
January 7	-	Launch vehicle pull test completed.

January 10	-	Solenoid valve on cyclic accumulator no. 1 replaced. Perform OCP-FO-K-0039 GSE interface test. Start circuit interrupter test. Main DSKY replaced due to burned out light on numeral.
January 11	-	Removed panel 31 and replaced suit pressure meter.
January 12	-	Circuit interrupter test completed. Start combined systems test OCP-FO-K-0005.
January 13	-	Start F/C cryogenic loading test, OCP-FO-K-4736.
January 14	-	OCP-FO-K-0005 completed.
January 15	-	Launch escape system (LES) mate completed.
January 16	-	S/C powered up for trouble shooting.
January 17	-	OCP-FO-K-4736 completed.
January 18	-	Electrical mate, OCP-FO-K-0004, started and completed.
January 20	-	Plugs in, integrated test, OCP-FO-K-0006 dry run without HFLT started and completed.
January 21	-	Potting of panel no. 12 initiated.
January 23	-	O2 purge valve on F/C no. 1 replaced. Potting on panel no. 12 reheated. Still not properly cured. Installed for test. Circuit interrupters between CM/SM opened in search of missing test spacer which prevents damage to the o-ring in the connector during test (not found in interrupters). Repair pyro battery wire.
January 24	-	MCCH interface test, OCP-FO-K-0045, started and completed. Pyro connector repaired. Water flush test completed. S/C power-on troubleshooting in work.
January 26	-	YAW ECA replaced due to electronic anomaly and new one retested. Started replacing DSEA connector. OCP-FO-K-0006 completed.
January 27	-	DSEA connector replacement completed. Plugs out, OAT, OCP-FO-K-0021-1 started.

3. SEQUENCE OF EVENTS

a. START OF PLUGS OUT TEST TO 23:30:00 GMT

The following is the time line for plugs out. OAT, OCP-FO-K-0021-1, January 27, 1967:

12:55 GMT	-	S/C bus power up.
13:20 GMT	-	S/C subsystems activation and systems test.
14:50 GMT	-	ECS systems test started.
16:00 GMT	-	T-3 hours and hold for 1 hour for ECS. ECS had trouble with O2K bottle hookup through GSE into pneumatically operated disconnect at service module.

17:00 GMT	-	ECS test completed.
17:05 GMT	-	Started pre-ingress switch checklist.
18:00 GMT	-	Command Pilot ingress. When Command Pilot changed over from the closed loop ventilator to S/C ECS, he said there was an odor in the systems like "sour milk." Continued with Pilot and Senior Pilot ingress.
18:09:56:5 GMT	-	SRP hooks up to communications cables after ingress and biomed data becomes available.
18:30 GMT	-	Begin hold for odor in suit loop. Bendix support called for to supply evacuated "watermelon" to take samples of suit circuit loop. Sample taken during hold.
19:25 GMT	-	Picked up count and performed suit circuit checks.
19:40 GMT	-	Post-ingress switch checklist performed silently by flight crew.
19:45 GMT	-	Inner hatch installed and started cabin purge and leak check.
20:00 GMT	-	Start emergency detection system (EDS) test.
21:00 GMT	-	EDS test complete. Start abort request checks.
21:15 GMT	-	Abort request checks complete.
21:50 GMT	-	Cabin purge and leak check complete. Start outer hatch and boost protective cover (BPC) installation. Could not properly latch BPC hatch.
22:40 GMT	-	Hold for communications problems. Proceed with terminal count functions where communications allowed.
22:45:15:5 GMT	-	SRP disconnects his communication cables and gives to CMD. This is done in an effort to isolate the communications problem.
22:45:28 GMT	-	CMD hooks up to SRP cables and runs communications check.
22:46:45:9 GMT	-	CMD disconnects from SRP cables.
22:46:51:2 GMT	-	SRP reconnects to communications cables and re-establishes biomed data.
22:47:33 GMT	-	CMD reconnects to his own communications cables.
22:53 GMT	-	Approximate time CMD replaced cobra cable.
23:10:00 GMT	-	Start simulated SM-RCS static fire.
23:15:00 GMT	-	Complete static fire.
23:20 GMT	-	Completed all terminal count functions up to transfer to internal power. Hold at T-10 minutes for communications problems.

b. 23:30:00 GMT TO LOSS OF DATA

Figure 3-1 shows the significant sequence of events time line as gathered from the recorded data. Figures 3-2 through 3-8 represent the actual recorded data.

The illustrations contained in this section are direct reproductions of the direct-write recordings made through the ACE S/C ground station decommutator. No smoothing techniques have been employed. However, during the last 5 seconds before final LOS three additional losses of data occurred. At these times the PCM wavetrain recovered as much as a second before the ACE decommutator was able to reacquire synchronization. In order to provide information during the portion of this time when the wavetrain was available but the decommutator not in synchronization, manual data reduction was employed.

4. SYSTEM

a. INSTRUMENTATION

(1). INSTRUMENTATION CONFIGURATION

Deviations from standard launch configuration were as follows:

(a). The transducer for measuring battery compartment manifold pressure, CC0188P (0 to 21.3 psia), was not installed in the port in the manifold. However, the instrument was electrically connected and stowed, and in this configuration provided a measure of cabin pressure.

(b). Batteries A and B case temperature measurements, CC0178T and CC0179T, were not connected.

(c). S/M - adapter separation monitor A, SS0120X, was inoperative at the time of the test. Refer to S/C DR No. 932.

(d). The gas chromatograph was not installed.

(e). Elapsed time indicators were installed on the PCM packages, the central timing equipment and the signal conditioning equipment. These indicators were to be removed prior to flight.

(2) SYSTEMS DESCRIPTION

(a). The engineering data used for the determination of the sequence of events was extracted via the spacecraft instrumentation system. The mechanism for accomplishing this task involves sensing S/C physical parameters, converting the parameters into varying direct current electrical signals, sequentially sampling the signals and then converting these signals into binary coded words which are transmitted for recording and display (see Figure 4.1-1). The basic hardware used includes sensors, signal conditioners, and the pulse code modulation system..

(b). The pulse code modulation system (PCM) samples the various sensors and signal conditioners in the S/C and encodes the information for transmission. The PCM basically is a number of electronic input switches and an encoder, all of which are controlled by a programmer. The input switches, through programmer control, are sampled sequentially with each sample period being 15 microseconds. The voltage passed through the switch during the sampling time is then converted by the encoder into an 8-bit, binary word of 156.25 microseconds duration. This results in each switch being sampled sequentially in 156.25-microsecond time increments. The number of times per second each input switch is sampled is controlled by the programmer. Programmed sampling rates are 200, 100, 50, 10 and 1 samples per second. The end result of this operation is a serial stream of data consisting of 6400 eight-bit binary words per second. The serial word stream is then transmitted to an area to be decoded, recorded and displayed (see Figure 4.1-2).

(c). A list of all active instrumentation parameters which were being monitored during OCP-FO-K-0021, S/V Plugs Out Integrated Test, is presented in Table 4.1-2 and an explanation is given in Table 4.1-1.

(3). COMMENTS ON DATA

Data quality was good except for three confirmed dropouts of the onboard PCM system at the following times (all GMT):

23:31:17.398 to 23:31:17.659
23:31:21.018 to 23:31:21.284
23:31:21.383 to 23:31:21.519

These dropouts were confirmed by prime frame count readouts of computer tabulations and strip chart recordings made from available data sources. Measurements with sampling rates of one and ten per second did not show good data on strip charts for one full second following the 23:31:17.398 GMT dropout, because after system recovery at 23:31:17.659 GMT the PCM prime frame counter picked up one count. Data are read from a digital frame dump in this period by reading the prime frame count and subtracting one for proper prime frame identification.

(a). DATA SOURCES

Four data sources were available (See Figure 4.1-2):
1. 51.2 kilo-bit bi-phase hard line data (S/C PCM)
2. 204.8 kilo-bit interleaved data (S/C and GSE PCM's)
3. 51.2 kilo-bit NRZ PCM data via the S/C very high frequency/frequency modulated (VHF/FM) transmitter (S/C PCM)

4. 51.2 kilo-bit NRZ data via the S/C S-band transmitter (S/C PCM). The VHF/FM and 41.2 kilo-bit bi-phase hardline sources were used here for data purposes since those sources showed fewer dropouts and bit errors than the interleaved data, and since trouble with the ground stations made data from the S-band link practically unusable.

(b). CABIN PRESSURE FROM BATTERY MANIFOLD PRESSURE

The pressure sensor for the battery manifold pressure measurement, CCO188P, was electrically connected to a signal conditioner. The sensor was not mounted to the battery manifold to avoid possible damage to the sensor during battery removals and installations. The port of the battery manifold in which the sensor was to be mounted was plugged. The sensor and coiled wire were wrapped in a plastic bag and stowed in an area under the battery mounting shelf between the shelf and the floor of the S/C. In this configuration, the instrument sensed cabin pressure. The upper limit of the sensor, 21.3 psia, was reached at 23:31:18.518 GMT.

(c). BATTERY CASE TEMPERATURES

The battery Aand B case temperature measurements, CCO178T (battery A) and CCO179T (battery B), were not active. The sensors are installed only on flight batteries, and since test batteries were used, no sensors were available. The signal conditioners for these measurements and associated wiring were installed. The two sensor connectors were packed in individual plastic bags, the wire cc d and stowed in the same area with the battery manifold pressure sensor. The output of the two measurement points was reviewed and found never to deviate from a full scale reading which, in this case, is normal.

(d). DATA DROP-OUTS

At 23:30:54.85 GMT a drop-out of the detected PCM signal from the S/C VHF/FM transmitter was noted. However, the hardline signal from the PCM system showed no change in any way; this is confirmed by all playback data from the hardline sources. Thus, no data interruption at this time was experienced.

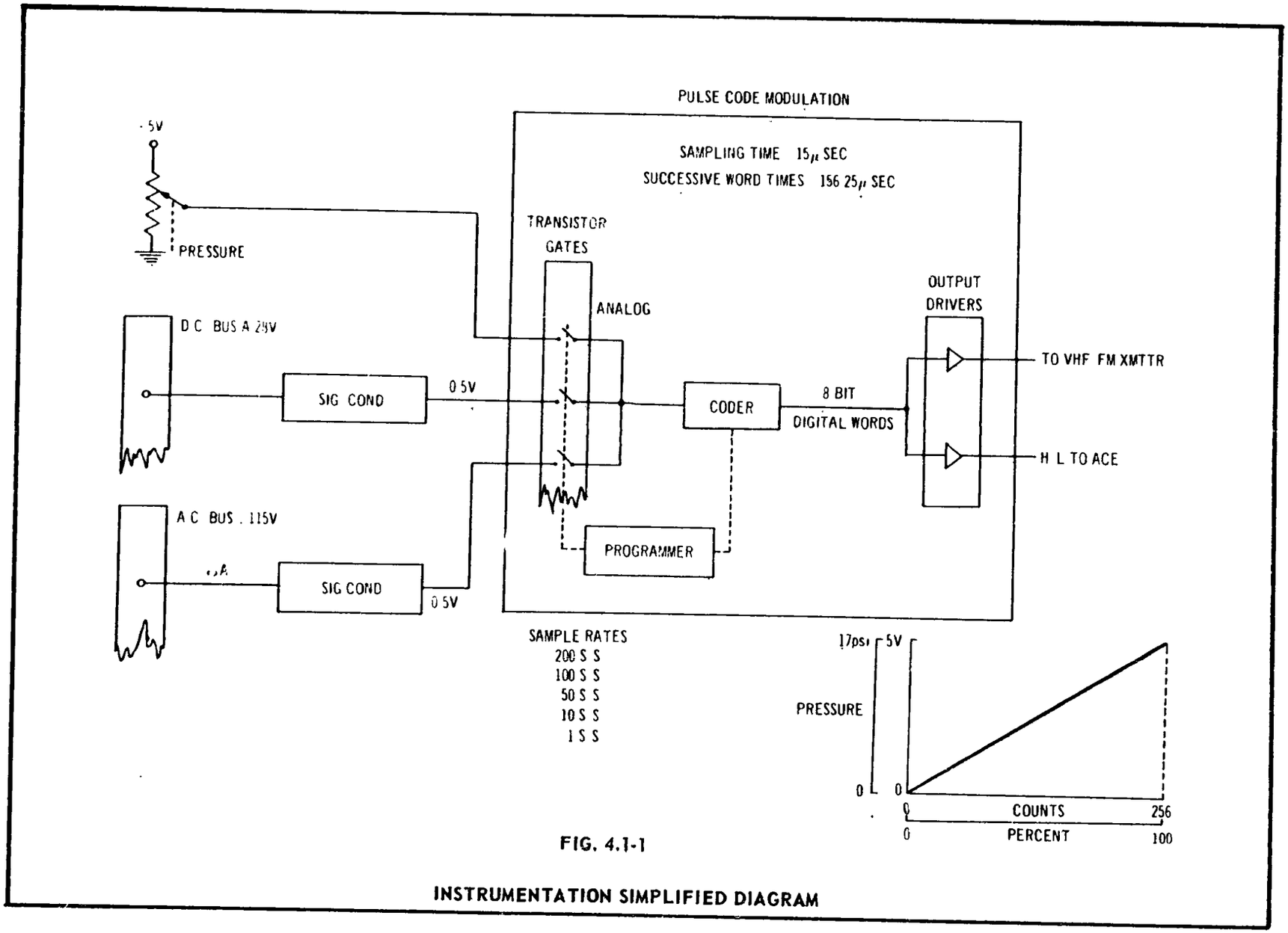


FIG. 4.1-1

INSTRUMENTATION SIMPLIFIED DIAGRAM

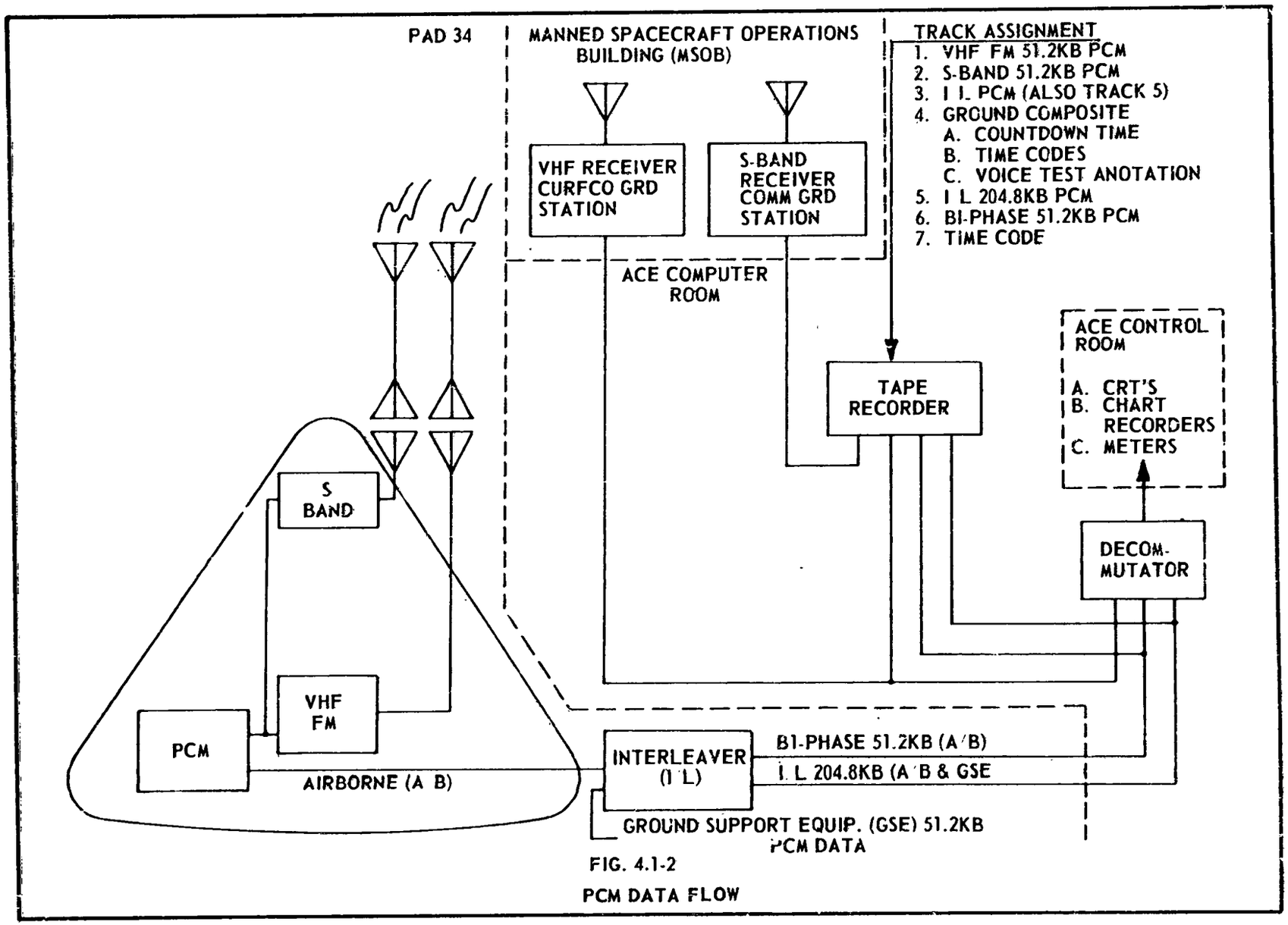


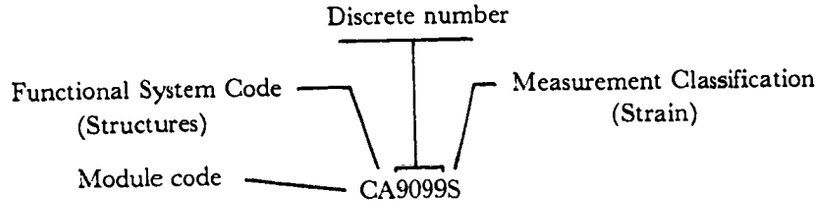
FIG. 4.1-2

PCM DATA FLOW

TABLE 4.1-1

MEASUREMENT IDENTIFICATION

The measurement identification consists of seven characters: two letters followed by four numbers and one letter.



The first letter (module code) designates the measurement location by module.

A Adapter
B Booster
C Command module
L Launch escape tower
S Service module

The second letter (functional subsystem code) denotes the subsystem within which the measurement originates.

A Structures
C Electrical power
D Master events sequence controller
E Earth landing sequence controller
F Environmental control
G Guidance and navigation
H Stabilization and control
J Crew equipment
K Flight technology
P Service propulsion.
R Reaction control
S Launch vehicle emergency detection
T Communications and instrumentation

Characters three through six are numbers assigned sequentially or grouped for clarity within each system. The seventh character, a letter, denotes measurement classification as follows:

A Acceleration
B Phase
C Current
D Vibration
E Power
F Frequency
G Force
H Position, Attitude
J Biomedical
K Radiation
L Velocity
M Mass
N Camera
P Pressure
Q Quantity
R Rate
S Strain
T Temperature
V Voltage
W Time
X Discrete event
Y Acoustical
Z pH-acidity

TABLE 4.1-2 ACTIVE PCM MEASUREMENTS FOR S/C 012

SUBSYSTEM STRUCTURES

MEAS. ID	MEASUREMENT DESCRIPTION	SAMPLE RATE	DATA RANGE LOW	DATA RANGE HIGH	UNITS
C A1502	T TEMP SIDE HS BOND LOC A	1 S/S	-260	+600	DEG F
C A1505	T TEMP SIDE HS BOND LOC B	1 S/S	-260	+600	DEG F
C A1509	T TEMP SIDE HS BOND LOC C	1 S/S	-260	+600	DEG F
C A5480	T TEMP AFT HS LOC 1-A	1 S/S	-100	+4000	DEG F
C A5481	T TEMP AFT HS LOC 1-B	1 S/S	-100	+4000	DEG F
C A5482	T TEMP AFT HS LOC 1-C	1 S/S	-100	+1600	DEG F
C A5483	T TEMP AFT HS LOC 1-D	1 S/S	-100	+1000	DEG F
C A5484	R FLUX AFT HS LOC 1-4	1 S/S	0+150	B/+150	B/F/S
C A5490	T TEMP AFT HS LOC 2-A	1 S/S	-100	+4000	DEG F
C A5491	T TEMP AFT HS LOC 2-B	1 S/S	-100	+1600	DEG F
C A5492	T TEMP AFT HS LOC 2-C	1 S/S	-100	+900	DEG F
C A5493	T TEMP AFT HS LOC 2-D	1 S/S	-100	+1000	DEG F
C A5494	R FLUX AFT HS LOC 2	1 S/S	0	+100	B/F/S
S A2361	T TEMP SECT 6 IN SURF	1 S/S	-100	+200	DEG F
S A2364	T TEMP SECT 3 FUEL TANK SURF	1 S/S	-100	+200	DEG F
S A2365	T TEMP SECT 6 FUEL TANK SURF	1 S/S	-100	+200	DEG F

SUBSYSTEM ELECTRICAL POWER

C C0175	T TEMP STATIC INVERTER 1	1 S/S	+32	+248	DEG F
C C0176	T TEMP STATIC INVERTER 2	1 S/S	+32	+248	DEG F
C C0177	T TEMP STATIC INVERTER 3	1 S/S	+32	+248	DEG F
C C0178	T TEMP BATTERY A CASE	10 S/S	0	+250	DEG F
C C0179	T TEMP BATTERY B CASE	10 S/S	0	+250	DEG F
C C0188	P PRESS BATT COMPARTMENT (MANIF)	10 S/S	0	+20	PSIA
C C0200	V AC VOLTAGE MAIN BUS 1 PHASE A	10 S/S	0	+150	VAC
C C0201	V AC VOLTAGE MAIN BUS 1 PHASE B	10 S/S	0	+150	VAC
C C0202	V AC VOLTAGE MAIN BUS 1 PHASE C	10 S/S	0	+150	VAC
C C0203	V AC VOLTAGE MAIN BUS 2 PHASE A	10 S/S	0	+150	VAC
C C0204	V AC VOLTAGE MAIN BUS 2 PHASE B	10 S/S	0	+150	VAC
C C0205	V AC VOLTAGE MAIN BUS 2 PHASE C	10 S/S	0	+150	VAC
C C0206	V DC VOLTAGE MAIN BUS A	10 S/S	0	+45	VDC
C C0207	V DC VOLTAGE MAIN BUS B	10 S/S	0	+45	VDC
C C0210	V DC VOLTAGE BATTERY BUS A	10 S/S	0	+45	VDC
C C0211	V DC VOLTAGE BATTERY BUS B	10 S/S	0	+45	VDC
C C0212	V DC VOLTAGE POST LANDING BTRY	10 S/S	0	+45	VDC
C C0213	F FREQUENCY AC BUS 1 PHASE A	1 S/S	+380	+420	CPS
C C0214	V DC VOLTAGE BATT CHARGER OUT	10 S/S	0	+45	VDC
C C0217	F FREQUENCY AC BUS 2 PHASE A	1 S/S	+380	+420	CPS
C C0222	C DC CURRENT BATTERY A	10 S/S	0	+100	AMP
C C0223	C DC CURRENT BATTERY B	1 S/S	0	+100	AMP
C C0224	C DC CURRENT POST LANDING BTRY	10 S/S	0	+100	AMP
C C0232	V DC VOLTAGE BATTERY RELAY BUS	10 S/S	0	+45	VDC
S C2060	P N2 PRESSURE F C 1 REGULATED	1S/S	0	+75	PSIA
S C2061	P N2 PRESSURE F C 2 REGULATED	1 S/S	0	+75	PSIA
S C2062	P N2 PRESSURE F C 3 REGULATED	1 S/S	0	+75	PSIA
S C2066	P 02 PRESSURE F C 1 REGULATED	10 S/S	0	+75	PSIA
S C2067	P 02 PRESSURE F C 2 REGULATED	10 S/S	0	+75	PSIA
S C2068	P 02 PRESSURE F C 3 REGULATED	10 S/S	0	+75	PSIA
S C2069	P H2 PRESSURE F C 1 REGULATED	10 S/S	0	+75	PSIA
S C2070	P H2 PRESSURE F C 2 REGULATED	10 S/S	0	+75	PSIA
S C2071	P H2 PRESSURE F C 3 REGULATED	10 S/S	0	+75	PSIA
S C2081	T TEMP F C 1 COND EXHAUST	1 S/S	+150	+250	DEG F
S C2082	T TEMP F C 2 COND EXHAUST	1 S/S	+150	+250	DEG F
S C2083	T TEMP F C 3 COND EXHAUST	1 S/S	+150	+250	DEG F
S C2084	T TEMP F C 1 SKIN	1 S/S	+20	+550	DEG F
S C2085	T TEMP F C 2 SKIN	1 S/S	+20	+550	DEG F
S C2086	T TEMP F C 3 SKIN	1 S/S	+20	+550	DEG F

S C2087 T TEMP FC 1 RADIATOR OUTLET	1 S/S	-50	+300	DEG F
S C2088 T TEMP FC 2 RADIATOR OUTLET	1 S/S	-50	+300	DEG F
S C2089 T TEMP FC 3 RADIATOR OUTLET	1 S/S	-50	+300	DEG F
S C2113 C DC CURRENT F/C 1 OUTPUT	10 S/S	0	+100	AMP
S C2114 C DC CURRENT F/C 2 OUTPUT	10 S/S	0	+100	AMP
S C2115 C DC CURRENT F/C 3 OUTPUT	10 S/S	0	+100	AMP
S C2120 X FUEL CELL 1 BUS A DISCONNECT	10 S/S	OFF	ON	EVENT
S C2121 X FUEL CELL 2 BUS A DISCONNECT	10 S/S	OFF	ON	EVENT
S C2122 X FUEL CELL 3 BUS A DISCONNECT	10 S/S	OFF	ON	EVENT
S C2125 X FUEL CELL 1 BUS B DISCONNECT	10 S/S	OFF	ON	EVENT
S C2126 X FUEL CELL 2 BUS B DISCONNECT	10 S/S	OFF	ON	EVENT
S C2127 X FUEL CELL 3 BUS B DISCONNECT	10 S/S	OFF	ON	EVENT
S C2139 R FLOW RATE H2 F/C 1	10 S/S	0	+0.2	LB/HR
S C2140 R FLOW RATE H2 F/C 2	10 S/S	0	+0.2	LB/HR
S C2141 R FLOW RATE H2 F/C 3	10 S/S	0	+0.2	LB/HR
S C2142 R FLOW RATE O2 F/C 1	10 S/S	0	+1.6	LB/HR
S C2143 R FLOW RATE O2 F/C 2	10 S/S	0	+1.6	LB/HR
S C2144 R FLOW RATE O2 F/C 3	10 S/S	0	+1.6	LB/HR
S C2160 X PH FACTOR WATER CONDITION F/C 1	10 S/S	NORMAL	HIGH	EVENT
S C2161 X PH FACTOR WATER CONDITION F/C 2	10 S/S	NORMAL	HIGH	EVENT
S C2162 X PH FACTOR WATER CONDITION F/C 3	10 S/S	NORMAL	HIGH	EVENT
S C2323 X FUEL CELL 1 SHUT OFF MON	10 S/S	CLOSE	OPEN	EVENT
S C2324 X FUEL CELL 2 SHUT OFF MON	10 S/S	CLOSE	OPEN	EVENT
S C2325 X FUEL CELL 3 SHUT OFF MON	10 S/S	CLOSE	OPEN	EVENT

SUBSYSTEM MASTER EVENTS SEQUENCE CONTROLLER

C D0002 X LES ABORT INITIATE SIGNAL A	10 S/S	OFF	ON	EVENT
C D0005 V DC VOLTAGE PYRO BUS A	10 S/S	0	+40	VDC
C D0006 V DC VOLTAGE PYRO BUS B	10 S/S	0	+40	VDC
C D0023 X CM-SM SEP RELAY CLOSE A	10 S/S	OFF	ON	EVENT
C D0024 X CM-SM SEP RELAY CLOSE B	10 S/S	OFF	ON	EVENT
C D0037 X ELS SEQ START RLY CLOSE A	10 S/S	OFF	ON	EVENT
C D0038 X ELS SEQ START RLY CLOSE B	10 S/S	OFF	ON	EVENT
C D0044 X BOOSTER CUT-OFF SIG A	10 S/S	OFF	ON	EVENT
C D0062 X LES ABORT INITIATE SIGNAL B	10 S/S	OFF	ON	EVENT
C D0105 X LES ABORT INITIATE SIGNAL B	10 S/S	OFF	ON	EVENT
C D 0105 X TWR JETTISON A	10 S/S	OFF	ON	EVENT
C D0106 X TWR JETTISON B	10 S/S	OFF	ON	EVENT
C D0120 X CANARD DEPLOY A	10 S/S	OFF	ON	EVENT
C D0121 X CANARD DEPLOY B	10 S/S	OFF	ON	EVENT
C D0125 X ADAPT-SM SEP INITIATE A	10 S/S	OFF	ON	EVENT
C D0126 X ADAPT-SM SEP INITIATE B	10 S/S	OFF	ON	EVENT
C D0127 X ADAPT SEPARATION A	10 S/S	OFF	ON	EVENT
C D0128 X ADAPT SEPARATION B	10 S/S	OFF	ON	EVENT
C D0130 X HAND CONTROLLER INPUT A	10 S/S	OFF	ON	EVENT
C D0131 X HAND CONTROLLER INPUT B	10 S/S	OFF	ON	EVENT
C D0132 X EDS ABORT LOGIC IN NO 1	10 S/S	OFF	ON	EVENT
C D0133 X EDS ABORT LOGIC IN NO 2	10 S/S	OFF	ON	EVENT
C D0134 X EDS ABORT LOGIC IN NO 3	10 S/S	OFF	ON	EVENT
C D0135 X EDS ABORT LOGIC OUT A	10 S/S	OFF	ON	EVENT
C D0136 X EDS ABORT LOGIC OUT B	10 S/S	OFF	ON	EVENT
C D0140 X DIRECT ULLAGE ON A	10 S/S	OFF	ON	EVENT
C D0141 X DIRECT ULLAGE ON B	10 S/S	OFF	ON	EVENT
C D0170 X RCS ACTIVATE SIG A	10 S/S	OFF	ON	EVENT
C D0171 X RCS ACTIVATE SIG B	10 S/S	OFF	ON	EVENT
C D0173 X CM RCS PRESS SIG A	10 S/S	OFF	ON	EVENT
C D0174 X CM RCS PRESS SIG B	10 S/S	+22	+37	VDC
C D0200 V DC BOLTAGE LOGIC BUS A	10 S/S	+22	+37	VDC
C D0201 V DC VOLTAGE LOGIC BUS B	10 S/S	OFF	ON	EVENT
C D0230 X FWD HS JETTISON A	10 S/S	OFF	ON	EVENT
C D0231 X FWD HS JETTISON B	10 S/S	OFF	ON	EVENT
C D0315 X EDS ENABLE A	10 S/S	OFF	ON	EVENT
C D0316 X EDS ENABLE B	10 S/S	OFF	ON	EVENT
C D1006 X LES MOTOR INITIATE A	10 S/S	OFF	ON	EVENT
C D1007 X LES MOTOR INITIATE B	10 S/S	OFF	ON	EVENT

SUBSYSTEM EARTH LANDING SEQUENCE CONTROLLER

C E0001 X DROGUE DEPLOY RELAY CLOSE A	10 S/S	OFF	ON	EVENT
C E0002 X DROGUE DEPLOY RELAY CLOSE B	10 S/S	OFF	ON	EVENT
C E0003 X MAIN CHUTE DEPL-DRG REL RLY A	10 S/S	OFF	ON	EVENT
C E0004 X MAIN CHUTE DEPL-DRG REL RLY B	10 S/S	OFF	ON	EVENT
C E0007 X BARO SW LOCK-IN RLY CLOSE A	10 S/S	OFF	ON	EVENT
C E0008 X BARO SW LOCK-IN RLY CLOSE B	10 S/S	OFF	ON	EVENT
C E0035 P BAROMETRIC PRESS STATIC REF	1 S/S	0	+15	PSIA
C E0321 X MAIN CHUTE DISCONNECT RELAY A	10 S/S	OFF	ON	EVENT
C E0322 X MAIN CHUTE DISCONNECT RELAY B	10 S/S	OFF	ON	EVENT

SUBSYSTEM ENVIRONMENTAL CONTROL

C F0001 P PRESSURE CABIN	1 S/S	0	+17	PSIA
C F0002 T TEMP CABIN	1 S/S	+40	+125	DEG F
C F0005 P PRESSURE CO2 PARTIAL	1 S/S	0	+30	MMHG
C F0006 P PRESS SURGE TANK	1 S/S	+50	+1050	PSIA
C F0008 T TEMP SUIT SUPPLY MANIF	1 S/S	+20	+95	DEG F
C F0009 Q QUANTITY WASTE WATER TANK	1 S/S	0	+100	PCNT
C F0010 Q QUAN POTABLE H2O TANK	1 S/S	0	+90	PCNT
C F0012 P PRESS SUIT DEMAND REG SUPPLY	1 S/S	0	+17	PSIA
C F0015 P PRESS SUIT COMPRESSOR DIFF	1 S/S	0	+1	PSID
C F0016 P PRESS GLYCOL PUMP OUTLET	1 S/S	0	+60	PSIA
C F0017 T TEMP GLYCOL EVAP OUTLET STREAM	1 S/S	+20	+95	DEG
C F0018 T TEMP GLYCOL EVAP OUTLET LIQUID	1 S/S	+25	+75	DEG F
C F0019 Q QUANTITY GLYCOL ACCUM	1 S/S	-10	+100	PCNT
C F0020 T TEMP SPACE RADIATOR OUTLET	1 S/S	-50	+100	DEG F
C F0025 P PRESS PUMP PACKAGE INLET	50 S/S	0	+75	PSIA
S F0030 Q QUANTITY H2 TANK 1	1 S/S	0	+25	LB
S F0031 Q QUANTITY H2 TANK 2	1 S/S	0	+28	LB
S F0032 Q QUANTITY O2 TANK 1	1 S/S	0	+320	LB
S F0033 Q QUANTITY O2 TANK 2	1 S/S	0	+320	LB
C F0034 P BACK PRESS GLYCOL EVAPORATOR	10 S/S	+0.25	+0.25	PSIA
C F0035 R FLOWRATE ECS O2	1 S/S	+0.2	+1.0	LB/HR
C F0036 P PRESS OUTLET O2 REG SUPPLY	1 S/S	0	+150	PSIA
S F0037 P PRESS O2 TANK 1	1 S/S	+50	+1050	PSIA
S F0038 P PRESS O2 TANK 2	1 S/S	+50	+1050	PSIA
S F0039 P PRESS H2 TANK 1	1 S/S	0	+350	PSIA
S F0041 T TEMP O2 TANK 1	1 S/S	-325	+80	DEG F
S F0042 T TEMP O2 TANK 2	1 S/S	-325	+80	DEG F
S F0043 T TEMP H2 TANK 1	1 S/S	-425	-200	DEG F
S F0044 T TEMP H2 TANK 2	1 S/S	-425	-200	DEG F
C F0120 P PRESS H2O AND GLYCOL TANKS	1 S/S	0	+50	PSIA
C F0135 R FLOW RATE MAN INLET TO SUIT 1	1 S/S	0	+25	LB/HR
C F0136 R FLOW RATE MAN INLET TO SUIT 2	1 S/S	0	+25	LB/HR
C F0137 R FLOW RATE MAN INLET TO SUIT 3	1 S/S	0	+25	LB/HR
C F0148 P DP SUPPLY AND RETURN MAN	1 S/S	0	+0.8	PSID
C F0153 T TEMP COMPRESSOR INLET	1 S/S	0	+200	DEG F
C F0184 T TEMP CO2 ABSORBER OUTLET	1 S/S	+90	+200	DEG F
C F0245 T TEMP O2 REG INLET	1 S/S	-50	+150	DEG F
C F0326 P PRESS POTABLE H2O TANK DRAIN	1 S/S	0	+50	PSIA
C F0327 P PRESS WASTE H2O TANK DRAIN	1 S/S	0	+50	PSIA
C F0481 T TEMP CP BR 1 INLET	1 S/S	+40	+150	DEG F
C F0482 T TEMP CP BR 1 OUTLET	1 S/S	+40	+150	DEG F
C F0483 T TEMP CP BR 2 INLET	1 S/S	+40	+150	DEG F
C F0484 T TEMP CP BR 2 INLET	1 S/S	+40	+150	BEG F
C F0549 P DIFF PRESS COLDPLATE BR 1	1 S/S	0	+2.0	PSID
C F0550 P DIFF PRESS COLDPLATE BR 2	1 S/S	0	+10	PSID
S F0665 T TEMP SPACE RADIATOR INLET	1 S/S	+60	+150	DEG F

SUBSYSTEM GUIDANCE AND NAVIGATION

C G0001 V COMPUTER DIGITAL DATA 40 BITS	50 S/S			
C G1101 V 28 VDC SUPPLY	10 S/S	0	-35	VDC
C G1110 V 2.5 VDC EM BIAS	1 S/S	0	+5	VDC

C G1503 X IMU +28 VDC OPERATE	10 S/S	OFF	ON	EVENT
C G1513 X IMU +28 VDC STANDBY	10 S/S	OFF	ON	EVENT
C G1523 X AGC +28 VDC	10 S/S	OFF	ON	EVENT
C G1533 X OPTX +28 VDC	10 S/S	OFF	ON	EVENT
C G2110 V IGA TORQUE MOTOR INPUT	10 S/S	-8	+8	VDC
C G2112 V IGA 1X RES OUTPUT SINE IN PHASE	10 S/S	0	+50	DEG
C G2113 V IGA 1X RES OUTPUT COS IN PHASE	10 S/S	45 DEG	135	DEG
C G2117 V IGA SERVO ERROR IN PHASE	100 S/S	0	0.5	VRMS
C G2140 V MGA TORQUE MOTOR INPUT	10 S/S	-8	+8	VDC PSA
C G2142 V MGA 1X RES OUTPUT SINE IN PHASE	10 S/S	-45	+45	DEG
C G2143 V MGA 1X RES OUTPUT COS IN PHASE	10 S/S	45	135	DE
C G2147 V MGA SERVO ERROR IN PHASE	100 S/S	0	0.5	VRM
C G2170 V OGA TORQUE MOTOR INPUT	10 S/S	-8	+8	VDC
C G2172 V OGA 1X RES OUTPUT SINE IN PHASE	10 S/S	-45	+45	DEG
C G2173 V OGA 1X RES OUTPUT COS IN PHASE	10 S/S	45	135	DEG
C G2177 V OGA SERVO ERROR IN PHASE	100 S/S	-5	+5	VRMS
C G2206 V IGA CDU 1X RES ERROR IN PHASE	10 A/S	-8	+8	VRMS
C G2236 V MGA CDU 1X RES ERROR IN PHASE	10 S/S	-8	+8	VRMS
C G2266 V OGA CDU iX RES ERROR IN PHASE	10 S/S	-8	+8	VRMS
C G2300 T PIPA TEMP	1 S/S	125	135	DEG F
C G2301 T IRIG TEMP	1 S/S	128	137	DEG F
C G2302 C IMU HEATER CURRENT	1 S/S	0	+5.000	AMP
C G2302 C IMU BLOWER CURRENT	1 S/S	0	+5.000	AMP
C G3102 V SXT TRUN MOTOR DRIVE IN PHASE	10 S/S	-5	+5	VRMS
C G3112 V SXT SHAFT MOTOR DRIVE IN PHASE	10 S/S	-5	+5	VRMS
C G3133 V SCT TRUN MOTOR DRIVE	10 S/S	-5	+5	VRMS
C G3141 V TRUN CDU 16X RES ERROR IN PHASE	10 S/S	-50	+50	MVRMS
C G3200 V TRUN CDU MOTOR DRIVE IN PHASE	10 S/S	-5	+5	VRMS
C G3220 V SHAFT CDU MOTOR DRIVE IN PHASE	10 S/S	-5	+5	VRMS
C G4300 T AGC TEMP MONITOR	1 S/S	20	220	DEG F
C G5000 X PIPA FAIL	10 S/S	OFF	ON	EVENT
C G5001 X IMU FAIL	10 S/S	OFF	ON	EVENT
C G5002 X CDU FAIL	10 S/S	OFF	ON	EVENT
C G5003 X GIMBAL LOCK WARNING	10 S/S	OFF	ON	EVENT
C G5005 X ERROR DETECT	10 S/S	OFF	ON	EVENT
C G5006 X IMU TEMP LIGHT	10 S/S	OFF	ON	EVENT
C G5007 X ZERO ENCODER LIGHT	10 S/S	OFF	ON	EVENT
C G5008 X IMU DELAY LIGHT	10 S/S	OFF	ON	EVENT
C G5020 X AGC ALARM 1 (PROGRAM)	10 S/S	OFF	ON	EVENT
C G5021 X AGC ALARM 2 (AGC ACTIVITY)	10 S/S	OFF	ON	EVENT
C G5022 X AGC ALARM 3 (TM)	10 S/S	OFF	ON	EVENT
C G5023 X AGC ALARM 4 (PROG CK FAIL)	10 S/S	OFF	ON	EVENT
C G5024 X AGC ALARM 5 (SCALAR FAIL)	10 S/S	OFF	ON	EVENT
C G5025 X AGC ALARM 6 (PARITY FAIL)	10 S/S	OFF	ON	EVENT
C G5026 X AGC ALARM 7 (COUNTER FAIL)	10 S/S	OFF	ON	EVENT
C G5027 X AGC ALARM 8 (KEY RELEASE)	10 S/S	OFF	ON	EVENT
C G5028 X AGC ALARM 9 (RUPT LOCK)	10 S/S	OFF	ON	EVENT
C G5029 X AGC ALARM 10 (TC TRAP)	10 S/S	OFF	ON	EVENT
C G5030 X COMPUTER POSER FAIL LIGHT	10 S/S	OFF	ON	EVENT
C G6000 P IMU PRESSURE	1 S/S	0	25	PSI
C G6020 T PSA TEMP 1 TRAY 3	1 S/S	10	250	DEG F
C G6021 T PSA TEMP 2 TRAY 2	1 S/S	10	250	DEG F
C G6022 T PSA TEMP 3 TRAY 4	1 S/S	10	200	DEG F

SUBSYSTEM STABILIZATION AND CONTROL

C H0024 R PITCH RATE	50 S/S	-25	+25	DEG/SEC
C H0025 V PITCH MAN ROTATION CONTROL	50 S/S	-4	+4	VAC
C H0034 H PITCH POS FEEFBACK IN	50 S/S	-10	+10	DEG
C H0047 C PTV DIFF CLUTCH VOLTS COMBINER	50 S/S	-800	+800	MANP
C H0050 R PITCH RATE ERR AMP OUT	100 S/S	-6	+6	DEG/SEC
C H0067 V P INTEGRATOR ATT ERROR SUMMING	10 S/S	-2.5	+2.5	VDC
C H0074 V MTVC PITCH RATE	50 S/S	-25	+25	DEG/SEC
C H0075 H PITCH SCS ATT ERROR	10 S/S	0	+10	VRMS
C H0087 X +PITCH +X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H0088 X -PITCH +X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT

C H0089 X +PITCH/-X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H0090 X -PITCH/-X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H0100 X G-N DV MODE CONTROL	10 S/S		OFF	ON
C H0101 X G-N ATT MODE CONTROL	10 S/S	OFF	ONN	EVENT
C H0102 X G-N ENTRY MODE CONTROL	10 S/S	OFF	ON	EVENT
C H0103 X MONITOR MODE CONTROL	10 S/S	OFF	ON	EVENT
C H1024 R WAW RATE	50 S/S	-25	+25	DEG/SEC
C H1025 V YAW MAN ROTATION CONTROL	50 S/S	0	5.0	VRMS
C H1034 H YAW POS FEEDBACK IN	50 S/S	-8.5	+8.5	VDC
C H1047 C YTV DIFF CLUTCH VOLTS COMBINER	50 S/S	-800	+800	MAMP
C H1050 R YAW RATE ERR AMP OUT	50 S/S	-6	+6	DEG/SEC
C H1067 V Y INTEGRA TOR/ATT SUMMING	10 S/S	-2.5	+2.5	VDC
C H1074 R MTVC YAW RATE	50 S/S	-25	-25	DEG/SEC
C H1075 H YAW SCS ATT ERROR	10 S/S	0	10	VRMS
C H1087 X +YAW/+X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H1088 X -YAW/+X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H1089 X +YAW/-X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H1090 X -YAW/-X SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H1100 X SCS DV MODE CONTROL	10 S/S	OFF	ON	EVENT
C H1101 X SCS ATT MODE CONTROL	10 S/S	OFF	ON	EVENT
C H1102 X SCS ENTRY MODE CONTROL	10 S/S	OFF	ON	EVENT
C H1103 X SCS LOCAL VERTICAL MODE	10 S/S	OFF	ON	EVENT
C H1104 X MTVC MODE CONTROL	10 S/S	OFF	ON	EVENT
C H2015 V COMBINED AG SMRD	10 S/S	0	800	CPS
C H2024 R ROLL RATE	50 S/S	-25	+25	DEG/SEC
C H2025 V ROLL MAN ROTATION CONTROL OUT	50 S/S	0	+5	VRMS
C H2026 V COMBINED RG SMRD	10 S/S	0	1600	CPS
C H2030 T COMBINED ATTTITUDE GYRO TEMP	1 S/S	0	5	VDC
C H2050 R ROLL RATE ERR AMP OUT	50 S/S	-6	+6	DEG/SEC
C H2070 H ROLL ATTITUDE ERROR AMP OUT	10 S/S	-25	+25	VDC
C H2075 H ROLL SCS ATT ERROR	10 S/S	0	10	VRMS
C H2087 X +ROLL/+Z SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H2088 X -ROLL/+Z SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H2089 X +ROLL/-Z SOLENOID DRIVER OUT	200 S/S	ON	OFF	EVENT
C H2090 X -ROLL/-Z SOLENOID DRIVER OUT	200 S/S	OFF	ON	EVENT
C H2091 X +ROLL/+Y SOLENOID DRIVER OUT	200 S/S	OFF	ON	EVENT
C H2092 X -ROLL/+Y SOLENOID DRIVER OUT	200 S/S	OFF	ON	EVENT
C H2093 X +ROLL/-Y SOLENOID DRIVER OUT	200 S/S	OFF	ON	EVENT
C H2094 X -ROLL/-Y SOLENOID DRIVER OUT	200 S/S	OFF	ON	EVENT
C H3185 X -05G MANUAL SWITCH	10 S/S	OFF	ON	EVENT
C H3186 V DV REMAINING POTENTIOMETER OUT	10 S/S	0	+-3K	FT/SEC
C H4100 H RESOLVER SIN OUT PITCH ATT	10 S/S	-12		+12
C H4101 H RESOLVER COS OUT PITCH ATT	10 S/S	0	160	DEG
C H4102 H RESOLVER SIN OUT YAW ATT	10 S/S	-12	+12	VAC
C H410 H RESOLVER COS OUT YAW ATT	10 S/S	-12	+12	VAC
C H4104 H RESOLVER SIN OUT ROLL ATT	10 S/S	-12	+12	VAC
C H4105 H RESOLVER COS OUT ROLL ATT	10 S/S	-12	+12	VAC
C H4320 X SPS SOLENOID DRIVER OUT 1	50 S/S	OFF	ON	EVENT
C H4321 X SPS SOLENOID DRIVER OUT 2	50 S/S	OFF	ON	EVENT

SUBSYSTEM CREW EQUIPMENT

C J0002 J PNEUM SLECTOR SW OUTPUT SIG	500 S/S	-5	+5	OHM
C J0066 J EKG AXIS 1 SEL SW OUT SIG	200 S/S	0.1	+5	MV
C J0067 J EKG AXIS 2 SEL SW OUT SIG	200 S/S	0.1	-5	MV
C J0210 X SEL SW POSITION ASTRO 1	10 S/S	OFF	ON	EVENT
C J0211 X SEL SW POSITION ASTRO 2	10 S/S	OFF	ON	EVENT
C J0212 X SEL SW POSITION ASTRO 3	10 S/S	OFF	ON	EVENT

SUBSYSTEM SERVICE PROPULSION

S P0001 P HE TANK PRESS	10 S/S	0	+5K	PSIA
S P0002 T HE TANK TEMP	1 S/S	-100	+200	DEG F
S P003 P PRESS OXIDIZER TANKS	10 S/S	0	+300	PSIA
S P0005 T TEMP OXIDIZER ENG FEEDLINE	10 S/S	0	+200	DEG F

S P0006 P PRESS FUEL TANKS	10 S/S	0	+300	PSIA
S P008 T TEMP FUEL ENG FEEDLINE	10 S/S	0	+200	DEG F
S P0009 P PRESS MAIN VLV ENG OXIDIZER IN	10 S/S	0	+300	PSIA
S P0010 P PRESS MA IN VLV ENG FUEL IN	10 S/S	0	+300	-PSA
S P0020 T TEMP CHAMBER OUTER SKIN 1	1 S/S	0	+500	DEG F
S P0022 H POSITION FUEL/OXIDIZER VLV 1	10 S/S	0	+90	DEG
S P0023 H POSITION FUEL/OXIDIZER VLV 2	10 S/S	0	+90	DEG
S P0024 H POSITION FUEL/OXIDIZER VLV 3	10 S/S	0	+90	DEG
S P0025 H POSITION FUEL/OZIDIZER VLV 4	10 S/S	0	+90	DEG
S P0045 T TEMP ENG VLV BODY	1 S/S	0	+250	DEG F
S P0048 T TEMP ENG FUEL FEEDLING	1 S/S	0	+200	DEG F
S P0049 T TEMP ENG OX FEEDLINE	1 S/S	0	+200	DEG F
S P0050 T TEMP NOZZLE CUTER SKIN 1	1 S/S	-25	+2500	DEG F
S P0054 T TEMP 1 OX DIST LINE	1 S/S	0	-250	DEG F
S P0055 T TEMP 2 OX DIST LINE	50 S/S	0	+250	DEG F
S P0057 T TEMP 1 FUEL DISTLINE	50 S/S	0	+250	DEG F
S P0058 T TEMP 2 FUEL DIST LINE	50 S/S	0	+250	DEG F
S P0060 T TEMP INJECTOR MAN	10 S/S	0	+200	DEG F
S P0600 P ENG VLV ACT SYS TENK PRESS PRI	1 S/S	-25	+2500	DEG F
S P0601 P ENG VLV ACT SYS TANK PRESS SEC	10 S/S	0	+5000	PSIA
S P0655 Q QUAN OX TANK 1 PRI-TOTAL AUX	1 S/S	0	+16K	LB
S P0656 Q QUAN OX TANK 2	1 S/S	0	+16K	LB
S P0657 Q QUAN FUEL TANK 1 PRI-TOTAL AUX	1 S/S	0	+8K	LB
S P0658 Q QUAN FUEL TANK 2	1 S/S	0	+8K	LB
S P0661 P PRESS ENGINE CHAMBER	100S/S	0	+150	PSIA
S P2054 T TEMP GIMBAL ACTUATOR CASE (YAW)	10 S/S	0	+200	DEG F
S P2055 T TEMP GIMBAL ACTUATOR CASE (PITCH)	1 S/S	0	+200	DEG F

SUBSYSTEM REACTION CONTROL

C R0001 P HE PRESS TANK A	1 S/S	0	+5K	PSIA
C R0002 P HE PRESS TANK B	1 S/S	0	+5K	PSIA
C R0003 T HE TEMP TANKS A	1 S/S	0	+300	DEG F
C R0004 T HE TEMP TANK B	1 S/S	0	+300	DEG F
C R0005 P PRESS FUEL TANK A	10 S/S	0	+400	PSIA
C R0006 P PRESS FUEL TANK B	10 S/S	0	+400	PSIA
C R0011 P PRESS OXIDIZER TANK A	10 S/S	0	+400	PSIA
C R0012 P PRESS OXIDIZER	10 S/S	0	+400	PSIA
C R2201 T TEMP OX VLV CCW ENG SYS A	50 S/S	-50	+250	DEG F
C R2202 T TEMP OX VLV -Y ENG SYS A	10 S/S	-50	+250	DEG F
C R2203 T TEMP OX VLV +Y ENG SYS B	1 S/S	-50	+250	DEG F
C R2204 T TEMP OX VLV -P ENG SYS B	1 S/S	-50	+250	DEG F
C R2205 T TEMP OX VLV -P ENG SYS A	50 S/S	-50	+250	DEG F
C R2206 T TEMP OX VLV CW ENG SYS B	1 S/S	-50	+250	DEG F
C R4561 T TEMP CCW ROLL ENG OUT WALL T3 SYS A	500 S/S	0	+1000	DEG F
C R4582 T TEMP CCW ROLL ENG OUT WALL T3 SYS B	50 S/S	0	+1000	DEG F
S R5001 P HE PRESS TANK A	1 S/S	0	+5K	PSIA
S R5002 P HE PRESS TANK B	1 S/S	0	+5K	PSIA
S R5003 P HE PRESS TANK C	1 S/S	0	+5K	PSIA
S R5004 P HE PRESS TANK D	1 S/S	0	+5K	PSIA
S R5013 T HE TEMP TANK A	200 S/S	0	+150	DEG F
S R5014 T HE TEMP TANK B	200 S/S	0	+150	DEG F
S R5015 T HE TEMP TANK C	100 S/S	0	+150	DEG F
S R5016 T HE TEMP TANK D	1 S/S	0	+150	DEG F
S R5055 Q QUANTITY SN RCS PROP BITS 1-8	10 S/S	0	+70	LB
S R5056 Q QUANTITY SN RCS PROP BITS 9-14	10 S/S	0	+140	LB
S R5065 T TEMP ENGINE PACKAGE A1	1 S/S	0	+300	DEG F
S R5066 T TEMP ENGINE PACKAGE B1	1 S/S	0	+300	DEG F
S R5067 T TEMP ENGINE PACKAGE C1	1 S/S	0	+300	DEG F
S R5068 T TEMP ENGINE PACKAGE D1	1 S/S	0	+300	DEG F
S R5729 P A HE MANIFOLD PRESS	10 S/S	0	+400	PSIA
S R5733 P A OXIDIZER MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R5737 P A FUEL MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R5776 P B HE MANIFOLD PRESS	10 S/S	0	+400	PSIA
S R5784 P B FUEL MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R5817 P C HE MANIFOLD PRESS	10 S/S	0	+400	PSIA

S R5821 P D HE MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R 5322 P C FUEL MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R5823 P D FUEL MANIFOLD PRESS	100 S/S	0	+300	PSIA
S R5830 P D HE MANIFOLD PRESS	10 S/S	0	+400	PSIA
S R7128 T TEMP INJ HEAD +Y ENG SYS B	50 S/S	0	+500	PSIA
S R7134 T TEMP INJ HEAD CCW ENG SYS A		50 S/S	0	+500

SUBSYSTEM LAUNCH VEHICLE EMERGENCY DETECTION

B S0016 X LAUNCH VEH BUIDANCE FAIL A	10 S/S	OFF	ON	EVENT
B S0020 X LAUNCH VEH RATE EXCESSIVE A	10 S/S	OFF	ON	EVENT
B S0030 X ENG NO 1 OUT A	10 S/S	OFF	ON	EVENT
B S0032 X ENG NO 2 OUT A	10 S/S	OFF	ON	EVENT
B S0034 X ENG NO 3 OUT A	10 S/S	OFF	ON	EVENT
B S0036 X ENG NO 4 OUT A	10 S/S	OFF	ON	EVENT
B S0038 X ENG NO 5 OUT A	10 S/S	OFF	ON	EVENT
B S0040 X ENG NO 6 OUT A	10 S/S	OFF ON	EVENT	
B S0042 X ENG NO 7 OUT A	10 S/S	OFF	ON	EVENT
B S0044 X ENG NO 8 OUT A	10 S/S	OFF	ON	EVENT
B S0060 X LIFT OFF SIGNAL A	10 S/S	OFF	ON	EVENT
B S0061 X LIFT OFF SIGNAL B	10 S/S	OFF	ON	EVENT
C S0080 X EDS ABORT REQUEST A	10 S/S	OFF	ON	EVENT
L S0090 X TOWER PHYS SEPARATION MON A	10 S/S	OFF	ON	EVENT
L S0091 X TOWER PHYS SEPARATION MON B	10 S/S	OFF	ON	EVENT
C S0100 X CM-CM PHYS SEPARATION MON A	10 S/S	OFF	ON	EVENT
C S0101 X CM-SM PHYS SEPARATION MON B	10 S/S	OFF	ON	EVENT
S S0120 X SM/ADAPTER PHYS SEPARATION	10 S/S	OFF	ON	EVENT
S S0121 X SM/ADAPTER PHYS SEPARATION	10 S/S	OFF	ON	EVENT
C S0150 X MASTER CAUTION-WARNING ON	10 S/S	OFF	ON	EVENT

SUBSYSTEM COMMUNICATIONS AND INSTRUMENTATION

C T0012 X TAPE MOTION MONITOR OPER	10 S/S	OFF	ON	EVENT
C T0013 X TAPE MOTION MONITOR R AND D	10 S/S	OFF	ON	EVENT
C T0015 V SIG COND POS SUPPLY VOLTS	10 S/S	0	+35	VDC
C T0016 V SIG COND NEG SUPPLY VOLTS	10 S/S	0	-35	VDC
C T0017 V SENSOR EXCITATION 5 VOLTS	10 S/S	0	+8	VDC
C T0018 V SENSOR EXCITATION 10 VOLTS	10 S/S	0	+17	VDC
C T0055 V TV CAMERA TARGET VOLTAGE	10 S/S	0	+500	FT LMB
C T0089 C-BAND XMTR OUTPUT MONITOR	10 S/S	100	1300	PRF
C T0098 F C-BAND DECODER OUT	10 S/S	100	1300	PRF
C T0108 K GAS ANALYXIX-SUIT AND CABIN	10 S/S	0	5	VDC
C T0120 X PCM BIT RATE CHANGE 8 BIT	1 S/S			DIGITAL
C T0125 V PCM HI LEVEL 85 PERCENT REF	10 S/S	0	5.0	VDC
C T0126 V PCM HI LEVEL 15 PERCENT REF	10 S/S	0	5.0	VDC
C T0127 V PCM LO LEVEL 85 PERCENT REF	1 S/S	0	.040	VDC
C T0128 V PCM LO LEVEL 15 PERCENT REF	1 S/S		.040	VDC
C T0141 X CTE TIMING MODE MONITOR	10 S/S	OFF	ON	EVENT
C T0142 F CENTRAL TIMING GMT 32 BIT	10 S/S			DIGITAL
C T0147 V S-BAND REC AGC VOLTAGE	10 S/S	-130	-40	DBM
C T0191 V VHF AM REC AGC VOLTAGE	10 S/S	-25	-1[illegible]	[illegible]
C T0212 V S-BAND REC STATIC PHASE ERROR	10 S/S	-60K	+60K	DEV CPS
C T0215 V S-BAND XMTR DETECTED RF OUTPUT	10 S/S	0	600	MW
C T0261 V UDL REC SIGNAL STRENGTH	10 S/S	-110	-90	DBM
C T0262 V UDL SYS VALIDITY SIGNAL 8-BIT	50 S/S			DIGITAL
C T0320 V VHF AM XMTR DETECTED RF OUTPUT	100 S/S	0	12	WATTS
C T0330 V VHF FM XMTR PA DETECTED RF OUT	10 S/S	0	18	WATTS
C T0340 X PCM TIMING SOURCE EXT OR INT	10 S/S	INT	EXT	EVENT

b. SEQUENTIAL SYSTEMS

(1) SEQUENTIAL SYSTEM CONFIGURATION

(a) Ordnance was only installed and electrically connected in the forward deck area under the forward heat shield. The forward deck harness was disconnected from pyro continuity verification box and shorting plugs were installed. All other ordnance which was installed did not contain the initiating devices.

(b) The flight connections, which are made to the GSE access connectors of the RCS control boxes in order to reset the 61-second time delays during the terminal count EDS test, were not connected, due to a checklist error.

(c) A circuit breaker box was inserted between the SM pyro batteries and the SM jettison controllers in order to terminate −x translation of the SM at CM/SM separation, to prevent SM jettison battery depletion.

(2). COMMENTS ON DATA

An analysis of the SC-012 sequential system data for the time period from 23:12:00 GMT through 23:31:17.398 GMT indicates normal system operation during this time.

At approximately 23:31:12 GMT the battery buses were switched on the main buses, which caused the logic buses to drop to the main bus voltage level. Refer to subsequent paragraph c. for further discussion of the switching.

At 23:31:15.5 GMT a master alarm occurred. This condition was caused by O2 high flow, in that O2 flow rate was saturated for the 15 seconds prior to this master alarm (See figure 3-5).

At 23:31:26.712 GMT, hardline data indicates that EDS "unsafe A" came on. This indicates that at this time one of the three EDS buses from the spacecraft to the launch vehicle was lost. Since two of the EDS bus circuit breakers were open when cockpit configuration was established post-incident, the determination is that the first circuit breaker was tripped at this time.

One non-instrumented anomaly was noted by the launch vehicle personnel during the EDS test at 20:52:23 GMT. At this time the launch Vehicle Attitude Reference Fail check was being performed. EDS bus 1 was turned off and astronaut was to verify no change in the panel 5 status light. However, he stated that the "Engine 8 Out" light went off. This light came back on 8 seconds later as reported by the astronaut and verified on the voice tape. Data review shows no switching in the cockpit from the time the EDS bus 1 went off for approximately 39 seconds. No further information is available since this is the "B" side of the light and it is not instrumented. At this time no explanation is available.

c. ELECTRICAL POWER

(1). SYSTEM CONFIGURATION

Just prior to the incident, the spacecraft DC buses were being powered from GSE ground power supplies via the S/M GSE flyaway umbilical. Spacecraft batteries were not connected to the main DC buses. The fuel cell (F/C) simulator (C14-395 battery pack) was connected to fuel cell no. 1 and fuel cell no. 3 harnesses (fuel cells 1, 2 and 3 were disconnected) but not tied to the spacecraft buses.

Spacecraft AC bus 1 was powered by inverter 1 which was powered from DC bus A, and AC bus 2 was powered by inverter 2 which was powered from DC bus B. Inverter 3 was not operating since it is used only for backup in the event of failure of inverter no.1 or 2.

Bus versus equipment configuration is shown in Table 4.3-1.

C-2

(2). COMMENTS ON DATA

(a). The electrical power system was operating normally throughout the performance of OCP-FO-K-0021-1 up to approximately 23:30:55 GMT. At that time a small, short duration increase in AC bus 2 voltages (all three phases) was noted. Prior to this time the AC bus 2 voltages were steady to within one bit of information and as follows (see Figure 3-2):

Phase A (CC0203) - 117.0 to 117.6 VAC
Phase B (CC0204) - 116.6 VAC
Phase C (CC0205) - 112.5 VAC

The voltages varied from this steady state value as follows:

TIME (GMT)	AMPLITUDE (VOLTS).	TIME (GMT)	AMPLITUDE (VOLTS)
Phase A 23:30:54.920	125.8	23:30:55.020	117.0
Phase B 23:30:54.920	120.8	23:30:55.026	117.2
Phase C 23:30:54.927	117.2	23:30:55.027	113

The voltages then returned to the values previously recorded (refer to Panel 18 Report, AC bus 2 voltage variations, for further discussion) and remained at those values up to LOS.

The only other unusual indication in the EPS system prior to LOS occurred at 23:31:13 GMT with indications that Bat B&C had been connected to the main DC buses, followed at 23:31:14 GMT by indications that Bat A&C had been connected to the main DC buses (see Figure 2-3). This was accomplished by crew manual connection of these batteries to the main buses. The switches used to accomplish this (panel 22 - main bus tie Bat B&C) were found during post-incident inspection to be in the positions that would connect these batteries to the main buses.

(b). There is no evidence of an electrical short indicated in any of the other EPS parameters.

(3). SYSTEM POWER REMOVAL

Following the incident, removal of external power was begun at 23:32:46 GMT and all external power was removed by 23:33:13 GMT. However, there was no way to remove Bat A, B, and C from the buses, and spacecraft buses remained powered until the batteries were depleted (estimated at approximately 05:30 GMT, 28 January 1967).

d. GUIDANCE AND NAVIGATION SYSTEM

(1). SYSTEM CONFIGURATION

The guidance and navigation system was in the normal launch configuration with the following exceptions:

(a). The coupling display units (CDU) hermetic sealing panel was not installed.

(b). The ground test access connector covers were not installed on the power-servo assembly trays.

(2). DATA EVALUATION

Data evaluation of all the instrumented parameters associated with guidance and navigation has not revealed any facts that would indicate a malfunction which might have contributed to the accident. All system operation was normal prior to the incident.

The physical characteristic of the system design lends itself to supplying nonsystem related facts associated with the incident, e.g.:

(a). Change in navigation base pitch angle correlates with crew compartment pressure changes, as discussed in the Panel 18 report.

TABLE 4.3-1 SC 012 EQUIPMENT VS BUS CONFIGURATION AT 23:30:00 GMT

EQUIPMENT	DC MN A	DC MN B	BAT A	BAT B	PYRO A	PYRO B	AC BUS 1	AC BUS 2
EPS								
Entry Bat A	N/C		Conn					
Entry Bat B		N/C		Conn				
Post Land Bat	N/C	N/C					–	
Pyro Bat A					Conn			
Pyro Bat B						Conn	N/C	
Bat Charger								
Inv 1 DC (Input)	Conn						Conn	
Inv 1 AC (Output)								
Inv 2 DC (Input)		Conn						Conn
Inv 2 AC (Output)								
Inv 3 DC (Input)	N/C	N/C					N/C	N/C
Inv 3 AC (Input)							Conn	Conn
Power Factor Corr Box							N/C	N/C
Phase Synch Box							Conn	Conn
AC O/V-U/V Unit								
DC U/V Unit	Conn	Conn						
FUEL CELL & CRYO								
None								
SEQUENTIAL								
MESC			Conn	Conn	Conn	Conn		
EISC			Conn	Conn	Conn	Conn		
PSC Contr Box			Conn	Conn	Conn	Conn		
C&W Power Sup/Lights	Conn	Conn						
Dig Event Timers	Conn	Conn						
PCVB			Conn	Conn				
Emerg Det System			Conn	Conn				
SCS AND G/N								
IMU	Conn	Conn						
IMU Heater	Conn	Conn						
Computer	Conn	Conn						
Lighting							Conn	
SCS Partial Power	Conn						Conn	
Rate Gyro							Conn	
Rotation Control								Conn
BMAG		Conn						Conn
TVC (1 & 2)								
RCS Direct Coils	N/C	N/C						
RCS Normal Coils	Conn	Conn						

NC: Not Connected. Conn: Connected.

TABLE 4.3-1 SC 012 EQUIPMENT VS BUS CONFIGURATION AT 23:30:00 GMT (Continued)

EQUIPMENT	DC MN A	DC MN B	BAT A	BAT B	PYRO A	PYRO B	AC BUS 1	AC BUS 2
INSTRUMENTATION								
PCM							Conn	
SCE	Conn	Conn					Conn	
Central Timing Equip	Conn	Conn						N/C
Flt Qual Rcdr			Conn					N/C
DSE	Conn	Conn						
Panel 204 (Non ESS)		Conn						
Panel 204 (ESS) -	Conn	Conn						
C14A12 Fuse Box		Conn						
MDAS		Conn						
COMMUNICATIONS								
UDL	Conn	Conn						
TV	Conn	Conn					N/C	Conn
VHF FM	Conn	Conn					Conn	N/C
S Band PA	Conn	Conn					Conn	N/C
PMP	Conn	Conn						
Audio Center	Conn	Conn						
VHF RCV BCN	N/C	N/C						
HF	N/C	N/C						
DSEA	N/C*	N/C						
VHF AM	Conn	Conn						Conn
C Band								
*Power connector not hooked up to DSEA. Circuit breaker was on.								
PROPULSION								
None								
ECS								
H_2O Accum	Conn	Conn					Conn	
Cabin Air Fan 1								Conn
Cabin Air Fan 2							Conn	N/C
Suit Compressors							Conn	N/C
Glycol Pumps								
Waste & Pot H_2O	Conn	Conn						
Xdcrs, Press GP 1&2	Conn	Conn						
ECS Xdcr, Temp	Conn	Conn					Conn	
Radiator Isol Valve 1								N/C
Radiator Isol Valve 2								
Pot H_2O	Conn	Conn						

(b). Changes in gimbal torque motor input voltages indicate vehicle movement, as discussed in the Panel 18 report.

Since the G&N system was in the gyrocompassing mode during the test, the system attempted to maintain the inertial platform horizontal to local gravity and the azimuth at a predetermined heading. Any motion that tends to alter these conditions results in a correcting voltage being applied to the platform gimbal torque motors. Crew activity can impart motion to the vehicle, which could result in torque motor voltages which can be discerned from normal signals applied during gyrocompassing.

(3). DATA PECULIARITIES

After the fire started, the Check Fail Alarm CG5005 and Error Detect PGNS alarm CG5023 came on at 23:31:17.3.

e. STABILIZATION CONTROL SYSTEM

(1). SCS CONFIGURATION

The SCS was configured to launch configuration, with the following exceptions:

(a). Only one (1) rotation controller was installed.

(b). Only one (1) translation control was installed.

(c). The A14-275 quad simulators were connected instead of the RCS engines.

(2). COMMENTS ON DATA

Data analysis indicates normal operation of all parameters until loss of data, with the following exceptions:

(a). ROTATION CONTROL OUTPUT SIGNALS

At 23:30:54:85 GMT, a momentary shift in level was noted on the rotation control output pitch (CH0025), yaw (CH1025), and roll (CH2025) measurements. The power for these parameters was supplied by AC bus 2, phase A. This occurrence is associated with the AC transient (see Figure 5.2-1 in the Panel 18 Report for further discussion).

At 23:31:14.6 GMT a signal was noted on the roll rotation control output of approximately 1.75 VAC and the associated signal of the roll error amplifier output which is equivalent to monitoring the controller for position roll. At the same time, small transients were noted on the pitch and yaw rotation control output measurements are proportional to the amount and direction of controller position.

At the time of the incident, the rotational control was pinned in a null position. Physical examination of the rotation controller following the incident showed the handle still pinned and with no apparent damage to the pin. Soot deposits on the pin indicated slight pin motion. Special tests indicate the pin will allow slight movement of the controller with an appreciable output signal.

(b). RATE ERROR AMPLIFIER OUTPUT OSCILLATIONS

Beginning at 23:31:04 GMT, and continuing to loss of signal, small amplitude oscillations were noted on the roll rate error amplifier output. Smaller oscillations and transients were noted on the pitch and yaw rate error outputs (see Figures 3-7 and 3-8). These changes correlate with spacecraft movement.

(c). MTVC ENGAGE

At 23:31:18.2 GMT, following a loss of signal of approximately 800 milliseconds, the event manual thrust vector control (MTVC) engage was noted to have changed state from OFF to ON. This condition continued until loss of signal.

Following this event, pitch and yaw MTVC rate gyro outputs showed activity indicating the MTVC circuits were active (see Figure 4.5-2). MTVC engage is actuated by physically rotating the T-handle on the translation controller to a CW position. Examination of the translation controller following the incident showed the T-handle to be in a MTVC ON position.

(d). Beginning at 23:31:20 GMT, RCS solenoid driver activity was indicated, which could be the result of shorts in spacecraft wiring. This time was just prior to the loss of data.

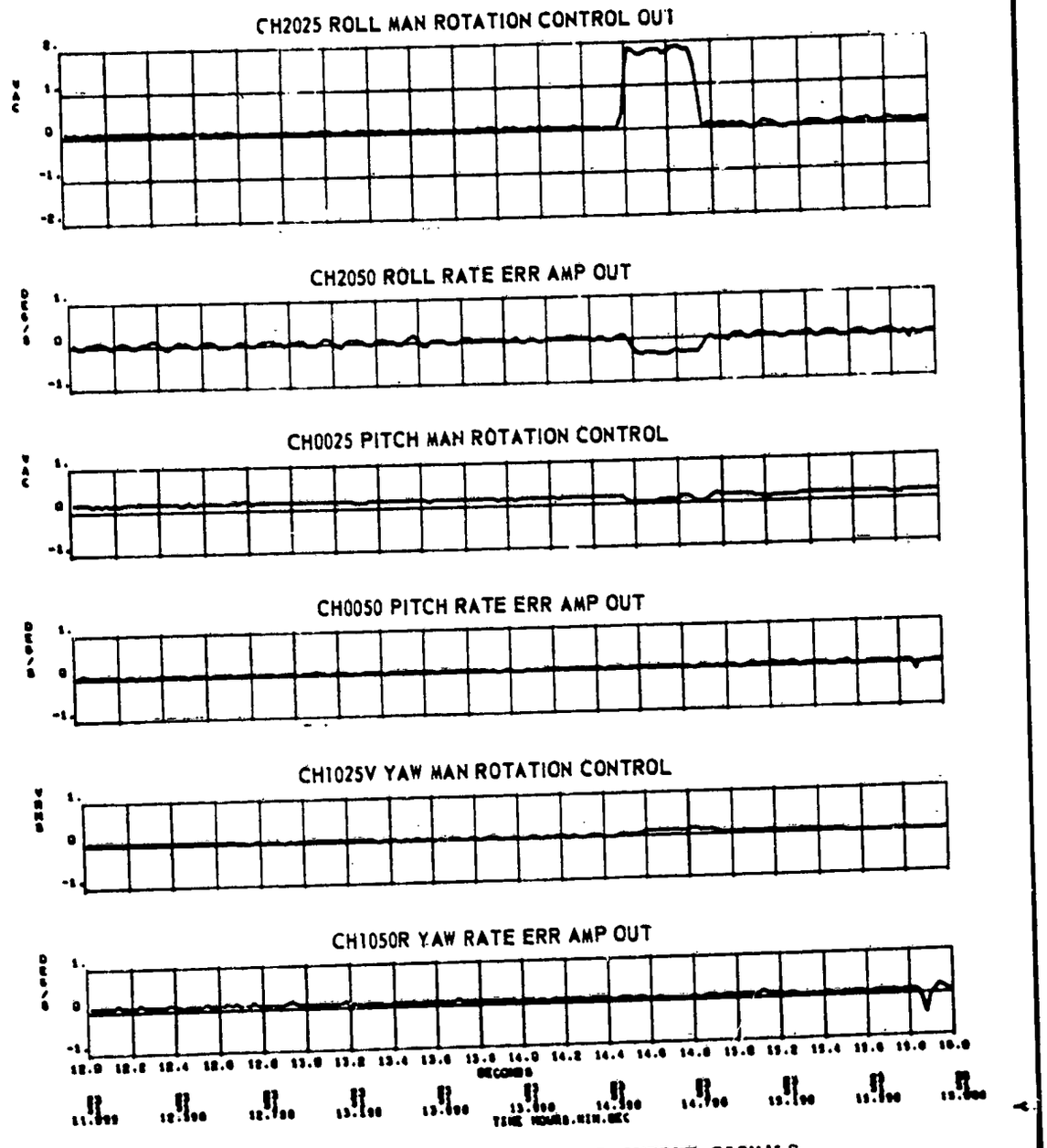


FIGURE 4.5-1 ROTATION CONTROLLER OUTPUT SIGNALS

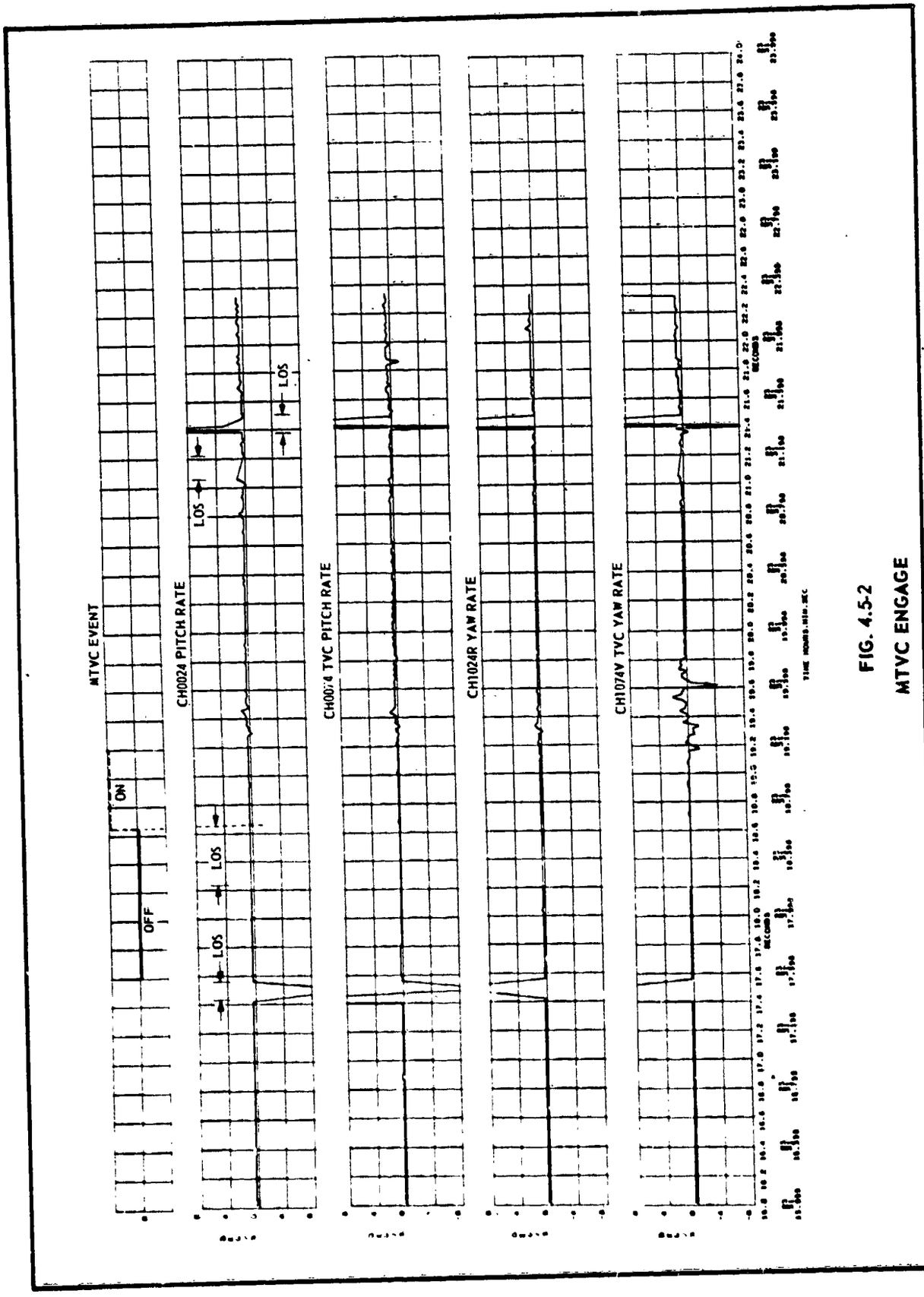


FIG. 4.5-2

MTVC ENGAGE

f. ENVIRONMENTAL CONTROL SYSTEM

(1). OXYGEN SUPPLY SUBSYSTEM CONFIGURATION (See Figure 4.6-1)

Gaseous oxygen from K-bottles was utilized for environmental oxygen throughout the test. The following GSE was used for support:

(a). K-Bottle and Regulator

The K-bottle regulator was adjusted at 14:15 GMT and maintained throughout the test at approximately 1000 psig to the gas pressure panel. One K-bottle change was performed at approximately 20:18 GMT.

(b). Gas Pressure Panel

The outlet from the K-bottle regulator was regulated down to 650-750 psig in the unit and maintained at this value throughout the test.

(c). Oxygen Valve Panel

This panel was used as an isolation interface between gas pressure panel and the service module oxygen pneumatically operated disconnect (POD).

(d). Spacecraft Oxygen System Configuration

The oxygen entering the service module was isolated from the cryogenic tanks by check valves. The O2 entered the command module through one of two available supply lines to the oxygen surge tank, one pound bottle, and regulators for distribution to various O2 subsystems.

(2). COMMENTS ON OXYGEN SUBSYSTEM DATA

The oxygen system worked normally both prior to and after the report of the fire, with the exception of the high O2 flow rate. This is discussed in the Panel 18 Report.

(3). SUIT CIRCUIT OXYGEN SYSTEM CONFIGURATION

Oxygen at 100 psig was supplied to the suit circuit through the demand pressure regulator (see Figure 4.6-2).

The demand pressure regulator is used for normal makeup, or demands of up to 0.70 lb/min of oxygen. The demand regulator test selector is used to pressurize the suit circuit for suit integrity tests.

(4). COMMENTS ON SUIT CIRCUIT OXYGEN SYSTEM DATA

The suit circuit oxygen system worked normally both prior to and after the report of the fire. At 23:31:09.6 GMT, the suit flow for the SRP suddenly went to lower limit for 2 seconds and back to full scale in a step function. See Panel 18 Report for further discussion.

(5). W/G SUBSYSTEM CONFIGURATION (see Figure 4.6-3)

Water glycol was being supplied from GSE (S14-053) and as it would be for normal launch, with one exception, the solenoid-operated valve on the return line in the service module was powered by an auxiliary 28 VDC supply to maintain flow after the umbilical disconnect (Plugs Out). Cold water glycol is supplied to the S/C from the trim control unit (S14-053) at constant pressure, temperature, and flow rate. The final adjustments of these conditions were made immediately following inner hatch installation at 19:45 GMT. Supply pressure was constant at 69.5 psia (FF5062).

Supply temperature was adjusted in order to achieve 40 ± 1 degree F at the glycol evaporator outlet.

Actual value was constant 40.9°F, measured at CFOO18T. Flow rate was adjusted to a constant 196.5 lb/hr (FF5063).

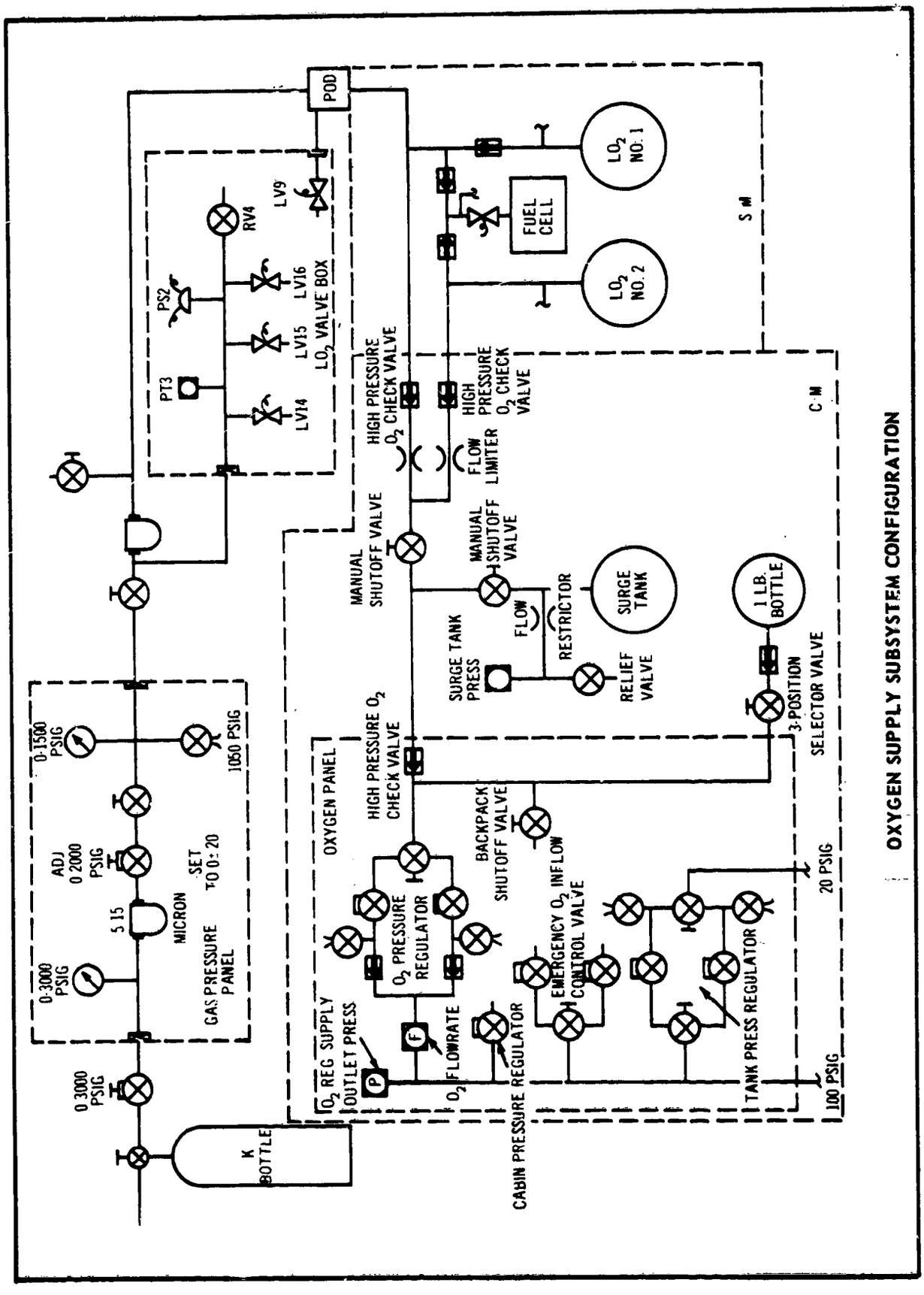
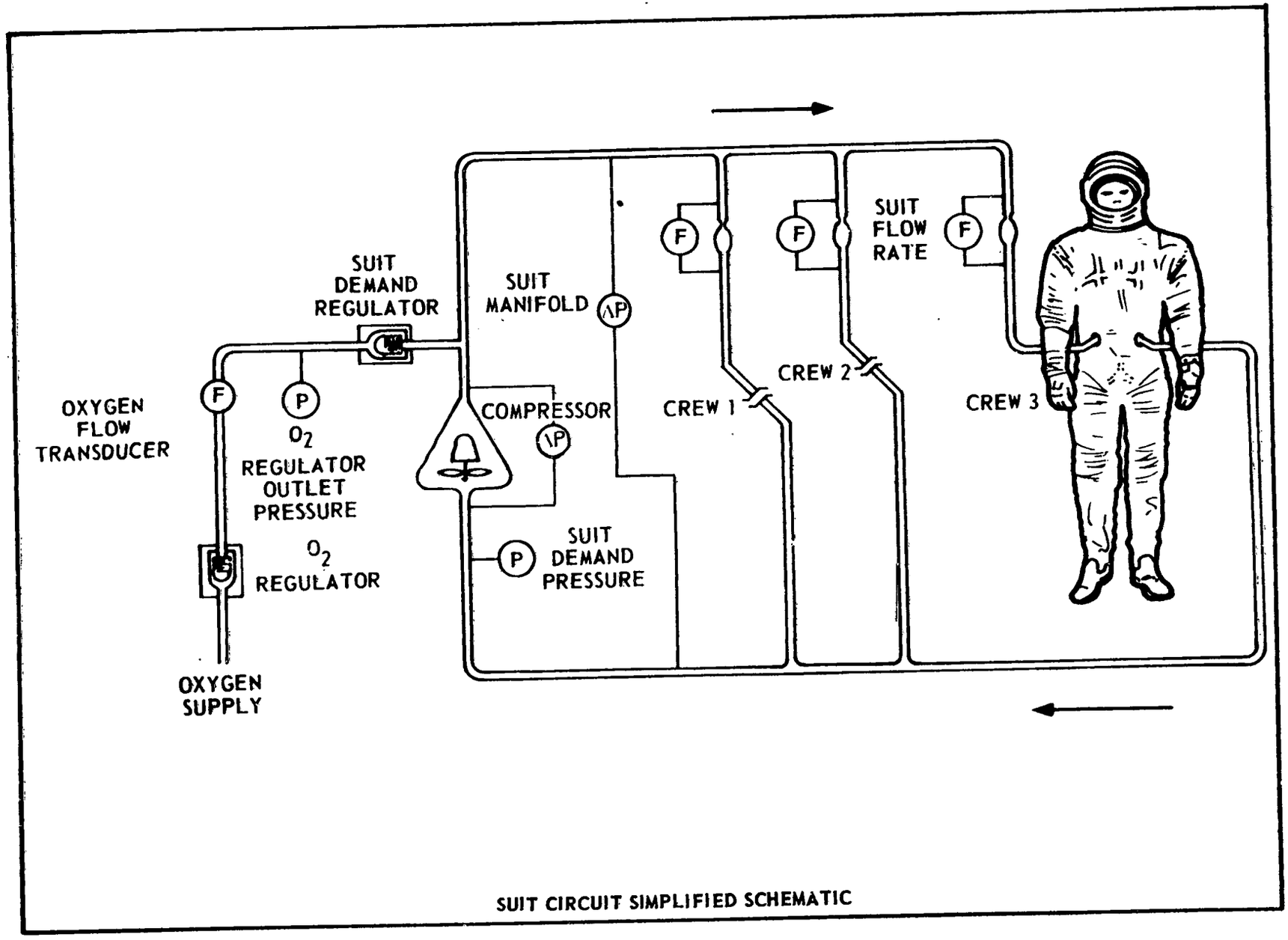
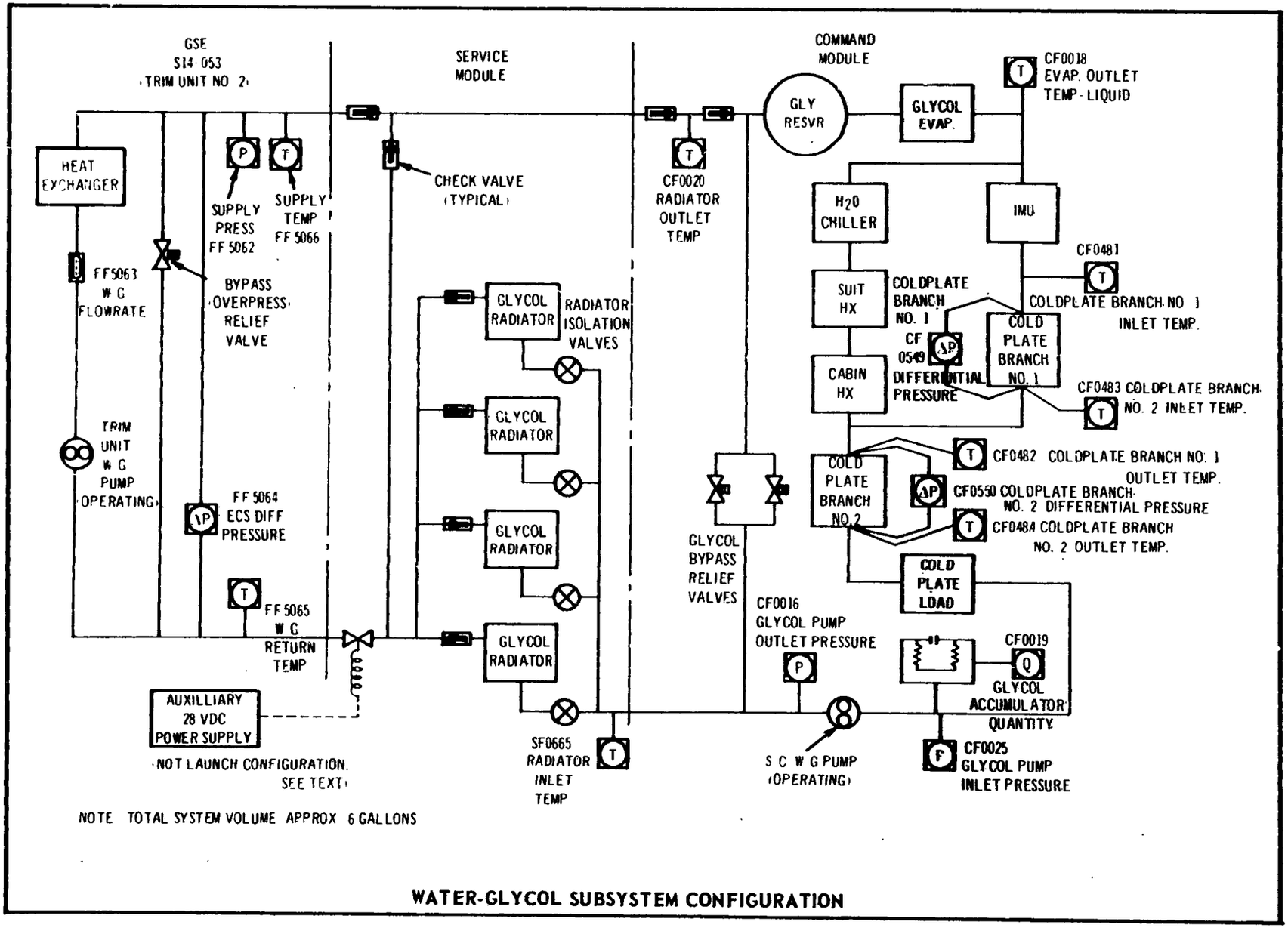

POD
RV4
LV9
PS2
LV16
LV15
LV14
PT3
LO2 VALVE BOX
LO2 NO. 1
LO2 NO. 2
FUEL CELL
S M
HIGH PRESSURE O2 CHECK VALVE
FLOW LIMITER
HIGH PRESSURE O2 CHECK VALVE
MANUAL SHUTOFF VALVE
MANUAL SHUTOFF VALVE
SURGE TANK
1 LB. BOTTLE
FLOW RESTRICTOR
SURGE TANK PRESS
RELIEF VALVE
3-POSITION SELECTOR VALVE
C M
0-1500 PSIG
1050 PSIG
ADJ 0 2000 PSIG
SET TO 0: 20
5 15 MICRON
0-3000 PSIG
GAS PRESSURE PANEL
OXYGEN PANEL
HIGH PRESSURE O2 CHECK VALVE
BACKPACK SHUTOFF VALVE
O2 PRESSURE REGULATOR
EMERGENCY O2 INFLOW CONTROL VALVE
20 PSIG
0 3000 PSIG
K BOTTLE
O2 REG SUPPLY OUTLET PRESS
O2 FLOWRATE
CABIN PRESSURE REGULATOR
TANK PRESS REGULATOR
100 PSIG
OXYGEN SUPPLY SUBSYSTEM CONFIGURATION

FIG. 4.6-1



SUIT CIRCUIT SIMPLIFIED SCHEMATIC

FIG. 4.6-2



WATER-GLYCOL SUBSYSTEM CONFIGURATION

FIG. 4.6-3

(6) COMMENTS ON DATA

At about 8 minutes prior to the crew call of fire the accumulator quantity pressure measurement started a gradual decrease which continued to the time when the cabin pressure rose because of the fire. The supply pressure measurement, which also senses changes of pressure within the glycol system, showed an associated change during this period of time. See Panel 18 Report for further discussion.

g. COMMUNICATION

(1). The communication system was in launch configuration except for the following:

(a). Only one data storage electronic assembly voice recorder (DSEA) was installed, but was not electrically connected. Two DSEA's are required for launch configuration, with only one connected.

(b). Only one bio-med tee adapter was installed (SRP position). For flight there would be three.

(c). CMD Pilot was using a flight-space cobra cable (-51) instead of the normal cable (-41); the cobra cable was changed during the "live mike" troubleshooting.

(d). Audio control panel and cobra cable switches were in position to facilitate testing as a workaround for the "live mike" problem.

(e). The USBE was in the "transponder only" mode (power amplifier "off"). The launch configuration transponder power amplifier mode would have been selected at T-10 minutes. Figure 4.7-1 shows the astronaut umbilical communication system cobra cable, tee adapter, etc.

(2). COMMENTS ON DATA

(a). All data reviewed indicates that the spacecraft communication system performed normally between 23:30:00 GMT and LOS, except for the following:

(1). VHF/FM DROPOUT - A momentary dropout occurred in the RF detected PCM video wave-train at 23:30:54.85 GMT and lasted for approximately 30 milliseconds. MSOB and the TEL IV signal strength parameters of the VHF/FM carrier had a momentary dropout coincident with the PCM video dropout. See Panel 18 Report for further discussion.

(2). C-BAND DROPOUT - A C-band dropout occurred at 23:30:54.85 GMT and lasted for 1.7 seconds (see Figure 3-2). The dropout was indicated in the receiver decoder and in the transmitter output. Both are PCM data points which are sampled 10 times per second, and both have RC time constants of 0.1 second. See Panel 18 Report for additional details.

(3). "LIVE MIKE" CONDITION - Voice tape analysis and PCM data records showed a "live mike" (constant keying) condition existed from the CMD Pilot position during a considerable portion of the final test period. See Panel 18 Report for greater detail.

(b). VOICE RECORDINGS

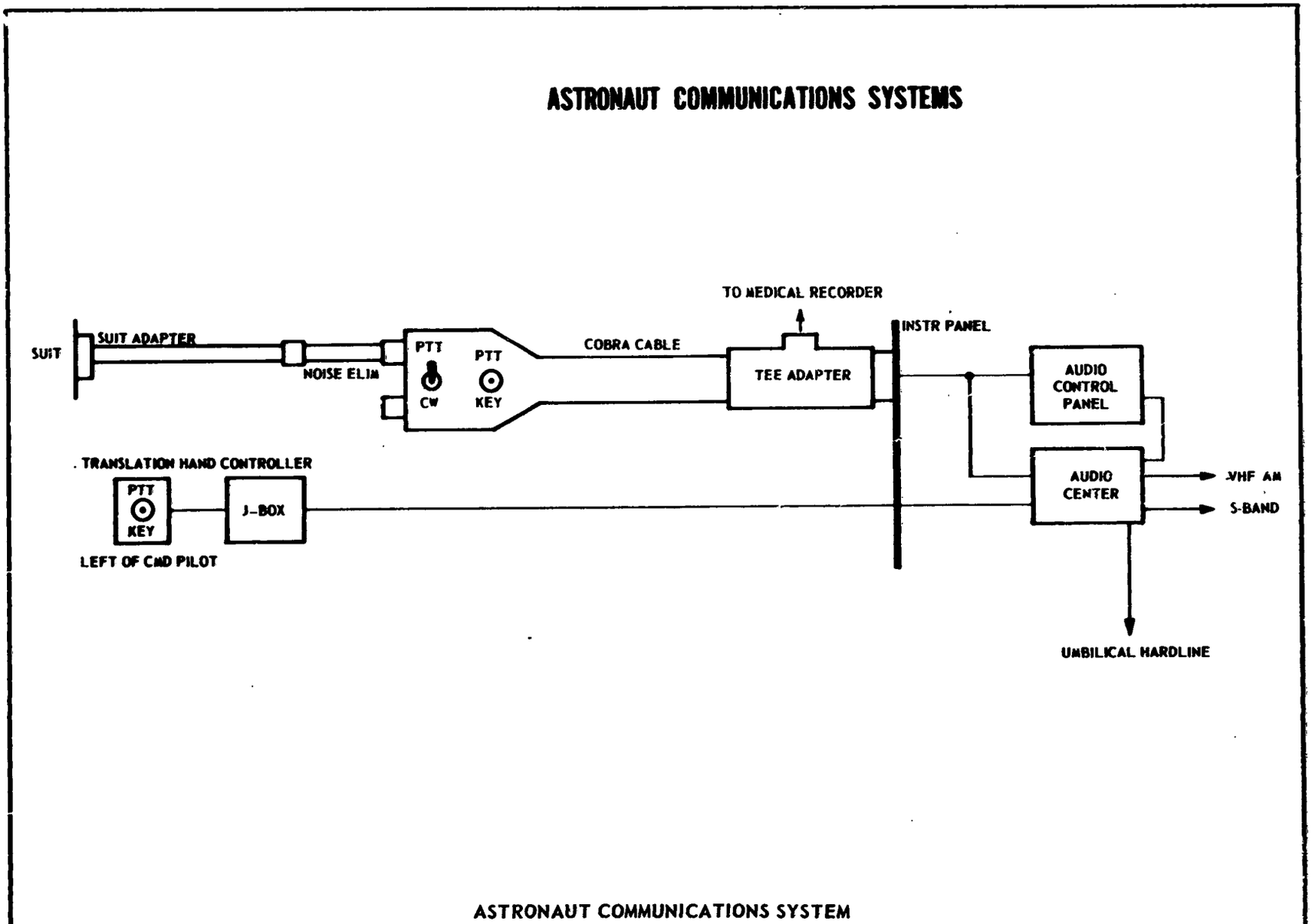
Voice recordings were made in the Manned Spacecraft Operations Building (MSOB) ACE Station, MSOB Open Loop Communication Station (MOLC), Blockhouse 34, MCCK at Cape Kennedy, MSC-Houston, and NAA Downey via Houston (see Figure 4.7-2). The data from these tapes were studied in an attempt to determine possible clues to the cause and crew reaction to the fire. A transcript was made of the S-band and VHF/AM tracks of the MOLC voice tape from 23:29:45.5 GMT to LOS. This tape was chosen because it contained the only direct S-band voice from the S/C and was less noisy than the OIS tapes.

(c). ANALYSIS OF OSCILLOGRAPH RECORDING

The voice transmissions shown in Figure 3-9 were analyzed with the use of MOLC tapes and PCM data. This figure shows the VHF/AM and S-band voice tracks oscillograph readout from 23:29:42.5 GMT to LOS.

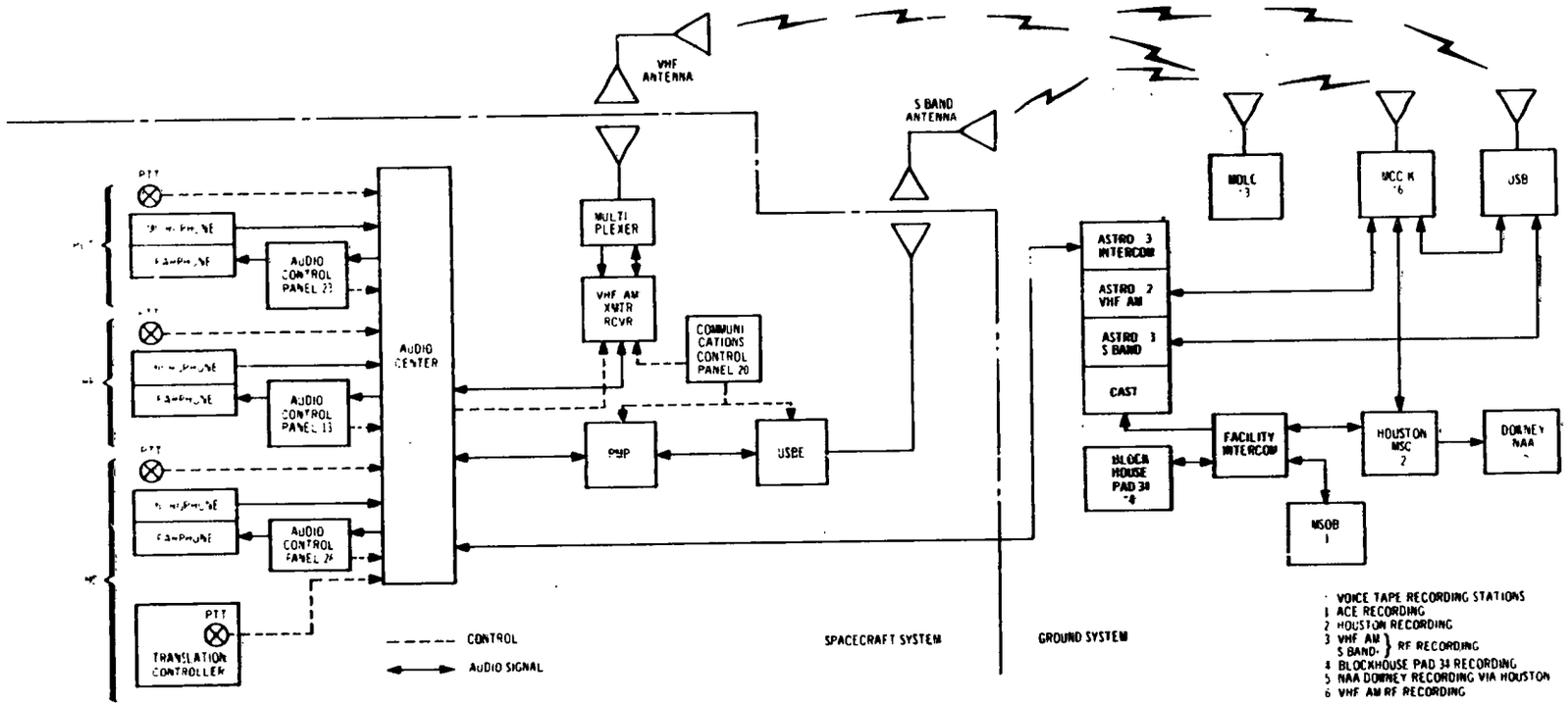
(1). 23:29:42.5 to 23:30:14 GMT

(a). The CMD was transmitting on S-band. The SRP made a voice transmission on S-band and VHF/AM. There was no voice transmission by the PLT.



ASTRONAUT COMMUNICATIONS SYSTEM

FIG. 4.7-1



AUDIO COMMUNICATIONS EQUIPMENT INTERFACES

FIG. 4.7-2

(b). The ground personnel were transmitting to the S/C on S-band. The voice of the CMD was being turned around by the CAST (astro communicator console) system and retransmitted to the S/C on VHF.

(c). The "live mike" noises are not evident, probably because of the higher noise level caused by the uplink S-band being patched to the MOLC RF recorder.

(2). 23:30:14 to 23:31:00 GMT

(a). There were no voice transmissions from the S/C.

(b). The ground personnel were not transmitting to the S/C on VHF.

(c). There was no change in the "live mike" condition. Considerable amounts of noise similar to those obtained when a microphone is brushed or tapped, including breathing sounds, were evident. Some of the louder noises appear to have had sufficient amplitude to trigger the uplink VHF/AM via CAST.

(3). 23:31:00 GMT TO LOS

(a). There were two series of voice transmissions on S-band. The times for these two transmissions are detailed in Figure 3-9. No voice communications on VHF were made from the S/C during this time period.

(b). The ground personnel were not transmitting to the S/C on VHF. The voice transmissions from the S/C were being turned around by the CAST system and were retransmitted to the S/C on VHF.

(d). ANALYSIS OF VOICE TAPES DURING THE PERIOD OF FIRE

The tape transcripts of the voice tapes from the Command Module during the time period of the fire (referred to as the first and second transmission, on Table 4.7-1), have been extensively analyzed. This analysis included a review of all transmissions prior to the fire that were made by the crew during the test in an attempt to aid in the determination of who made these last two transmissions and what was said. This analysis was made by NASA personnel familiar with the communication systems, the crew and their voice characteristics, the sequence of events before, during and after the fire as determined during the accident investigation. The Apollo 204 Review Board also reviewed these transmissions. Experts at the Bell Telephone Laboratories also performed extensive analysis of the tape record. Review by other experts, such as Civil Aeronautics Board accident investigation personnel, is currently in progress. Any new findings from these additional reviews will be included in Appendix G of the Final Report.

Except for a portion of the first transmission, which is quite clear, the remainder of the first and second transmission is not clear and it is impossible to define exactly what was said by the crew. Two points made by the Bell Telephone Laboratory experts, however, should be noted:

(1). The present state-of-the-art of analysis of voice records is such that little, if anything, can be determined as to what was said if the recording is not sufficiently clear to be intelligible by listening alone. Analysis, however, can, under these circumstances, provide some clues; but these clues cannot be used to definitely determine which crew member initiated the transmission.

(2). When the recording of the transmission is not clear, there will be nearly as many interpretations of what was said as there are qualified listeners. Many interpretations of what was said have been made. A summary of these interpretations is made in the following paragraphs.

The analysis of the first voice transmitted is as follows:

This transmission began at 23:31:01.7 GMT with an exclamatory remark. This transmission is not clear. Most listeners believe this initial remark was one of the following:

"Hey"
"Fire"
"Break"

Most listeners believe, and laboratory analysis supports this belief, that this transmission was made by the Command Pilot. This remark is followed by a short period of noise (bumping sounds, etc.).

TABLE 4.7-1 TRANSCRIPT OF VOICE CHANNEL FOR LAST 27 SECONDS

MOLC VHF/AM TRACK TRANSCRIPT		MOLC S-BAND TRANSCRIPT	
		23:30:55.5	(Noise)
		23:30:56	(Breathing sound)
		23:30:56.5	(Noise)
		23:30:58.1	(Noise)
23:30:58.5	(Short noise 0.6 sec)		
		23:31:04	(Breathing sound)
23:31:04.7	*(First voice transmission)	23:31:04.7	(First voice transmission of spacecraft problem)
23:31:10.0	(End of first transmission)	23:31:10.0	(End of transmission)
		23:31:16.8	(Second voice transmission of spacecraft problem)
23:31:17.1	(Second voice transmission)		
23:31:21.8	(End of second transmission)	23:31:21.8	(End of second transmission)
		23:31:22.4	(LOS)

* Analysis of these transmissions appears in paragraph 4.7

The second portion of this first transmission begins at 23:31:06.2 GMT with an unclear word. Most listeners believe the first to be one of the following:

"I've"

"We've"

The remainder of this transmission is quite clear and is: ".....Got a fire in the cockpit", followed by a clipped word sounding like "VHEH", which ended at 23:31:10 GMT. Many listeners believed this transmission to have been made by the Pilot. Some believe it could have been made by the Command Pilot or the Senior Pilot. However, laboratory analysis assigns the greatest probability that it was made by the Pilot, but the results of the analysis do not negate the possibility that one of the other crew members could have made the transmission.

The analysis of the second voice transmission is as follows:

Following a 6.8 second period of no transmission the second transmission began at 23:31:16.8 GMT and ended at 23:31:21.8 GMT. The entire second transmission is somewhat garbled. This second transmission, therefore, is subject to wide variation of interpretation as to content and as to who was making the transmission or transmissions. The general content is what appears to be three separate phrases and it has been interpreted several ways by many listeners. The following is a list of some of the interpretations that have been made:

(1). "Fighting a bad fire - Let's get out.....
Open 'er up."

(2). "We've got a bad fire - Let's get out.....
We're burning up."
"I'm reporting a bad fire....I'm getting out..Oh, AAH." (Scream)

Some people feel that the very end of this second transmission is a scream or the start of one. Many listeners believe this transmission was made by the Pilot.

It should be noted that:

(1). The total time duration of these two transmissions was brief, lasting 17.1 seconds; the first lasted 5.3 seconds and the second lasted 5.0 seconds, with a 6.8 second period of no transmission between.

(2). The transmissions provide evidence only of the time the crew first transmitted a report of the existence of the fire and do not provide any direct information as to the cause of the fire.

H. FUEL CELL AND CRYOGENIC GAS STORAGE SYSTEM

(1). FUEL CELLS

Fuel cells were inactive and were not being monitored during the incident. A review of the data from 23:26:00 GMT to the incident indicated no fuel cell anomalies.

(2). CRYOGENIC GAS STORAGE SYSTEM (CGSS)

The CGSS was inactive during the test. Gas was supplied to the environmental control system from "K" bottles through port OP on the service module. A review of data from 23:26:00 GMT to the incident indicated no anomalies in the CGSS.

i. PROPULSION (SPS AND RCS)

(1). SERVICE PROPULSION SYSTEM CONFIGURATION

The differences from the normal launch countdown configuration were as follows:

Propellant tanks, helium storage tanks, and engine actuation system GN2 tanks were not serviced to flight pressures but were at low (normal) blanket pressures (using GN2).

(2). COMMENTS ON SPS DATA

All data on the SPS remained normal and constant until loss of data.

(3). REACTION CONTROL SYSTEM CONFIGURATION

CSM RCS was configured for launch with the following exceptions:

(a). The engine simulators were installed in lieu of actual engine circuitry.

(b). No consumables were on board. The scupper supports were in place.

(c). A temperature thermocouple was taped to CM "B" system oxidizer isolation valve to monitor valve temperature rise during plugs out mission run.

(d). The engine throat plugs and flow sensors were partially installed in preparation for flight readiness test. The engine covers were installed on quad engines. CM engines were environmentally sealed with tape.

(4). COMMENTS ON RCS DATA

A simulated. SM RCS +X engine static firing had been completed at approximately 23:15:00 GMT using Pilot's rotation controller. No anomalies were observed in this test. Following the simulated static firing the CSM RCS system was monitored for remainder of the active test. A review of the data tapes for the period 23:26:00 GMT to 23:31:30 GMT did not disclose any system anomalies. Significant RCS data peculiarities are detailed below:

(a). A linear rise in temperature from an ambient condition of 70° F to 197° F occurred between 23:31:19.858 GMT and loss of signal at 23:31:22:432 GMT on CR4561T. This transducer is a resistance thermometer type and is spot welded to the upper surface of CM RCS "A" CCW engine between frames No. 21 and 22, (closer to frame 21), and behind panel CM 18. It is also covered with 3/4 inches of insulating Q-felt. A second transducer, CR2201T, mounted on the oxidizer injector value of the same engine, showed no temperature increase. Although this transducer is of a similar resistance type, it was bonded to and encapsulated in silicon rubber. It was also 90 degrees further around the engine on its outward side and located between frames no. 20 and 21 (closer to frame 21). Although partially covered by the boost protective cover, CR2201T was exposed to ambient conditions (panel CM 19). The sudden rise in temperature of CR4561T is indicative of exposure to flame at the time of cabin pressure vessel rupture. Time correlation with other rupture data points must take into account the fact that the engine and transducer are enclosed with insulating Q-felt as noted above.

(b). The RCS propellant isolation circuit breakers (CB16 and CB15) on panel 25 were found to be open during post-fire inspection. Further inspection revealed that the circuit breakers' stems were only slightly smutted indicating that the circuit breakers opened after the fire started to subside.

(c). The RCS selector switch was found in the SM-A position rather than the SM-D position called for by the procedure. This switch selects a particular SM quad for parameter monitoring and has no change-of-state function. The SM-A position is assumed to be a pilot's natural reaction to return to the initial monitoring position instead of leaving it in the final position following simulated static fire.

j. CREW SYSTEMS, BIOMED, AND EXPERIMENTS

(1). SYSTEM CONFIGURATION

The biomed system was in launch configuration with the following exceptions:

(a). An E. O. was released to pot the octopus cable connectors to prevent breakage of connector back shells. Planning was also in work to wrap the cable with tefglas and attach Velcro to provide attach points for support of the cable.

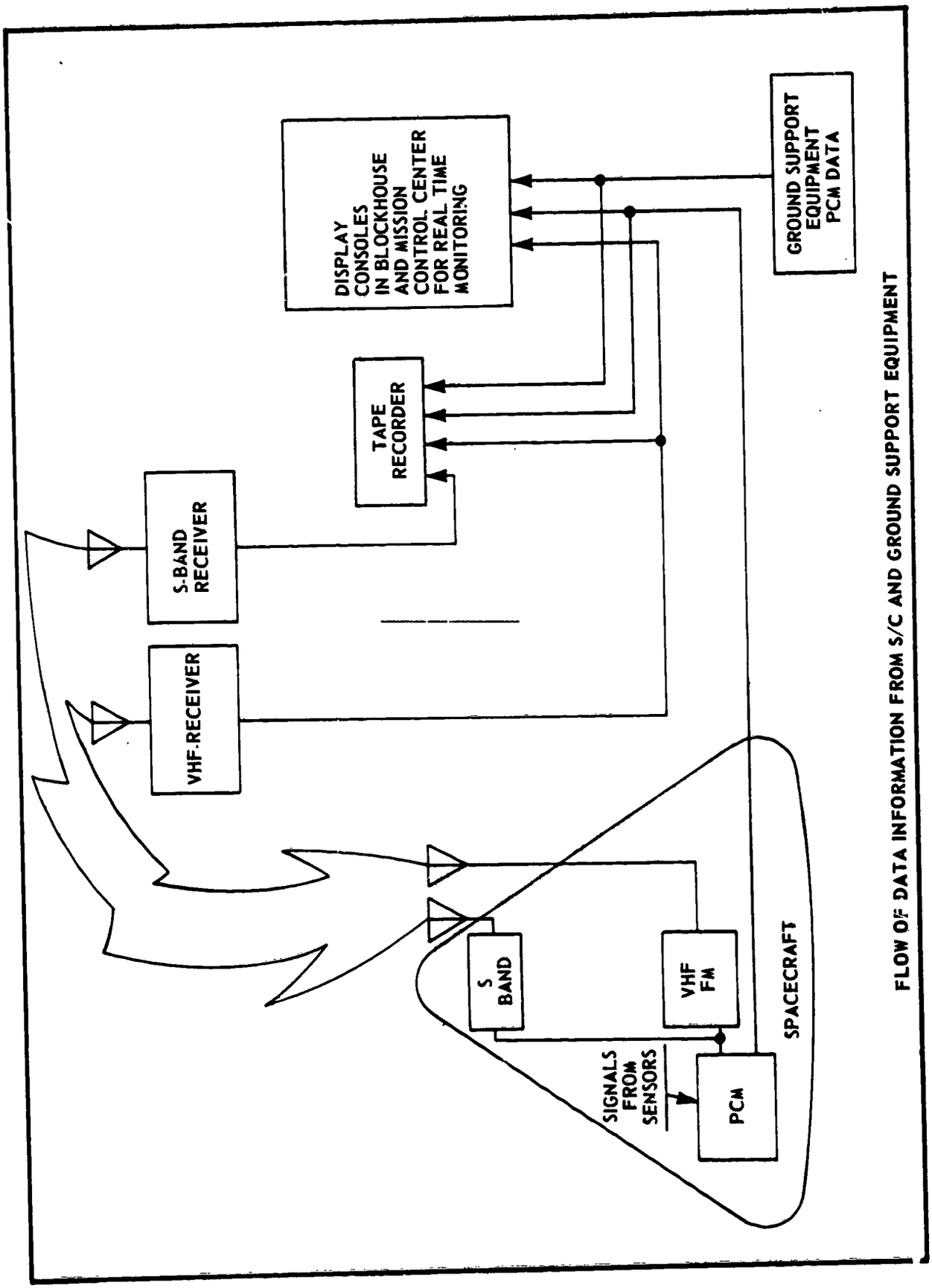
(b). Only one biomed tee adapter was installed and this was in the SRP position. The biomed parameters for the SRP position were being monitored on both PCM and the MDAS recorder and the time of incident.

Only the crew systems equipment required to support OCP-FO-K-0021-1 was stowed in the S/C. The stowed crew systems equipment which has an electrical interface with the S/C (cameras, hygrometer, alignment sight) were not connected to the S/C at the time of the accident.

(2). COMMENTS ON DATA

(a). PCM and MDAS recorder data throughout the test was normal except for several noise glitches which appeared on the biomed data channels. Physicians verified these glitches were not normal biomedical data. The first glitch occurred at 18:28:02 GMT and recurred randomly with the last one at 23:24:00 GMT. These noise spikes are believed to be caused by RFI, which has been duplicated during post-incident bench test by glitching the input power. From the time the MDAS was turned on and the timer reset to zero (17:36.02 GMT) until LOS of the timer (23:31:21.2 GMT), the timer operated normally with no loss of, or change in, timing

(b). Based on the PCM and MDAS data available from S/C 012, there is no indication that the biomed system contributed to the case of the incident.



ENCLOSURE 3-2

REPORT OF PANEL 4
DISASSEMBLY ACTIVITIES PANEL
APPENDIX D-4
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

DISASSEMBLY ACTIVITIES PANEL

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Disassembly Activities Panel, 4. The task assigned for accomplishment by Panel 4 was prescribed as follows:

> Develop plans and procedures for progressive disassembly of Apollo Spacecraft 012 for purposes of inspection and failure analysis. Disassembly should be configured to proceed on a step-by-step basis, in a manner to obtain the maximum amount of information prior to disturbing the evidence. Contents of testing requirements shall also be considered. Disassembly plans should consider both the cockpit and the area outside the pressure hull. Means for cataloging documentary information within the spacecraft and for the display of removed items shall be a part of these plans and procedures.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Disassembly Activities Panel:

Mr. Scott H. Simpkinson, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. Samuel T. Beddingfield, Kennedy Space Center (KSC), NASA
Mr. Robert G. Covel, Jr., Kennedy Space Center (KSC), NASA
Mr. Paul J. Graf, Kennedy Space Center (KSC), NASA
Mr. Robert J. Reed, Kennedy Space Center (KSC), NASA
Mr. Harry C. Shoaf, Kennedy Space Center (KSC), NASA
Mr. Charles G. Stevenson, Kennedy Space Center (KSC), NASA
Mr. Joseph C. Campbell, Manned Spacecraft Center (MSC), NASA
Mr. Dean F. Grimm, Manned Spacecraft Center (MSC), NASA
Mr. Patrick J. Hanifin, North American Aviation (NAA), Downey
Mr. John M. Moore, North American Aviation (NAA), Kennedy Space Center

2. COGNIZANT BOARD MEMBER:

Colonel Frank Borman, U. S. Air Force, Board Member, Manned Spacecraft Center (MSC), NASA, was assigned to monitor the Disassembly Activities Panel.

C. PROCEEDINGS

1. INVESTIGATIVE APPROACH

a. SPACECRAFT 012 DISASSEMBLY PROCEDURES. Immediately after the accident, at 6:31 p.m., EST (23:31 GMT) on January 27, 1967, NASA Kennedy Space Center Security placed Launch Complex 34 under additional security. Special guards were assigned to the service structure and to the adjustable-eight (A-8) level at the entrance to the Command Module (C/M). Controls were established for personnel access to the service structure and the C M. Everything located at the Launch Complex such as Ground Support Equipment (GSE), spare parts, documents and drawings, special clothing, breathing apparatus and fire fighting equipment, etc., was impounded. The NASA Test Supervisor in the blockhouse, in conjunction with NASA Security, controlled all activities on the service structure. Implementation of these directions was coordinated through the NASA Operations Engineer and the NAA Pad Leader at the C M.

After the fire, prior to disturbing any items in the spacecraft, a series of photographs were taken. Several photographs were made of the surrounding areas on adjustable levels A-7 and A-8. Photographs showing the configuration of the area around the Pad Leader's desk on A-8 and a closeup of the desk may be seen in Enclosures 4 1, 4-2, and 4 3. The step-by-step photography method was established as a standard operating procedure for the entire activity of the Disassembly Activities Panel

After the last crewman was removed at approximately 2:00 a.m., EST on January 28, 1967, two spacecraft observers entered the C/M at 3:00 a.m. to verify certain panel switch positions. Other than this there was no activity inside the C/M on the day after the accident. Small groups of NASA and NAA management, the Apollo 204 Review Board Members, Representatives, and Consultants and others with a need to know, inspected the exterior of Spacecraft 012. They looked in through the open hatch, but did not enter the C/M.

At 1:00 a.m., EST, Sunday, January 29, 1967, a NASA photographer took additional pictures inside the C/M and an astronaut entered the spacecraft to verify additional switch positions needed to clarify the data. Considerable inspection of the exterior of the spacecraft and the A-8 level was accomplished throughout the day. At 10:00 a.m. EST, a second astronaut entered the C/M and removed a few items of Government-furnished crew equipment after it was determined that they had no relation to the accident. Following this, one member of the Press was escorted to the A-8 level and was permitted to take pictures, with the stipulation that he could not enter the spacecraft. No more activity took place inside the spacecraft on that day.

At noon on Monday, January 30, 1967, a NASA operation engineer entered the C/M to examine the Gas Chromatograph Cable and direct a photographer to take pictures in the vicinity of the cable. At about the same time, the Apollo 204 Review Board created a Hardware Removal and Disposition Panel (later retitled Disassembly Activities) to establish the procedures for disassembly of Spacecraft 012. This Panel immediately established criteria that required a standard Apollo Test Preparation Sheet (TPS) for any work or inspection on Spacecraft 012. Each TPS had to be signed by both NASA and NAA systems engineers and by the Panel Chairman (NASA) or his delegate (NASA) and a NAA member of the Panel. These TPS's were necessary to assure proper coordination and will remain as a permanent record of the work accomplished. All prepared TPS's are contained in the Apollo 204 Review Board General File.

The first step toward an orderly disassembly was to assure safe working conditions at the spacecraft. A meeting was held with KSC and Air Force Eastern Test Range (AFETR) Safety personnel in which it was decided that (1) the Launch Escape System (LES) should be removed and properly stored, (2) the forward heat shield should be removed and all pyrotechnics removed and stored or made safe, (3) the structure should be examined by structural engineers, and (4) all pressure vessels should be declared safe, or the pressure should be relieved. It was also decided that work inside the spacecraft would not be allowed until dust samples were taken and the air declared free from possible harmful concentrations of beryllium dust. (Beryllium is used in the structure of the Guidance and Navigation (G&N) System.) After obtaining Board approval, these tasks were accomplished and Spacecraft 012 was considered safe for investigative purposes by 10:00 p.m. EST on Thursday, February 2, 1967.

The Hardware and Disposition Panel prepared and issued a memorandum which stated the mode of operation for those concerned. It is included as Enclosure 4-4 to this report.

Members of Panel 5, Origin and Propagation of Fire, cleaned the couches in a carefully planned manner and documented all phases of the task. Charred data books and procedure manuals removed from the couches were carefully packed and hand carried to the Federal Bureau of Investigation Laboratory, Washington, D. C., in an attempt to identify any notes that may have been made by the crew.

After a specially constructed plywood cover was installed on the couches, NASA and NAA Quality Control (QC) inspectors entered the spacecraft and recorded all unusual appearances of hardware, including damaged components, but not including superficial damage such as smoke discoloration and other accident effects. After more than four hours of inspection by QC, the systems engineers then entered the spacecraft. Each system engineer was allotted sufficient time to visually

inspect all of the exposed hardware of his system. This was necessary in order to formulate an effective plan for an orderly disassembly and to establish an overall priority for component removal. Following approximately four hours of engineering inspection, a NASA photographer took a series of close-up stereo photographs of the C/M interior, including many special points of interest required by various systems engineers. Before removing the couches, the top egress hatch was removed.

It was recognized that the task of searching the physical evidence would be difficult and time consuming because of the confined area within the C/M and the small hatch through which everything had to enter and leave. In order to remove the components as quickly as possible and keep the members of the investigating team informed of the findings, it was necessary to have an engineer and a technician enter the spacecraft to remove the equipment and then have a photographer take the place of the technician and document the conditions after each removal. With proper distribution of the engineer's findings and the color photographs, all parties with a need to know were informed of the progress and considerable time was saved in the disassembly process.

Removal of the couches posed a unique problem in that it was desirable not to disturb the aft bulkhead (crew compartment floor) in any way. The normal removal requires technicians to lie on the floor and work on the couches from the underside. To accomplish removal of the couches without disturbing evidence, a special platform was built which was supported from the hatch sill at one end and from strut attachment fittings at the other end. The technicians were able to lie on this platform and perform the work necessary to remove the couches.

After the couches were removed, a special false floor, fabricated from aluminum angles supporting removable 18-inch squares of 3/4-inch thick Plexiglass, was suspended from the existing couch strut fittings to provide access to the entire inside of the spacecraft including the floor, without disturbing any of the evidence. The false floor, after a check fitting in Spacecraft 014, is shown installed in Spacecraft 012 in Enclosure 4-5. A NASA photographer then entered the spacecraft and took a series of precision scale photographs of the interior which were later glued to the inside of a one-half scale model for a three dimensional reference. Members of Panel 10, Analysis of Fracture Areas, then enteres the spacecraft for an inspection of the structural failures in the aft bulkhead.

At this point, with the couches removed, Panel 5, Origin and Propagation of Fire, with Members and Consultants of the Apollo 204 Review Board, entered the spacecraft to look over the cabin from the vantage provided by the transparent false floor.

A decision was made to repeat investigation inspections by QC and the various systems engineers. In order to disseminate information and to retain a permanent record of important observations during this type of inspection, a TPS was generated requiring a written summary of all significant findings after performing an inspection but before leaving the A-8 level of the service structure. These summary sheets were distributed to all parties with a need to know.

The preparations for disassembly proceeded quite well; however, upon entering the next phase involving the need for closely controlled and coordinated equipment removal, it became obvious that new procedures were required. To implement these procedures, the Board appointed a Panel Coordination Committee (PCC), which included three Board Members and several Consultants.

The first order of business of this Committee was to amend the procedures for accomplishing work in the C/M. Panel 4 was redesignated the Disassembly Activities Panel instead of Hardware Removal and Disposition Panel. Apollo 204 Review Board Administrative Procedure Number 18 concerning the Use and Control of Test Preparation Sheets was published. This procedure covered the plan and control by which spacecraft hardware would be removed, inspected, analyzed or otherwise modified. Under this plan, requirements were reviewed by the PCC and presented to the Board for approval. After approval of a specific requirement by item number, TPS's to implement

the required action were generated by the appropriate NASA/NAA systems engineers and approved by members of:

NASA-MSC and NASA-KSC Engineering
NAA Engineering
Panel 5, Origin and Propagation of Fire
Panel 18, Integration Analysis
Materials Analysis Branch, KSC
Panel Coordination Committee
Panel 4, Disassembly Activities (only in those cases where execution of the TPS involved work inside or on the C/M)

Concurrently, two new categories of investigation TPS's were established. These were the Component Analysis (CA) for testing a removed component or a component from spares stock and the Material Analysis (MA) for analyzing a sample of material from the spacecraft or from the stockroom.

By February 7, 1967, this system was fully operational. The concentrated effort of organized and coordinated equipment checkout and removals continued on a three-shift seven day a week basis. All unusual or suspect circumstances or conditions were immediately brought to the attention of Panel 5, Origin and Propagation of Fire, and the appropriate systems engineers for any desired change in direction.

During the equipment removal, electrical connectors used to connect large bundles of wires were in general disconnected; however, if any connectors showed physical evidence of damage, the wires were cut at the point where they were the least damaged and were clearly identified with separate tags on each cut end. In the case of tubing, lines were generally cut at a convenient distance from the joints to allow a leak check to be performed on the original joint. Exact interfaces were photographed and marked prior to disassembly, where possible, so that original conditions could be reassembled if desirable.

All interfaces, such as electrical connectors, tubing joints, physical mounting of components, etc., were closely inspected and photographed immediately prior to, during, and after disassembly as shown in Enclosure 4-6. All disconnects were made over clean plastic bags to catch any debris or contamination. Every item removed or taken from the C/M was appropriately tagged, sealed in clean plastic containers and transported under the required security to bonded storage.

On February 17, 1967, the Review Board was satisfied that removal and wiring tests had progressed to the point that moving the spacecraft would not disturb any remaining evidence. The C/M was moved to the Pyrotechnic Installation Building (PIB) at KSC where better working conditions were available. The structural integrity of the damaged C/M was questionable; therefore, a special sling was constructed to be used to remove the C/M and lower it to ground level. This sling consisted of the standard sling designed to hoist the entire stacked Apollo spacecraft (including the Lunar Module) plus two straps at approximately ninety degrees going around the C/M and under the aft heat shield. These added straps were designed to support the entire C/M in case of a structural failure in the spacecraft. The verification test of this sling using a boilerplate Flight Verification Vehicle (C/M), with the structural interconnection points disconnected to simulate a failure, is shown in Enclosure 4-7.

After verification of the sling, it was attached to the 012 Command Module and used to lower it to a mounting ring on a trailer at the base of the service structure. The trailer was used to transport the C/M to the PIB. In order to minimize vibration, the speed was held to below five miles per hour over the 6.6 miles traveled. The moving operation is shown in Enclosures 4-8, 4-9, 4-10, and 4-11. At the PIB, the C/M was placed in the fixture normally used for alignment of the Launch Escape System. This fixture, shown supporting the aft heat shield in Enclosure 4-12, was used for a period of 18 days to support the spacecraft during equipment removal and special testing.

With the improved working conditions in the PIB, it was found that a work plan of two eight-hour shifts per day for six days a week was sufficient to keep pace with the analysis and disassembly planning. The only exception to this was a three-day period of three eight-hour shifts per day, utilized to remove the aft heat shield, move the C/M to a more convenient work station (Enclosure 4-13), and remove the crew-compartment heat shield (foreground of Enclosure 4-12). This activity took place on March 7, 8, and 9, 1967. The planned disassembly of the C/M was completed on March 27, 1967.

In general, non-functional panels and low-suspect hardware were removed from around areas of suspect or heavy damage. This was done to gain better access for inspection and component removal within damaged areas without disturbance of evidence.

b. CATALOGING AND DISPLAY OF ITEMS REMOVED FROM THE SPACECRAFT

In accordance with the task assignment for Panel 4, Disassembly Activities, the Panel took immediate action to catalog and place on display, the hundreds of items that would be removed from C/M 012 during the course of the investigation. The KSC PIB was assigned to the Apollo 204 Review Board as an area in which components removed from the C/M could be placed in bonded storage, but be available for inspection by personnel associated with the investigation.

The following areas were established within the PIB:

(1) BOND ROOM — A bonded area to receive components as they were removed from C/M 012. This area was provided with a receiving table; ten storage cabinets for small components, areas for large components and items associated with the investigation, but not from the C/M itself. Enclosures 4-14 and 4-15 show the interior of this room.

(2) ASTRONAUT EQUIPMENT ROOM AND WORK ROOM — An area in which the spacesuits and other Government furnished crew equipment were investigated.

(3) BONDED DISPLAY AREA — An area in which components could be displayed under controlled conditions. The purpose of this area was to permit investigators to make visual examination of C/M 012 components. Work other than visual examination was not permitted in the display area. Enclosure 4-16 shows the components that were on display on February 21, 1967, and Enclosure 4-17 on March 14, 1967.

During the course of the disassembly, there were approximately 1025 items removed from the spacecraft, logged, and either placed on display or held in bonded storage. Enclosure 4-18 is a list of these items by log number. This list does not include nearly 250 items that were logged into the PIB Bond Room from the launch complex and similar areas of concern (not removed from the C/M); however, these items were numbered in the same series, resulting in a total of over 1250 items. A set of C/M drawings was prepared and distributed that was marked with the removed-item log numbers, indicating the area in or on the spacecraft from which each one was removed. In addition to these documents, which were issued weekly as the disassembly progressed, a third document showing the display location of each removed item was prepared daily and distributed weekly, and a fourth document was updated daily and distributed weekly showing the location of all logged items that were carried out of the PIB for further analysis.

(4) COMMAND MODULE 012 WORK AREA - At the PIB, the C/M was placed in a supporting ring within an existing workstand. The C/M remained in this area until the aft heat shield was removed. The C/M was then transferred to a standard support ring in the north end of the building. While in these areas, technicians continued to disassemble the C/M in accordance with approved TPS's. These two work areas are shown in Enclosures 4-12 and 4-13. After a component was removed from C/M 012, it was photographed and then sent to the appropriate bond area.

(5) SPACECRAFT 014 COMMAND MODULE — Spacecraft 014 Command Module was shipped to KSC on February 1, 1967, to assist the Apollo 204 Review Board in the investigation. This C/M was placed in the PIB as shown in the foreground of Enclosure 4-19, and was used as

a vehicle for practicing difficult removals of C/M 012 components.

(6) MOCK-UP NO. 2 — Mock-up No. 2, a full-scale plywood C/M, was also brought to KSC and placed in the PIB on February 8, 1967, as shown in the background of Enclosure 4-19. This mock-up was configured with Velcro, debris traps, couch positioning, etc., to duplicate the C/M 012 configuration at the time of the fire.

(7) HALF-SCALE MOCK-UP — A half-scale mock-up of a C/M interior was placed in the bonded display area on February 8, 1967. This mock-up was used to display half-scale interior surface photographs taken after the fire in C/M 012.

Drawing SCX 311905, Rev. A, indicates the layout of the various areas within the PIB (Enclosure 4-20). Security was maintained within the PIB through the use of access lists, sign in/out lists, and guards stationed at the main entrance and at the entrance to each of the bonded areas within the building. (See guard station A, B, and C on Enclosure 4-20.) Guard station B was discontinued after C/M 012 was moved to the bonded work area at the north end of the PIB. A member of Panel 4 Disassembly Activities was also present in the PIB throughout all work periods.

c. RELEASE OF IMPOUNDED EQUIPMENT — Immediately after the accident, all Spacecraft 012 equipment and associated data, and also the Launch Vehicle, at KSC were impounded. This was done to establish the configuration of the spacecraft, associated GSE, documents, personal tools, and miscellaneous items.

A Material Release Record System (MRR) was devised by the Review Board to control the release of all impounded items. The MRR was the method used to classify items in one of three categories as determined by the Apollo 204 Review Board. The three categories were as follows:

(1) CATEGORY A — Items which may have a significant influence or bearing on the results or findings of the Apollo 204 Review Board.

(2) CATEGORY B — Items other than Category "A" that are considered relevant to the Apollo 204 Review Board investigation.

(3) CATEGORY C — Material released from Board jurisdiction.

Impounded items were systematically reviewed and approved on MRR's for release from Category A to Category B or C by the Apollo 204 Review Board. In those cases for which no constraints to release were made, the items were processed for release by TPS's written and signed by the appropriate NASA or NAA systems engineers and signed by the Chairman of the Disassembly Activities Panel. In addition, the TPS's were accompanied by release letters signed by the Disassembly Activities Panel Chairman.

In those cases for which constraints to release were made by the Review Board, TPS's were required to show precisely what steps were to be worked in order to clear the restraints. When the restraints were removed, the items were released by TPS's and release letters.

The Spacecraft 012 C/M, its systems and components, will be retained in bonded storage in Category A or B at KSC. All GSE was appropriately released by MRR. All prepared MRR's are contained in "Schedule of Physical Evidence"; Appendix F to the Final Report of the Apollo 204 Review Board.

D. SUPPORTING DATA

List of Enclosures

Enclosure	Description	Drawing or Neg. No.
4-1	Level A-8 - looking toward East Wall	B-128-1-C
4-2	Level A-8 - looking toward North Wall	B-128-2-C
4-3	Level A-8 - close-up of Pad Leader's desk	B-128-5-C

4-4	Hardware removal and disposition panel modus operandi	Memo dated Feb. 2, 1967
4-5	False floor installed in spacecraft	33-72C-3
4-6	Electrical interface photography	139-315C-11
4-7	Special sling verification test	94-205-2
4-8	C/M being moved out of service structure	109-281C-3
4-9	C/M on special sling being lowered to ground	113-276C-1
4-10	C/M being lowered onto trailer	109-282C-6
4-11	C/M moving out of gate at Complex 34	111-286C-4
4-12	Aft heat shield in alignment fixture with crew-compartment heat shield in the foreground	303-651C-2
4-13	C/M in final work station, with all heat shield removed	303-654C-1
4-14	PIB bond room looking toward the North wall	303-654C-2
4-15	PIB bond room looking toward the South wall	303-654C-3
4-16	PIB bonded display area on February 21, 1967	142-322C-3
4-17	PIB bonded display area on March 14, 1967	303-651C-3
4-18	Items removed from S/C 012 and placed on display or in bonded storage.	
4-19	C/M 014 and C/M Mock-up 2	303-651C-5
4-20	AS-204 component arrangement in PIB	SCX-311905

TO: Those Concerned

SUBJECT: Designation of Hardware Removal and Disposition Panel

A Hardware Removal and Disposition Panel has been established to plan and control the removal and disposition of AS-204 spacecraft hardware. The Chairman of the panel will report to the Chairman of the Board of Inquiry who will approve the plan and be kept informed of all removal and disposition actions. The composition of the panel is as follows:

Scott H. Simpkinson	Chairman
Sam Beddingfield	Member
John Moore	Member
Patrick J. Hanifin	Member

The panel may call upon MSC, KSC and NAA for necessary assistance in accomplishing its assigned task.

After an intended removal and disposition action has been planned and approved by the Chairman of the Board of Inquiry, the actual removal and disposal work within the local KSC area will be executed by the Panel through the normal NASA and NAA pad and industrial area organizations. The Panel will provide written instructions (in accordance with APOP procedures) and broad supervision to designated NASA and NAA operations engineers. The designated operations engineers are Ernie Reyes, NASA, and Bruce Haight, NAA. The two designated engineers will arrange for necessary alternates to act for them during extra shift operations. The operations engineers will arrange for access to the pad and scheduling of their work through the Test Supervisor on duty at Launch Complex 34.

The following will govern the operation of hardware removal and disposition:

1. WORK AUTHORIZATION AND DOCUMENTATION

a. TEST PREPARATION SHEET

All work on S C 012 and on the spacecraft GSE that is, or has been connected to the spacecraft, is to be authorized by Test Preparation Sheets (TPS's). The TPS is required to be written and signed by NAA and NASA KSC-SCO Systems Engineering. The TPS is approved by signature of a NASA and a NAA member of the Hardware Removal and Disposition Panel.

(1) A specific and complete statement of the "reason for work" is required on each TPS.

(2) The TPS's are to consist of step-by-step work items written in a detailed manner that will leave no question as to what is specifically required to be done.

(3) No wire bundle electrical connectors are to be disconnected without specific call-out by W/B connector number of the TPS.

(4) All work on the spacecraft is to be accomplished by NAA technicians unless otherwise indicated on the TPS.

(5) All work is to be witnessed by NASA KSC-SCO and NAA Inspection. In addition, it is the responsibility of the HRD panel to make sure that the TPS includes the necessary requirements for official observers when required. Upon completion of each TPS work item, the item is to be stamped by NASA, NAA Inspection indicating completion.

(6) It is required that TPS's which authorized removal of equipment from the spacecraft conclude with the following statement as the last item of work: "Transport equipment to the Pyro Installation Building (PIB) and stock in bonded storage."

(7) Work or examination of the equipment upon removal from the spacecraft must be authorized by a subsequent TPS which is to begin with a statement that authorizes removal of the equipment from the bonded storage room, if required.

(8) Upon completion of work authorized by a TPS, it is required that a summary statement be made on the last TPS mod sheet by the NASA NAA Systems Engineers. The summary statement is to include all items of a significant nature that were observed during the work activity indicating where follow-up action is needed.

b. TPS MODIFICATION SHEETS

Whenever a TPS is required to be modified in order to allow continuance of work activity, a TPS mod sheet is required. The TPS mod sheet is required to be written and signed by NAA and NASA KSC SCO Systems Engineering and the Chairman of the Hardware Removal and Disposition Panel. In addition

(1) A specific and complete statement of the reason for the mod sheet is required on each TPS.

(2) The TPS mod sheet must authorize work that is within the intent of the original TPS.

c. PARTS INSTALLATION AND REMOVAL RECORD

All equipment or material removed from the spacecraft must be documented on a Parts Installation and Removal Record (PIRR). The information noted on the PIRR consists of a part number (if available or applicable); a description of the equipment or material; and time and date of removal.

The PIRR is to be used as noted in the APOP, with Q C required to buy off all entries.

d. PARTS TAG.

All equipment or material removed from the spacecraft must be tagged with a parts tag. The tag is to be attached to the hardware in such a manner that will not affect the condition of the equipment. The tag is to be attached to the container or bag that the material is placed into.

(1) The parts tag is to accompany the equipment or material at all times.

(2) Hardware removal tape:

It is required that prior to, removal of spacecraft hardware; spacecraft system components; disconnect of spacecraft electrical connectors; and, disconnect of spacecraft plumbing lines, a short length of silver-gray tape be attached across the mating line between the hardware to be removed and the adjacent hardware remaining in the spacecraft.

An indexing line is to be then marked on the tape with a black ball-point pen at right angles to, and across, the hardware mating line. A number correlating to the spacecraft hardware removal form entry is also to be written on each end of the tape

The tape is then cut along the hardware mating line and the hardware is removed from the spacecraft

The purpose of the indexing tape is to provide a capability of duplicating the as-was installation as accurately as possible, if and when necessary.

e. APOLLO PRE-FLIGHT OPERATIONS PROCEDURES MANUAL (APOP).

The APOP is the reference document to be used during all work activity on the spacecraft Where differences exist between this memo and the APOP, this memo is the ruling document.

f. A separate investigation TAIR book has been establishing and all TPS's associated with spacecraft work, including GSE, will be retained in the investigation TAIR book. Copies of completed TPS with all deviations, mod sheets, summaries, and other notations, shall be furnished to the Chairman, one to be distributed to the Board

2 WORK SUPPORT

a. OPERATIONS ENGINEERING.

It is required that NASA KSC SCO and NAA Operations Engineers be on duty at the spacecraft on an around the clock basis

(1) The Operations Engineers represent the HRD Panel at the spacecraft and at the PIB They are in charge of the operations at the sites

(2) The Operations Engineers have the responsibility to schedule the daily spacecraft activity in detail They also have the authority to stop work on the spacecraft when deemed necessary

(3) The Operations Engineers are responsible to maintain a spacecraft log, which documents all activity on the spacecraft on an hourly basis A copy of the log is to be provided to the HRD Panel and is to be updated on a daily basis

b SYSTEMS ENGINEERING

It is required that NASA KSC-SCO and NAA SYSTEMS Engineers be on duty on a first shift basis with an evening shift contact specified by name.

c. QUALITY CONTROL.

It is required that NASA KSC-SCO and NAA Inspection personnel be assigned at the spacecraft on an around-the-clock basis. It is required that NASA KSC-SCO and NAA Inspection be assigned in the PIB bonded storage room on an around the-clock basis.

GENERAL.

1. No task will be initiated until those individuals assigned to accomplish the task are thoroughly briefed by the responsible engineer and the Accident Investigator. No disassembly task will be performed on S C 012 until the same task has been performed on S C 014 by the same individual.

2. Access to the spacecraft area will be tightly controlled and will be restricted to those individuals who have a specific task associated with the accident investigation. Specific pad access will be controlled by the test supervisor on duty at Launch Complex 34 through the pad leader at the Command Module.

3. Requests for work in the spacecraft or on any equipment attached to the spacecraft will come from only one source, defined as follows.

THE APOLLO 204 REVIEW BOARD. When a specific task has been defined by the Apollo 204 Review Board, the applicable systems group will be directed by the Hardware Removal and Disposition Panel to prepare a TPS of the task for submittal to the Review Board for approval, if indicated in the task request by the Board. The TPS, a more detailed plan of the task to be accomplished, will contain the applicable signatures of the Hardware Removal and Disposition Panel as discussed in paragraph 1 above.

s Scott H. Simpkinson
Chairman

s John M. Moore
Member

s J. Janokaitis for S. T. Beddingfield
Member

s Patrick J. Hanifin
Member

Modification to Memo "Designation of Hardware Removal and Disposition Panel"

Mr. Dean F. Grimm is assigned as a special representative of the HRD panel to work in the PIB. Mr. Grimm is authorized to sign all TPS and mod sheets for the HRD panel for work in the PIB. The designated operations engineers are Mr. R. G. Covel of NASA, and R. A. Gore of NAA. The two designated engineers will arrange for necessary alternates to act for them during extra shift operations.

Paragraph 1. (a) step 5 is modified to read "All work is to be witnessed by both NASA KSC-SCO and NAA Inspection unless specified otherwise on the TPS".

Paragraph 1. (b) is modified to read "Whenever a TPS is required to be modified in order to allow continuance of work activity, a TPS mod sheet is required. The TPS mod sheet is required to be written and signed by NAA and NASA-KSC-SCO system engineering and the Chairman of the Hardware Removal and Disposition Panel if the Chairman is present. Mr. S. T. Beddingfield is authorized to sign in the chairman's absence. If Mr. Beddingfield is not present then the astronaut on duty can sign."

(1) A specific and complete statement of the reason for the mod sheet is required on each TPS.
(2) The TPS mod sheet must authorize work that is within the intent of the original TPS.
(3) The Chairman of the committee must be appraised of the mod as soon as practical.

The following astronauts will be on duty:

Major Donn Eisele
Captain Stuart Roosa
Major Ed Givens
Captain John F. Swigert

s/ Scott H. Simpkinson
Chairman

s S. T. Beddingfield
Member

s J. M. Moore
Member

s Patrick J. Hanifin
Member

(Sheet 1 of 1)

ENCLOSURE 4-4

ITEM REMOVED FROM S/C 012 AND PLACED ON DISPLAY OR IN BONDED STORAGE

Revised 3/4/67

LOG No.	NOUN	PIRR No.	TPS
1	Bolt Assy	38	001
2	Bolt Assy	36	001
3	Bolt Assy	39	001
4	Bolt Assy	37	001
5	Screw	21	004
6	Splice	19	004
7	Splice	15	004
8	Splice	17	004
9	Splice	18	004
10	Splice	16	004
11	Splice	13	004
12	Mating Hardware	40	001
13	Mating Hardware	42	001
14	Mating Hardware	44	001
15	Mating Hardware	43	001
16	Switch Lock	N/A	N/A
17	Debris	1	001
18	(Oil) Debris	3	004
19	Debris	5	004
20	(Rubber Finger) Debris	6	004
21	Debris	11	004
22	Debris	12	004
23	Debris	14	004
24	Debris	20	004
25	Debris	23	010
26	Debris	25	010
27	Debris	32	001
28	(Filler) Debris	47	003
29	(Filler) Debris	48	003
30	(Filler) Debris	49	003
31	(Filler) Debris	50	003
32	(Tape) Debris	51	010
33	(QC Note) Hardware	--	--
34	B.P.C. FWD Sect.	36-44	001
35	Boost Protect Hatch	--	--
36	Boost Protect Cover	10	004
37	Boost Protect Cover	9	004
38	Boost Protect Cover	7	004
39	Boost Protect Cover	8	004
40	FWD Heat Shield	105	003
41	Switch Checklist	142	012
42	Pilot Logbook	140	012
43	Divider	145	012
44	Debris	147	012
45	Debris	150	012
46	Pack-Pad	146	012
47	(Cover) Divider	144	012
48	(R.H. Couch) L.H. Arm Rest	139	012

49	Back Pad	148	012
50	Handbook	141	012
51	(Pilot) Logbook	138	012
52	Debris	149	012
53	Debris	151	012
54	Paper	143	012
55	Cobra Cable	158	012
56	Small Debris	159	012
57	Small Debris	156	012
58	Small Debris	160	012
59	Small Debris	157	012
60	Small Debris	154	012
61	Cable Run	153	012
62	Loose Debris	155	012
63	Debris	137	012
64	Back Pad	152	012
65	Head Rest (Center)	161	015
66	Hardware for Head Rest Center Couch	162 thru 167	015
67	Head Rest L.H. Couch	168	015
68	Hardware for Head Rest L. H. Couch	169 thru 174	015
69	Head Rest R. H.	175	015
70	Head Rest R.H. Hardware	176 thru 181	015
71	Leg Rest R.H. Couch	182	015
72	Hardware Seat Belt	183	015
73	Screw	184	015
76	Inner Hatch	189	016
77	Outer Hatch	190	016
83	Debris	135	004
97	Hand Controller	187	015
99	CTR Couth Leg Rest	191	015
100	L.H. Couch Leg Rest	221	015
101	Debris	225	015
102	L.H. Crew Couch Hardware	222 thru 224	015
103	Bracket	192 thru 194	015
120	Base Assy	226	015
131	SCS Phase Inverter	256	018
136	Translation Controller	268	022
141	Egress Tun. Hatch	276	023
149	1 Bag Debris	271	015
150	1 Bag Debris	272	015
151	1 Bag Debris	273	015
152	1 Head Rest Pad	275	018
159	Debris	292	018
160	Debris	259	018
161	Pip Pin	295	024
162	02 Hose Umbilical	279	023
163	02 Hose Umbilical	278	023
164	02 Hose Umbilical	280	023
165	Torque Tube	293	024
166	Book	336	012
167	Book	335	012
168	Book	337	012

169	L.H. Crew Couch	358	024
170	R.H. Crew Couch	308	024
171	CNTR Crew Couch Back Rest	301	024
172	R/H ZZ Strut	302	024
173	Z Axis L.H. Strut Assy	354	024
174	R.H. Couch Strut Assy Head	307	024
175	L.H. XX Strut	360	024
181	Pitch RCS 8 PC Access	325	018
192	Debris	359	
193	Bolts	299	024
194	Bolts	298	024
195	Loose Debris	300	024
196	Bolt-Nut Washer	357	024
197	Bolt-Nut 2 Washers	353	024
198	Docking Handle	297	024
199	Bolt-Nut 2 Washers	306	024
200	Bolt-Nut Washer	304	024
201	Pip Pin	296	024
202	Bolt-Nut Washer	356	024
203	Bolt-Nut Washer	305	024
204	Bolt-Nut Washer	355	024
229	Panel 319	339	032
230	Atten. Panel Assy	340	032
232	Insulation from Translation Controller	269	022
233	Comp "C" Scientific	351	011
234	MDAS	348	011
235	(For MDAS) Screws	350	011
236	Food Compt. Door	341	033
237	Garment Compt. Door	366	033
238	Disconnect P101 (in S, C)	349	
240	G&N Panel Screws	367	048
241	Screws	352	048
242	Panel	363	048
243	G&N Front Panel (102)	368	048
249	Water Gun	373	050
250	W G Bracket	374	050
251	Panel	376	050
252	Screws	375	050
254	Panel Assy	383	053
258	Entry "A" Battery	402	060
259	Entry "B" Battery	403	060
260	Post Landing Battery	404	060
261	Batt Mounting Hardware	405	060
262	Suit Ventilator	NA	014
263	Suit Ventilator	NA	014
264	Suit Ventilator	NA	014
265	Suit Ventilator	NA	014
266	Suit Ventilator	NA	014
267	Suit Ventilator	131	014
268	Suit Ventilator	132	014
269	Suit Ventilator	130	014
270	Terminal Board Cover	408	040
272	Screws	409	040
273	Screws	410	040

274	Terminal Board Cover	411	040
275	Terminal Board Cover	413	040
276	Screw	412	040
278	Main Chute	419	067
279	Main Chute	420	067
280	Main Chute	421	067
281	Retention Flap	426	067
282	Retention Flap	421	067
283	Retention Flap	425	067
284	Screws	423	067
285	Screws	422	067
286	Brake Cord	430	067
287	Tyrap's	427	067
288	Nor Mex Cord	429	067
289	02 Analyzer	108	007
290	02 Analyzer	109	007
291	16 mm Sequential Camera	480	081
292	Cable Assy	476	071
293	Spit Cobra Cable	436 & 437	071
294	16 mm Sequential Camera	480	081
295	Sensor Cable & Sensor	483	081
296	Power Cable	484	081
297	Cobra Cable (SS RP)	477 thru 479	071
298	Hydro Meter Control Unit	482	081
299	16 mm Power Cable	481	081
300	Lithium & Charcoal	447	039
301	SCMD Cable Assy	439 & 440	071
302	Sample on Kim Wipe	432	062
303	Attenuation Panel (313)	486	039
304	Bag of LIOH Crystals	450	039
305	Comp. A Odor Absorber	446	039
306	Vacuum Cleaner Bag	485	039
307	Bag of Carbon	449	039
308	Screws	487	039
309	Connector Module	448	069
310	18 ea. Samples	451	079
311	02 Panel	493	063
312	Screws	494	063
313	H20 Panel	491	065
314	Panel R.H. E. B.	489	070
315	Screws	490	070
316	Screws	492	065
317	Metal Chip	506	086
318	L.H. Piece of Wire Switch Guard	507	086
319	R.H. Piece of Wire Switch Guard	508	086
320	Screws (4) Nuts (3) Washers (2)	512	070
321	Cover Plate & Mount Hardware	509	082
322	CO2 Sensor	513	090
323	Bracket CO2 Mount	514	090
324	02 Tank	525	092
325	02 Tank Mounting Hardware	524	092
326	Steam Duct & Mounting Hardware	526 thru 529	094
329	Screws (2 ea.)	558	109
330	Screws (2 ea.)	559	109
331	Tube	555	108

332	Water Glycol in Plastic Bag	622	108
333	Pyro "A" Battery	556	109
334	Pyro "B" Battery	557	109
335	Access Panel	550	100
336	Tube	560	108
340	Screws	644	112
341	Samples	623	079
346	Sector #1 Fairing	652	112
352	Screws	650	112
353	Screws	649	112
354	Screws	670	112
355	Lock	640	112
356	Lock	639	112
357	Lock	638	112
358	Clamps	654	112
359	Elect. Module	651	562
368	Container	656	155
370	Debris Valastat	667	
376	String Tie	665	116
377	Melted Metal	666	116
382	Tension Tie Bolt	668	112
383	Counter Sunk Washer	669	112
384	Spacer	670	112
385	Washer	671	112
386	Nut	672	112
387	Tension Tie Bolt	673	112
388	Counter Sunk Washer	674	112
389	Spacer	675	112
390	Washer	676	112
391	Nut	677	112
392	Tension Tie Bolt	678	112
393	Counter Sunk Washer	679	112
394	Spacer	680	112
395	Washer	681	112
396	Nut	682	112
397	Strap Assy	684	S/C 012/S/C 112
398	Clamp	549	S/C 012/S/C 097
401	Bolt	693	112
402	Ablator Plug	685 thru 687	112
403	Bolt	688	112
405	Panel 24	001	IV S/C 012 C/M 041
406	Panel 24 Hardware 16 Screws	002	IV S/C 012 C/M 041
407	02 Valve Handle	003	IV S/C 012 C/M 041
408	LIOH Canister	007	IV C/M 061
409	Plug Ablator	008	IV C/M 043
410	Shims	012	IV C/M 061
411	Debris	011	IV C/M 061
418	Gas Chromatograph Conn. & Wiring	031	IV S/C 012 C/M 075
419	A-N Tee Bulkhead	019	IV S/C 012 C/M 074
420	Water Line Assy	014	IV S/C 012 C/M 074
421	CO2 Sensor Line	016	IV S/C 012 C/M 074
422	CO2 Sensor Line	017	IV S/C 012 C/M 074
423	Water Line	015	IV S/C 012 C/M 074
424	Delta P Sensor	020 & 023	IV S/C 012 C/M 074

425	Compression Pads	025	S/C 012 C/M 036
426	Diffuser	024	036
427	Bracket	030	036
428	Screws	033	S/C 012 S/C 036
429	Floodlight Hardware	033	032
430	Floodlight Guard Connector	034	032
431	Floodlight Hardware	037	033
432	Floodlight	033	032
433	Floodlight	037	032
434	Watch	046	IV C/M 076
435	Sunglasses	047	IV C/M 076
436	Scissors	048	IV C/M 076
437	Penlight	049	IV C/M 076
438	Survival	050	IV C/M 076
439	Neck Dam & Pocket	051	IV C/M 076
440	Shroud Cutter	052	IV C/M 076
441	Penlight	053	IV C/M 076
442	Inlet Temp. Transducer	045	IV C/M 074
443	Bolts	054	IV C/M 074
444	Debris	061	IV C/M 074
445	Debris	062	IV C/M 074
446	Washers	057	IV C/M 074
447	Debris	065	IV C/M 074
448	Kim Wipes	064	IV C/M 074
449	Debris	063	IV C/M 074
450	ECU	054	IV C/M 074
451	Bolt ECU Mount	055	IV C/M 074
452	Washer ECU	058	IV C/M 074
453	Nuts (ZEA) ECU	059	IV C/M 074
454	Washer ECU	060	IV C/M 074
455	Bolt ECU	066	IV C/M 074
456	Line, Tubing ECU 3/8" OD (Debris)	068	IV C/M 074
457	Line Tubing 1/4" OD (Debris ECU)	069	IV C/M 074
458	LIOH Debris (ECU Removal)	072	IV C/M 074
459	Hardware (ECU Removal)	073	IV C/M 074
460	R.H. (XX Foot) Floodlight	075	IV C/M 059
461	L.H. (XX Foot) Floodlight	074	IV C/M 059
462	Console Floodlight	079	IV 029
463	Console Floodlight	078	IV 028
464	Vial of Liquid (ECU)	082	IV C/M 074
465	Food Compt. B-C-D-E	083	091
466	Plate & Mount Hardware	084	091
467	Panel Assy	087	091
468	Screws, Food Compt. Doubler	085	091
469	Doubler	086	091
470	DSE Recorder	092	046
488	Panel #25	097	IV C/M 025
489	Hardware for Panel #25	102	IV C/M 025
490	R.H. Rendezvous window	108	IV C/M 089
491	Screws, R.H. Rendezvous Window	107	IV C/M 089
492	Ablator Plugs R.H. Rend. Window	103 & 104.	IV C/M 089
493	L.H. Rend Window	106	IV C/M 089
494	Screws, L.H. Rend. Window	105	IV C/M 089
495	Ablator Plugs L.H. Rend Window	093 & 094	IV C/M 089

496	Mylar (Small piece in Bag)	111	S/C 012 S/C 090
497	Signal Conditioner Bolts	113	IV S/C 012 C/M 049
498	Dummy Module	121	IV S/C 012 C/M 049
499	Dummy Module	118	IV S/C 012 C/M 049
500	Dummy Module	120	IV S/C 012 C/M 049
501	Dummy Module	117	IV S/C 012 C/M 049
502	Dummy Module	119	IV S/C 012 C/M 049
503	Power Supply	115	IV S/C 012 C/M 049
504	Spacer	116	IV S/C 012 C/M 049
505	Front Retaining Plate	114	IV S/C 012 C/M 049
506	Front Retaining Panel	129	IV S/C 012 C/M 049
507	Attenuator Module	123	IV S/C 012 C/M 049
508	Amplifier	124	IV S/C 012 C/M 049
509	Attenuator Module	127	IV S/C 012 C/M 049
510	Dummy Module	122	IV S/C 012 C/M 049
511	Attenuator Module	125	IV S/C 012 C/M 049
512	Amplifier Module	126	IV S/C 012 C/M 049
513	Attenuator Module	128	IV S/C 012 C/M 049
514	Front Retaining Plate	130	IV S/C 012 C/M 049
515	Dummy Module	135	S/C 049
516	Attenuator Module	133	S/C 049
517	Dummy Module	136	S/C 049
518	Reg. Module	132	S/C 049
519	Reg. Module	131	S/C 049
520	AMP Module	138	S/C 049
521	AMP Module	134	S/C 049
522	AMP Module	137	S/C 049
523	Data File, Door & Hinge Pin	141	IV C/M 106
524	Spacers - Top & Bottom, Sig. Cond	142 & 143	IV C/M 049
525	J1 Module	152	IV C/M 049
526	J2 Module	151	IV C/M 049
527	J3 Module	150	IV C/M 049
528	J4 Module	149	IV C/M 049
529	J5 Module	148	IV S/C 012 C/M 049
530	J6 Module	147	IV S/C 012 C/M 049
531	J7 Module	146	IV S/C 012 C/M 049
532	J8 Module	145	IV S/C 012 C/M 049
533	J27 Module	153	IV S/C 012 C/M 049
534	J28 Module	154	IV S/C 012 C/M 049
535	J29 Module	155	IV S/C 012 C/M 049
536	J30 Module	156	IV S/C 012 C/M 049
537	J31 Module	157	IV S/C 012 C/M 049
538	J32 Module	158	IV S/C 012 C/M 049
539	J33 Module	159	IV S/C 012 C/M 049
540	J34 Module	160	IV S/C 012 C/M 049
541	J35 Module	168	IV S/C 012 C/M 049
542	J36 Module	167	IV S/C 012 C/M 049
543	J37 Module	166	IV S/C 012 C/M 049
544	J38 Module	165	IV S/C 012 C/M 049
545	J39 Module	164	IV S/C 012 C/M 049
546	J40 Module	163	IV S/C 012 C/M 049
547	J41 Module	162	IV S/C 012 C/M 049
548	J42 Module	161	IV S/C 012 C/M 049
549	Spacer	169	IV S/C 012 C/M 049

550	Spacer.	170	IV S/C 012 C/M 049
551	Screws (SCE Base Plate)	176	IV S/C 012 C/M 049
552	Screws (SCE Base Plate)	174	IV C/M 049
553	SCE Base Plate	175	IV C/M 049
554	Hardware, Washers & Screws	178	IV C/M 090
555	Ablator Plugs	110	IV C/M 090
556	Hardware, Screw & Washer	177	IV C/M 090
557	Ablator, Astro-Sextant	109	IV C/M 090
558	Seal	181	IV C/M 090
559	Seal	182	IV C/M 090
560	S-Band X-Ponder	185	IV C/M 125
561	SCT Crown (Lower)	192	IV C/M 090
562	Screws (4 ea.)	200	IV C/M 090
563	Screws (3 ea.)	190	IV C/M 090
564	SCT Crown Half	193	IV C/M 090
565	Screws (4 ea.)	202	IV C/M 090
566	Sextant Crown Upper Half	195	IV C/M 090
567	SCT Crown, Half Lower	194	IV C/M 090
601	Ablator Plugs	201	IV C/M 090
602	Telescope Cover	184	IV C/M 090
603	Sextant Cover	183	IV C/M 090
604	G&N Computer	203	IV C/M 070
605	Screws	204	IV C/M 070
606	Controller	None	P.I. 031
607	Box of Controllers	None	P.I. 031
608	Panel #2	207	018
609	Panel #2 (Howe)	208	018
610	Panel #1	210	019
611	Hardware for Panel #1	209	019
612	Hand-Hold	215	019
613	Hardware for Hand-Hold	216 & 217	019
614	Connector Octopus Cable	219	IV S/C 012 C/M 130
615	Flight Qual. Recorder	212	IV S/C 012 C/M 045
621	Bolts	787	S/C 012 S/C 161
622	Washers	801	S/C 012 S/C 161
623	Barrel Nuts	802	S/C 012 S/C 161
624	Bolts	800	S/C 012 S/C 161
625	Poly Tape	803	S/C 012 S/C 161
626	Ablator Panel	198	IV C/M 090
627	Q. Felt	231	IV C/M 090
628	Nutplate Strips	230	IV C/M 090
629	Z Strip	221	IV C/M 090
630	Ablative Panel Inner	228	IV C/M 090
631	Insulation Strip	220	IV C/M 090
632	Washers (34 ea.)	197	IV C/M 090
633	Yaw ECA	222	IV C/M 052
634	Display ECA	229	IV C/M 051
635	AUX ECA	238	IV C/M 053
636	Roll ECA	243	IV C/M 055
637	Panel 22	257	IV C/M 023
638	Panel 21	254	IV C/M 022
639	Cam Locks	249	IV C/M 055
640	MDP Panel #3	266	IV C/M 015
641	Hardware for Panel #3	265	IV C/M 015
642	D&C Panel #10	269	IV C/M 002

643	Hardware for Panel #10	268	IV C/M 002
644	D&C Panel 11	272	IV C/M 003
645	Hardware, D&C Panel 11	271	IV C/M 003
646	D&C Panel #16	276	IV C/M 010
647	D&C Panel #15	280	IV C/M 011
648	Hardware, Panel #16	275	IV C/M 010
649	Hardware, Panel #15	279	IV C/M 011
650	Pads	SM 077	S/C 012 161
651	Washer	SM 076	S/C 012 161
652	Safety Wire	SM 073	S/C 012 161
653	Screws	SM 064	S/C 012 161
654	Washer	SM 065	S/C 012 161
655	Cotter Pin	SM 068	S/C 012 161
656	Nut	S/M 069	S/C 012 161
657	Washer	S/M 070	S/C 012 161
658	Screw	S/M 071	S/C 012 161
659	Bolt	S/M 074	S/C 012 161
660	Nut	S/M 075	S/C 012 161
661	Washer	S/M 078	S/C 012 161
662	Debris	S/M 083	S/C 012 161
663	Half Ring	S/M 066	S/C 012 161
664	Support	S/M 079	S/C 012 161
665	Ring	S/M 080	S/C 012 161
666	Seal	S/M 081	S/C 012 161
667	Screws, Mount Panel #12	284	C/M 009
668	D&C Panel #12	285	C/M 009
669	PCM #1	287	IV S/C 012 C/M 047
670	Nut (PCM #1) L.H.	289	IV S/C 012 C/M 047
671	Cold Plate Fuzz	297	IV S/C 012 C/M 047
673	PCM #2	290	IV S/C 012 C/M 048
674	VHF Multiplexer	300	IV C/M 127
675	S-Band Pwr. AMP	301	IV C/M 126
676	Pitch ECA	310	IV C/M 054
677	Main DSKY	312	IV C/M 020
678	Mount Screw for Main DSKY	313	IV C/M 020
679	Shock Washers for Main DSKY	315	IV C/M 020
680	Shock Washer Triangle Main	314	IV C/M 124
681	DSKY	319	IV C/M 124
682	Cold-Plate Fuzz	320	IV C/M 124
683	"C" Band	321	IV C/M 132
684	Cold Plate Fuzz	324	IV C/M 132
685	Panel #5	334	IV C/M 017
686	UHF FM Xmitter	325	IV C/M 131
687	UHF AM Recovery Beacon	330	IV C/M 123
688	UHF AM Rec. Cold Plate Fuzz	330	IV C/M 123
689	Nut UHF AM Rec.	340	IV C/M 123
690	Panel #4 FDAI	337	IV C/M 016
691	Cold Plate Fuzz	339	IV C/M 016
692	Pre-Modulation Processor	345	IV C/M 138
693	P&C Panel #7	349	IV C/M 013
694	Panel #6	352	IV C/M 014
695	Door Assy. & Screws	S/M 155	IV S/M 006
696	#2 Inverter	C/M IV 353	IV C/M 085
697	Bolts Inverter	C/M 354	IV C/M 085

698	Panel S/M -4	S/M 170	IV S/M 006
699	Cover Assy.	S/M 165	IV S/M 006
700	Cover Assy.	S/M 167	IV S/M 006
701	Cover Assy.	S/M 164	IV S/M 006
702	Cover Assy.	S/M 166	IV S/M 006
703	Inverter #1	C/M 355	IV C/M 085
704	Mount Bolts	C/M 355	IV C/M 085
706	#3 Inverter & Hardware	357 & 358	IV C/M 085
716	Splice BPC	359	IV C/M 050
717	Audio Center	363	IV C/M 144
727	Panel #8 Display	375	IV S/C 012
728	Screws	371	IV S/C 012 012
729	Debris	372	IV S/C 012, 012
730	Panel 19	373	IV S/C 012 07
731	Screws	375	IV S/C 012 07
732	Blank Panel #17	376	IV S/C 012 C/M 139
733	Mount Screws Panel #17	377	IV C/M 139
734	Hand Hold	380	IV C/M 005
735	Panel #18	378	IV C/M 005
736	Screws Panel #18	379	IV C/M 005
737	Debris	S/M 146	IV S/M 004
738	Burned Paper	See Note on Q11 Tag	See Note on Q11 Tag
739	D&C Panel #20	390	IV C/M 008
740	Panel #20 Screws	389	IV C/M 008
741	AC Control Box	395	IV C/M 135
742	AC Control Box Mount Bolt	396	IV C/M 135
743	AC Cont. Unit Nut Plate Bracket	394	IV C/M 135
744	Separation Monitors	154	S/M IV 008
745	Debris	171	IV S/M 008
746	Debris	172	IV S/M 008
747	Debris	174	IV S/M 008
748	Debris	173	IV S/M 008
749	Biomed. Ext. Cable	244	IV 018
750	Physio Simulator	244	IV 018
751	Battery, Charger & hardware	397	IV 133
752	Motor Switch C14-56	402	IV 134
753	Motor Switch C14-53	404	IV 134
754	Motor Switch & Hardware C14-52	403	IV 134
755	Cable Clamps	400	IV 134
756	Screws	401	IV 134
757	NAV DSKY	422	IV C/M 092
758	Screws	423	IV C/M 093
759	Eye Piece (Unit 103) Stowage Compt.	C/M 425	IV S/C 012 C/M 093
760	G&N Indicator Panel 105	C/M IV 427	IV S/C 012 C/M 094
761	Mounting Bolts for G&N Panel 105	C/M 428	IV S/C 012 C/M 094
762	W/B Assy. Insul. Rotation Cont.		C/M 049 C/A
763	PSA Tray #9	430	IV C/M 103
764	PSA Tray #10	429	IV C/M 104
765	PSA Tray #2	432	IV C/M 102
766	PSA Tray #1	431	IV C/M 101
767	PSA Tray #4	434	IV C/M 096
768	PSA Tray #3	433	IV C/M 095
769	PSA Tray #5	435	IV C/M 097
770	PSA Tray #6	436	IV C/M 098

771	PSA Tray #7	437	IV C/M 099
772	PSA Tray #8	438	IV C/M 100
773	CDU #1	439	IV C/M 112
774	CDU #2	439	IV C/M 112
775	CDU #3	439	IV C/M 112
776	CDU #4	439	IV C/M 112
777	CDU #5	439	IV C/M 112
778	Signal Conditioner	444	IV C/M 119
779	Panel 101 & Hardware	446	IV C/M 113
780	Rate Gyro	448	IV C/M 056
781	Gyro Attitude	449	IV C/M 057
782	Master Event Seq. Cont.	405	IV C/M 062
783	Master Event Seq. Cont.	413	063
784	Debris	204	IV S/M 005
785	Piece of Glass	202	IV S/M 005
786	Panel 150 Conn. Mount Screws	460	IV C/M 149
798	"C" Band Antenna	461	IV C/M 121
799	Panel C/M 5	463	IV C/M 121
800	Clamps	485	IV C/M 174
801	Clamp	492	IV C/M 174
802	Clamps	469	IV C/M 174
803	Cushion	495	IV C/M 174
804	Clamps	488	IV C/M 174
805	Clamp	490	IV C/M 174
806	Clamp	482	IV C/M 174
807	Clamp	483	IV C/M 174
808	Life Preserver	473	IV C/M 174
809	Screws	470	IV C/M 174
810	Screws	489	IV C/M 174
811	Screws	486	IV C/M 174
812	Screws	487	IV C/M 174
813	String Tie	494	IV C/M 174
814	Clamp	491	IV C/M 174
815	Clamp	493	IV C/M 174
816	Unidentified Material	478	IV C/M 174
817	Clamp	484	IV C/M 174
818	Teflon Wrapping	471	IV C/M 174
819	Screw C/M 6	470	IV C/M 121
820	Clamp Set	456	IV C/M 121
821	Metal Bead	465	IV C/M 171
822	Screws	455	IV C/M 171
823	Rod	472	IV C/M 121
824	T/B Cover	481	IV C/M 174

825	Panel 150 String Tie	IV C/M 149
826	Screws C M 18	IV C/M 121
827	Felt	IV C/M 121
828	G.Felt	IV C M 121
831	Mounting Screws	IV C M 145
832	Mount Screws	IV C/M 145
833	Panel 150 Pyro Bat C B	IV C/M 149
834	Adhesive	MA 008
835	Sample Bottle	S/C 017
836	Stowage Door Vacuum Clean	IV C M 145
837	Panel 201	IV C/M 145
838	Panel 202 Waste Management	IV C M 145
839	Screws for Pnl. 202	IV C M 145
840	Bolts, Heat Shield	IV C M 093
841	Scissors & Suit Debris	IV C M 147
842	Suit Debris	IV C M 147
843	Sun Glasses	IV C M 147
844	Case - Sun Glasses	IV C M 147
845	Dosimeter	IV C M 147
846	Molten Metal	IV C M 147
847	Molten Metal & Wire	IV C M 147
848	Molten Metal	IV C M 147
849	Metal	IV C M 147
850	Metal	IV C M 147
851	Tubing	IV C M 147
852	Screws & nuts	IV C M 147
853	Clamps	IV C M 147
854	Asbestos Insulation	IV C M 043
855	Piece of Fiberglass	IV C M 043
856	Shims	IV C M 043
857	Fiberglass Tape	IV C M 043
858	Q Felt	IV C M 121
859	RF Cable Clamp	IV C M 121
860	J87 Mounting Hardware	IV C M 121
861	AFT Heat Shield	IV C M 043
862	Cable Clamps	IV C M 121
863	Cable Tray	IV C M 121
864	Bolts for Cable Tray	IV C M 121
865	Bolts for Cable Tray	IV C M 121
866	Samples L H Crew Couch L H Foot Rest	C M MA 007
867	Safety Wire	IV C M 062
868	Cable Tray Assy., With Hardware	IV C M 121
869	Air Diffuser & Cable Tray	IV C M 121
871	Cable Tray & Hardware	IV C M 121
872	Debris from above Cable Tray	IV C M 121
873	Insulation CM6	IV C M 140
874	Heat Sink	IV C M 140
875	Bolts Heat Sink Mounting	IV C M 140
876	Wire Twisted Pair	IV C M 178
877	Roll Engine CW	IV C M 140
878	Panel & Engine Roll CCW	IV C M 121

879	Pencil, Debris Red Matl.	603	C/M 073
880	Q. Felt	601	IV C/M 121
881	Bolts	579	IV C/M 140
882	Q. Felt	584	IV C/M 043
883	Cable Tray & Hardware	605	IV C/M 121
884	Cable Tray & Hardware	602	IV C/M 121
885	Cable Tray & Hardware	598,600	IV C/M 121
886	Cable Tray	595	IV C/M 121
887	Q. Felt	584	IV C/M 043
888	Blanket CCW Engine	606	IV C/M 140
889	Blanket CW Engine	611	IV C/M 140
890	Heat Sink	583	IV C/M 140
891	Engine Bolts	614	IV C/M 140
892	Hardware	599	IV C/M 121
893	Bolts	613	IV C/M 140
894	Blanket "A"	592	IV C/M 140
895	Blanket "B"	593	IV C/M 140
896	Panel & Engine CW Roll	616, 477	IV C/M 140
897	Q. Felt	594	IV C/M 043
898	Engine, Yaw System "B"	590	IV C/M 140
899	Engine, Yaw System "A"	591	IV C/M 140
900	Engine CCW	615	IV C/M 140
901	Bolts	589	IV C/M 589
902	Cable Tray & Hardware	604	IV C/M 121
903	Q. Felt	584	IV C/M 140
904	Cable Tray & Hardware	617	IV C/M 121
905	Blanket & + Yaw	629	IV C/M 140
906	Blanket & + Yaw	628	IV C/M 140
907	Hardware	637	IV C/M 140
908	Nuts & Washers	547, 548	IV C/M 121
909	Engine + Pitch System A	644	IV C/M 140
910	Engine + Pitch System B	645	IV C/M 140
911	Engine + Yaw System A	635	IV C/M 140
912	Engine + Yaw System B	634	IV C/M 140
913	Protective Cover "Pitch"	646	IV C/M 140
914	Bolts & Washers	643	IV C/M 140
915	Steam Duct	549	IV C/M 121
916	Debris	549	IV C/M 121
917	+ Pitch Engine Blankets	638	IV C/M 140
918	RCS Cont. Box C19A1	673	IV C/M 067
919	Screws & Washers	674	IV C/M 067
920	Air Vent	672	IV C/M 121
921	Washer	659	IV C/M 121
922	Nuts	658, 670	IV C/M 121
923	Washer	671	IV C/M 121
924	RCS Cont. Box	669	IV C/M 068
925	RCS Motor SW Assy.	697	IV C/M 069
926	Clamps & Screws	711, 712	IV C/M 069
927	Debris	--	IV C/M 069
928	- Pitch Engines A&B and Mounting Struct	721	IV C/M 140
929	Mounting Hardware - Pitch	720	IV C/M 140
930	Insulation & Blanket	627	IV C/M 140
931	Cable Clamp	715	IV C/M 121

932	Bracket	754	IV C/M 121
933	Screws	753	IV C/M 121
934	Screws for RCS Cont. Box	670	IV C/M 068
935	Screws for H20 Water Panel	492	S/C 012 065
936	Water Glycol	--	IV C/M 121
937	Washers, Bolt, Spacer	750, 751, 752	IV C/M 121
938	Nut Plate Assy.	741	IV C/M 121
939	Bolts Stringer #5	732	IV C/M 121
940	C/C Heat Shield	742	IV C/M 121
941	Q. Felt	648	IV C/M 121
942	Cobra Cable	762	C/M C/A 065
943	Wire	767	IV C/M 179
944	Hardware	764 thru 766	IV C/M 179
945	Hardware	710, 713, 714	IV C/M 121
946	Bonding Jumpers	761	IV C/M 121
947	Cotter Pins	676	IV C/M 121
948	Bolts	624	IV C/M 121
949	Debris	760	IV C/M 121
950	Hardware and Mounting	726	IV C/M 121
951	Washers	626	IV C/M 121
952	Safety Wire Umbilical	763	IV C/M 121
953	Spacer	625	IV C/M 121
954	Scanning Telescope	768	IV C/M 151
955	Optics Shroud Assy.	770	IV C/M 111
956	Screws Optics Mount	769	IV C/M 111
957	D&C Panel G&N	771	IV C/M 118
958	Screws D&C Mount	773	IV C/M 118
959	Samples		IV C/M 099
960	Soot Samples		MA C/M 008
961	Soot Sample		MA C/M 008
962	Ring Phenolic	783	IV C/M 176
963	Ring Teflon	782	IV C/M 176
964	Ring Phenolic	784	IV C/M 176
965	Seal Teflon Sxt.	781	IV C/M 176
966	Bolts	791	IV C/M 126
967	Nav. Base Optics Assy.	795	IV C/M 176
968	IMU	780	IV C/M 176
969	Bolts	785	IV C/M 176
970	Bolts w. washers	796	IV C/M 176
971	Control Elec. Assy.	790	IV C/M 176
972	USBE Front Panel	814	IV C/M 168
973	O_2 Surge Tank	812	S/C 012 S/C 095
975	O_2 Valve Assy.	804	S/C 012 IV C/M 153
976	Hardware Surge Tank	814	IV C/M 153
977	Outlet Line Surge Tank	800	IV C/M 153
978	Surge Tank ISO Valve Inlet Line	799	IV C/M 153
979	Bolts	807	IV C/M 153
980	Tube Assy	816	IV C/M 153
981	O_2 Relief Valve	808	IV C/M 153
982	Water Glycol Valves	834	IV C/M 153
983	Hand Controller Cable	833	IV C/M 122
984	Tee (Adapter)	830	IV C/M 122
985	Valve	826	IV C/M 153
986	Cobra Cable	832	IV C/M 122

987	Cobra Cable	829	IV C/M 122
988	Cobra Cable	831	IV C/M 122
989	Mtg. Brkt. Hardware	828	IV C/M 153
990	CMC "Y" Wire Assy	839	IV C/M 193
991	Press-Xducer 02 Surge Tank	809	IV C/M 153
992	Box Assorted Items		PI 047
993	Panel 316 C23Z2	842	IV C/M 107
994	Hand (Long) Hold Assy	843	IV C/M 084
995	Short Hand Hold Assy	844	IV C/M 084
996	LM Ret. Cont. Mount	846	IV C/M 084
997	G&N Eye Relief	845	IV C/M 084
998	Loop Clamp G&N.	817	IV C/M 180
999	Screws Panel 316	840	IV C/M 107
1000	Bracket & Hardware	822	IV C/M 192
1001	Wire Harness Cover	824	IV C/M 192
1002	ELSC	866	IV C/M 064
1003	ELSC	861	IV C/M 065
1004	Shim, Toe Cap	884	IV C/M 120
1005	Screw	880	IV C/M 120
1006	Screw & Nuts	881	IV C/M 120
1007	PSA Toe Plate	883	IV C/M 190
1008	Thermal Interface Mat'l.	847	IV C/M 120
1009	Wire Covering	852	IV C/M 192
1010	Screws	879	IV C/M 180
1011	Connectors w Screws	879	IV C/M 180
1012	Clamps & Hardware	885	IV C/M 120
1013	CDV Frame Assy	879	IV C/M 180
1014	Stringers		IV C/M 121
1015	PSA & Connector Assy	873	IV C/M 180
1016	Panel 209 Invert Sync	886	IV C/M 183
1017	Bracket for Panel 209 Invert Sync	904	IV C/M 183
1018	Screws Panel 209 Mount	887	IV C/M 183
1019	Panel 208 Invert Sync Box	903	IV C/M 184
1020	Screws Panel 208 Mount	902	IV C/M 184
1021	Plate Below Frame R. H Side	910	IV C/M 179
1022	Panel 203 & Hardware	905 & 907	IV C/M 169
1023	Attenuator Panel	908	IV C/M 169
1024	Atten. Panel Mtg. Screws	909	IV C/M 169
1025	Relay Box (VDL)	913	IV C/M 198
1026	PCVB & Hardware	918	IV C/M 066
1027	Heat Shield Sample	930	IV C/M 191
1028	Aft Heat Shield Sample	928	IV C/M 191
1029	TV Camera	931	IV C/M 082
1030	Wire Harness	934	IV C/M 081
1031	DSEA Voice Tape Recorder	933	IV C/M 081
1032	Film Magazine 16 mm	480	C/M MA 013
1033	Panel 100	936	IV C/M 027
1034	Screw for Pnl 100	934	IV C/M 027
1035	Guard Plate Assy	941	IV C/M 026
1036	Panel 200	940	IV C/M 026
1037	Hardware for Pnl 200	937, 943, 942	IV C/M 026
1038	Guard Plate Assy	947	IV C/M 182
1039	C14A8 Phase Correcting Box	946	IV C/M 182
1040	Screws (C14A8)	944	IV C/M 182

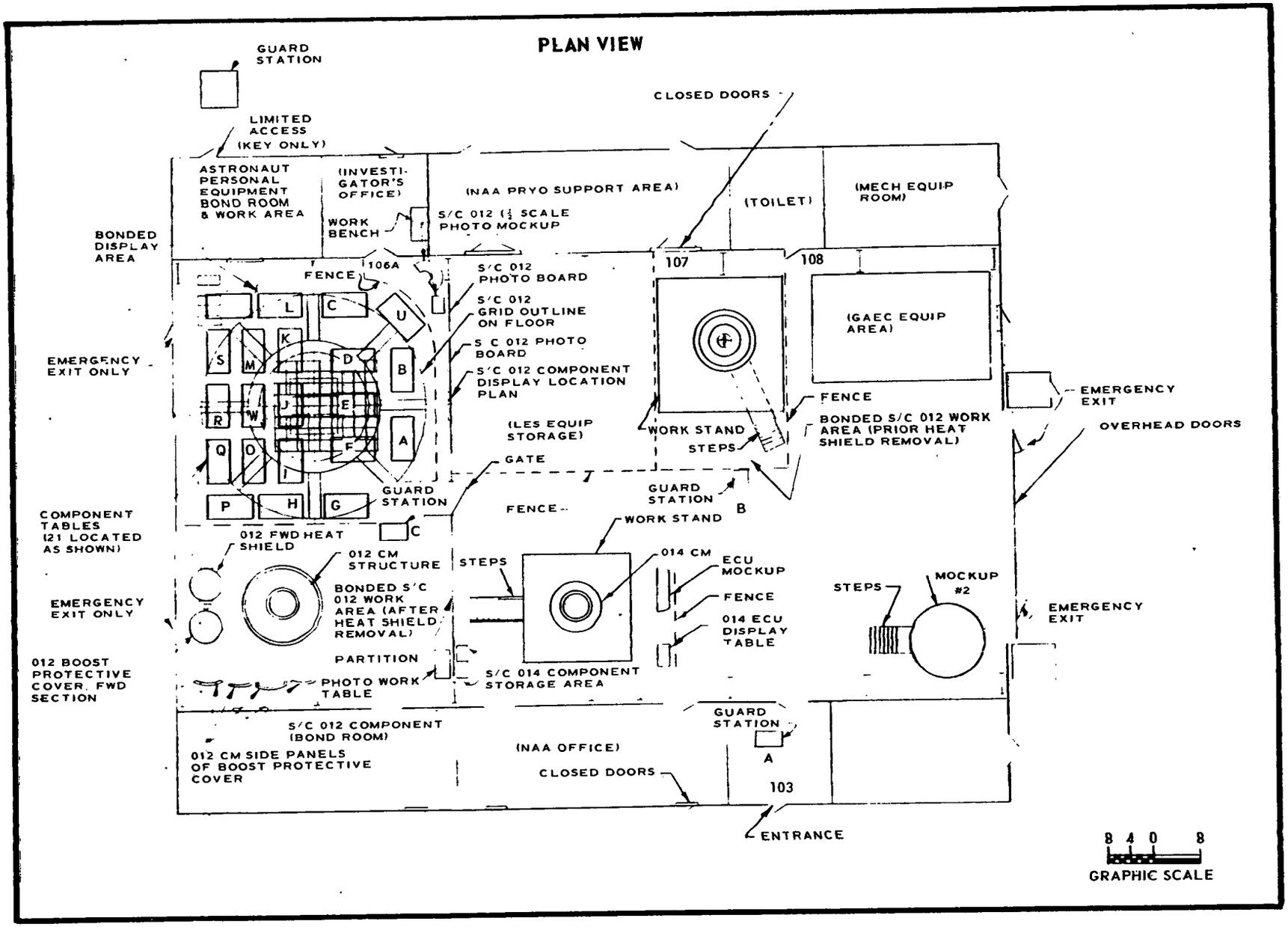
1041	Fuse Box	949	IV C/M 185
1042	Fuse Box Bolts & Tee Bracket	952	IV C/M 185
1043	Fuse l x Mtg. Bolts	948	IV C M 185
1044	R.H. Control Unit Anti Rotational Casing	958	IV C/M 188
1045	Control Level Knobs	954	IV C/M 188
1046	Anti Rotational Casing	953	IV C/M 188
1047	Cabin Press Control Lever Support	955	IV C/M 188
1048	Cabin Press Control Unit	956	IV C/M 188
1049	R.H. Control Assy	957	IV C/M 188
1050	RIV Cabin Press	960	IV C/M 188
1051	2 Brkts. Cover	927	IV C/M 175
1052	Screws	920	IV C/M 175
1053	Mtg. Hdwr.	925	IV C/M 175
1054	Mtg. Screws	926	IV C/M 175
1055	J185 Plug	961 & 962	IV C/M 179
1056	Hardware	964	IV C/M 179
1057	Harness Brkts.	965	IV C/M 179
1058	Sleep Adapter	983	IV C/M 116
1059	Sleep Adapter	984	IV C/M 116
1060	CWG Adapter Cable	986	IV C/M 116
1061	CWG Adapter Cable	985	IV C/M 116
1062	D.C. Pwr. Control Box	981	IV C M 195
1063	Screws for D. C. Pwr.	980	IV C/M 195
1064	C14A13 Cont. Box Uprighting	990	IV C/M 194
1065	Screws for C14A13 Mount	989	IV C/M 194
1067	Hatch Tool	1002	IV C. M 072
1068	Vacuum Cleaner Assy	991	IV C. M 078
1069	Louver Cabin Air Valve	1001	IV C/M 189
1070	Xducer Front Cabin Air Valve Louver	1003	IV C. M 189
1071	Suit Hose Connector	1004	IV C M 189
1072	Suit Hose Connector	1004	IV C/M 189
1073	Heat Exchanger	1010	IV C. M 189
1074	Screws	1011	IV C/M 192
1075	Suit Host Contr.	1016	IV C. M 189
1076	Contr. Hdwre.	1016	IV C M 189
1077	Access Panel	1022	IV C M 189
1078	Utilization Panel	1018	IV C M 181
1079	Clamp & Hardware	1021	IV C. M 181
1080	Honeycomb		IV C M 191
1081	Cabin Press Xducer	999	IV C M 189
1082	Screws Cobra Cable	1000	IV C M 189
1083	Xducer Cabin Temp	1023	IV C M 189
1084	Closure Valve	1026	IV C M 189
1085	Amplifier Xducer Cabin Temp.	1013	IV C. M 189
1086	Fans Cabin Air	1025	IV C M 189
1087	Cabin Temp. Controller	1012	IV C M 189
1088	Xducer Cabin Temp.	1024	IV C M 189
1089	Debris	1025	IV C/M 189
1090	Panel #13	1034	IV C M 004
1091	Panel 13 Hardware	1033	IV C M 004
1092	Panel 23 Hardware	1035	IV C M 021
1093	Panel 23	1038	IV C M 021
1094	Panel 26	1042	IV C M 024

1095	Panel 26 Hardware	1039	IV C/M 024
1096	Mtg. Brkt. C151A52	1043	IV C/M 205
1097	Cable Clamp	1044	IV C/M 205
1098	Motor SW Panel C14A3	1045	IV C/M 205
1099	Helmet Bag	1047	IV C/M 080
1100	Helmet Bag	1046	IV C/M 080
1101	Helmet Bag	1048	IV C/M 080
1102	Close-Out Panel	1049	IV C/M 001
1103	Potable Water Assy.	1053	IV C/M 001
1104	LEB Hardware	1057	IV C/M 179
1105	Hardware Data Tray	1058	IV C/M 192
1106	Access Panel 206	1059	IV C/M 206
1107	1/4 "Snap On" Socket	1063	IV C/M 192
1108	LEB Hardware & Brackets	1062	IV C/M 192
1109	Wire Harness Wrap	1064	IV C/M 192
1110	Clamps	1065	IV C/M 192
1111	Xducer Mount Hardware	1068 & 1069	IV C/M 201
1112	Press Xducer	1070	IV C/M 201
1113	Press Xducer	1068	IV C/M 201
1114	Press Xducer	1069	IV C/M 201
1115	Signal Cond.	1067	IV C/M 201
1116	Pwr. Dist. Box	1083	IV C/M 187
1117	Hardware Bolts & Nuts Washers	1084	IV C/M 187
1118	Pwr. Dist. Box	1080	IV C/M 187
1119	Accelerometer	1089	IV C/M 202
1120	Accelerometer	1090	IV C/M 202
1121	Panel 204	1094	IV C/M 202
1122	Sig. Conditioner	1072	IV C/M 202
1123	accelerometer	1092	IV C/M 202
1124	Sig. Conditioner	1075	IV C/M 202
1125	Sig. Conditioner	1071	IV C/M 202
1126	Current Limiter	1086	IV C/M 186
1127	Current Limiter	1087	IV C/M 186
1128	Current Limiter Hardware	1088	IV C/M 186
1129	Washer	1103	IV C/M 192
1130	Hardware Clamps Brackets	1102	IV C/M 192
1131	Hardware	1114	IV C/M 038
1132	Hardware	1111, 1112, 1113, 1115	IV C/M 038
1133	Elect. Cable Wrapping	1126	IV C/M 192
1134	Check Valve	1128	IV C/M 038
1135	Relief Valve	1107	IV C/M 038
1136	Shut-Off Valve	1108	IV C/M 038
1137	W/G Line Insulation	1129	IV C/M 038
1138	Shut-Off Valve 2.28DE	1119	IV C/M 038
1139	Relief Valve 2.2AB	1118	IV C/M 038
1140	Water Glycol Sample	1120	IV C/M 038
1141	Water Glycol Sample	1130	IV C/M 038
1142	Temp. Sensor	1110	IV C/M 038
1143	Check Valve 22.1	1109	IV C/M 038
1144	S. TXY Canister	1132	IV C/M 073
1145	Stowage Canister	1134	IV C/M 073
1146	TV Flex Coil Cord	1137	IV C/M 208
1147	Debris	1139	IV C/M 073

1148	Debris	1138	IV C/M 073
1149	COAS	1136	IV C/M 073
1150	COAS Bulb	1135	IV C/M 073
1151	Hardware Cover S & T	1131	IV C/M 073
1152	Hardware Canister	1138	IV C/M 073
1153	Clamps & Screws	1140	IV C/M 209
1154	Storage Box	1141	IV C/M 200
1155	Shelf, Vacuum Cleaner	1099	IV C/M 200
1156	SCS J Box	1148	CA C/M 231
1157	Knobs Cont. WMS Panel	1149	IV C/M 200
1158	Panel & Hardware WMS	1150	IV C/M 200
1159	Panel & Hardware WMS	1151	IV C/M 200
1160	Vert. Angle & Hardware	1142	IV C/M 200
1161	Horiz. "T" & Hardware	1143	IV C/M 200
1162	Back-Up Valve	1154	IV C/M 200
1163	Back-Up Valve	1157	IV C/M 200
1164	UDL Line	1158	IV C/M 200
1165	Line, Fr. WMS Sel. Valve	1160	IV C/M 200
1166	Valve Selector WMS	1161	IV C/M 200
1167	Line Assy	1162	IV C/M 200
1168	Valve Check	1164	IV C/M 200
1169	Clamp	1165	IV C/M 200
1170	Line Assy	1174	IV C/M 200
1171	Line Assy Waste Man.	1171	IV C/M 200
1172	Blower Waste Management	1170	IV C/M 200
1173	Urine Dump Lock	1163	IV C/M 200
1174	Check Valve	1172	IV C/M 200
1175	Check Valve	1173	IV C/M 200
1176	ECU P-33 Connector	1177	IV C/M 209
1177	ECU P-34 Connector	1178	IV C/ M 209
1178	Events Conditioner	1179	IV C/M 117
1179	Canister Med. Science	1185	IV C/M 117
1180	Events Conditioner Hardware	1180	IV C/M 117
1181	Bolts for J-80 J Box	1182	IV C/M 117
1182	RF Coax Switch	1186	IV C/M 203
1183	Hardware for RF Coax Switch	1188	IV C/M 203
1184	Dust Cap and Tape	1204	IV C/M 162
1185	Sample W/G	1294	IV C/M 207
1186	Sample W, G	1294	IV C/M 207
1187	Debris	1226	IV C/M 211
1188	Debris	1224	IV C/M 211
1189	Debris	1223	IV C/M 211
1190	Debris	1225	IV C/M 211
1191	Debris	1229	IV C/M 211
1192	Debris	1222	IV C/M 211
1193	Debris	1230	IV C/M 211
1194	Debris	1231	IV C/M 211
1195	Debris	1219	IV C/M 211
1196	Debris	1232	IV C/M 211
1197	Debris	1227	IV C/M 211
1198	Debris	1228	IV C/M 211
1199	Debris	1221	IV C/M 211
1200	Debris	1220	IV C/M 211
1201	Debris	1234	IV C/M 211

1202	Debris	1233 IV C/M 211
1203	Debris	1236 IV C/M 211
1204	RF Conn. Loc. Clamps	1237 IV C/M 203
1205	C and W Detection Unit	1238 IV C/M 006
1206	Hardware for C and W Detection Unit	1203 IV C/M 006
1207	Access Panel	1239 IV C/M 006
1208	J11 Brkt. Hardware	1241 IV C/M 006
1209	J9 Brkt. Hardware	1240 IV C/M 006
1210	Sample #1	MA C/M 026
1211	Sampe #2	MA C/M 026
1212	Sample #3	MA C/M 026
1213	Sample #4	MA C/M 026
1214	Dye Marker	1242 IV C/M 112
1215	Dye Marker Swimmer	1247 IV C/M 112
1216	End Cap Dye Marker	1243 IV C/M 112
1217	Circuit Interrupter	1249 IV C/M 152
1218	Circuit Interrupter	1248 IV C/M 152
1219	Tube Sample	1250 IV C/M 190
1220	Tube Sample	1251 IV C/M 190
1221	Tube Sample	1252 IV C/M 190
1222	Tube Sample	1253 IV C/M 190
1223	Tube Sample	1254 IV C/M 190
1224	Tube Sample	1255 IV C/M 190
1225	Tube Sample	1256 IV C/M 190
1226	Tube Sample	1257 IV C/M 190
1227	Tube Sample	1258 IV C/M 190
1228	Brkt. Bundle Clamp	1259 IV C/M 192
1229	Line End "A"	1264 IV C/M 190
1230	Brkt. Assy. & Hardware	1268 IV C/M 190
1231	Tubing End "B"	1265 IV C/M 190
1232	Tubing H20 Waste Tank	1269 IV C/M 190
1233	Tube End "C"	1266 IV C/M 190
1234	Tube End "D"	1267 IV C/M 190
1235	Bracket	1270 IV C/M 179
1236	Clamp Section	1261 IV C/M 192
1237	Hdwre. & Clamps	1263 IV C/M 192
1238	Teflon & Spot Tie	1262 IV C/M 192
1239	Food Compt. "A"	1271 IV C/M 105
1240	Wire from C28 AR173	1272 IV C/M 179
1241	G & N Loose Equipment	1276 IV C/M 115
1242	Test Panel	1277 IV C/M 115
1243	Door Scientific D	1275 IV C/M 115
1244	Panel	1278 IV C/M 115
1245	Door, Assembly RHEB	1281 IV C/M 141
1246	Door, Assembly RHEB	1280 IV C/M 141
1247	Door, Assembly RHEB	1279 IV C/M 141
1248	Door, Assembly RHEB	1282 IV C/M 141
1249	ECS Restrictor Assembly	1291 IV C/M 086
1250	Filter Assembly	1292 IV C/M 086
1251	Filter Assembly	1293 IV C/M 086
1252	Check Valve	1294 IV C/M 086
1253	Check Valve	1295 IV C/M 086
1254	Line Assembly	1296 IV C/M 086
1255	Line Assembly	1297 IV C/M 086

1256	Line Assembly	1298	IV C/M 086
1257	Line Assembly	1299	IV C/M 086
1258	Clamp	1300	IV C/M 086
1259	Hardware	1301	IV C/M 086
1260	02 Line	1302	IV C/M 086
1261	Oxygen Restrictor Assembly	1303	IV C/M 086


PLAN VIEW
GUARD STATION
LIMITED ACCESS (KEY ONLY)
CLOSED DOORS
ASTRONAUT PERSONAL EQUIPMENT BOND ROOM & WORK AREA
(INVESTI-GATOR'S OFFICE)
(NAA PRYO SUPPORT AREA)
(TOILET)
(MECH EQUIP ROOM)
WORK BENCH
S/C 012 (1/2 SCALE PHOTO MOCKUP
BONDED DISPLAY AREA
FENCE
106A
107
108
S/C 012 PHOTO BOARD
S/C 012 GRID OUTLINE ON FLOOR
S C 012 PHOTO BOARD
S/C 012 COMPONENT DISPLAY LOCATION PLAN
(GAEC EQUIP AREA)
EMERGENCY EXIT ONLY
EMERGENCY EXIT
FENCE
BONDED S/C 012 WORK AREA (PRIOR HEAT SHIELD REMOVAL)
WORK STAND
STEPS
OVERHEAD DOORS
(LES EQUIP STORAGE)
GATE
GUARD STATION
B
FENCE
WORK STAND
COMPONENT TABLES (21 LOCATED AS SHOWN)
012 FWD HEAT SHIELD
C
012 CM STRUCTURE
STEPS
014 CM
ECU MOCKUP
FENCE
014 ECU DISPLAY TABLE
STEPS
MOCKUP #2
EMERGENCY EXIT
EMERGENCY EXIT ONLY
BONDED S/C 012 WORK AREA (AFTER HEAT SHIELD REMOVAL)
PARTITION
012 BOOST PROTECTIVE COVER, FWD SECTION
PHOTO WORK TABLE
S/C 014 COMPONENT STORAGE AREA
S/C 012 COMPONENT (BOND ROOM)
012 CM SIDE PANELS OF BOOST PROTECTIVE COVER
(NAA OFFICE)
GUARD STATION
A
CLOSED DOORS
103
ENTRANCE
8 4 0 8
GRAPHIC SCALE

END

DATE

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FEB 3 1982

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REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-TM-X-64461) REPORT OF APOLLO 204 REVIEW, BOARD APPENDIX D, PANEL 5 Final Report (NASA) 66 p CSCL 22A N74-71940

Unclas 00/99 15864

APPENDIX D

PANEL 5

APOLLO SPACECRAFT

The spacecraft consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated KSCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

REPORT OF PANEL 5
ORIGIN AND PROPAGATION OF FIRE
APPENDIX D-5
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

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ORIGIN AND PROPAGATION OF FIRE

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Origin and Propagation of Fire Panel, 5. The task assigned for accomplishment by Panel 5 was prescribed as follows:

> Conduct inspections, chemical analyses spectrographic analysis of spacecraft, parts or rubble, or use any other useful techniques to establish point of fire origin, direction and rate of propagation, temperature gradients and extremes. The nature of the fire, the type of materials consumed, the degree of combustion shall be determined.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Origin and Propagation of Fire Panel:

*Mr. F. J. Bailey, Chairman, Kennedy Space Center (KSC), NASA

Mr. J. Craig, Manned Spacecraft Center (MSC), NASA

Mr. I. Pinkel, Lewis Research Center (LeRC), NASA

Mr. A. Krupnick, Marshall Space Flight Center (MSFC), NASA

Mr. T. Horeff, Federal Aviation Agency (FAA)

Dr. H. Carhart, Naval Research Laboratory (NRL)

Mr. J. Leak, Civil Aeronautics Board (CAB)

Mr. J. Yardley, McDonnell Company, St. Louis, Mo.

2. COGNIZANT BOARD MEMBER:

Dr. R. W. Van Dolah, Bureau of Mines, U.S. Department of Interior, Board Member, was assigned to monitor the Origin and Propagation of Fire Panel.

C. PROCEEDINGS

1. DETAILED OBJECTIVES:

The detailed objectives of Panel 5 are listed as follows:

a. Determine from direct visual examination of the physical evidence available at the scene of the fire, what facts can be established relative to the point of origin and the direction and method of propagation of the fire.

b. Recommend any procedures, analyses, or tests that would be expected to establish additional pertinent facts from this physical evidence.

c. Review or monitor the performance of these procedures, analyses or tests. Review the results obtained and report any additional facts established.

d. Recommend any further action deemed appropriate.

In the performance of this task, the Panel will keep itself informed as to the data being obtained by the other Panels and will make appropriate use of all pertinent information being generated by these Panels. The Panel will give verbal reports of its results to the Board at frequent intervals and will develop its studies with the continuing advice of the Board. It will report its final results and conclusions in writing to the Board.

2. APPROACH:

Acting under the direction of the Board, Panel 5 considered the related problems of identifying the ignition source and establishing the fire propagation course through the Command Module (C/M). While the main course of the fire can be reconstructed with confidence from the available evidence, the identification of the ignition source is more difficult and will require supporting facts derived from relevant laboratory studies. While several ignition sources remain suspect, none have been confirmed and perhaps no positive ignition source will be found because the evidence may have been destroyed by the fire.

This report treats the subject of ignition sources and fire development separately since each is controlled by different factors.

3. IGNITION SOURCE:

In the conduct of its work, the Panel adopted the following points of view regarding the identification of the origin of the fire:

a. A determination of the origin of a fire requires identification of the first combustible to burn and its ignition source. Proof that the identification is correct requires that the following checks be made:

(1) The observed fire damage following the ignition can be demonstrated or explained.

(2) The expected rate of the spread of fire and associated pressure rise in the C/M is consistent with pressure and temperature indications recorded during the event.

(3) All other combustibles are eliminated as being the first combustible to burn by virtue of one or more of the following points:

(a) No available source to ignite the combustible.

(b) Possible ignition source is known to be inactive at time of fire start.

(c) If ignited, fire would not propagate from the combustible to produce the observed damage and the increase of pressure in the C/M.

b. Information was gathered during the post-fire study of the C/M to facilitate the determination of the fire origin according to this plan.

c. Ignition sources pertinent to the C/M include:

(1) Electric arcs and sparks

(2) Electrostatic sparks

(3) Friction sparks

(4) Spontaneous combustion through the gradual heating of combustible by slow oxidation in thermally insulated zones.

The investigation included an appraisal of these modes of ignition where they are applicable.

d. Areas of the C/M containing electrical lines and fluid-bearing tubes in close proximity have burned and melted away. Therefore, the actual components involved in the start of the fire may no longer exist. Every effort was made to identify original components from the ash to assess their role in the fire start. Careful examination of these components along with related records of electrical, fluid flow and fluid pressure anomalies were undertaken to establish which of the damaged systems were abnormal shortly before the fire began and which damage was a consequence of the fire.

e. It is typical of fires involving energized electrical systems for arcs and short circuits to develop during the fire as insulation fails. Therefore, if the ignition source is electrical, only those electrical arcs, sparks, and short circuits that preceded the fire are meaningful in establishing the probable fire origins. The section of this report containing observations and analyses presents that portion of the investigation devoted to sorting out these questions.

f. One example of wire insulation damage that may have preceded the fire is illustrated by photograph (Enclosure 5-2). The circled area in the figure shows a wire bundle which lies over a bare stainless steel tube that is a waste management line. This tube lies below the aluminum access door to the carbon dioxide and odor absorber compartment of the Environmental Control Unit (ECU). When the door was opened and closed, its lower edge may have chafed the wires of this bundle. There was no chafing guard for the Teflon insulation on these wires; this made them vulnerable to damage. Teflon is particularly vulnerable to cold flow and mechanical damage. Wire splices close by increased the susceptibility of the insulation to chafing damage. Careful investigation showed that the splices were too far from the chafing point to matter. Combustibles in the form of polyurethane foam and nylon netting lay close to the electrical arcs and sparks that would occur if the Teflon insulation were defeated. The same wires damaged by fire are shown encircled in photograph (Enclosure 5-3).

g. As of March 29, 1967, most of the electrical wiring in the C/M had been exposed to view. The ECU had been disassembled. Units containing electrical and electronic gear were examined to see if internally generated flames or incendiary arcs and sparks could have issued from the openings. Only in three instances did the visual evidence justify detailed inspection of the electronic components. These units were the Translation and Rotation Control and the Central Timing Equipment. Careful examination showed that the damage to these components was a consequence of the fire and thus they are not considered the source of ignition (References 5-1, 5-2).

h. All wiring was inspected for faults and have been judged for their fire starting potential. The locations of these faults were recorded in Enclosure 5-4 and its attached diagram. Those which were clearly the result of the fire have been dismissed from further consideration. The remainder were studied in detail. Results on these investigations are reported in paragraphs i. through m. of Section 5. Items still under investigation will be included in Appendix G after completion.

i. Electrostatic and friction spark ignition possibilities were studied by Panel 8 in a program to establish the susceptibility of C/M materials to ignition by these sources. This is a cooperative effort with Panel 5, which has stimulated complementary work on the ignition process in 100

percent oxygen atmospheres at government and contractor laboratories. The effect of contaminants, such as water/glycol leakage and cleaning solvents on the ignition and fire development processes of C/M materials will be a principal feature of these studies.

j. More than one potential ignition source for the C/M fire may be found in this investigation. Every effort is being made to establish their relative probability as the 012 C/M fire initiator. Laboratory tests and mock-up fires are the principal tools for these determinations.

4. DESCRIPTION AND COURSE OF THE FIRE:

a. Since the course of the fire was determined by the quantity and arrangement of the C/M combustibles, reference is made to the report of Panel 8 in which these are detailed. Briefly summarized, the combustibles contained in C/M 012 included a liquid combustible water/glycol in a widely distributed system, and solid combustibles - mostly plastics in the nylon, polyurethane, and silicone rubber class. The nylon is mostly in cloth form; the others appear as thin films, thick tapes with exposed pile, and foam plastics used largely for heat insulation and protective padding. A view of the Command Module from the hatch, photograph (Enclosure 5-6) shows the destribution of exposed solid combustibles. Throughout this report reference to location of C/M zones will be as viewed through the hatch in the manner of the photograph. The following description of the fire is divided into three stages for reasons of clarity and convenience in describing when the fire probably started and the specific phases of fire propagation.

Stage 1 - Stage 1 began when the fire started, probably some seconds before the astronaut's first verbal indication of the fire at 23:31:04.7 GMT (6:31:04.7 pm EST). This inference is based upon several anomalies in the telemetry data. Stage 1 concluded at about 23:31:19.4 GMT when the internal pressure ruptured the pressure vessel.

Stage 2 - Stage 2 is the period of greatest conflagration due to forced convection resulting from the out-rush of gases through the rupture. It probably lasted for about 5 seconds; it is estimated that the pressure reached ambient at about 23:31:25 GMT.

Stage 3 - Stage 3 continued from about 23:31:25 GMT through the decaying phase of the fire, when high concentrations of carbon monoxide and smoke were produced, for an undetermined time but which could not have exceeded several seconds.

Note: During the later stages of the fire a localized, extremely intense, fire in the ECU lingered beyond the culmination of Stage 3.

b. From observations of post-fire damage and witness statements, the fire first appeared to be at the lower portion of the left side of the C/M, presumably near the lower left corner (Enclosure 5-7). The slow rate of rise of recorded cabin pressure caused by the heat released by the fire suggests that the fire was not intense until about 23:31:12 GMT (Enclosure 5-8). This slow rate of pressure rise is consistent with the view that the early fire was either located in a zone containing little combustible or one containing much bare aluminum structure which could absorb an appreciable portion of the heat. The first significant indication of pressure rise was shown by telemetry data at 23:31:08.4 GMT.

c. By approximately 23:31:12 GMT, the fire had propagated out of its initial confines to involve additional combustibles. Estimated extent of fire following this time is shown schematically in Enclosure 5-9. The presumption is strong that flames along the left wall prevented the Command Pilot, who occupied the left couch, from operating the valve which vents the C/M to the ambient atmosphere. Such operation of the valve was an initial step in the established emergency fire procedure. However, this emergency procedure would have been to no avail because the venting capacity of the cabin pressure relief system was too low to prevent buildup of pressure within the C/M due to the fire. The heavy damage to the upper wall and ceiling in the left front corner, shown in Enclosure 5-10, shows the

intensity of the fire in this area. Since the oxygen concentration in the C/M was above 90 percent the first flames would be hot, bright, and relatively smoke free. They would rise vertically and spread out under the cabin ceiling. The Senior Pilot, who occupied the center couch, had the responsibility of unlatching and removing the hatch. The Senior Pilot's harness buckle was found in the latched position in accordance with standard procedures.

Some burning of the lower portion of the Command Pilot's suit may have been started by the flames rising from the ECU area and the adjacent nylon debris trap. Tests of nylon debris trap(Raschel net) burning in oxygen show its tendency to sputter off firebrands of burning molten nylon which may be projected several inches horizontally from their origin. These firebrands increase the spread rate over that measured in small scale flame propagation studies of this material, particularly as the convection currents generated by the fire increase. During this period the Inertial Measuring Unit (IMU) record indicated that there was motion in the C/M. The inference is that the Command Pilot was moving energetically at this time, in reaction to the emergency. His communication was interrupted some time before (23:31:10 GMT) or about five seconds after the first recognition of fire. His Cobra Cable is presumed to have been disconnected before this time.

d. Because there had been a history of electric arcs from the Pyro Battery to adjacent structure at the aft bulkhead level in the right front corner, this area was reviewed carefully as a possible site of the fire origin. The main combustible here is the nylon debris trap (Raschel Net) that extends from floor to ceiling. The extensive melting of this net (Enclosure 5-11), visible as fused yellow plastic adhering to C/M components in the corner indicates that the oxygen concentration at the time of its ignition was too low to burn it to completion. For this reason the right front corner is not regarded as the location of the origin of the fire.

e. The second stage of the fire began at about 23:31:19 GMT when the cabin pressure record can be interpreted to mean that the pressure had risen to a range of 29 to perhaps 37.7 pounds per square inch absolute (psia). This is the estimated failure range of the pressure vessel (Enclosure 5-8). This pressure would have resulted from the burning of three or four ounces of nylon, assuming adiabatic conditions. Cooling of the cabin atmosphere by the structure, would substantially increase this estimated quantity.

f. A major failure in the aft bulkhead occurred at the junction of the wall and aft bulkhead in the vicinity of the umbilical (Enclosure 5-12). Cabin gases and flame flowed in the direction of the break in the floor. The flames, debris, and oxygen flowed into the toroidal space between the pressure shell and the heat shield where the thermocouples registered rapidly rising temperature at 23:31:20 GMT. Flames in the toroidal space burned and melted components of the Reaction Control System and the insulation and honeycomb structure of the aft heat shield. These flames also poured from access hatches in the crew compartment heat shield and set fire to combustibles situated on and around the spacecraft at levels A-8 and A-7. These fires endangered pad personnel and impeded rescue.

g. After cabin failure, the gas flowing toward the floor break swept the flames to other combustibles and increased the rate of fire spread markedly. Flames rising above the couches were directed into a horizontal plane to spread the fire over the couches. Examination of the couches and astronauts' suits after the fire indicates the movement of these flames in the manner indicated in Enclosure 5-13. Flame damage to the suits, harness, and helmet visors show that it was most severe for the Command Pilot and least for the Pilot. Witnesses at monitors of the television camera mounted outside the cabin hatch view port reported movement of flame from left to right inside the cabin.

h. Inspection of the pressure vessel floor and aft heat shield, after separation, shows that fragments of Command Pilot's suit were swept there by the flow of cabin atmosphere through the floor break. This implies penetration of his space suit by fire just prior to the second stage of the fire when the convective currents were near maximum.

i. Further evidence that fire crossed the couches from left to right is given by the melting and burning of the leg rest control handle on the left side of the left couch. This handle is formed from aluminum tubing. Tongues of flame flowing over the handle melted and burned its left side where heat transfer would be greatest. The result was a softened and deformed ledge of aluminum on the right side where the heat transfer was less (Enclosure 5-14). A plastic button at the base of the handle shows little deformation and no burning. An aluminum ingot deposited by molten metal from the handle lies adjacent to the plastic button.

j. Some of the fire below the couch also swept in the direction of the floor break (Enclosure 5-15). Fire damage to the three helmet covers lying on the floor below the Senior Pilot's (middle) couch indicated that some of this flame spread around the lithium hydroxide (LiOH) canister storage box to the left of the helmet covers (Enclosure 5-16). Fire damage to these covers is greatest on their left sides where the flames impinged. The fire damage to the helmet covers, shown in this photograph, is consistent with this view of the path taken by the flames at this location. Enclosure 5-17 is a view of the helmet cover which lies closest to the hatch. Because the camera faces the hatch, the left side of the C/M is on the viewer's right.

k. Absence of substantial heat damage to the LiOH canister storage box and the clean underside of the couch above the helmet covers indicates that these flameslasted for only a few seconds. Discrete damage to wire bundles at floor level along the right side of the C/M indicates part of these flames reached completely across the floor.

l. Flames also moved from left to right along the front panel at slightly above floor level. With reference to Enclosures 5-18 and 5-19, which show a portion of the floor in front of this panel, the damage to wire bundles where fire impinged is shown to be greater than to those which lie to their right, as indicated by the arrows on the photograph. The same relative fire damage is apparent on the metal clamp covering the wire bundles, being greatest on the left and least at the right.

m. Substantial fire damage to paint and wiring insulation appears along the front panel, particularly above the batteries and inverters as shown in Enclosure 5-20.

n. Fire damage lessens with displacement from left to right across the front panel above the floor. The modest damage to paint on the upper right section of the front panel shown in the above enclosure demonstrates this point. Soot marks on the panels around the rectangular protuberances indicate the passage of a smoky flame moving upward and from left to right. Some of this smoky flame was provided by small local patches of Velcro which burned incompletely. A tongue of flame extended momentarily to the two wire bundles in the corner to do the localized damage visible in the photograph.

o. Strong convection currents induced by the flow toward the aft bulkhead break may have swept some of these flames across the front panel. Patches of Velcro on the front panel and the nylon net in the right front corner may have been ignited by these momentary flames.

p. Some of the failed 100 and 900 psia oxygen tubing below the Environmental Control Unit are shown in Enclosure 5-21. This photograph shows separated solder joints and burst aluminum tubing relatively near floor level below the suit circuit heat exchanger. The adjacent portion of the ECU, which contains the LiOH canisters shown in Enclosure 5-3, revealed broken coolant tubing (upper circle), more failed oxygen lines in the oxygen control panel area, and holes burned through the aft bulkhead and pressure vessel wall. The container for the LiOH canisters and adjacent structure show severe damage from a hot, sustained fire.

q. The third and final stage of the fire followed the loss of pressure in the C/M through the aft bulkhead break. The remaining cabin atmosphere quickly became too deficient in oxygen to support flaming combustion and heavy smoke was formed which deposited soot on most C/M surfaces as they cooled. High concentrations of carbon monoxide also developed rapidly at this time. An intense

fire lingered under the ECU and the water and oxygen panels. There, broken oxygen and water/glycol lines continued to supply oxygen and fuel from the supply tanks to support the fire that melted the aft bulkhead and burned the adjacent aft heat shield in this area.

r. Inspection of components taken from many areas of the C/M panel shows momentary penetrations of hot gases and flame through unsealed openings. These penetrations were probably assisted by the rapid increase in pressure difference across the face plates. This is associated with the rapid expansion of the hot cabin atmosphere shortly before aft bulkhead burst and the pressure fluctuation that followed the burst. Local melting and burning of potting compounds, wire insulation and plastic electric connectors are evident. Details of this damage by flame and hot gas penetration is given in the enclosures.

s. Flames penetrated zones behind side and overhead panels and traveled for a distance of up to a foot along thermal insulation on water/glycol lines. This fire damage was confined to the insulation along which the fire traveled. Such fires could cause crippling damage to adjacent electrical components and serious fire spreading can result.

t. In the same areas, there is also a considerable amount of very localized directional burning as would be produced by jets of hot gas or flame. Details of such damage are given in the enclosures.

5. OBSERVATIONS:

a. Observations from the post-fire inspection of the C/M are summarized in the following paragraphs. Supporting photographs are listed. Significant findings which bear on the search for the origin of the fire, the mechanics of fire propagation and the effects of the fire are given. An over-all representation of the areas suffering the most severe fire damage is illustrated in Enclosures 5-3 and 5-21. It is apparent that the highest intensity fire generally emanated from the left front, -Y, +Z, area. Descriptive details, by equipment and/or panels in each of the bay areas, are given in the Enclosures 5-23, 5-27, 5-20, 5-32, 5-35, and 5-37. It must be emphasized that some of the features of the early fire are probably masked by the damage that occurs in the later stages of the fire.

b. Fire started near the left-front (-Y, +Z) corner in the area adjacent to carbon dioxide and odor absorber compartment. Boilerplate mock-up tests conducted at MSC with a fire starting in this location showed a history very close to that deduced from an inspection of the damage to C/M 012. The pressure development associated with mock-up fire correlates well with the pressure-time trace recorded during the C/M 012 fire.

c. The following observations were made of the flame propagation and damage to the three couches. In general, there is no visible structural damage of the aluminum couch structure and sheet material except for, in some cases, destruction of the anodized coating..

(1) Conditions - The sooting patterns reveal that the "as-found" positions of the seat pans, lower leg rests and foot rests were the same as when the sooting took place: (a) The keyways of the trunnion locks are sooted except for the left couch 170° keyway, the center couch 96° keyway, and the right couch 264° keyway, (b) The lock pins and their receptacles are sooted or not sooted to conform to these same positions, and (c) The foot rest side panels are sooted to indicate no motion from their present positions after sooting.

The foot rest area of the three couches offered several indications of decreasing temperature from the left side to the right. The nylon sheathing material on the foot restraint cables of the left couch is completely gone except for a very small quantity near the swaged ball fittings. Proceeding to the right there is an ever increasing amount of sheathing material remaining on the cables.

The Velcro hook patches on the left sides of the leg rests are melted down completely; whereas, the ones on the right side, although heat damaged, retain their identity as hook material.

The foot restraint straps follow the same left to right pattern. Those of the left couch are completely melted away. The straps of the center couch are present, but semi-melted, the left one still attached at both ends, the right one connected only to the right arm. The right couch straps are completely connected; they are partially melted but to a lesser extent than those of the center couch.

It is noted that the left lower arm rest pad assembly of left couch had been attached to the lower arm rest tube with epoxy; whereas all others had been attached by six rivets each (three on each attachment bracket). The left lower arm rest pad assembly was the only one separated. Some of the epoxy shows application of heat after separation; all epoxy remained on the tube. The lower arm rest pad assembly was found on the aft bulkhead of the C/M on the -Y side directly under the reentry oxygen bottle. It was inverted. The bracketry at the bracket/epoxy interface was clean. The nylon pad (face down on the aft bulkhead) was badly burned as are all other arm rest pads with the exception of the left pads of the right couch.

The left seat pan lock handle has had the aluminum tube wall melted away at the front formed bend (outer curvature only); most of the remaining portions of the tube show heat cracking. The plastic striker plug on this handle shows signs of flowing and has partially exited the tube although the plug had retained its basic shape. The other two lock handles were not heat damaged nor were the plastic plugs.

The left couch right foot rest has a collection of molten aluminum in its right-hand trough at the foot restraint arm. This aluminum appears to have dripped from the access panel of the potable water tank. This panel is in the +X direction from this foot rest when the rest is in the usual position and the pan lowered to the 170° position. The collection appears to have dripped rather than to have been blown to this area.

All Dacron restraint harness material shows some signs of melting. The bayonets of the left and right harnesses were out of the buckle and sooted after removal. All three bayonets of the center harness are still inserted in the buckle. The center harness had extensive melting of the webbing between the buckle and the three left attachment points. The sooting patterns on all the head rests indicate that the head rest tabs were, at the time of sooting, in the same positions as found following the fire.

The cushioned areas of the seat pans had almost all cushion material burned or melted away with some sooting action taking place under the cushion area. This pattern is completely different from the cushioned area of the back pans which are almost completely clean. The Velcro hook for the back cushions is darkened but still retains its blue color and hook appearance.

(2). Observations

(a) When the couch exposed areas were sooted, the seat pans, foot rests and head rest tabs were in the as-found position, i.e.:

1. Left seat	-170°
Left head rest tabs	-folded
Left foot rests	-extended
2. Center seat	-96°
Center head rest tabs	-left folded, right extended
Center foot rests	-stowed
3. Right seat	-264°
Right head rest tabs	-folded
Right foot rests	-stowed

(b) The hottest area was under and to the left of the left couch foot rests (in the -Y, +Z direction from the foot rests).

(c) There was a directed flame path from the area described in (b) across the left couch seat pan lock handle (and translation controller).

(d) The conditions of the couches indicate that the flame front spread from the left to right (Velcro facing "upwind" highly damaged; Velcro facing "downwind" less damaged under and along the foot rests and seat pans).

(e) There are no major heat sources indicated by couches other than those described above.

d. There is no evidence to indicate that water/glycol from the ECU contributed significant fuel in the first two stages of the fire. After the lines failed it was the principal combustible for the sustaining fire in this area. However, the water/glycol system cannot be exonerated as a potential contributor to an electrical ignition source. Laboratory analysis of ash taken from the aft bulkhead shows presence of glycol and there was a history of prior glycol spills in this area

e. Due to the condition of the carbon dioxide and odor absorber compartments the possibility was considered that an explosion and fire originated in these compartments, resulting from hydrogen produced by a reaction of lithium hydroxide with water and aluminum. However, both of the lithium hydroxide canisters in the spacecraft at the time of the fire were of the impregnated fiberglass variety. They were so constructed that the lithium hydroxide pellets were not in direct contact with aluminum metal. In order to produce significant quantities of hydrogen, liquid water must be present to dissolve lithium hydroxide and bring it in contact with aluminum metal. Qualification data for the dew point of the gas leaving the compartment is 60° F, yet the temperature measured at 23:30:50 GMT was 89° F. Also, the cabin temperature was 76.5° F, hence water could not have condensed in the lithium hydroxide canisters.

f. Electrostatic discharge from nylon or similar material was considered by the Panel to be a remote possibility, it cannot be completely discounted at this time. Consequently, experiments were conducted to assess this possibility. (See Appendix D-8)

g. For simplicity and where practical, the results of investigations of the equipment bays are combined and a summary of conditions and conclusions are presented.

(1) Right Hand Equipment Bay

The instrumentation, wiring, panels, and rear pressure vessel wall were sooted and fire damage was slight. Some debris resulting from fire damage was found on the aft bulkhead in the open areas. The compartment floor under the Earth Landing Sequencer and Circuit Interrupter areas showed moderate fire damage which was probably due to fire sweeping under these compartments to the break in the aft bulkhead. None of this fire damage is indicative of a fire source. Enclosures 5-24, 5-25, and 5-26 visually show the subject area and Enclosure 5-27 is a detailed tabulation of findings.

Based upon visual observations of the extent of damage and condition of equipment, the Right Hand Equipment Bay cannot be considered as the ignition source area even though the combustible materials in this area provided fuel.

(2) Forward Equipment Bays (Right and Left Hand)

The conditions observed in the Right Hand Forward Equipment Bay showed only minimal fire damage (Enclosure 5-28 and 5-29). However, in the Left Hand Forward Equipment Bay (LHFEB) some of the bottom panels received very severe damage due to localized flame impingement originating from the Left Hand Equipment Bay. Heavy sooting in this area occurred during

the third stage of the fire. Based upon the above evidence, the Forward Equipment Bays cannot be considered as a ignition source.

(3) Lower Equipment Bay (LEB)

The conditions found in the upper portion (+X, -Y) of the LEB indicate that the fire damage to the external surfaces of panels and instrumentation was more severe on the left and decreased in intensity as it progressed toward the right. Food panels B through E showed severe heating. Jet effects were observed on the front face of the Guidance and Navigation instruments; however, the electronic portions in the interior were relatively unscathed except for some localized damage due to intense heat. The resultant damage was due to melting and burning of some of the potting compound. In a few cases the wire insulation was damaged. The flame patterns in this area indicated that damage was a result of a secondary fire and hot gases. Enclosures 5-30, 5-31, 5-31A and 5-32 present the detailed conditions found in this area.

In the -X, -Y portion of the LEB, fire damage was found to be more severe on the left and decreases toward the right. The cover plate on junction box (15-1A-52) and an adjacent wire show evidence of arcing. The wiring between this panel and inverter shows evidence of being mashed as well as fire damaged. In the area below this panel, most of the wires are stripped of insulation due to intense heat. The external wiring showing the most severe damage was the biomedical adapter "Octopus" cable, extending across the LEB from + to -Y, and the gas chromatograph cable harness tied to an exposed cable harness above inverter No. 3. These two items are discussed in more detail in Enclosure 5-32.

While the faces of the instrumentation in the LEB showed sever to slight damage from left to right, the interior of the instrument packages showed only superficial damage. In some cases, however, there was observed localized entry of flame and heat into some of the instruments in and around the connectors. Based upon the condition of the instrumentation, condition of the face panels, and interior compartments of the LEB, none of the instrumentation in this area is considered to be the primary ignition source. However, the electrical cable to connector "J-185" in the lower left hand corner was investigated in the laboratory.

(4) Left Hand Equipment Bay (LHEB)

The most extensive fire damage to tubing and wiring was observed in the water panel area and below the carbon dioxide abosrbers. Severe to moderate damage to the insulation and some cables was observed in the Environmental Control Unit. Penetrations through the aft bulkhead and pressure vessel wall were found to be a result of a high temperature flame jet. The side panel between the oxygen/water panels and the carbon dioxide absorber melted through and the melt collected on the aft bulkhead in front of the panel. Lithium hydroxide and charcoal were found under this ingot indicating that the carbon dioxide absorbers had failed prior to melting of the panel. Wiring below the carbon dioxide absorbers show possible arcing. Enclosures 5-33, 5-34 and 5-35 show detailed conditions of the LHEB. The left hand portion of the LHEB shows less fire damage than the right hand section. Based upon the conditions observed in the LHEB the right hand portion of this bay cannot be exonerated as a possible fire source.

(5) Main Display Console (MDC)

In general the front panel faces of the MDC showed decreasing fire and heat damage from left to right with the flash angle being between 30° to 45° in the -Y, -Z direction. Some buttons, switches and dial faces showed severe damage. Instrument panel 21 (Enclosure 5-33) shows the type of generalized sooting and damage to electronic components, particularly of sooting and heat entry at the thumb wheel opening. However, except for a few localized heat damaged areas, the instrumentation and electronics only showed superficial heat and smoke damage. The comditions found in and around the MDC are presented in Enclosure 5-36 and 5-37. This evidence indicates that the Main Display Console is not a probable ignition source.

h. The wiring in the Spacecraft was subjected to a meticulous survey under 7x power magnification to detect possible arcing. As a result of this survey of the wire damage, only ten wires were considered as likely ignition sources. All other wire damage occurred during the fire. The ten electrical faults

have been or are under study as possible ignition sources. These possible sources are:

(1) Gas Chromatograph Cable (Enclosure 5-4, Source No. 3, Coordinates G-15).
(2) Biomedical Adapter "Octopus" Cabel (Enclosure 5-4, Source No. 20, Coordinates E-15).
(3) Arcing in and under the Carbon Dioxide and Odor Absorber Compartment (Enclosure 5-4, Source No. 15 and 16, Coordinates L-11 and L-14).
(4) Wires in Channel H (Enclosure 5-4, Source No. 19, Coordinates F-17).
(5) Wire between Inverter No. 3 and Junction Box C-15-1A-52 (Enclosure 5-4, Source 17, Coordinates G-15).
(6) DC power to Connector J-185 (Enclosure 5-4, Source No. 3, Coordinates G-15).
(7) AC power to Suit Compressor No. 1 and No. 2 (Not located in Enclosure 5-4).
(8) Suit Biomedical Adapter Harness (Not located in Enclosure 5-4).
(9) Cable Harness to Cabin Fans (Not located in Enclosure 5-4).
(10) Cable Harness to ECU Instrumentation Power Supply and its mating harness.

i. A detailed study of the disposition of the gas chromatograph cable harness and connector before and during the fire was made (Enclosure 5-23). From observational evidence of photographic enlargements and the condition of the connector it has been ascertained that the gas chromatograph cable did not reside on the aft bulkhead before the fire started, where it was found after the fire, but was in or near the gas chromatograph bay. Metallurgical and spectrographic studies of the 115 VAC wires, as well as laboratory experiments, indicates that the melting of the copper wire within the nickel sheath was a result of external heating, which burned away the Teflon insulation, with subsequent shorting of 115 VAC lines. The results of these events caused molten copper to exude through discontinuities in the nickel sheath. Therefore, as based upon these findings, the has chromatograph cable harness and connector cannot be considered as an ignition source.

j. The Biomedical Adapter "Octopus" cable and connector were studied visually by microscopic examination. Several areas were observed that indicated possible arcing along the twisted wire pairs of the cable harness. These areas were replicated and submitted to electron microscopic examination at a magnification of approximately 5000 diameters. The photomicrographs of the suspicious areas indicated point source melting and defects in the metal surfaces produced by low energy intermittent arcing. Based upon the degree of melting and the depth and length of these defects it was determined that this type of arcing could not raise the temperature of the Teflon to a spontaneous ignition level. In addition, the number and condition of arc spots along a length of twisted pair of wires indicated that the Teflon insulation had been burned from the cable harness prior to arcing. Investigation of the shielded cable did not reveal any suggestions of arcing; therfore, it is concluded that the wiring in the "Octopus" cable harness did not provide a primary ignition source. X-ray examination, resistance, and continuity checks of the "Octopus" cable connectors were negative and showed no anomalies.

k. The cable harness to the ECU Instrumentation sensor power supply contained both 28VDC Bus A and 28VDC Bus B to provide redundant power. Because of the redundancy, a short in the power conductor of one Bus would not be revealed by the telemetery data from these instruments. Whether or not a short occurred cannot be determined because of extensive destruction of the wire bundle by the lingering fire in this area.

In order to provide clarity in assessing the damaged area in the lower left hand area (-Y, +Z) of the Equipment Bay it is necessary to consider several components and the wiring in this area. The subjects are cover plate to C-15-1A-52 and adjacent wiring, the DC power cable to connector J-185 and the Gas Chromatograph Cable Harness, the Flight Qual Recorder, and the extreme left hand portions of the Patch and Auxillary Electronic Control Assemblies (ECA's).

(1) The abraided wire and adjacent cover in front of Junction Box C-15-1A-52 was investigated to determine whether this wire had shorted to the panel and to assess the results if arcing had occurred. Both the wire and the panel were submitted to microscopic and metallurgical examination to determine the extent of arcing and thermal profile. Microscopic examination of the wire revealed

evidence of arcing and that the Teflon insulation had been cut prior to the arcing, as determined from tear fragment remaining on the insulation around the arc site and the decomposition level of the insulation.

(2) A transverse section of the wire was carefully polished in 0.001 to 0.002 inch increments and etched to obtain the grain structure in the unaffected and affected heat zones and to establish the thermal profile. The grain structure revealed that the arc site was localized in an area of approximately 0.1 inch and the fire damage to the wire was exceedingly slight. The cover plate also revealed an arc site in the lower right hand corner (Enclosure 5-31A) under microscopic examination, however, the nylon chafing guard adjacent to the arc point and running along the bottom of the plate received only minor damage as a result of melting due to heat. The rear of the nylon guard closest to the arc point was almost intact.

(3) Emission spectrographic analysis of this panel revealed that it was made of type 2024 aluminum alloy. Hardness and conductivity tests showed that the alloy was in a T-6 condition (type of heat treatment); however, the extreme left side was found to be in a T-3 condition. This indicates that the left side of the panel was exposed to temperatures between 425°C and 475°C but that center and right side were never exposed to this thermal level.

(4) The DC power cable to the J-185 connector which supplies the Medical Data Acquisition System Recorder was found to be damaged where it turns in a right angle bend to run along channel K below the Gas Chromatograph (GC) Bay. This damage was just below and to the right of the Flight Qual Recorder. Microscopic and metallurgical examination revealed that this cable was exposed to the same thermal environment as the Gas Chromatograph cable harness. Therefore, the insulation and subsequent melting and shorting was the result of exposure to a short duration but intense flame.

(5) The Flight Qual Recorder face plate was checked for conductivity profile. The analysis indicated no variation in temper. The Velcro on the surface showed melting primarily with slight fire damage; however, the adhesive was intact and no damage was done to the paint below the adhesive.

(6) The left hand edges of the Pitch and Auxiliary ECA's originally had Velcro, attached to their surface; however, after the fire the Velcro, its adhesive, and panel paint had been completely consumed except for a small amount of adhesive and Velcro residue on the lower portion of the Pitch ECA face plate. It is inferred that damage to these panels was a result of flame jet arising from the ECU area which damaged the cable harness to the J-185 connector and the Gas Chromatograph.

(7) Little evidence was found to indicate that the arc between the cover plate to C-15-1A-52 and the adjacent wire could have been an ignition source, based only on the observations and analyses in the preceding paragraphs. While the adjacent areas to this panel do not show severe damage one cannot preclude the possibility that water/glycol residue on the wiring and adjacent metal parts may have provided a propagation path. It is also possible from the size of the arc spots, and the nylon chafing guard remaining after the fire, to conclude that the resultant flash was too small to have ignited the nylon chafing guard along the bottom of the cover plate. However, the arc could have ignited glycol residues, had they been present, resulting in a flash in the upward direction which in turn ignited the large Velcro patch on the Flight Qual Recorder. Therefore, based on this possibility the arcing in the above area cannot be eliminated as a possible primary ignition source. A series of experiments are in order to establish whether or not the above hypothesis is reasonable.

D. FINDINGS AND DETERMINATIONS

1. FINDING:

Damage to components, wiring and compartments in Right Hand Equipment Bay was found to be superficial.

DETERMINATION:
This bay could not have provided a primary ignition source, even though it provided some fuel for fire.

2. FINDING:
Damage in most of the areas of the Forward Equipment Bays was found to be superficial. Some panels in the Left Hand Forward Equipment Bay received severe fire damage from flames arising from the Left Hand Equipment Bay.

DETERMINATION:
These bays did not provide a primary ignition source.

3. FINDING:
Severe damage to wiring was found at the bottom of the Lower Equipment Bay along the aft bulkhead. Evidence of arcing was found on the cover in front of C-15-1A-52 and adjacent wires. Damage was less severe in the +Y (right hand) direction in this bay.

DETERMINATION:
Electrical arcing in the extreme lower left hand corner of this bay could have provided a primary ignition source.

4. FINDING:
Right hand portions of the Left Hand Equipment Bay received severe damage. Wiring, tubing and components in the carbon dioxide absorber compartment and oxygen/water panel compartment were burned and melted. Penetrations in the aft bulkhead and pressure vessel wall were observed. The carbon dioxide absorber compartment showed heavy fire damage and failure was due to pressure overload and melting caused by the fire in this area.

DETERMINATION:
Electrical arcing in the right hand portion of this bay could have provided a primary ignition source.

5. FINDING:
Main Display Consoles (MDC) showed evidence of heavy fire and heat damage on left side; however, the interior of the instrumentation showed only superficial damage.

DETERMINATION:
The MDC did not provide a primary ignition source.

6. FINDING:
There is strong evidence that fire effects on the couches resulted from fire originating in the Left Hand Equipment Bay.

DETERMINATION:
These couches were not a primary ignition source.

7. FINDING:
The Rotation Controller bore evidence of external heating and indications that flame penetrated the control from the upper rear area of the C/M. The Translation Controller had a large part of the upper rear corner missing which is probably due to the controller being hit by an external object after it had been weakened by flame impingement.

DETERMINATION:
There is no evidence that any failure occurred in either the Rotation or Translation Controllers that could have been the probable cause of fire ignition.

8. FINDING:
The spacecraft was thoroughly searched for unaccounted for objects or other evidence that the fire may have been deliberately set.

DETERMINATION:
No evidence was uncovered that suggested sabotage.

9. FINDING:
Evidence of electrical arcs from conductor to conductor and conductor to structure was found.

DETERMINATION:
No arc could be positively identified as the unique ignition source. Three were found that had, all of the elements needed to cause the disaster. Two of these showed evidence of poor engineering and installation.

10. FINDING:
Investigation of certain panels or components is incomplete. The remaining investigations are primarily concerned with determining functionality and adquacy of design.

DETERMINATION:
The possibility that these incomplete investigations will uncover information that will modify these determinations is remote.

E. SUPPORTING DATA

LIST OF ENCLOSURES

5-1	Not used	
5-2	Photograph	108-KSC-266C-88/6
5-3	Photograph	189-478C-25
5-4	Electrical System Damage and Figure 1	
5-5	Not Used	
5-6	Photograph	189-478C-9
5-7	Photograph	189-478C-10
5-8	Photograph	189-478C-11
5-9	Photograph	189-478C-12
5-10	Photograph	189-478C-13
5-11	Photograph	189-478C-14
5-12	Photograph	189-478C-15
5-13	Photograph	189-478C-16
5-14	Photograph	189-478C-18
5-15	Photograph	189-478C-19
5-16	Photograph	189-478C-20
5-17	Photograph	189-478C-21
5-18	Photograph	A-3-34C
5-19	Photograph	189-478C-22
5-20	Photograph	189-478C-23
5-21	Photograph	189-478C-24
5-22	Not used	
5-23	Gas Chromatograph Laboratory Examination	
5-24	Photograph	17-43C-5
5-25	Photograph	32-7C-11
5-26	Photograph	104-268C-2
5-27	Table - Right Hand Equipment Bay	
5-28	Photograph	17-45C-11
5-29	Table - Forward Equipment Bay	
5-30	Photograph	21-51C-5
5-31	Photograph	23-57C-10
5-31A	Photograph	218-509C-12
5-32	Table - Lower Equipment Bay	
5-33	Photograph	32-7C-8
5-34	Photograph	70-150C-4
5-35	Table - Left Hand Equipment Bay	
5-36	Photograph	32-7C-2
5-37	Table - Main Display Console	
5-38	Photograph	324-666C-12
5-39	List of References	

WIRING UNDER CO_2 ABSORBER ACCESS DOOR

ENCLOSURE 5–2

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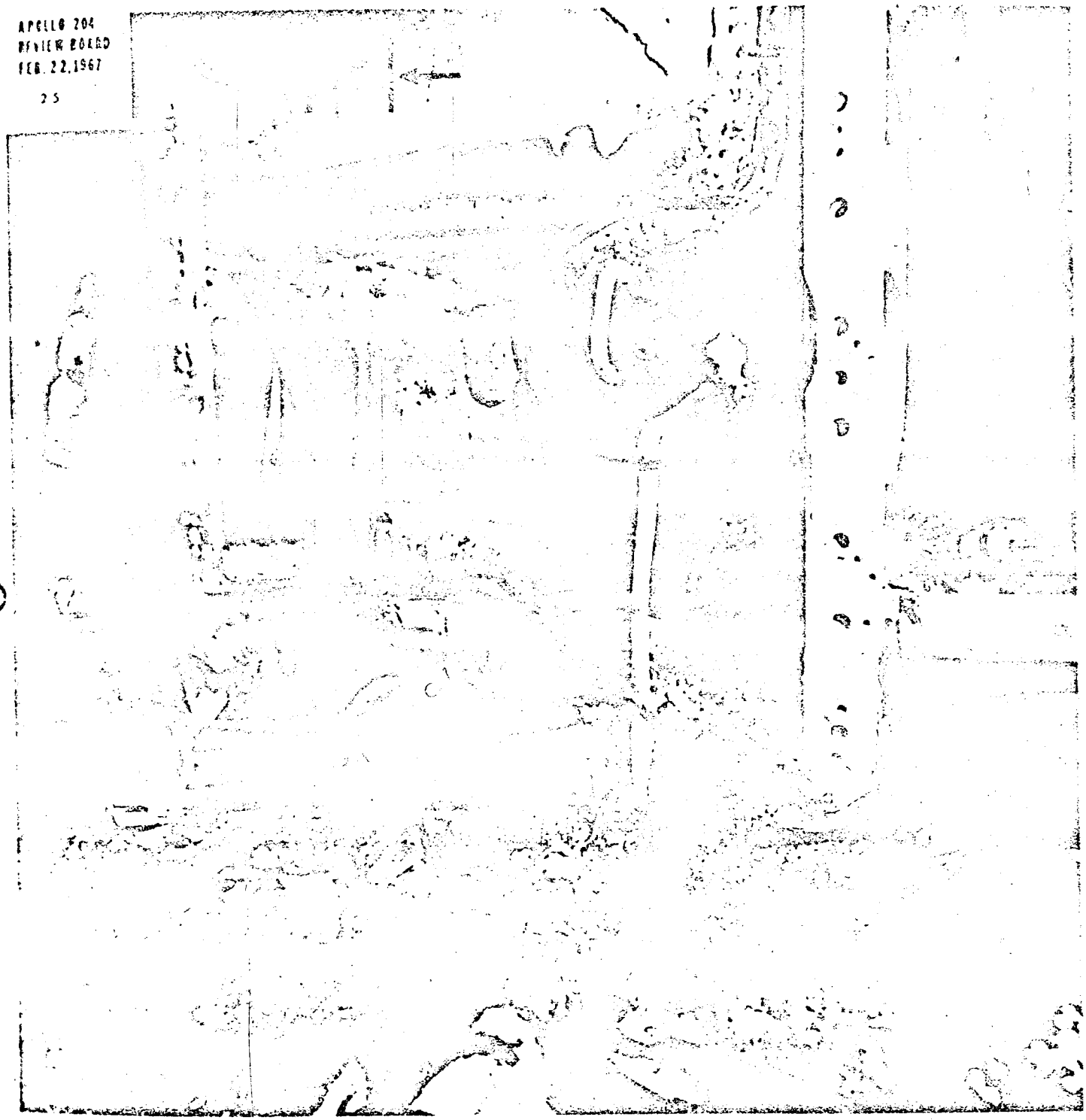


DAMAGED WIRING UNDER ACCESS DOOR

ENCLOSURE 5-3

ELECTRICAL SYSTEM DAMAGE

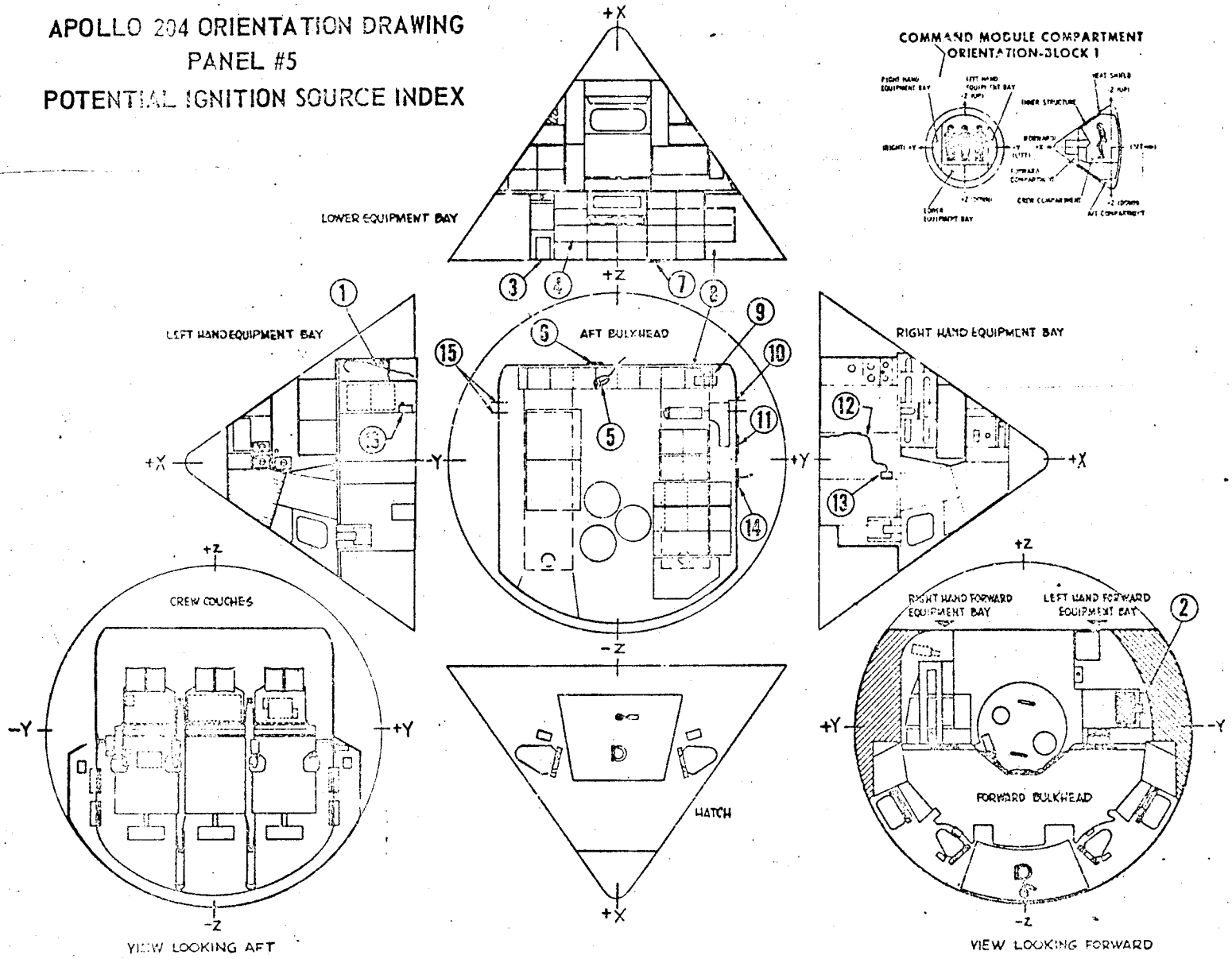
SOURCE NO.	COORD.	DESCRIPTION
1.	K-11	Two small wire runs behind water and oxygen control panel lower LHEB. Run comes up (−X direction) from the aft bulkhead via wire clamps on the rear of the water panel and on the side wall to connections on the O2 control panel. Bare wires are seen in this run approximately 2 inches either side of the wire clamps located on the water panel.
2.	U-33	Cable and connector to small "Black Box" (3 in. X 3 in.) located inside LHEB on the hinged side of the cabin air intake screen. Bare wire is seen at right angle bend in this run where it turns outboard and forward to join main wire harness located on the side wall. Fraying may have been introduced by chafing against hinged door (screen) during repeated opening and closing.
3.	G-15	Outboard harness and inboard harness in LEB run below gas chromatograph installation. Significant damage is seen to have occurred to the outboard run with minor damage to the inside of the inboard run.
4.	F-16	Wire run located in trough below Scientific Equipment B storage compartment in LEB. Bare places are seen in small gage wire on the inboard side of this run.
5.	K-17	Battery instrumentation leads located in a plastic bag on the aft bulkhead under the right hand battery in the LEB.
6.	K-17	wire bundle running in+Y, -Y direction under the inboard edge of the LEB. Bare wires are seen in the top (+X side) of this bundle.
7.	G-19	Center wire bundle of three which run outboard on aft bulkhead between inverter no. 2 and inverter no. 3. Bare wires are seen in the top of this bundle.
8.	K-20	Wire bundle running to connector portion of panel 150 on aft bulkheat. Bare wires are seen for about 5 inches
9.	K-20	small gage wire running to the top row of circuit breakers on panel 150 on aft bulkhead. Fraying is seen to occur about 1 in. from the panel and running several inches back along this run.
10.	L-21	Wire run going outboard on bulkhead underneath sequencer area (RHEB). Bare wire is seen in the top of this bundle at approximately the point beneath the access panel.
11.	M-21	Wire bundle on bulkhead running in &Z,Z direction along the edge of the RHEB. Bare wires are seen in the top of this dundle beneath the location of the red streamer "Remove Before Flight" tag associated with the Earth Landing System (ELS) shorting plug.

See Attached Diagram

SOURCE NO.	COORD.	DESCRIPTION
12.	M-25	Wire bundle running up (S-X) left side of the RHEB compartment and looping to the right. Bare wire is seen along the inboard edge of this run in several places.
13.	N-26	Small gage wires running to small black boxes to the top right of the cavity described previously in source 12 Bare wires are seen on several strands.
14.	N-21	Wire bundle intersection on bulkhead of a&Z,-Z and &Y, -Y run located beneath the edge of the RHEB below cavity desorbed in Source 12. Many bare wires are seen on the top and towards the center of this bundle.
15.	L-14	Wire bundle running outboard under hinged LiOH canister door. fraying is seen in the top of this bundle at the attenuator line.
16.	L-11	Connector panel for ECU in LHEB. Damage to connectors is seen on top side, but less severe on bottom side of these connectors.
17.	G-15	Evidenxe of arc between wire and cover plate of C-15-1A-52 junction box. Wire appeared to press on edge of plate. Nylon chafing guard on cover plate is 3.16. in from arced spot.
18.	L-14	Severely burned residue from wire bundle running under brace for wall between LiOH canister and remainder of ECU.
19.	F-17	Wires severely burned, melted and fused in Channel H.
20.	E-15	Octupus cable had highly localized melting and arcing on twisted pairs.

See Attached Diagram

APOLLO 204 ORIENTATION DRAWING
PANEL #5
POTENTIAL IGNITION SOURCE INDEX



COMMAND MODULE COMPARTMENT ORIENTATION-BLOCK 1

ENCLOSURE 5-4

D-5-23

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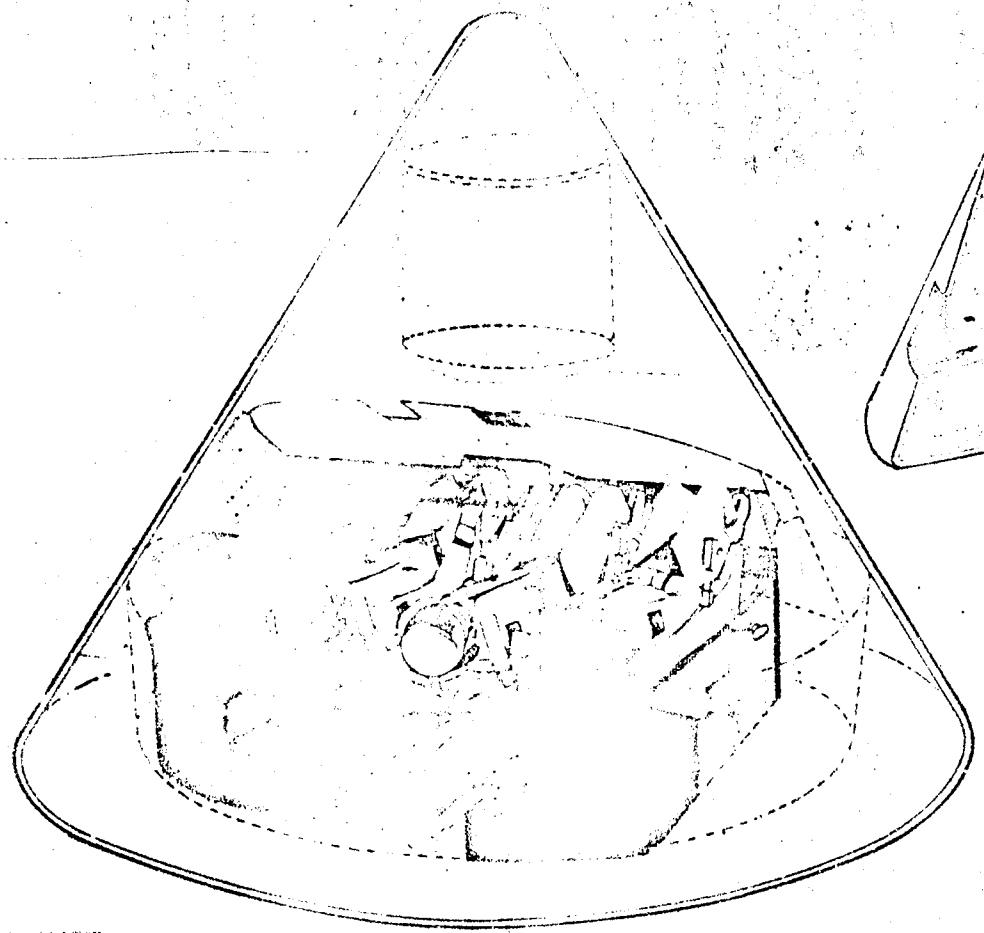
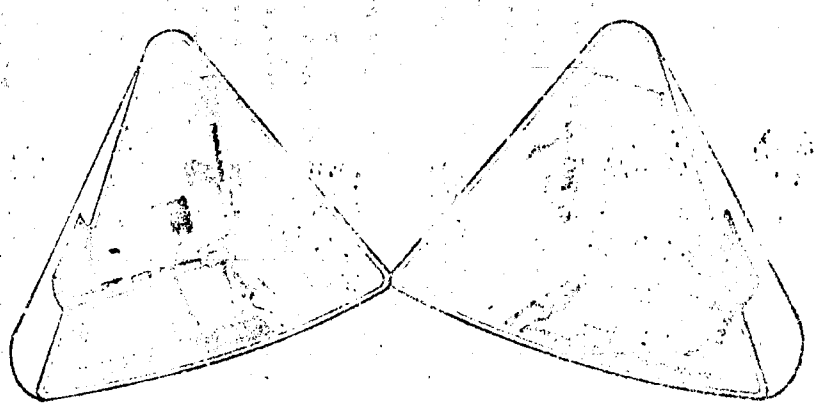
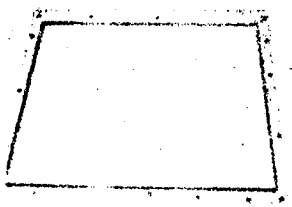




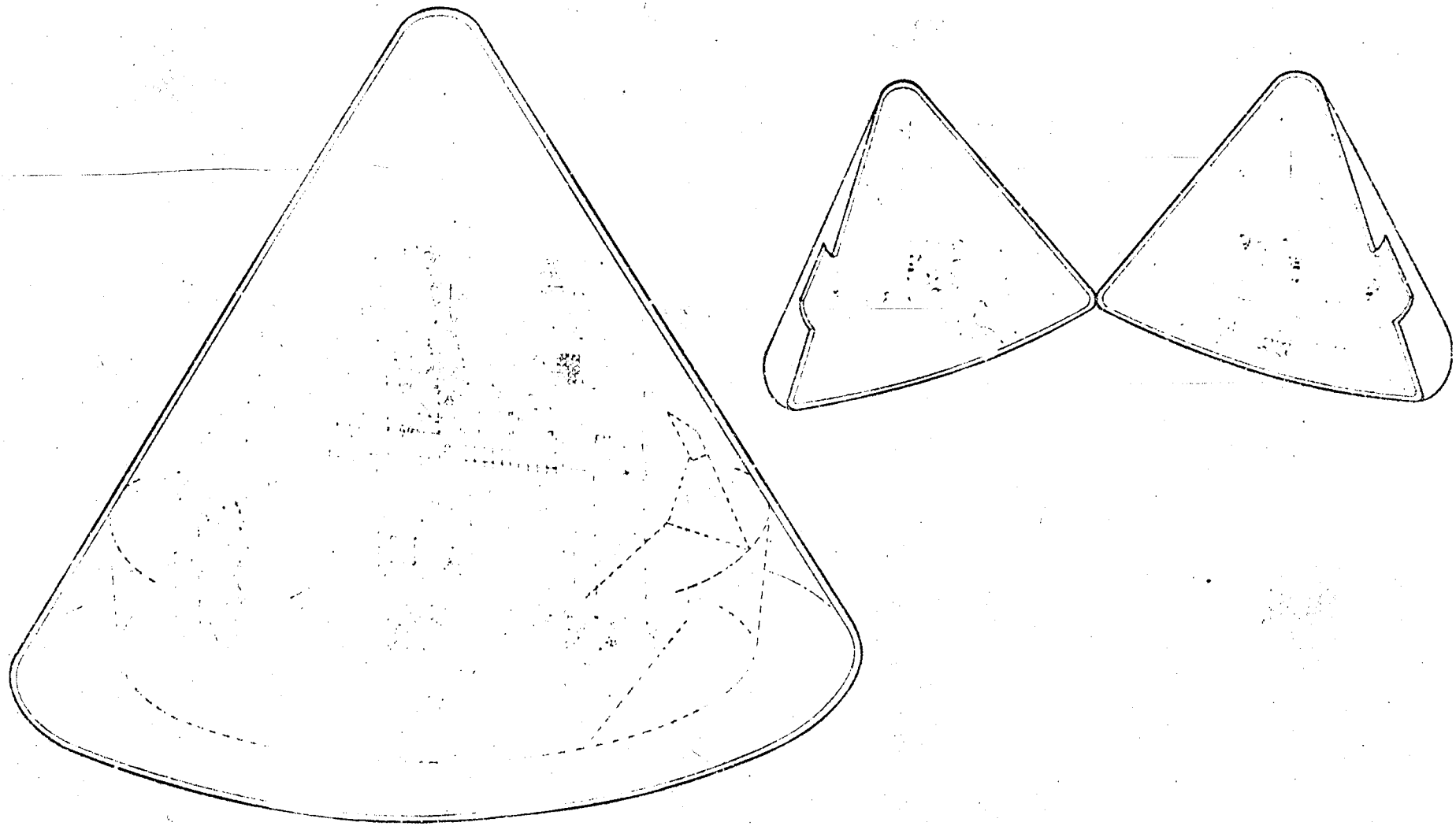
VELCRO
TRIALAKE
RASCHEL KNIT
TRILOCK AND RASCHEL COVERING
RASCHEL KNIT (AFT BULKHEAD)



EXPOSED NON-METALLIC MATERIALS

ENCLOSURE 5-6

ENCLOSURE 5-7



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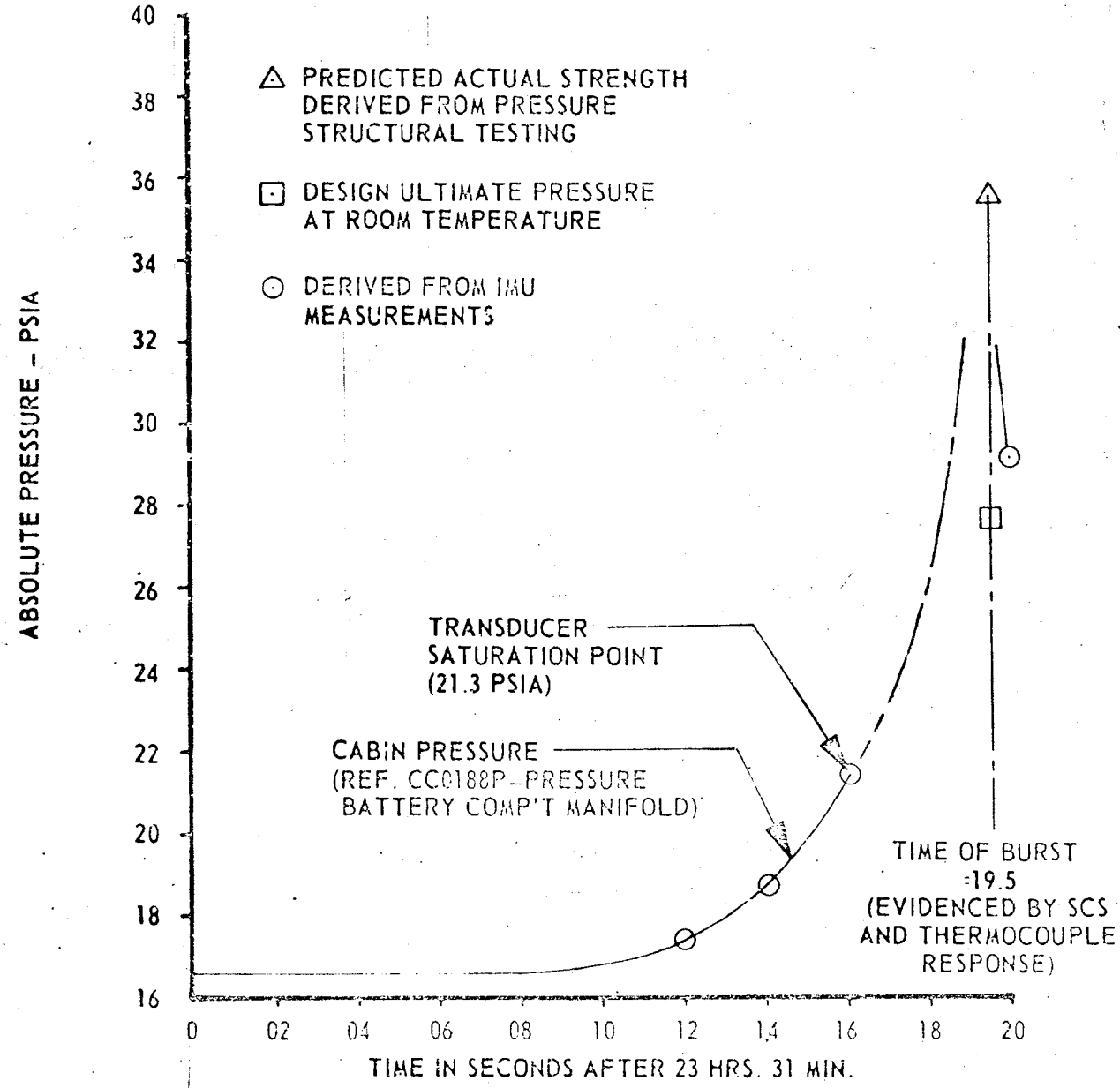
VIEW OF LOWER LEFT HAND CORNER

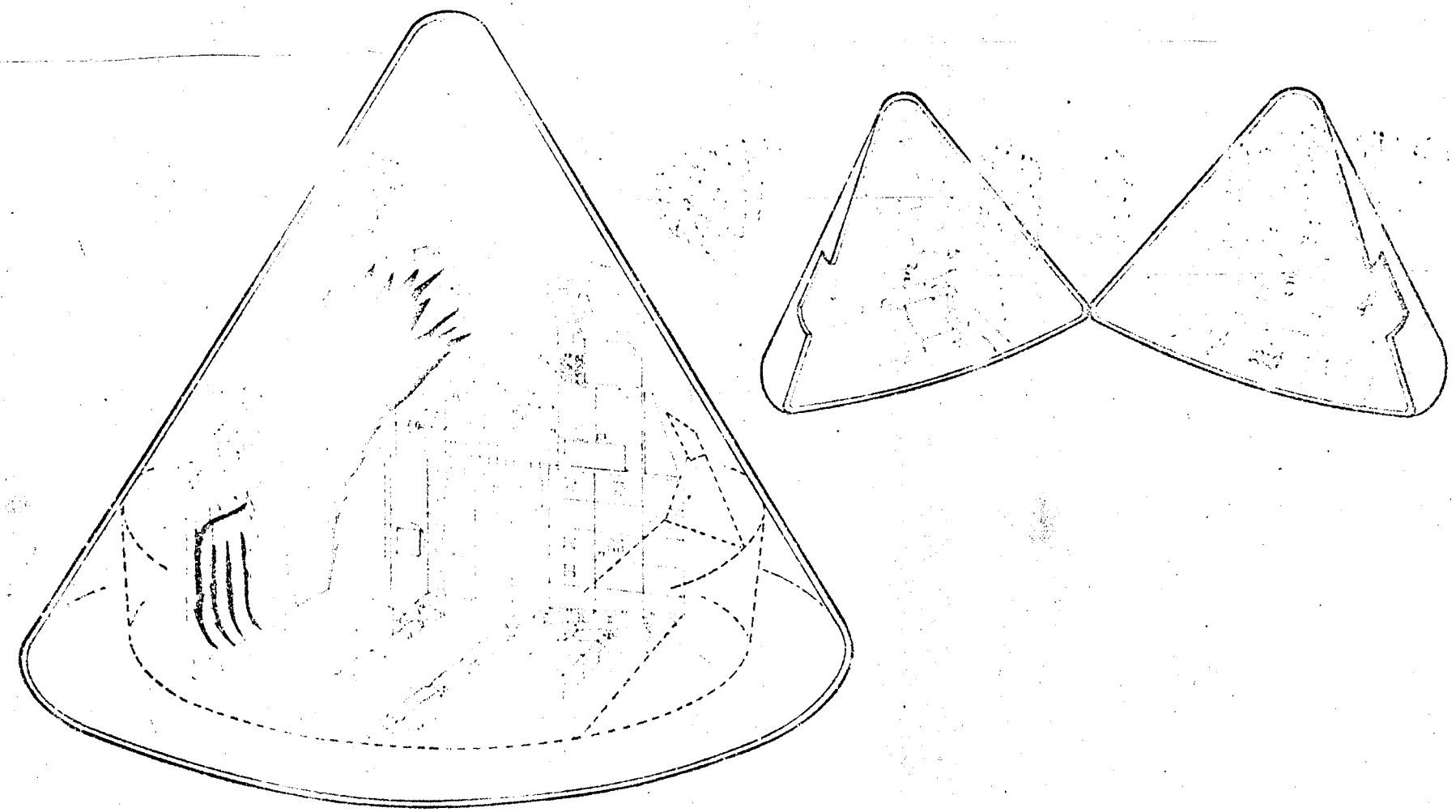
CABIN PRESSURE



CABIN PRESSURE CHART

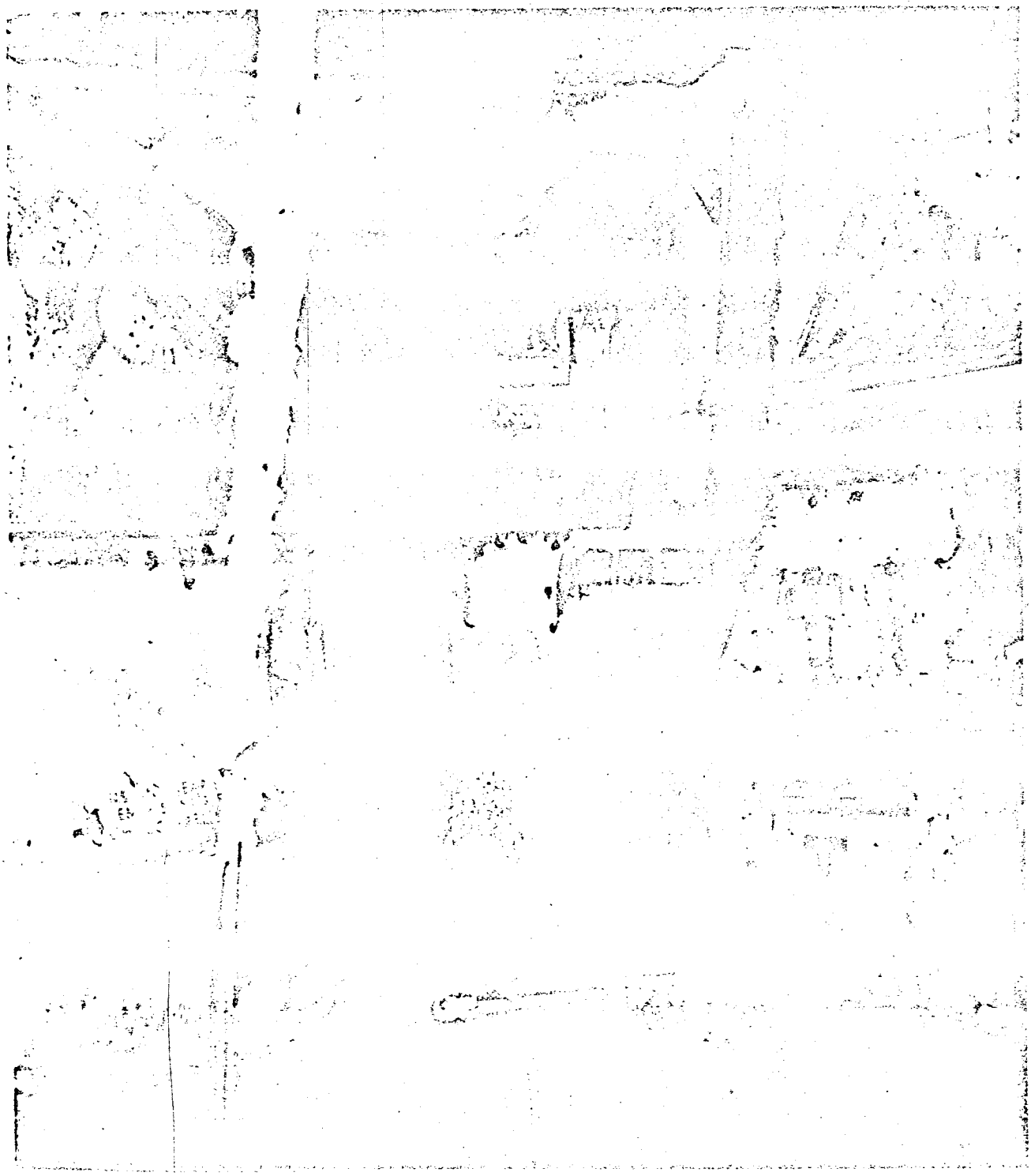
ENCLOSURE 5–8

C/M FIRE
FIRST PHASE

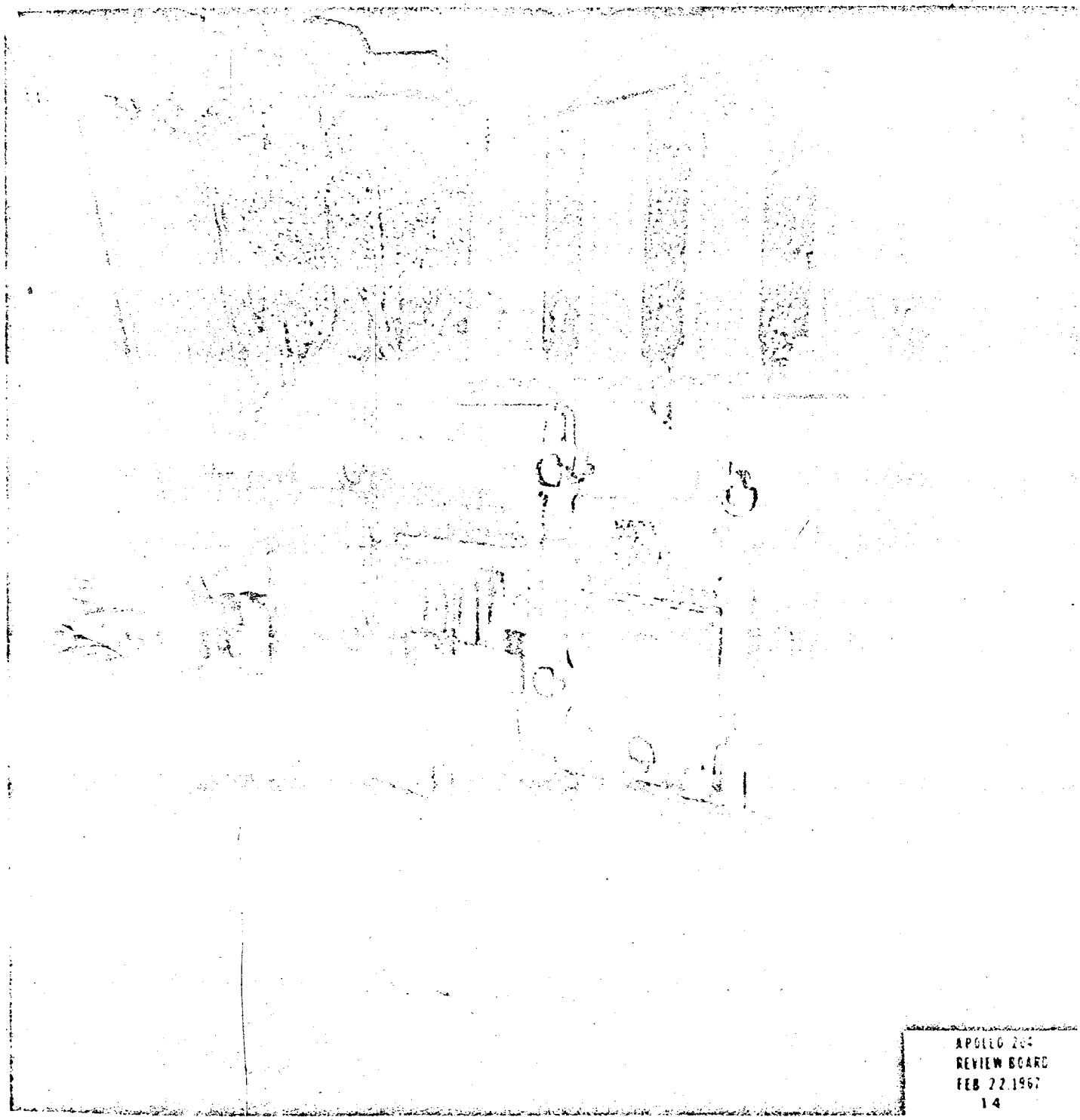


ENCLOSURE 5-9

FIRST PHASE OF FIRE



EXTREME UPPER LEFT HAND CORNER BETWEEN LOWER EQUIPMENT BAY AND LEFT HAND EQUIPMENT BAY



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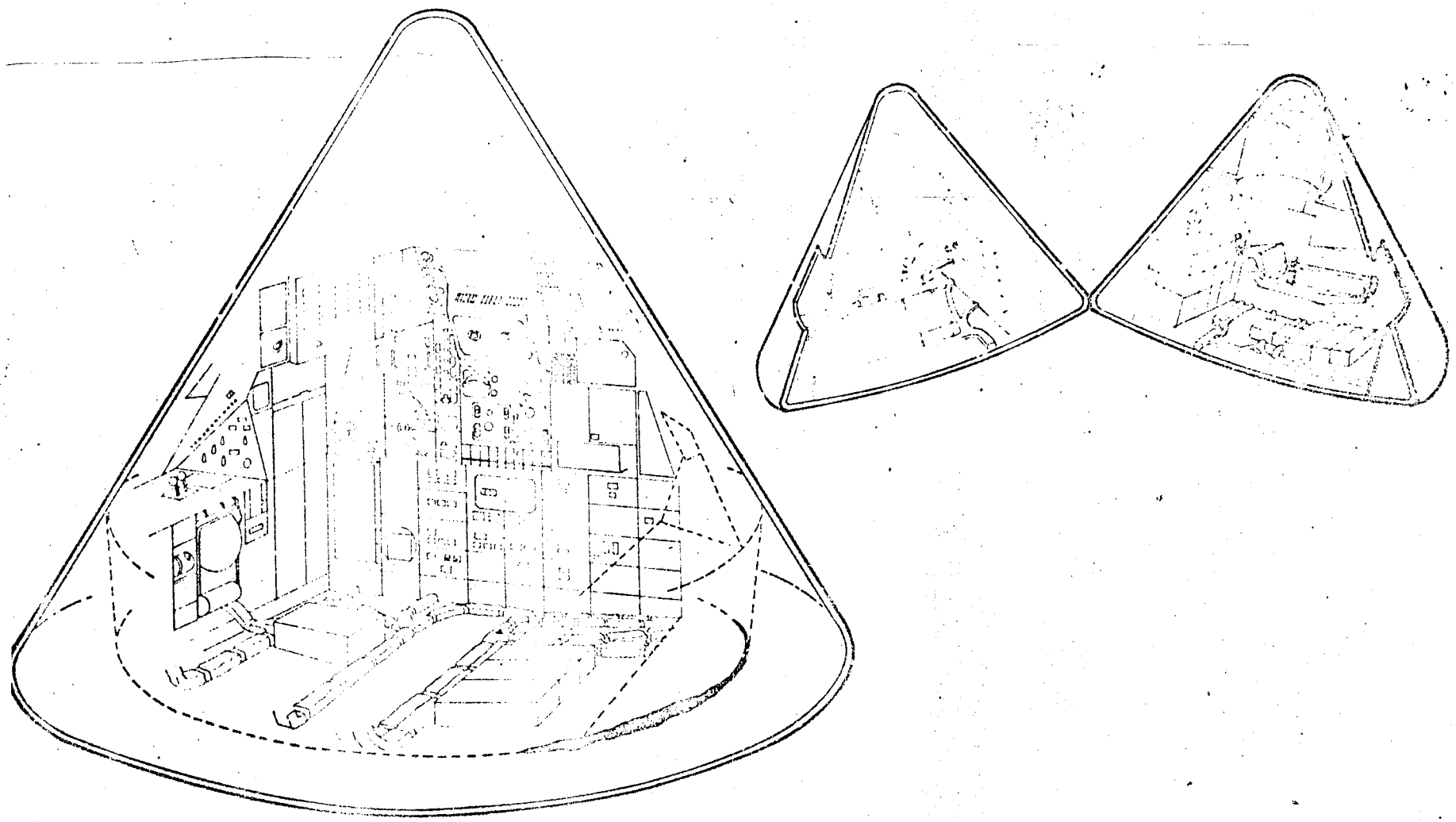
EXTREME RIGHT HAND CORNER ABOVE LOWER EQUIPMENT BAY AND RIGHT HAND EQUIPMENT BAY

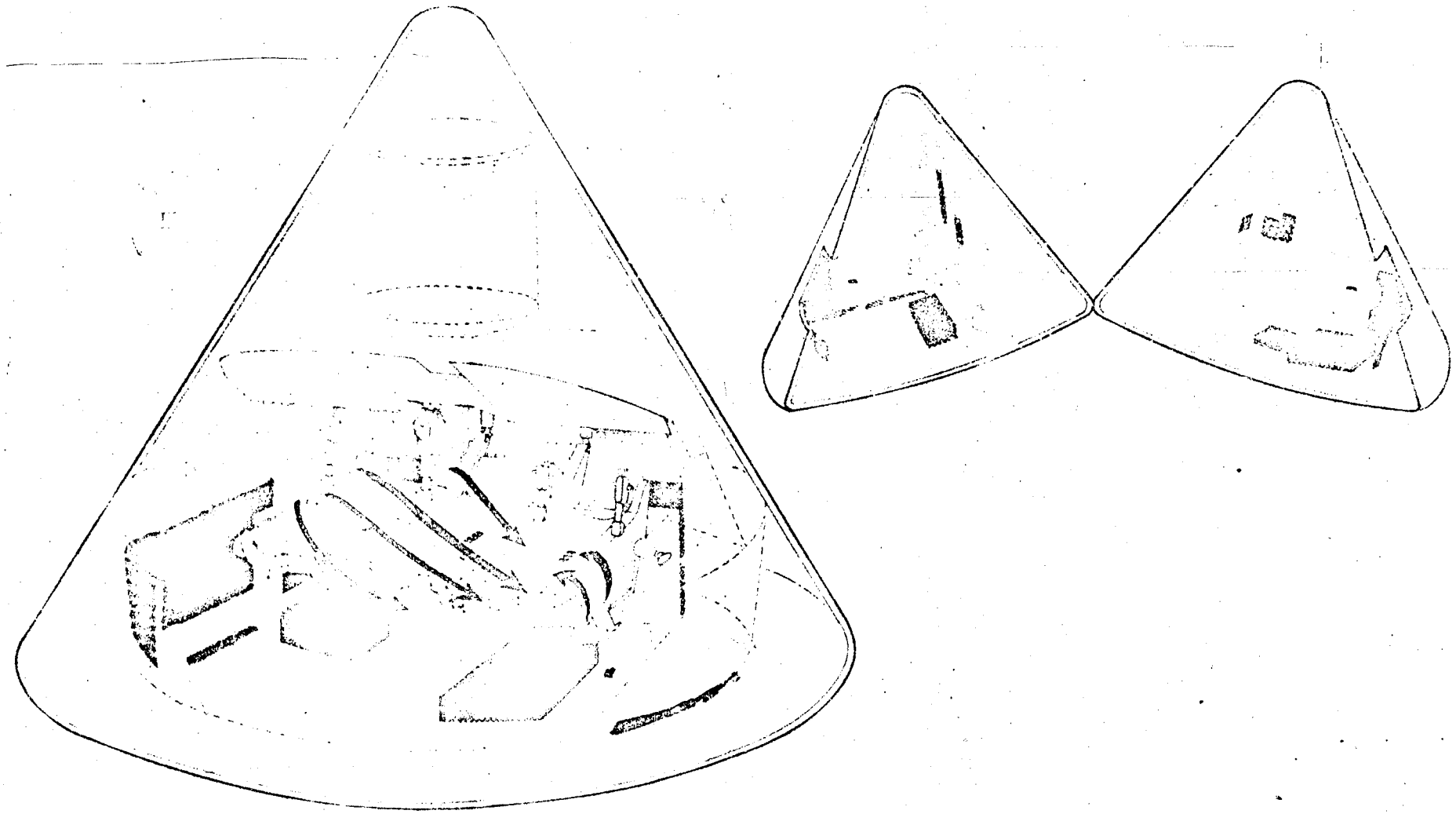
FIRST MAJOR FLOOR FRACTURE



FIRST PRESSURE VESSEL FAILURE

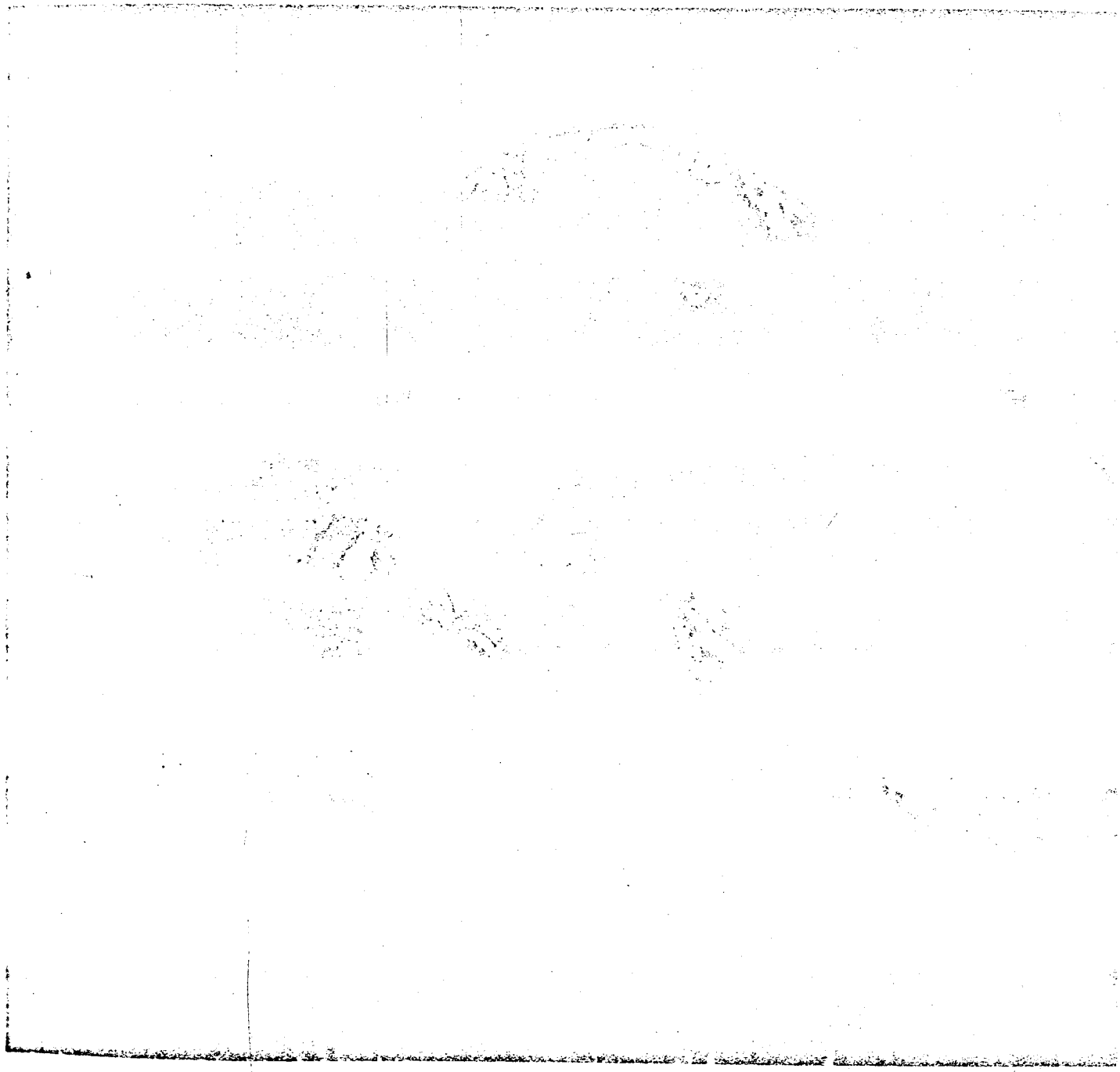
ENCLOSURE 5-12

FIRE OVER COUCHES
2nd FIRE PHASE



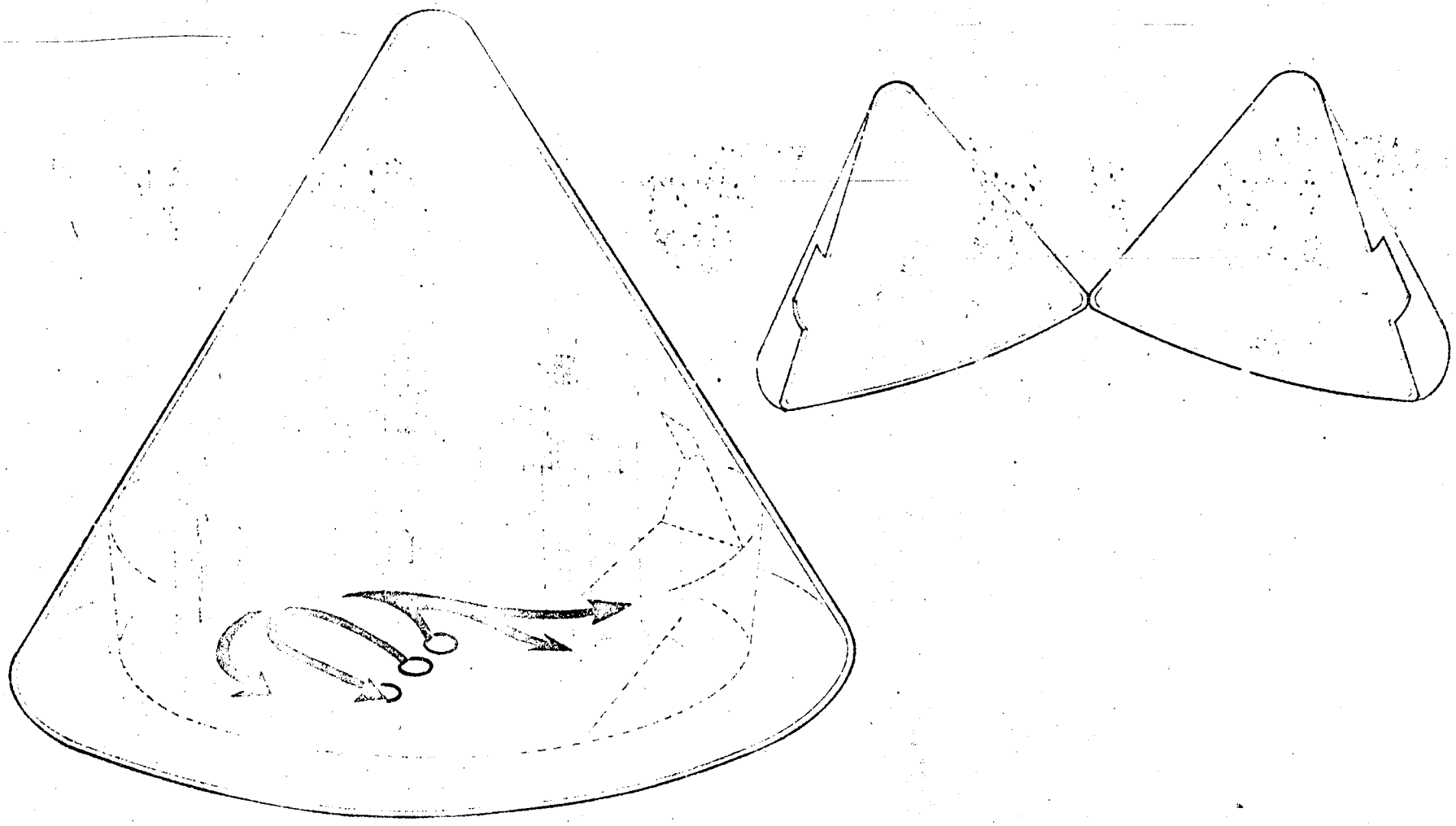
ENCLOSURE 5-13

SECOND FIRE PHASE OVER COUCHES



LEG REST CONTROL HANDLE

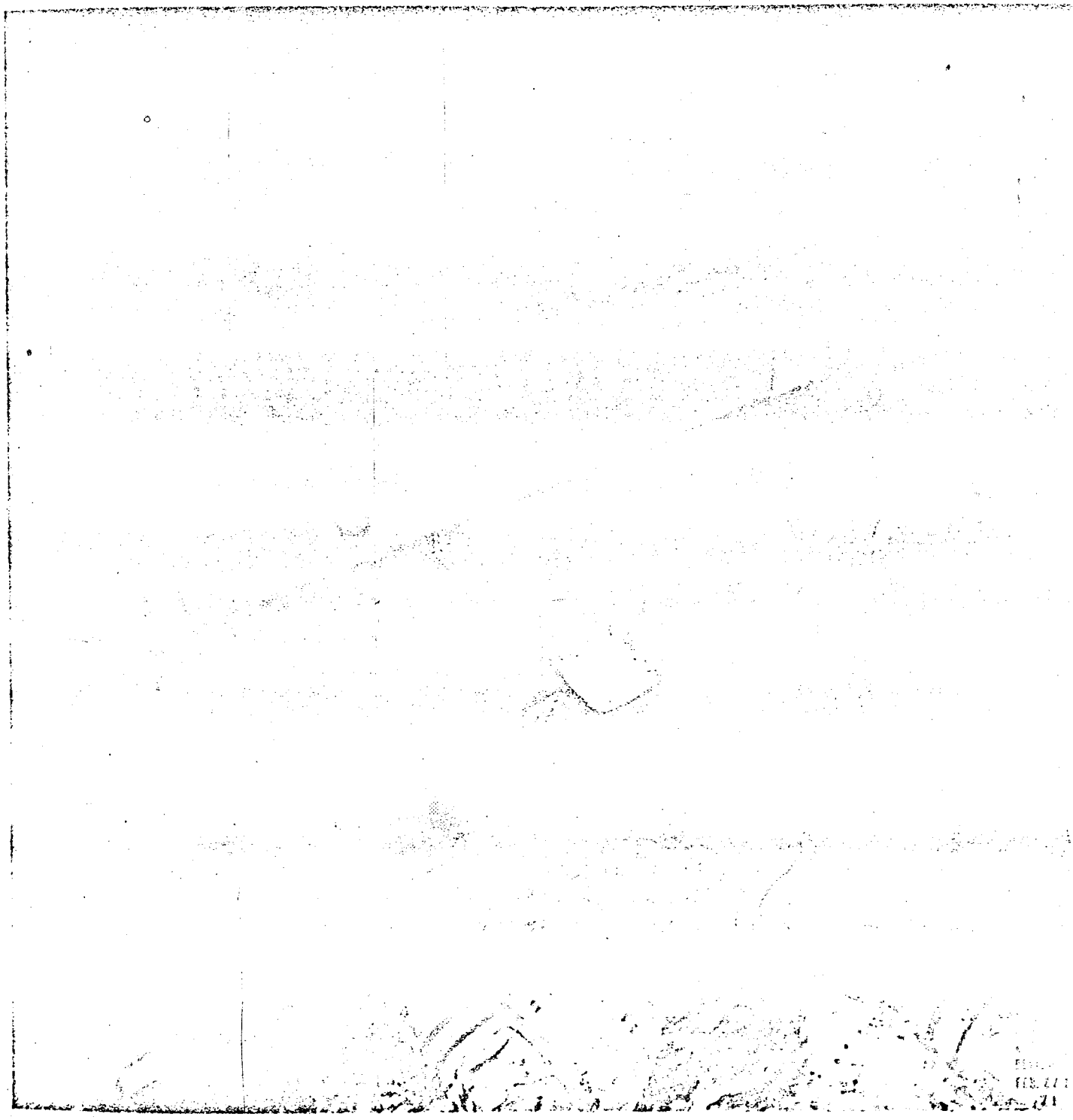
FIRE ON C/M FLOOR
2nd FIRE PHASE



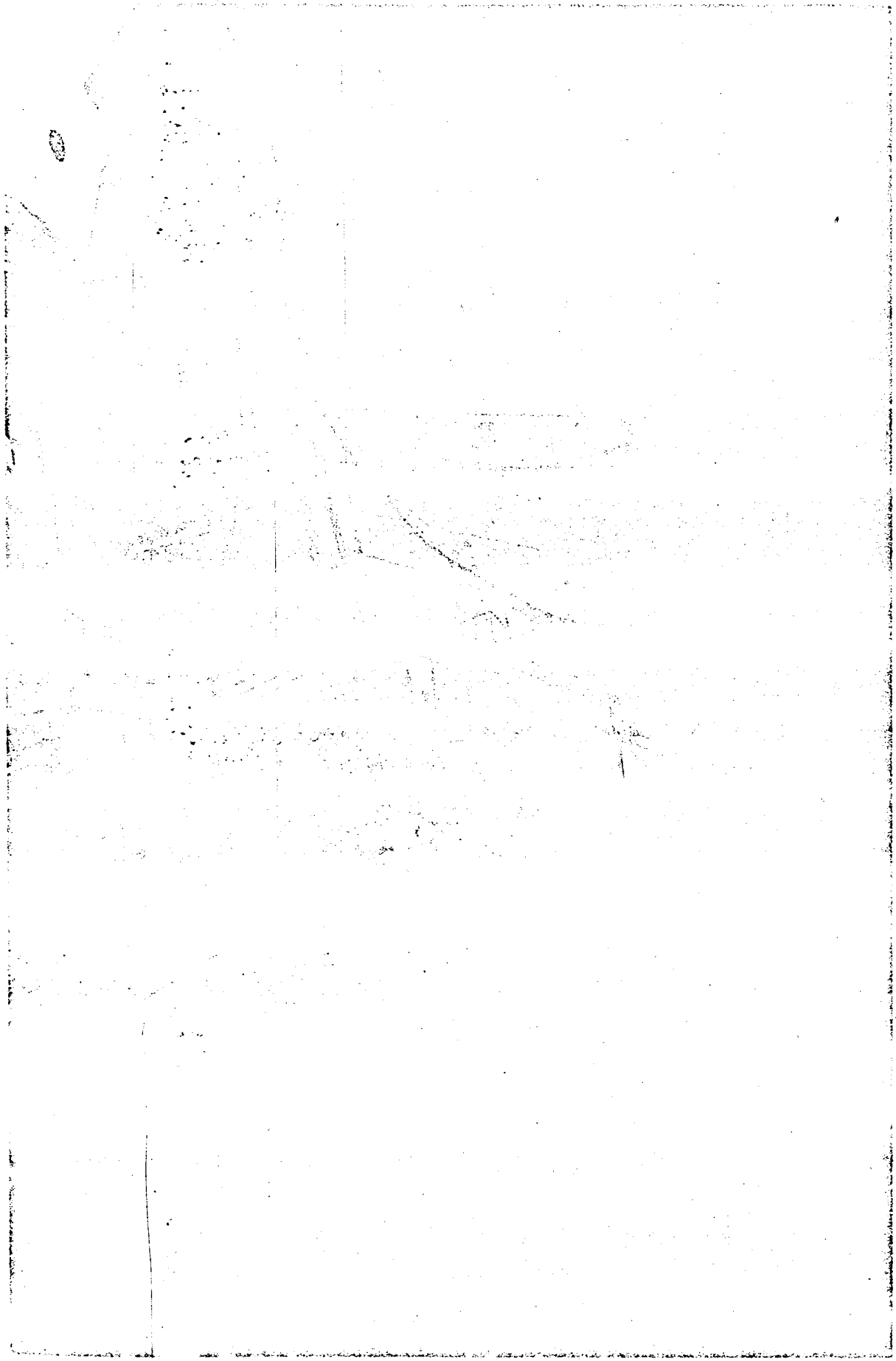
ENCLOSURE 5-15

SECOND PHASE OF FIRE – ON THE FLOOR

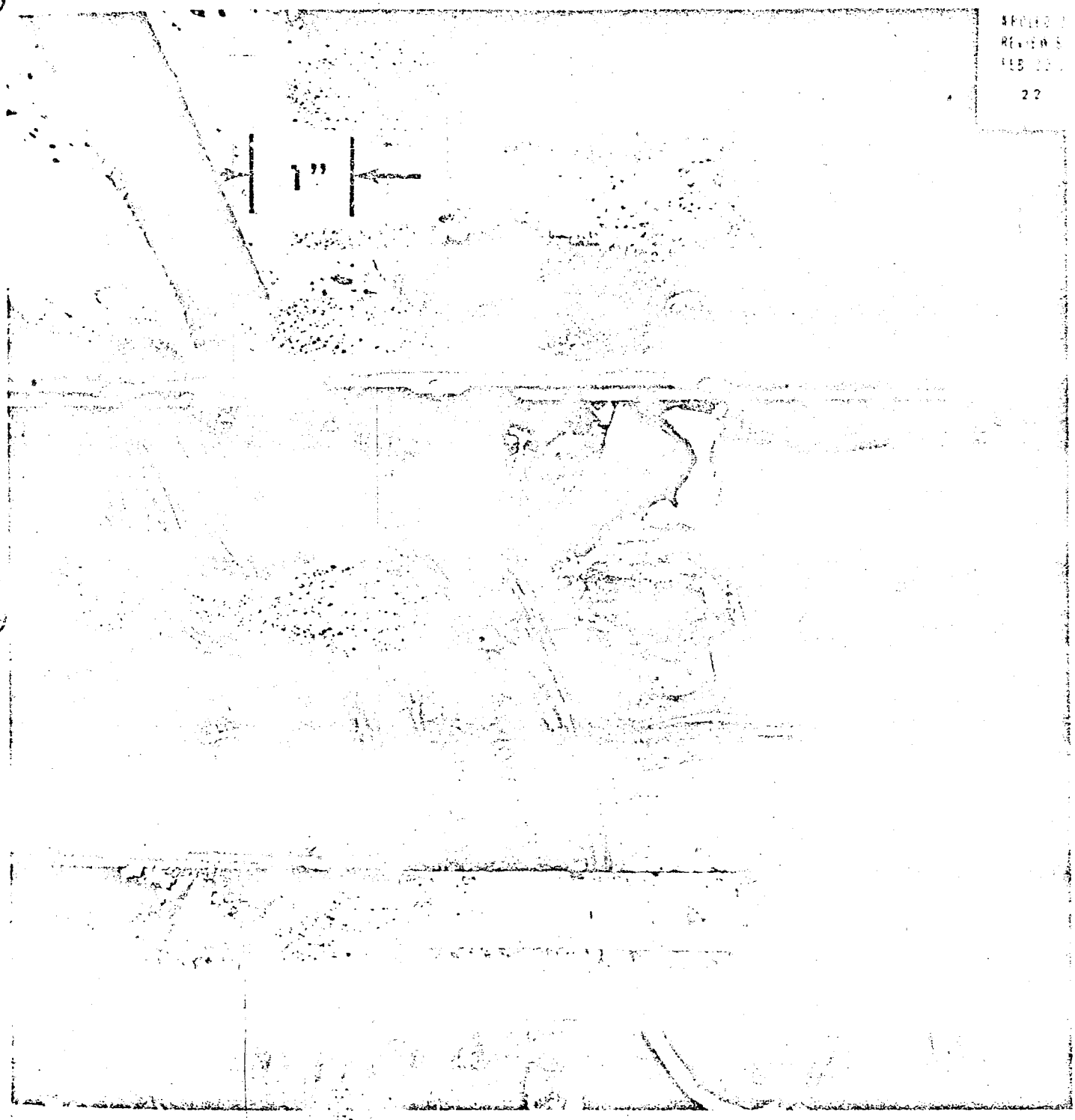
ENCLOSURE 5-16



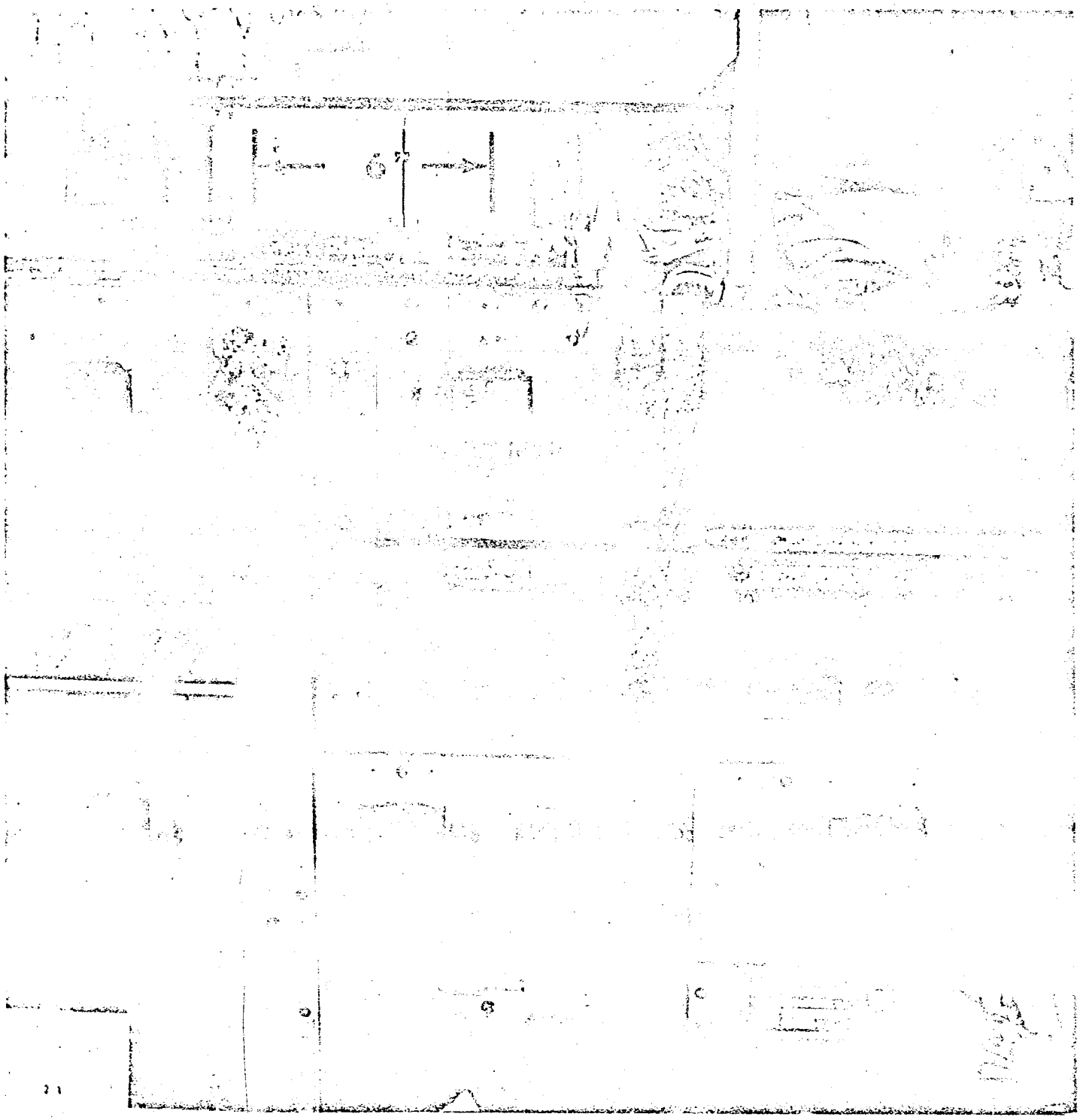
VIEW OF HELMET COVERS



VIEW OF FLOOR BELOW LOWER EQUIPMENT BAY



VIEW OF AFT BULKHEAD WIRING BELOW INVERTERS



INSTRUMENTATION ABOVE INVERTERS

GAS CHROMATOGRAPH CABLE EXAMINATION

A. Disposition of Gas Chromatograph (GC Cable Harness and Connector)

Description	Condition	Analysis
Observations on disposition of gas chromatograph cable harness and connector.	(1) Insulation from 117 V AC wires stuck to Pyro cable harness. (2) 117 V AC wire insulation broke through insulation (stuck to Pyro cable) as it fell to aft bulkhead. (3) Bare wires in cable harness match up with insulation residues adhering to Pyro cable. (4) Melted fiber glass tie wraps on cable harness in Channel "J" and Pyro cable harness, and GC cable harness match up. (5) Set condition of GC cable harness near connector as it rested on aft bulkhead in a strained configuration. (6) GC connector was burned in 360° (spherical geometry).	As based upon analyses the GC cable harness was tied to the cable harness (J-185) below and in front the GC bay above Inverter No. 3. The connector was either lying on the floor of the GC Compartment or hanging in free space at left hand corner of the Pitch ECA. When the tie wrap on the cable harness burned through it fell to the floor.

ENCLOSURE 5-23

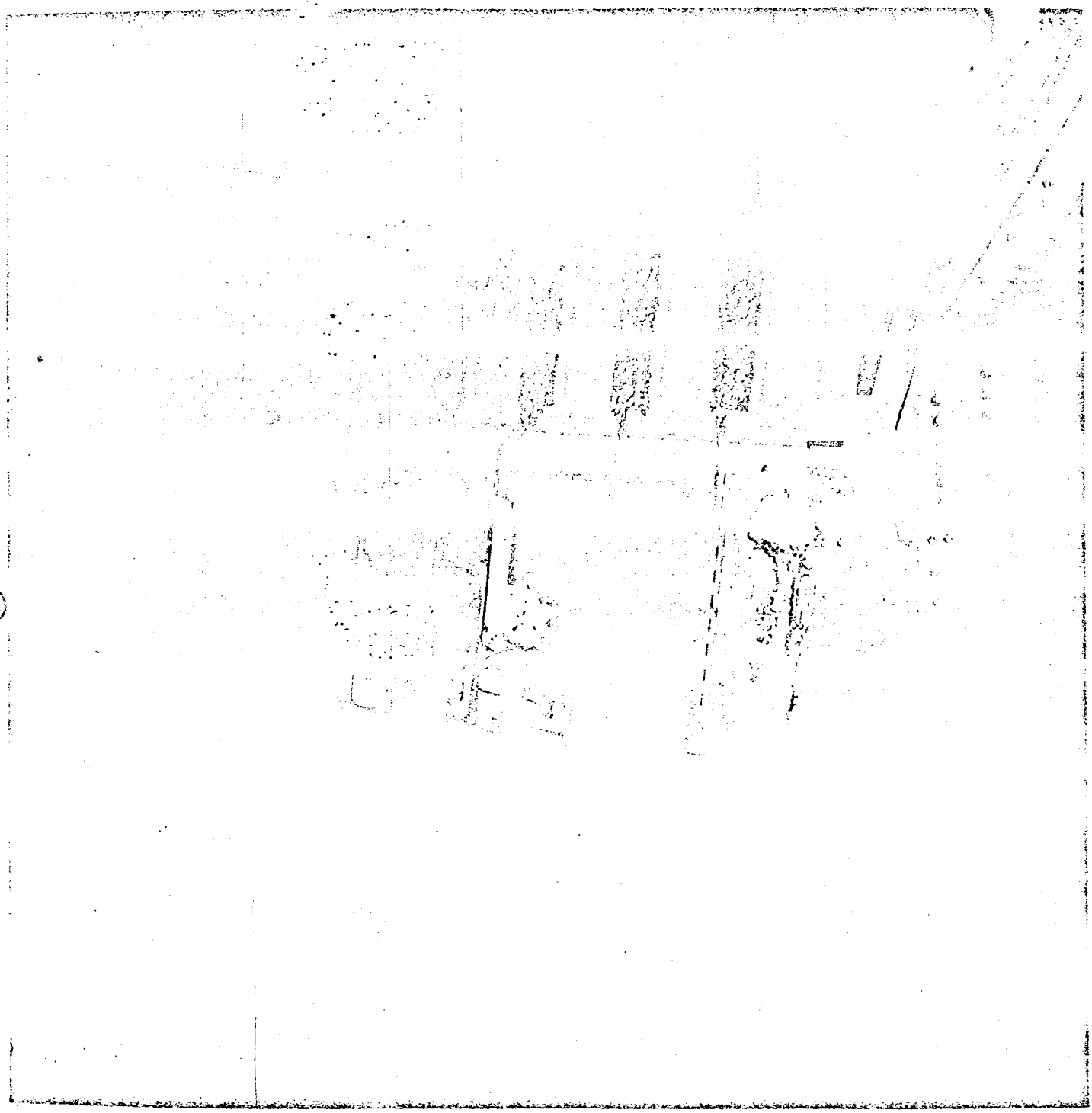
D-5-57

GAS CHROMATOGRAPH CABLE EXAMINATION

B. Metallurgical Examination of Gas Chromatograph Cable Harness

Description	Condition	Analysis
(1) Samples of 117 V AC wire from a thermally unaffected zone in transverse and longitudinal mode.	(1) Fine grain structure and twinning. A finite uniform nickel plate was observed.	(1) Wire in normally annealed condition. No alloying of nickel coating.
(2) As per item 1 except sampled in thermally degraded zone.	(2) Copper bead hollowed out. Extensive loss of copper from plated copper wire. Dendritic and gross grain structure with no twinning. Path of melting from wire to strand to bead clearly defined. Sharp grain structural zones between unaffected and affected heat zones. Tunneling and cavitation effects evident. Little alloying of nickel sheath and copper (only localized at nickel defects). Copper integrity below nickel sheath evident shows controlled melting phenomenon. Nickel plate was in a quench condition above tunnel.	(2) Highly concentrated and localized flame degraded Teflon and raised temperature to some value less than the melting point of copper between 600°C and 1000°C. Degradation of insulation allowed shorting of 117 V AC wires which provided further heat input driving the local temperature above the melting point of copper. Exclusive external or internal heating (arcing) cannot account for the metallurgical condition of wire but was a result of combined effects, one preceding the other, as evidenced by cavitation effects, sharp grain structural zoning, and unalloying of copper and nickel.
(3) GC Connector	X-ray, resistance, and conductivity measurements were negative and showed no anomalies. No evidence of arcing was found on dielectric material.	Shorting of connector pins did not occur.

VIEW OF EXTREME LEFT SIDE FORWARD



RIGHT HAND FORWARD EQUIPMENT BAY

PARTIAL VIEW OF RIGHT HAND EQUIPMENT BAY

ENCLOSURE 5-26

RIGHT HAND EQUIPMENT BAY	
Equipment and/or Panel	Conditions
DC Power Panel Instrument Circuit Breaker Panel Uprighting System Distributor Boxes	Sooted. Slight fire damage. Melted and partly burned plastic adhering to faces, tops, wires and back bulkhead.
Circuit Interruptors	Same as above. Wires at base show greater fire damage. Debris on base.
Earth Landing Sequencer	Sooted. Moderate fire damage on wires outside panels. Paint blistered on panel face.
Ground Support Equipment	Wire bundle compressed by cover panel, insulation split lengthwise after fire.
Others	Little soot. Slight fire damage. Some melted plastic. More damage in the +Z direction.

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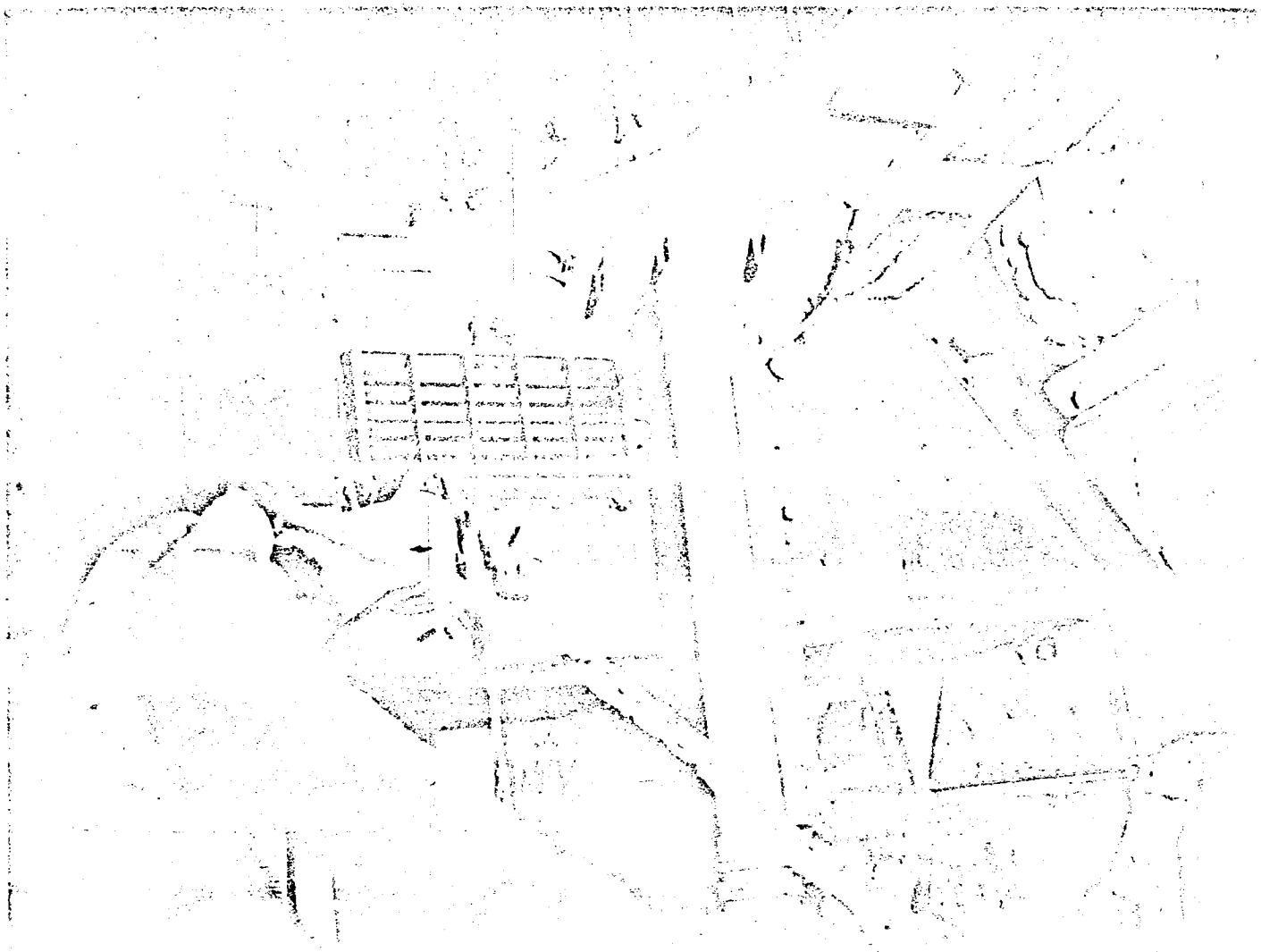

GENERAL VIEW OF CABIN AREA INLET

FORWARD EQUIPMENT BAYS	
Equipment and/or Panel	Conditions
Cabin Intake Fan and Heat Exchanger Area	Heavily sooted. Burned plastic. Moderate fire damage.
Drinking Water Fountain	Panel on bottom burned through. Heavy soot. Burned plastic inside.
Loose Equipment Storage	Heavy soot.
Suit Loop Outlets	Hot jet burn. Heavy soot.
Access Tunnel Above Suit Loop Outlets	Hot jet burn. Velcro slightly melted.
Tunnel	Slight fire damage.
Escape Hatch	Melted nylon on intake vent fan. Dripped plastic on wire. Soot.
Right Hand Bay	Minimal fire damage.

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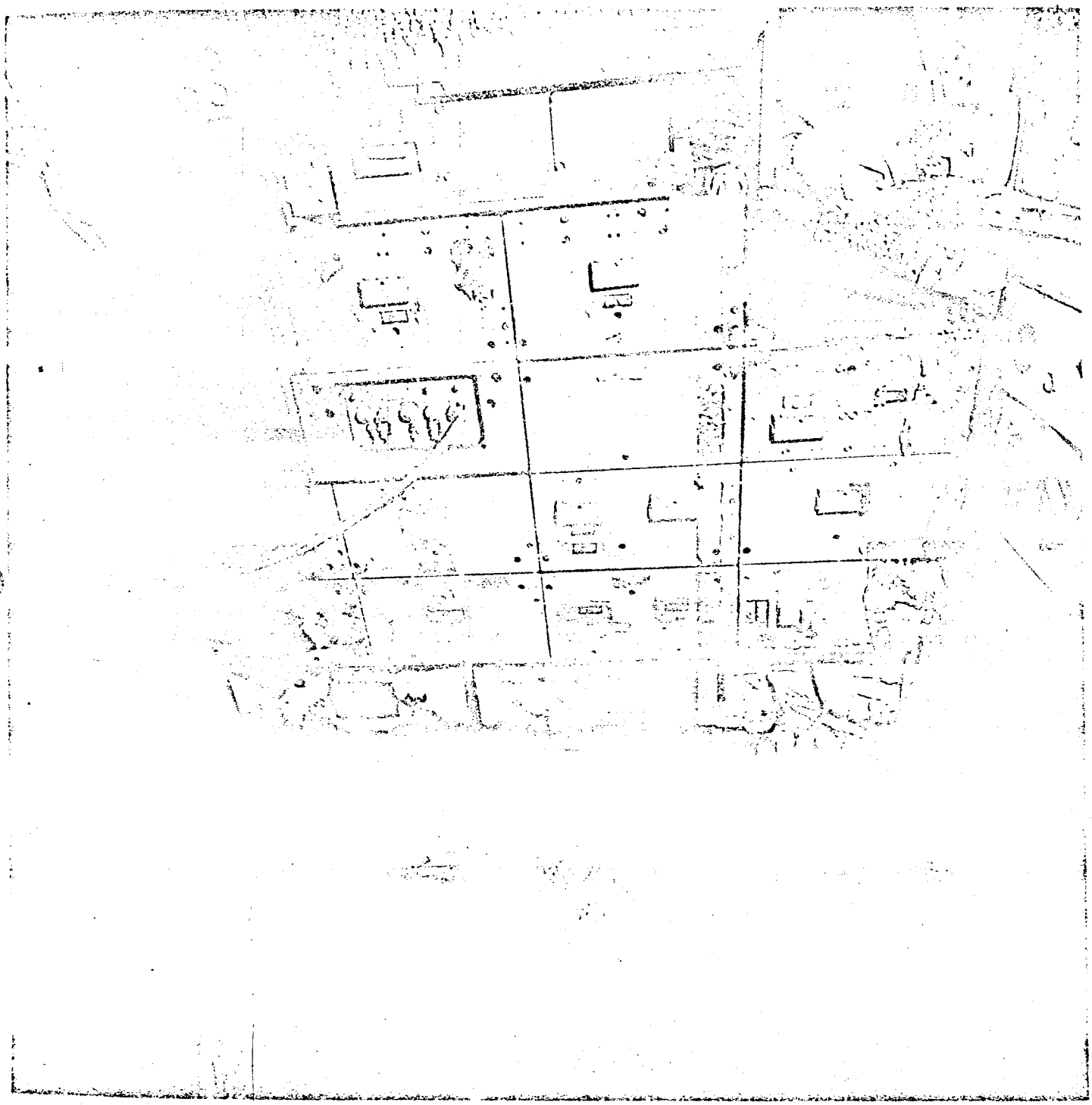
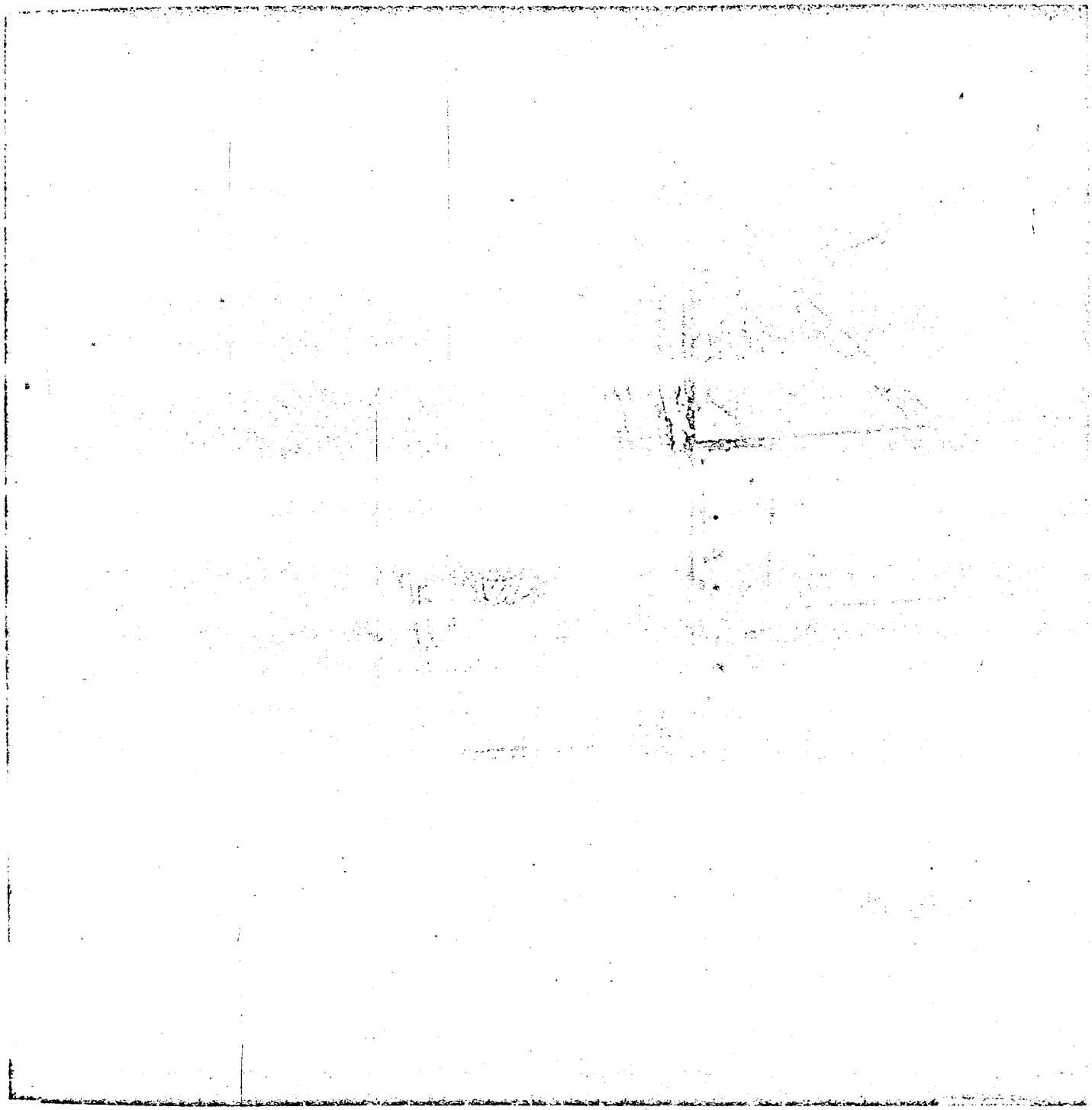
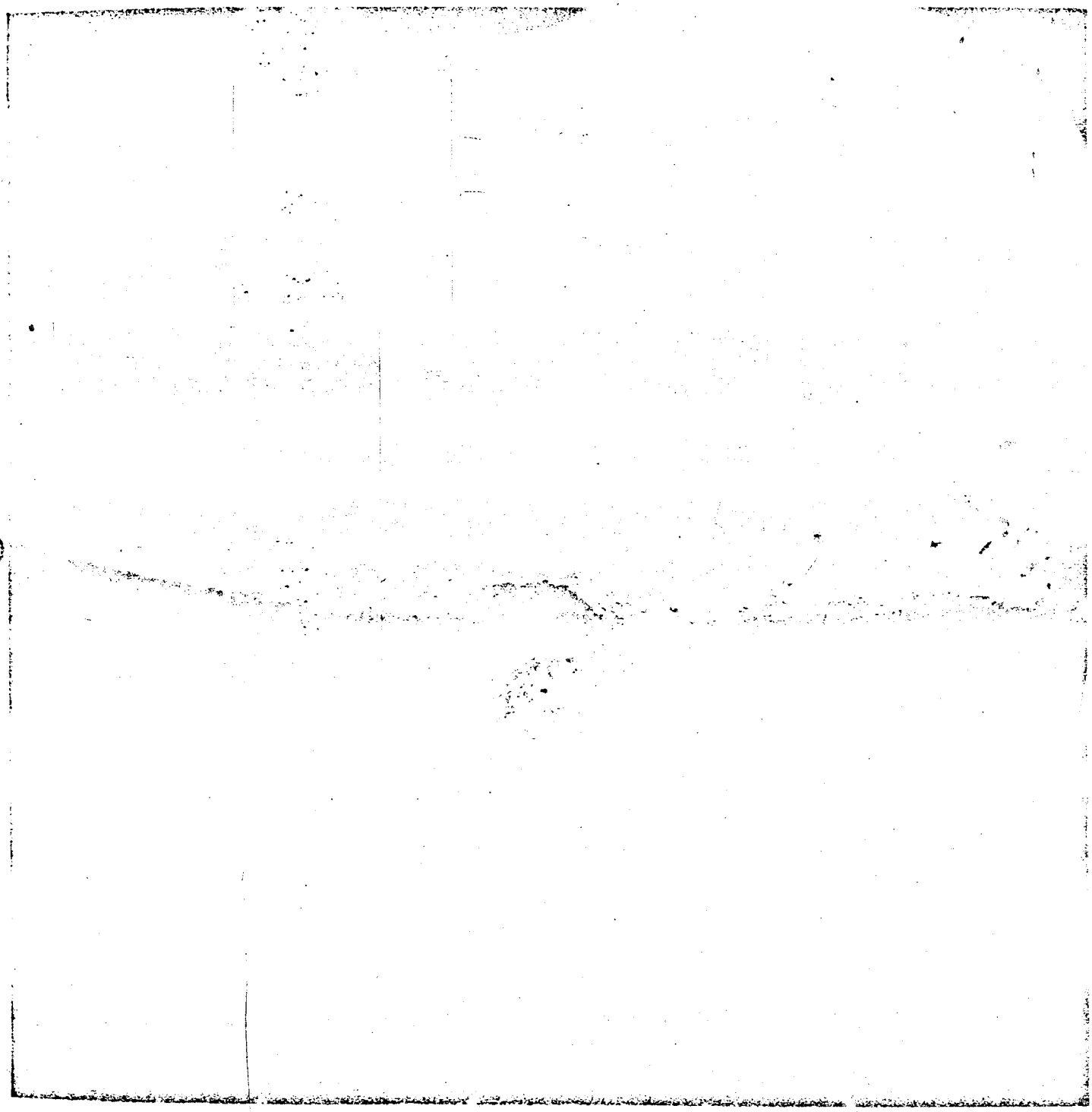


RIGHT HAND SECTION OF LOWER EQUIPMENT BAY



LOWER LEFT HAND SECTION OF LOWER EQUIPMENT BAY

ENCLOSURE 5-31



VIEW OF ARC ON PANEL 109

ENCLOSURE 5-31A

LOWER EQUIPMENT BAY, +X HALF	
Equipment and/or Panel	Conditions
Food (Panel A)	Blistered paint. Warped panel.
Food (Panels B, C, D, E)	Melted metal on doors, more severe on C and E. Melted Velcro inside. Fire damage to insulation on glycol line at rear.
Instrument Storage Unit	Fire damage to foam insulation, worse on outside and left, and to rubber on instruments. Bay relatively clean.
Guidance and Navigation Optics	Burned gasket, blistered paint, melted plastic on left, slightly melted on right.
Guidance and Navigation Instrument Computer	Hot jet effect from lower left corner. Melted potting on connectors. Melted plastic, peeled tape, corrosion inside. No apparent fire damage in bay, melted plastic on wire bundle upper right.
Power Servo Amplifiers	Plotting melted and dripped plastic on left hand amplifiers. No apparent fire damage to bay.
Coupling Display Units	Erosion of insulation on wire pairs.
Altitude Gyro Accelerometer Package. Altitude Gyro Accelerometer Bay. Navigation Display and Keyboard.	Heavy soot. Melted potting. Fire damage to insulation on glycol line back of Accelerometer Bay.
Data Storage Equipment Signal Conditioner	Heavy soot. Slightly melted Velcro.

LOWER EQUIPMENT BAY, -X HALF (CONT)	
Equipment and/or Panel	Conditions
In-flight Recorder Scientific Package A Gas Chromatograph Bay	Moderate Soot. Burned and bare wires in front of panels. Fire damage to Teflon wrap on wire bundle at right and top, wire harness squeezed. Fire damage to insulation on water/glycol line at right rear. Burned Teflon overlay in bottom plate cutout. Dried condensate streamers on pressure vessel.
Altitude gyro Accelerometer display yaw, pitch, roll auxiliary electronic control assemblies	Burned paint on face. Melted potting on connectors (More severe on left). Melted plastic on panels. Broken connector lips on assemblies with soot on gaskets and fractured lip. Slight fire penetration behind left face of panels. Moderate soot.
Apollo Guidance Computer Scientific B Package. Unified S-Band Equipment Up Data Link	Blistered and burned paint on face. Slight fire damage to wire bundle in Computer bay Moderate soot.
Pulse Code Modulation (1 and 2) Quality Telemetry Recorder	Heavy soot. Decreasing fire patterns left to right. Melted Velcro on faces.
VHF - AM and FM	Heavy soot. Melted potting on side connectors. Melted Velcro on faces.
VHF Multiplexer	Melted Velcro on faces.
S-Band	Melted plastic adhering to face. Burned blow-hole in potting behind face plate. Melted potting on connectors. Bare wires on top connector.
C-Band	Upward flame streak on face.
Data Wiring	Slightly melted Velcro
Pre-Modulation Processor	Melted Velcro. Melted plastic adhering to face. Melted potting on connector. Bare wire on right side connector. Light soot in bay.
Audio Center	Melted Velcor. Face sooted. Melted plastic adhering to face. Cracked Hughes connector, with bare wires. Melted potting. Light soot in bay.

LOWER EQUIPMENT BAY, -X HALF (CONT)	
Equipment and/or Panel	Conditions
Central Timing	Melted Velcro. Melted potting and bare wire on lower left connector. Light Soot in bay.
Connector C-15-1A-52	Severe fire damage. Panels heavily sooted. Melted chafing guard. Evidence of arc in lower right hand corner. Nylon chafing guard in cover plate 3/16 in. from arced spot. Burned wired in harness at bottom. Squeezed wire bundle against Inverter No. 3.
Inverter No. 3	Buckled bottom and face plates. Heavy soot.
Batteries A, B, C	Severe fire damage. Slight separation of outer container. No penetration to electrolyte.
Inverter and Battery Compartment	Sooted. Debris. Little fire damage. Exposed wires in slot above B battery burned bare and fused. Slight fire damage to insulation of glycol line back of Inverter No. 1. Melted and burned hole in pressure vessel.

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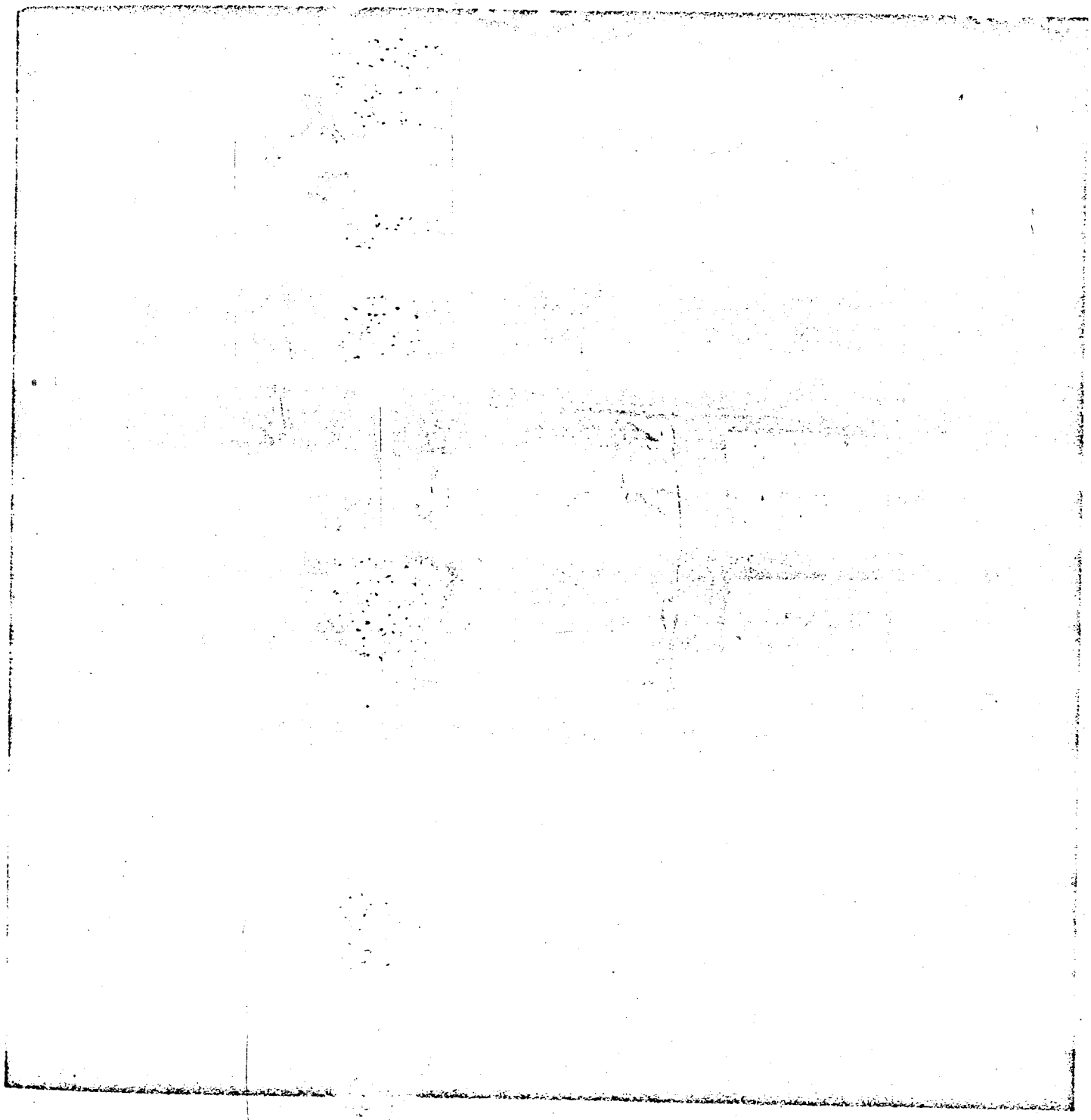
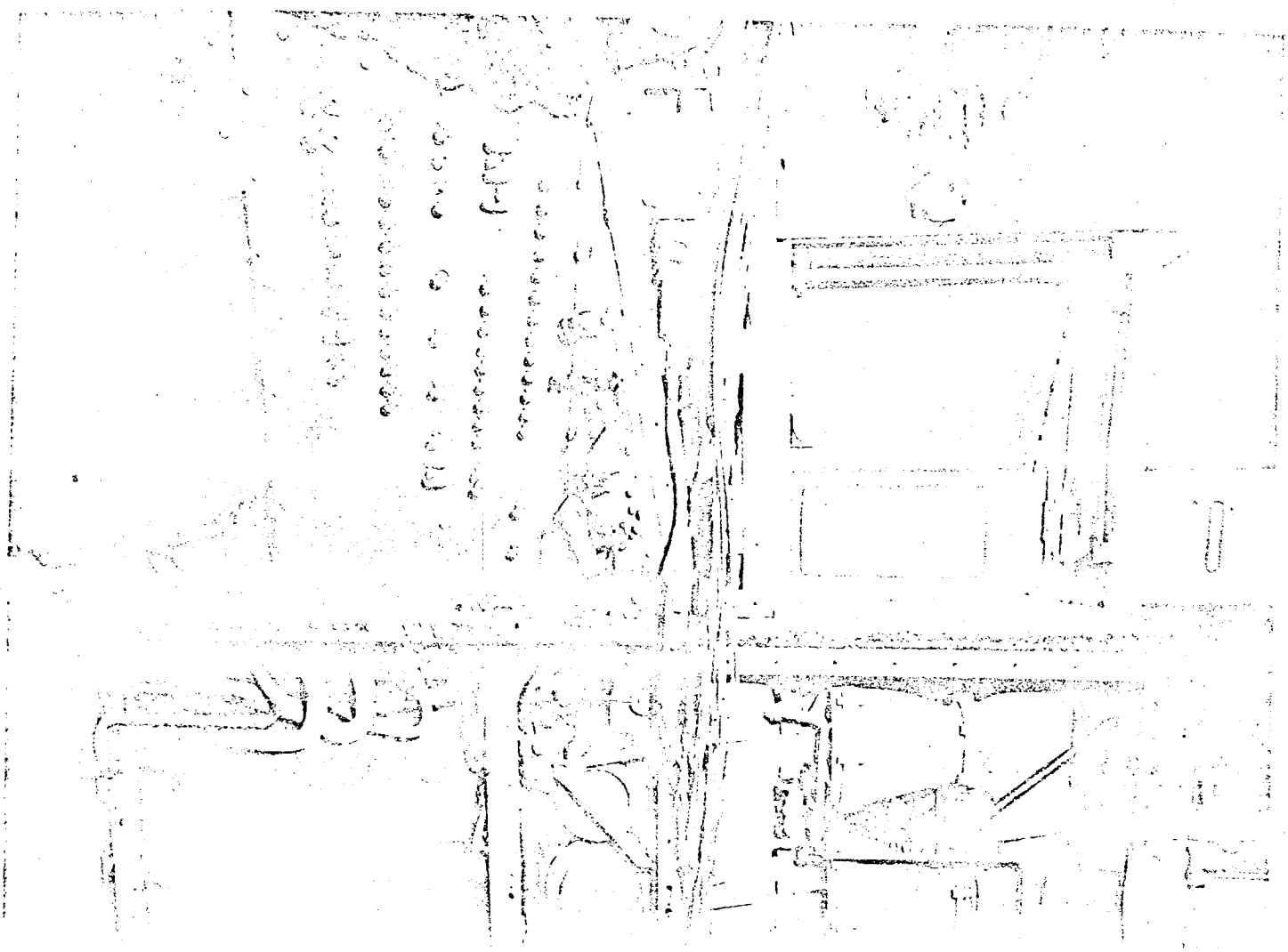


LEFT HAND FORWARD EQUIPMENT BAY



VIEW OF ENVIRONMENTAL CONTROL UNIT

LEFT HAND EQUIPMENT BAY	
Equipment and/or Panel	Conditions
Oxygen Panel	Burned Velcro on face. Melted cabin emergency valve on face. Severe fire damage, worse on inside. Potting blown out of solenoid. No apparent tube failure.
Water Panel	Very severe fire damage inside. Tubing burned away. Melted plastic adhering to face and tubing. Torch-like hole burned in pressure vessel wall on back of bay. Bare wires and wires burned away. Severe melting of wire harnesses. Massive hole burned in pressure vessel in aft bulkhead, extending to CO_2 Absorber Bay. Right hand bay bulkhead severely burned and melted. Molten ingot on floor covering wire cables leading to CO_2 Absorber Bay.
CO_2 Absorber	Severe heat and fire damage, melted and burned across bottom of door. Melted plastic adhering to hinge. Compartment A showed low order explosion door blown open, LiOH spilled, felt pads missing, housing distorted, activated carbon present in rear. Compartment B had hole burned through lower right side and bottom, LiOH spilled and partly fused, no front felt pad. Very severe fire damage in lower section of compartment, burned, melted and fused wiring, burned and melted gas transfer lines, water line blown open. Massive hole burned in floor. Left hand wall severely burned at bottom, molten ingots present.
Environmental Control Unit	Insulation completely burned on front of heat exchanger, decreasing fire damage toward rear and left. Tubing on floor separated and melted. Condensate streaks on back wall. Moderate fire damage to floor.
Surge Tanks and One-lb. Oxygen Bottle Area	Hot jet effect upper rear right-hand corner. Heavy soot. Moderate heat damage to insulation on front tubing. Melted plastic adhering to components in area.
Surge Tank, Cabin and Glycol Pressure Relief Valves	Slight to moderate heat damage from top to bottom. Heat damage to insulation on glycol lines. Debris in bottom of bay. Extensive melted plastic adhering to left-hand bulkhead and bottom.

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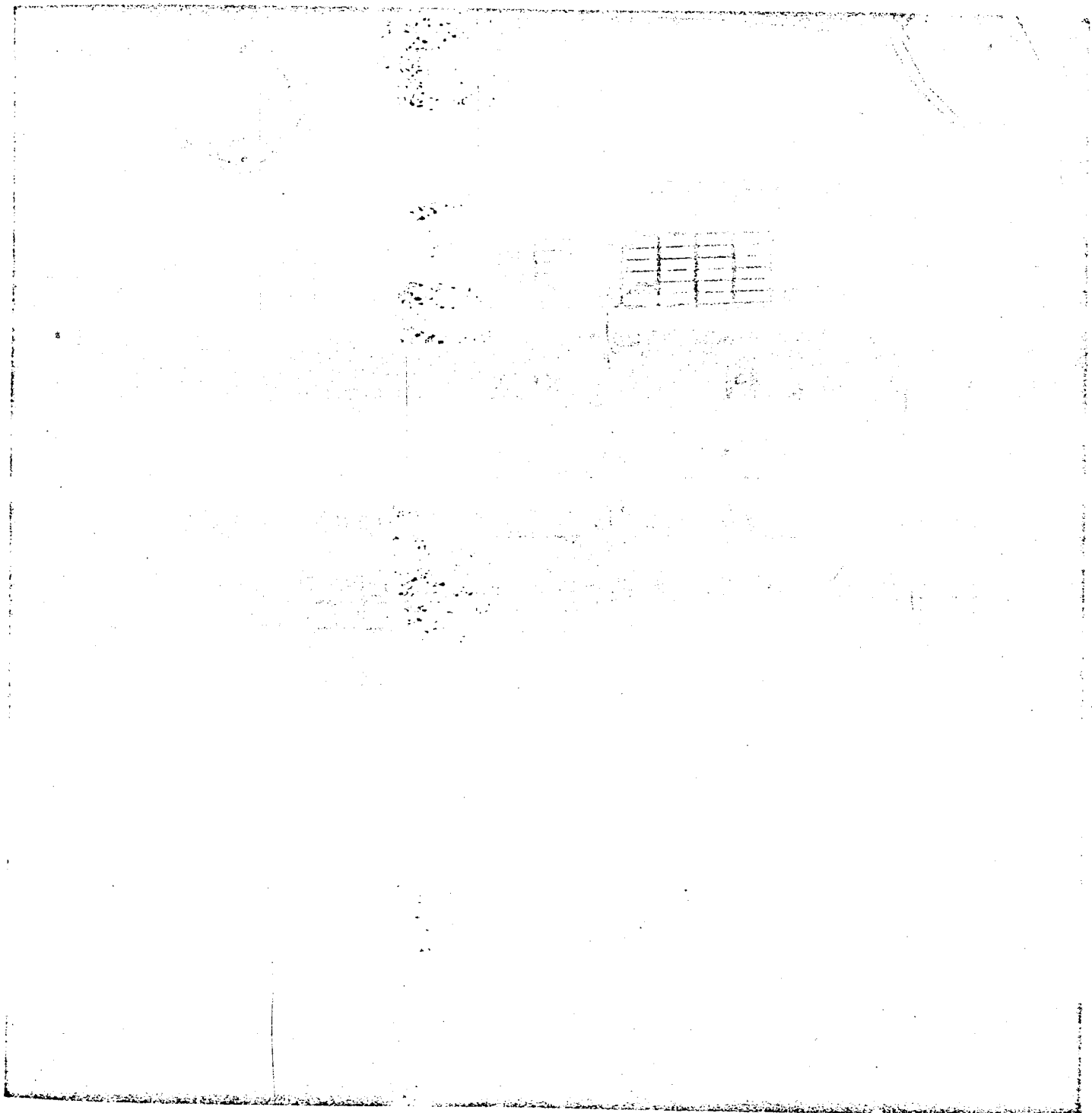
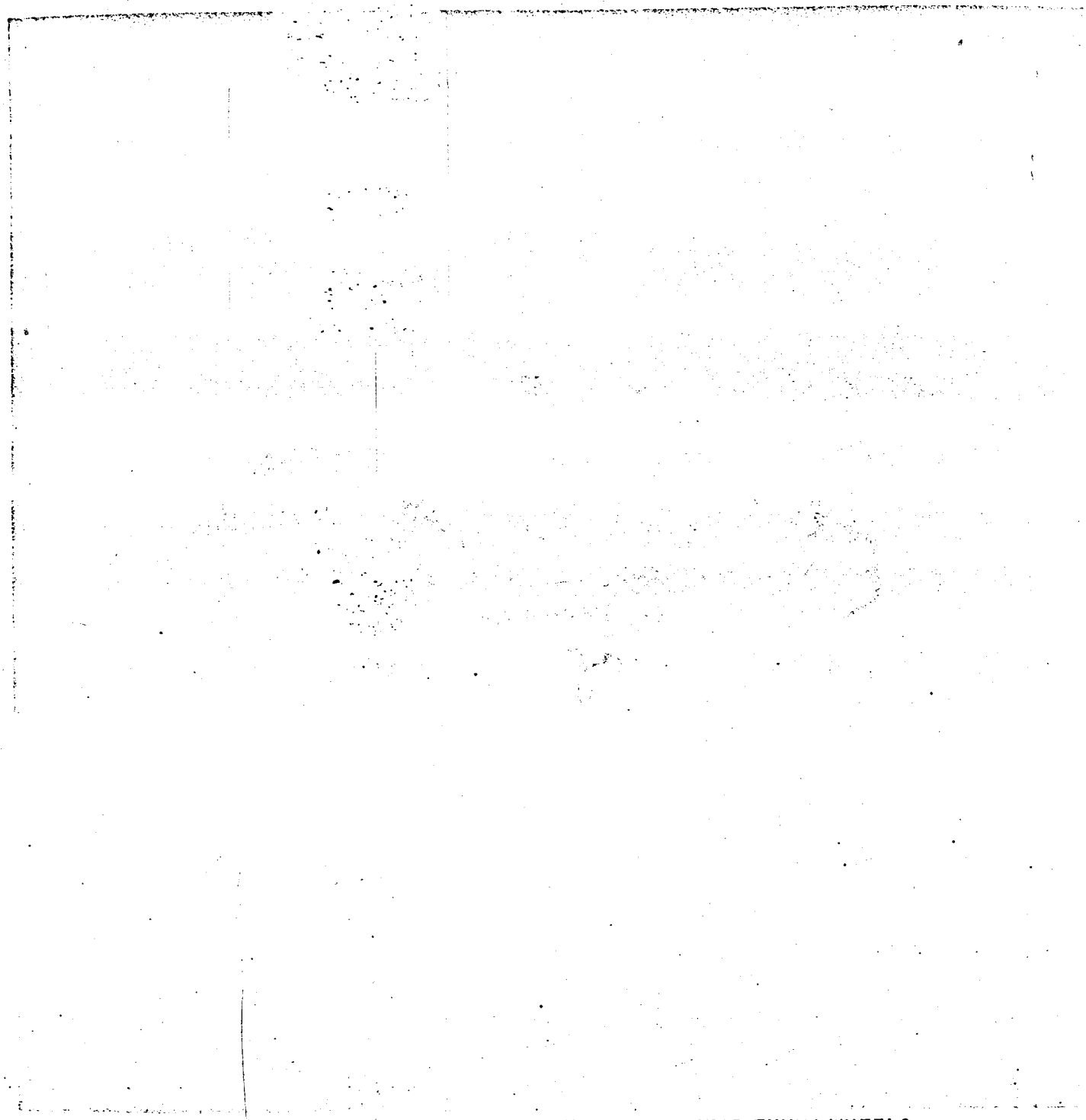


VIEW OF MAIN DISPLAY CONSOLE

MAIN DISPLAY CONSOLE	
Equipment and/or Panel	Conditions
Panel 24	Melted knobs, soot on face, burned potting on Switch S-1, burned wires around S-1 and S-4, hot jet burn inside compartment, burned insulation on glycol line. Melted Velcro on Access Panel.
Panel 25 Panel 26	Melted thumb knobs. Heavy scoting. Slight fire damage upper part Panel 25. Sooted and melted thumb wheels. Soot and heat on rear face of panel by entry around thumb wheels. Potting compound on Switch No. 6 and No. 7 shows some burning.
Panel 4 (FDAI)	Melted potting on connector. Bare wires. Soot.
Panel 5	Lower five push-buttons burned out. Heavy fire damage on face. Hot jet burn from lower left corner inside. Condensate streaks on bay walls.
Panel 6 Panel 12	Melted thumb bottons or knobs. Glass cracked. Moderate soot.
Panel 7	Melted push bottons. Broken guard rings. Burned paint. Melted potting on connectors. Hot jet burn upper area.
Panel 8	Soot heavier on left. Condensate streaks inside.
Panel 14	Hot jet burn from lower left corner. Melted push buttons. Moderate heat damage. Burned potting. Bare wires.
Panel 13 Panel 18	Thumb wheels on lower left side melted (lower thumb wheel more damaged than the two above). Rear of face plate, Switch to left of S-27 shows burned potting compound, tape around mechanical portion of switch burned away. Push buttons slightly melted. Burned paint on face. Light soot inside, heavier on left.
Panel 16	Melted Velcro. Soot. Melted plastic adhered to face. Soot inside.

MAIN DISPLAY CONSOLE (CONTD)	
Equipment and/or Panel	Conditions
Panel 15	Covers around guages melted. Cracked glass. Knobs slightly melted. Inside, soot heavier on left.
Panel 20	Melted squelch knob. Light soot inside.
Panels 1, 2, 3, 10, 11, 19, 21, 22, 23	Slight fire damage. Soot.



INTERIOR VIEW OF PANEL 13 SHOWING DAMAGE NEAR THUMB WHEELS

LIST OF REFERENCES

REFERENCE

5-1 Report on Translation Controller TPS No. S/C 012 PIB 002 February 11, 1967.

5-2 Report on Rotation Controller TPS No. S/C 012 PIB 004 February 15, 1967.

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REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANELS 6 thru 10

REPORT OF PANEL 6
HISTORICAL DATA
APPENDIX D-6
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

JAN 1982
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Historical Data Panel 6. The task assigned for accomplished by Panel 6 was prescribed as follows:

Assemble, review, and summarize historical data on Spacecraft and associated systems as pertinent to the fire incident. Data to be analyzed shall include records such as included in Spacecraft log, failure reports, other quality engineering and inspection documents. Make interpretation on data as to applicability to subject problem.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Historical Data Panel:

Mr. T.J. Adams, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. J.H. Dickinson, Kennedy Space Center (KSC), NASA
Mr. J.L. Hansel, North American Avis tion, Inc., (NAA), KSC
Mr. D. Buffington, North American Aviation, Inc., (NAA), KSC

2. COGNIZANT BOARD MEMBER:

Mr. G.C. White, Jr., NASA, Washington, D.C., Board Member, was assigned to monitor the Historical Data Panel.

C. PROCEEDINGS

1. GENERAL

a. Panel 6, Historical Data, was established to assemble and review records on Spacecraft (S/C) and associated systems in order to determine the applicability of these records to the Apollo 204 accident. In addition, historical narratives (Enclosures 6-6 and 6-7) were prepared to reflect the relationship and flow of significant review and acceptance points, highlight documentation pertinent thereto, and to present a brief history of the prelaunch operational performed on S/C 012 at Kennedy Space Center.

b. Enclosure 6-2 lists the records reviewed by Panel 6, with an explanation of these records, and the criteria used for judgement of applicability.

c. Throughout the Panel's activities, contact was maintained with MSC-Houston and NAA-Downey and several requests for records review were placed on both organizations.

2. IMPOUNDING AND INVENTORY

a. Impound Procedure - Action was begun within an hour of the Apollo 204 accident to impound all S/C 012 quality documents in accordance with the guidelines contained in the Apollo Mission Failure Contingency Plan dated May 15, 1966. (Reference 6-1.) The impounded records from Launch Complex 34, Flight Crew Systems Laboratory, and Acceptance Checkout Equipment Control Room No. 1 were collected and delivered to the Quality Records Center. A NASA Security guard was posted, with access permitted only to personnel approved in writing by the Board. NAA Downey Quality and Reliability Assurance was notified and immediately impounded all quality pertinent to S/C 012 concurrent with notification to applicable vendors to impound same.

b. Inventory Procedure - The impounded records were inventoried and all documents applicable to the Apollo 204 accident were segregated.

Approximately 42,500 pages of records were catalogued, representing 12,000 documents. Three documents were not accounted for adequately. These documents were Test Preparation Sheet (TPS) S/C 012-SLA-004. Temporary Installation and Removal Record (TIRR) S/C 012-CME-42 and Parts Installation and Removal Record (PIRR) S/C 012-PIRR-(010) No. 132. An evaluation of the type documents concerned discounted any relevance to the accident.

As the documents were catalogued, significant information was recorded on special review forms prepared to enhance accountability and evaluation.

3. REVIEW TEAMS

a. The review teams consisted of Quality and Reliability Engineering Personnel drawn from government, NAA, and the General Electric Company (Apollo Support Division). All review personnel had previously been associated with S/C 012 operations and were familiar with the test history. The review was conducted on a continuous basis in order to make pertinent information available to Panel 6 and other Panels for consideration as rapidly as possible.

4. REVIEW PROCEDURE

a. Data review consisted of determining which Command Module (C/M) records were considered significant (in consonance with criteria delineated in Enclosure 6-2) so as to warrant consideration by other Panels, e.g., the Materials Review Panel 8 was provided with all records pertaining to use of nonmetallic materials. Dissemination of significant records was conducted in accordance with the following criteria:

(1) Relevant Items and Their Disposition:

(a) Chemicals:

All records documenting the use of chemicals, such as cleaning solvents, paints, and other chemicals were forwarded to the Materials Review Panel 8. This category included any reports of leakage in fluid systems.

(b) Nonmetallics:

All records documenting the use of nonmetallic materials in the crew compartment were forwarded to the Materials Review Panel 8.

(c) Electrical:

All pertinent records documenting problems with electrical systems were forwarded to the Integration Analysis Panel 18.

b. Panel 7 activities continued in support of the other Panels. Mainly, this consisted of researching the records to provide data requested other Panels. One example of this is the use of the methyl-ethyl-ketone, (MEK), as a cleaning agent. Since this is a flammable material, and because a partially filled bottle of MEK was found in the White Room after the fire, there was concern over the use of this material. The records search, combined with the interrogation of personnel who were known to have used MEK in the S/C in the three days immediately preceding the accident, enabled Panel 6 to supply information to Panel 8 for their evaluation.

c. Panel 6 also conducted a review of Problem Action Records (PAR's) and Unsatisfactory Reports (UR's). These records are defined in Enclosure 6-2, and the results of the review are given below:

(1) Problem Action Records - Failure Category:

All problem reports in the failure category were reviewed by support personnel at MSC. The reports covered failure-type problems from inception of the Apollo Program through development, qualification tests, manufacturing-vendor tests, field tests, checkout, and flight testing of all Command Modules and Command Modules Systems, subsystems and components throughout the country. Any previous conditions that could be related in some manner to the Apollo 204 accident were reviewed and evaluated. Upon completion of the Panel 6 review of these reports, a total of 39 were identified as requiring further evaluation for applicability by Panel 18 (Enclosure 6-2). In cases where conclusions drawn by an original failure analysis seemed questionable, the results were re-examined. No new conclusions relevant to the Apollo 204 accident were found in the review.

(2) Problem Action Record - Unsatisfactory Condition (PAR-UC):

A review of PAR-UC's was conducted and yielded no new significant information.

(3) Unsatisfactory Reports (UR's):

All UR's written at KSC prior to the accident were reviewed, and only one was considered applicable, i.e., bent electrical connector pins. This problem was identified to Panel 18 as a result of the Discrepancy Record Review (Enclosure 6-4).

5. DISCUSSION

a. Ingress-Egress Log

(1) In reviewing the Ingress-Egress Log, pertinent discrepancies were noted. An Ingress-Egress Log is maintained in accordance with Apollo Preflight Operations Procedures (APOP) No. 0-201, "Access Control of Test and Work Areas" (Reference 6-2). Personnel entering the C/M are required to record on log sheets all tools and other items carried into the C/M. The log sheets for S/C 012 were reviewed and in several cases showed that tools were recorded as having been carried into the C/M, but no record of removal of these items was made. Considering that tools could come in contact with electrical equipment and cause an arc, Panel 6 initiated an investigation of the S/C to look for these specific tools.

b. Shakedown Inspection

(1) Shakedown inspection is defined as a pre-scheduled period when all other operations are discontinued while inspection personnel conduct a visual inspection. This is in accordance with established and approved criteria to detect and record hardware discrepancies.

(2) Panel 6 conducted an investigation to determine how shakedown inspections were scheduled and performed on the S/C. From this investigation, it was learned that there were shakedown inspections performed prior to major test and milestones. However, these inspections were performed without definitive inspection criteria, but were conducted using the inspector's knowledge of previous S/C practices. In addition, the S/C 012 Master Flow Plan was reviewed (Reference 6-5 and it was found that shakedown inspections while not shown in the S/C test flow plan at KSC, are scheduled in bi-weekly and in daily work schedules.

c. Inspection Procedures During Test Operations

At the request of Panel 18, inspection procedures just prior to C/M hatch installation were reviewed. This review disclosed that Inspection monitored this phase of the test operations over the communications network because the White Room space and weight loading limitations prevented having an Inspector witness these functions in the White Room. Procedure APOP-0-202, "Operational Checkout Procedure", (Reference 6-3), states that Inspection will stamp each line item in the procedure requiring Inspection verification. Spacecraft Operations Letter SCO-2-104-65 (Reference 6-11) defines the verification requirements and the functions being performed prior to hatch installation that would have normally required Inspection physical verification.

d. Constraints List

(1) As a result of investigation of open work items, questions arose regarding conduct of tests. The investigation revealed that prior to the start of any test, an open-item review meeting is held by NASA/NAA, in accordance with APOP-0-202, "Operational Checkout Procedure". From this meeting, a list of those items which must be worked prior to the start of test is prepared, and approved by NASA/NAA engineers. The constraints list for Operational Checkout Procedure (OCP) FO-K-0021-1 was examined for content (Reference 6-6) to see if previous tests were listed as constraints. Research disclosed that OCP FO-K-0034 and OCP FO-K-0005 summarysheets (Reference 6-7) had not been signed off as accepted prior to OCP FO-K-0021-1, but were not listed on the constraints list for OCP FO-K-0021-1. It should be noted that OCP numbers are not related to the sequence of test accomplishment. APOP-0-202 does not contain a requirement to list open tests as constraints to subsequent tests, although there is a requirement to review the open items. Individual open items from previous tests are listed on the constraint list for subsequent tests if they are constraints to that test.

Analysis revealed that constraints lists are signed only by NASA/NAA Operations and Engineering with no NASA or NAA Quality control signature indicating approval of the constraints lists.

e. Mandatory Inspection Points

(1) As a result of questions which arose regarding Inspection coverage, APOP-0-202, "Operational Checkout Procedure", was examined to determine if there were any requirements for Mandatory Inspection Points (MIP's). The requirement is not clearly defined in the APOP, although many OCPs do contain MIP's.

MIP's are defined as inspection of actual hardware status.

Normally, Inspection monitors the test to insure adherence to the procedure.

f. Review of Engineering Changes

(1) As a result of review of open work, it was found that a large number of engineering changes were incorporated into the S/C at KSC. Many of these changes resulted from non-fit or non-function problems.

Some of the changes were due to the fact that S/C 012 was the first manned Apollo Spacecraft. Some of the changes were requested by the crew members. The large number of changes made it difficult to establish the vehicle configuration. An example of a major change is shown in Reference 6-8.

g. Retest Requirements

(1) As a result of the review of Discrepancy Records to determine open work, it was discovered that the requirement for retest may in some cases be deferred to a later test, (Reference 6-10). The records covering the work were closed out prior to the retest.

(2) Panel 6 investigated the requirements for retesting of components or subsystems after rework. APOP-T-502, "Discrepancy Recording System", (Reference 6-9) covers the retest requirement, but there is no requirement to keep the discrepancy records open until the retest has been verified. The records are closed out with a statement that the retest will be done in a subsequent test. This can then be deleted by on-the-spot deviations to the subsequent test.

h. Subsystem History

(1) In an attempt to obtain a complete subsystem history from the records, considerable difficulty was experienced. This was due to the fact that the records are not maintained by subsystem. Records are presently filed by category of document (Discrepancy Record, Test Preparation Sheet, etc.). In the event of subsystem problems, it is often necessary to develop the history of the subsystem, including failures, reworks, test results, etc. The present system required a great deal of effort to retrieve the necessary records to provide this history.

D. FINDINGS AND DETERMINATIONS

1. FINDING:

The Ingress-Egress Log (Reference 6-4) discloses several instances where tools and equipment were carried into the S/C, but the log does not show these tools as removed.

DETERMINATION:

The maintenance of the Ingress-Egress Log is inadequate.

2. FINDING:

a. Shakedown inspection periods are not shown in the Master Flow Plan. (Reference 6-6).

b. There are no definitive inspection criteria to perform shakedown inspections for the Apollo Program.

DETERMINATION:

a. Hardware condition prior to major tests and milestones is difficult to establish.

b. Inspection personnel are not able to assess the condition of the S/C for compliance with definitive criteria, but rather assess it in accordance with their knowledge of standard practices.

3. FINDING:

Inspection personnel do not perform a pre-scheduled inspection with a checklist prior to hatch closing.

DETERMINATION:
Inspection personnel could not verify these functions during this period.

4. FINDING:
Formal approval by NASA or NAA Quality Control of the constraints list is not required (Reference 6-6).

DETERMINATION:
NASA/NAA Quality Control cannot discharge their responsibilities without approving the constraints list.

5. FINDING:
The requirements for Mandatory Inspection Points (MIP's) are not clearly defined in the Apollo Preflight Operations Procedures.

DETERMINATION:
Proper Inspection coverage is not assured without clearly defined MIP'S).

6. FINDING:
At the time of shipment of the S/C to KSC, the contractor submitted an incomplete list of open items. A revision of the said list significantly and substantially enlarged the list of open items.

DETERMINATION:
The true status of the S/C was not identified by the contractor.

7. FINDING:
There is no efficient system which readily identifies that results accomplished by rework are verified by retest.

DETERMINATION:
The present system of verification of rework by retest is cumbersome.

8. FINDING:
There is no requirement to maintain records by subsystem classification, nor does the system present status in this fashion.

DETERMINATION:
The recovery of pertinent historical information is extremely difficult.

E. SUPPORTING DATA

Enclosures

6-1	Not Used
6-2	List of documents reviewed by Panel 6, including criteria for determining applicability to the AS-204 accident.
6-3	List of Problem Action Records submitted to other Panels.
6-4	Unsatisfactory Report on Bent Pins
6-5	List of References
6-6	Historical Narrative
6-7	Historical Narrative of Prelaunch Operations at Kennedy Space Center

LIST OF DOCUMENTS REVIEWED

The following are the types of documents reviewed by Panel 6, including a description of each type of document, and the criteria used in judging the applicability of these documents to the Apollo 204 accident.

1. TEST PREPARATION SHEET (TPS):

A document which authorizes work, provides engineering instructions, establishes a method of work control, furnishes historical records, and facilitates inspection under the two categories defined below:

a. Type "A" TPS: Required to authorize work involving a change of configuration (design change).
b. Type "B" TPS: Required to authorize all other planned work and tests.

Criteria for review

a. Agreement between Engineering Order (EO) and TPS.
b. Unworked, or partially worked, EO/TPS's which are considered significant.
c. Any configuration changes by TPS without EO coverage.
d. All non-metallics.
e. Questionable design changes.
f. All electrical items.
g. All solvents or cleaning agents.

2. DISCREPANCY RECORD (DR):

A document utilized to record significant and/or test discrepancies. This document provides for engineering instructions and dispositions, authorizes work of disposition, authorizes facilities inspection, and furnishes historical records under the two categories listed below:

a. Significant Discrepancy: A discrepancy that (a) cannot be returned to specified configuration, or (b) requires engineering disposition, i.e., (1) functional failure, (2) defective component, (3) discrepancy affecting test schedule, (4) action which could invalidate previously accepted tests, or (5) a discrepancy which could have an adverse effect on mission objectives or be a safety hazard.
b. Test discrepancy: Any anomaly encountered during integrated testing (testing which unites two or more space systems, e.g., Acceptance Checkout Equipment, Spacecraft Systems or components, etc.) except an obvious deviation or human factor which is immediately recognized and corrected without disturbing the normal progress of the test.

3. DISCREPANCY RECORD SQUAWK SHEET (DRSS): A document used to record minor discrepancies, provide technician supervision instructions, authorize work of the disposition, authorize facilities inspection, and furnish historical records under the category of discrepancy listed below:

Minor Discrepancy: Any deficiency which can be returned to drawing configuration without engineering disposition, e.g., workmanship items, string ties, oversize clamps, unclean areas, past-due calibration, etc.

Criteria for review

a. All solvents or cleaning agents.
b. Unapproved non-metallics.
c. Questionable deviations to drawings.
d. Any dispositions and/or conclusions not clearly defined.
e. Dispositions without retest.

4. OPERATIONAL CHECKOUT PROCEDURE (OCP): An engineering document which provides

detailed instructions to personnel for operational checkout and verification of equipment performance. OCP's are based on NAA Process Specifications and those applicable are referenced in the OCP by document number. OCP's: (1) provide technical step by step delineation of required personnel activity for the operation, assembly, handling or test of the equipment and for system(s) involved, (2) provide for insertion of program requirement record data, (3) provide NASA/NAA Engineering and Inspection Acceptance, (4) provide for safety of personnel and equipment.

5. DEVIATIONS: A change to a published OCP, such as changes in equipment lists, test parameters, sequences added or deleted or modified by order of occurrence or content to permit accomplishment of the test. Obvious errors, such as typographical errors, wrong page numbers, etc., are not considered deviations.

Criteria for review

a. Open Interim Discrepancy Records (IDR's).
b. Unsatisfactory Closed IDR's (vague).
c. Parameter Deviations.
d. Unexplained Deviations.
e. Deviations not satisfactorily documented.
f. Other suspected deviations.

6. PARTS INSTALLATION AND REMOVAL RECORD (PIRR): A document utilized to record selected new installations and all removals and reinstallations of previously installed parts. Removals and installations are those components of the end item configuration which are removed or installed, connected or disconnected. This document by itself does not authorize any work.

Criteria for review

a. Open installations or removals.
b. Unsatisfactory closeouts.
c. Unsatisfactory transfers (recapped PIRR or TIR).
d. Unauthorized installations or removals.
e. Installations of non-metallics.
f. Installations without retest.
g. Part number/serial number changes.

7. TEMPORARY INSTALLATION AND REMOVAL RECORD (TIRR): A document utilized extensively to record Spacecraft installations. It must be removed prior to flight and serves as a historical record. Temporary installations are non-flight Command and Service Module hardware and temporarily installed flight hardware (e.g., fit-check installations), which must be removed prior to flight.

CRITERIA for review

a. Open installations or removals.
b. Unsatisfactory closeouts.
c. Unsatisfactory transfers (recapped PIRR or TIR).
d. Unauthorized installations or removals.
e. Installations of non-metallics.
f. Installations without retest.
g Part number serial number changes.

8. PROBLEM ACTION RECORDS (PAR's): The PAR is a NAA form on which hardware problems are reported for failure or cause analysis, and corrective action. There are two uses for the PAR, i.e.; (a) Failure Reporting, (PAR-F), and (b) Unsatisfactory Condition reporting, (PAR-UC).

Criteria for review

The PAR-F's were reviewed for failure analysis to determine what caused the malfunction and applicability to the Apollo 204 accident. PAR-UC's were reviewed to determine if significant items had been reported on this record that had not appeared in other records.

9. UNSATISFACTORY RECORDS (UR's): The UR is a NASA document, used by the government to report conditions which are repetitive, or involve safety of flight. The condition reported may or may not have been reported by the contractor in his paperwork system.

Criteria for review

UR's were reviewed to determine if any significant item was not reported through other mediums.

PROBLEM ACTION RECORDS SENT TO OTHER PANELS

PAR	TO PANEL	PROBLEM
27094 27049 27057 3958	8	ECS LEAKS
27017 27056	18	UNQUALIFIED PARTS IN GAS CHROMATOGRAPH
24201	18	LEAKS IN QUICK DISCONNECT
163286 171589 171612	18	INTERNAL SHORTS IN TEE-ADAPTER
27204 12460 13484 13485 12470 16605 23437 23500 23502 23686 23660 163740 163378	18	GSE ETHYLENE/GLYCOL FLUID - TRANSDUCER AND RELAY FAILURES
27235		CONTACT RESISTANCE OUT OF SPECIFICATION
23592 16726		GSE CIRCUIT BREAKER OPERATION ERRATIC
3951		ELECTROLUMINESCENT BAR FAILED TO LIGHT
28637		ECS WATER/GLYCOL PUMP FAILED TO OPERATE
171560		CLUTCH VOLTAGE OSCILLATES
171578		TRANSISTOR FAILURE IN CONTROLLER

ENCLOSURE 6-3

PROBLEM ACTION RECORDS SENT TO OTHER PANELS (CONTD)

PAR	TO PANEL	PROBLEM
12032 12040 14555 16696 23495 23526 23603	18	GSE - WATER/GLYCOL SERVICE SET
15833	18	BURNT SPOTS ON RELAY MODULE PINS
164203	18	CYCLIC ACCUMULATOR SOLENOID VALVE STICKS IN FULL OPEN POSITION

NASA - Manned Spacecraft Center

UNSATISFACTORY REPORT - PART I

1. Category	2. System	3. U.R. No.
S/C	EPS	A-054

4. Contractor Part Name	5. Contractor Part No.	6. Serial No.	7. Date Reported
Cable Harness Assy. (Crew Compartment)	V16-420302	012	10/11/66

8. Supplier	9. Supplier Part No	10. Contr. Ref. Drawing No.	11. Time In Use	12. Cycles
NAA	V16-420302	V16-000002	hr. N/A min. sec.	N/A

13. Mission	14. Photos Enclosed	15. No. Previous Failures	16. Previous Failure References
Apollo	[X] Yes [ ] No	N/A	N/A

17. Unsatisfactory Condition

This Unsatisfactory Report documents a recurring problem concerning bent pins in S/C electrical connectors, which if not corrected, could seriously impair the checkout schedules and/or jepardize subsequent Apollo missions. The following is a summary of the failures encountered at KSC during checkout of S/C 012 which were a direct result of this unsatisfactory condition:

1. During Seq. 11-040A of Combined Systems Test (OCP-K-0035), the RCS transfer "B" light was not observed. Troubleshooting isolated the problem to a short circuit within C/M - S/M umbilical connector J3A3. Further investigation revealed that pins # 75 and # 51 were bent and shorting against pins # 50 and # 52 respectively. (Ref. IDR 028 vs OCP-K-0035; DR S/C 012 - S/C 0189; PAR#27056)

2. On September 16, 1966, a check of S/C 012 separation monitor circuits via PCM was made per TPS-099 during Seq. 04 of OCP-K-0035, Combined Systems Test. During this test an out-of-tolerance (O%) indication was obtained. Subsequent troubleshooting isolated the problem to a blown fuse which was later found to have been caused by open jumper wires between Matrix Terminal Boards. (Ref. DR S/C 012 - S/C 0191; PAR#27096) During the repair operation of this problem, connector P1116 was disconnected from J54 of the V16-764042, Event Conditioner to facilitate the connection of a spare fuse into the circuitry previously protected by the blown fuse. Visual inspection of the disconnected plugs P1116 and J54, revealed 8 bent pins. (Ref. DR S/C 012-S/C 0258 and S/C 0264)

3. Following power-up for the sea level run of the Altitude Chamber Test (OCP-K-0034), an indication of C/M - S/M separation was observed. Troubleshooting revealed a short circuit within the C/M - S/M umbilical connector, J3B3. Further investigation of the connector disclosed that pin # 32 was bent and shorting against pin # 33. It was further noted that pins # 1, # 18, and # 36 were also bent. (Ref. IDR 022 vs OCP-K-0034; DR S/C 012 - S/C 0431; PAR#27105)

Since many electrical connectors are practically inaccessible, mating is often a blind operation. As a result, the pins are often bent due to improper connector alignment. To preclude recurrences of this problem, we recommend the following:

18. Initiator (Signature & Date)	19. Systems Engineer (Signature & Date)
Charles E. Welly 10-14-66	M. Gundy 10-14-66
20. Approved by (Signature, Title & Date)	21. Approved by (Signature, Title & Date)
Joseph M. Dobik 10-14-66.	FM Bond 10-14-66

ENCLOSURE 6-4

NASA - Manned Spacecraft Center
UNSATISFACTORY REPORT - Continuation Sheet (PART I, II, III)

27. U.R. No. A-054

1. Only connectors/receptacles with sufficient alignment features should be utilized in inaccessible areas. eg. Use of connectors with pin guides would lessen mating difficulties.

2. Circuits which route through connectors and/or receptacles that have been interrupted subsequent to Integrated Testing at NAA Downey should be reverified prior to shipment of the CSM to KSC. Adherence to this policy would effectually eliminate the prelaunch problems resulting from bent or broken pins incurred during connector remating operations.

It should be further noted at this time that the NAA Standard Repair Manual repair No. 1 EL1.4, authorizes straightening of all pins, size twenty or smaller, for all bend angles up to 90 degrees. We feel that this is a very unreliable fix, as damage may be done to the pins internal to the connector which would not be detected through the prescribed visual inspection. In addition, there is no practical method of determining how many times a particular pin has previously been straightened. Due to these facts, we recommend that the following changes be made to the NAA Standard Repair Manual:

1. Pins with bend angles of less than 20 degrees may be straightened and accepted through visual inspection if it can be definitely determined that the pin has not been previously straightened.

2. Pins that are straightened after being bent at angles of more than 20 degrees should be accepted only after a satisfactory X-ray examination has been made.

3. Pins that are bent in excess of 20° and are inaccessible for X-ray should be replaced. If replacement is not practical, the bent pins should be broken-off and the associated circuit routed through undamaged spare pins if available.

Enclosures:
1. DR S/C 012 - S/C-0189, PAR#27056
2. DR S/C 012 - S/C-0191, PAR#27096
3. DR S/C 012 - S/C-0258
4. DR S/C 012 - S/C-0264
5. DR S/C 012 - S/C-0431, PAR#27105
6. Standard Repair Manual, Repair No. EL1.4
7. Photos (3 ea.)

REFERENCES

6-1 Apollo Mission Failure Contingency Plan

6-2 Apollo Preflight Operations Procedure Number 0-201 "Access Control of Test and Work Areas"

6-3 Apollo Preflight Operations Procedure Number 0-202 "Operational Checkout Procedure"

6-4 Apollo Ingress-Egress Log Sheets

6-5 Spacecraft 012 Schedule, KSC

6-6 Constraint List, Spacecraft 012 Operational Checkout Procedure FO-K-0006 0021-1

6-7 OCP FO-K-005A 1 and OCP F-K-0034A, A-1

6-8 TPS-012-SC100, "Modification of Quad Heater"

6-9 Apollo Preflight Operations Procedure Number T 502, entitled, "Discrepancy Recording System"

6-10 DR-SC0838 and DR-SC012-0810

6-11 Spacecraft Operations Letter SCO-2-104-65

1. APOLLO DEVELOPMENT/REVIEW PROCESS

Apollo Program Directive (APD) No. 6A defines the sequence and flow of hardware development and key inspection, review and certification checkpoints for Apollo spacecraft and is included as reference 6-12. This directive is the basic document that controlled the evolution of milestones for Spacecraft 012.

These checkpoints insure that sufficient visibility is obtained of the status of design, manufacture and testing to adequately determine the integrity of the spacecraft prior to mission accomplishment.

The six key checkpoints defined by APD 6A are:

- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- First Article Configuration Inspection (FACI)
- Certification of Flight Worthiness (COFW)
- Design Certification Review (DCR)
- Flight Readiness Review (FRR)

The PDR, CDR, FACI and COFW are accomplished at selected booster and spacecraft levels of assembly (stages and modules). The DCR and FRR encompass the total mission complex. With the exception of the COFW, the requirements for these formal reviews were further defined by NASA, Houston, in the Apollo Spacecraft Program Office Configuration Management Plan (Reference 6-13), see Appendix E), however, only the PDR, CDR, FACI and the FRR were implemented by the North American Aviation (NAA) in the NAA CSM Configuration Management Plan, SID 65-100 (Reference 6-14) as approved by NASA, Houston, Paragraph 10.6 on page 10-16 was never approved by NASA, Houston, and therefore is not contractual. The Certification of Flight Worthiness (COFW) requirements were established by separate Apollo Program Office direction to NAA (Reference 6-15) and the DCR requirements were implemented by a letter from the Program Manager to NAA, Downey, as confirmed by a supplemental agreement to the contract (Reference 6-16).

These six formal reviews are scheduled jointly by NASA and North American Aviation.

a. Preliminary Design Review (PDR)

The purpose of the PDR is to formally review the design approach of a spacecraft prior to, or very early in, the detail design phase. (See paragraph b. below for a further discussion.)

b. Critical Design Review (CDR)

The purpose of a CDR is to formally review the design of a spacecraft when the design is essentially complete and is intended to precede the release of engineering drawings for manufacture. This review for S/C 012 was in reality a PDR as well as a CDR. It was accomplished after the spacecraft had been released for manufacturing and was a review of both the design and the requirements. The negotiation of the Block I Spacecraft Technical Specification, the Block I Spacecraft Master End Item Specification accomplished the PDR for each spacecraft. This approach was taken because S/C 012 was the first major Block I vehicle with the second manned Spacecraft (S/C 014) being identical. All other Block I spacecraft were to be unmanned and, therefore, were not to be fully configured. The S/C 012 PDR was appropriately used to represent all Block I spacecraft. A Delta CDR was also conducted for S/C 012 prior to testing. The Delta CDR is discussed in detail later.

c. First Article Configuration Inspection (FACI)

The purpose of the FACI is to establish the Configuration Baseline for the spacecraft. It is accomplished by establishing the relationship of the spacecraft as described by released engineering documentation (drawings, specifications) to the spacecraft as manufactured, assembled, and tested. The FACI checkpoint has been implemented for Block II spacecraft only. It was not implemented for S/C 012 or Block I because of the differences between each spacecraft. A baseline configuration is not established until Block II where each spacecraft is to be of the same configuration. Two integrated reviews known as the Systems Assesment Review (SAR) and the Customer Acceptance

Readiness Review (CARR) were conducted to support the acceptance and delivery from the Contractor (NAA). These reviews are discussed later.

d. Certification of Flight Worthiness (COFW)

The Certificate of Flight Worthiness (COFW) is a requirement of NASA-Apollo Program Directive No. 6 dated 15 August 1965. NAA was directed to implement this requirement in accordance with the MSC-Houston procedure, "Procedure for the Certification of Flight Worthiness (COFW)" dated 20 June 1966 (Reference 6-15). The COFW is used to certify that each flight stage and module is a complete and qualified item prior to shipment, and is supported by adequate supporting documentation, i.e., the Acceptance Data Package (ADP) and the Material Inspection and Receiving document (DD Form 250). The COFW informs the Apollo Program Director of any deficiencies prior to shipment from the manufacturing sites and from the static firing site. The COFW has requirements for the following documents for the following endorsements: Endorsement one is executed and signed at the completion of checkout at the Contractor's plant by the Contractor, MSC quality representative, and the MSC Program Manager's designee. Endorsement one reflects the final action taken at the CARR and information contained on the DD Form 250. Endorsement number two is executed and signed at the completion of receiving inspection at KSC and is signed by the KSC representative, the MSC quality representative, and the MSC Program Manager's designee. Endorsement number three is executed and signed at the time the Launch Vehicle and Spacecraft are mated, by the same people that signed endorsement number two. Endorsement number four is executed and signed at the completion of the Flight Readiness Review (FRR) by the KSC representative and the MSC Program Manager's designee. The final certification is executed at the time the Spacecraft is declared flight worthy and requires the signature of the Apollo Spacecraft Program Manager (Reference 6-15 and 6-17).

e. Design Certification Review (DCR)

The purpose of the DCR is delineated in Apollo Program Directive No. 7 (Reference 61-8) is to examine the design of the total mission complex (spacecraft, booster, GSE, launch complex, communications network, etc.) for proof of development maturity and assess and certify the design of the Space Vehicle, Launch Complex, Mission Control Center and Manned Space Flight Network for manned flight safety.

f. Flight Readiness Review (FRR)

The FRR as delineated in Apollo Program Directive No. 8 (Reference 6-19) is a two part review consisting of a Program Director's FRR and a Mission Director's FRR. The purpose of the Program Director's FRR is to determine that the space vehicle hardware and Launch complex are ready to commence the mission period. The purpose of the Mission Director's FRR is to make a judgement for initiating the mission period and committing the deployment of world wide forces to support the mission.

g. Review Schedule

The following bar-chart illustrates the Apollo development review process (See figure 1).

2. DISCUSSION OF SPACECRAFT 012 CHECKPOINTS

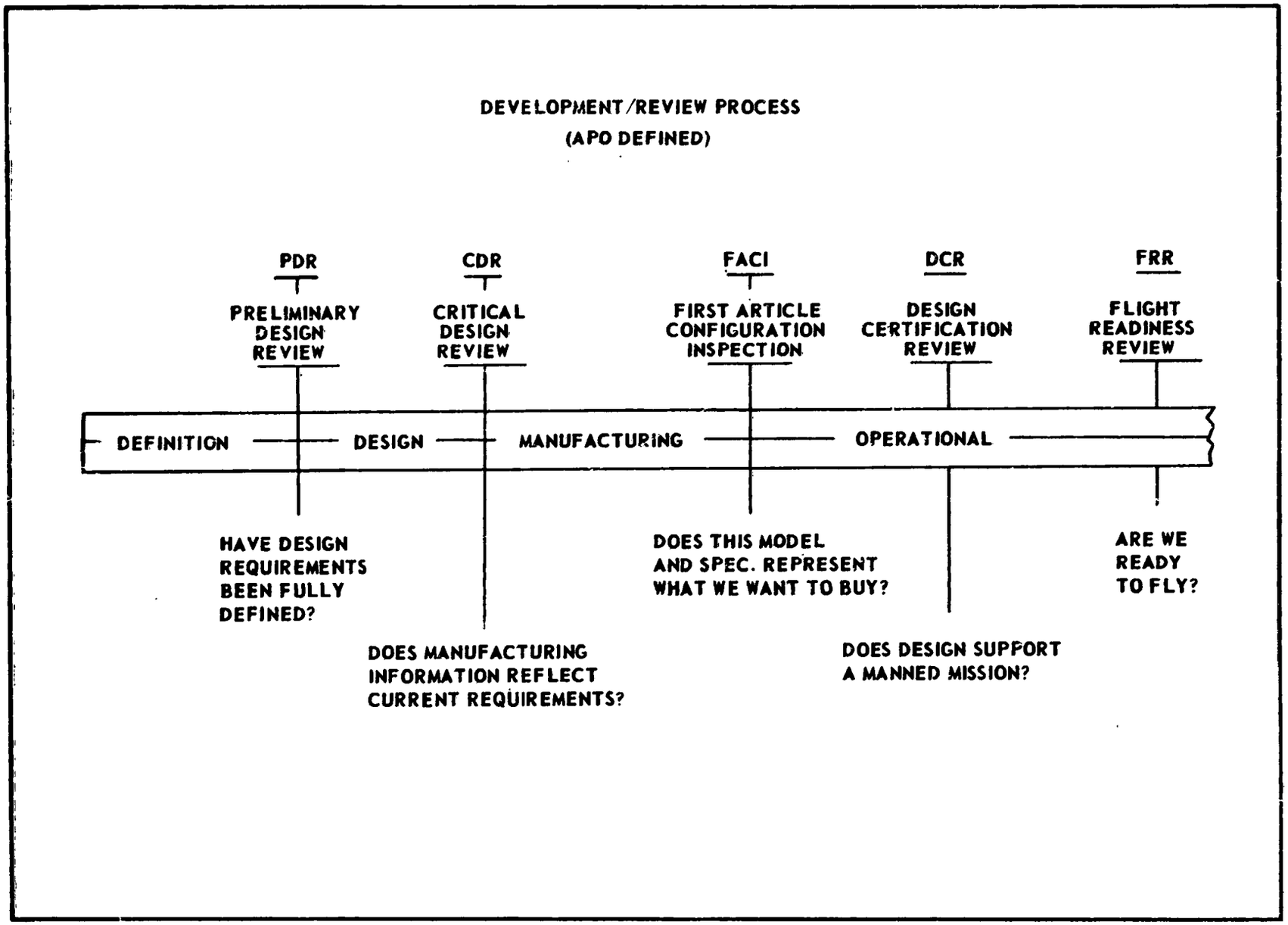
This section describes the specific Spacecraft 012 checkpoints in detail. The checkpoint activities, locations, dates, personnel involved, and significant results are included. The checkpoints are discussed in chronological order and present a complete historical summary of the flow of hardware development and key inspection, review and certification checkpoints.

a. Preliminary Design Review (PDR)

The PDR checkpoint was conducted during the period from November 1964 through January 1965 for all Block I spacecraft including Spacecraft 012. As mentioned previously this was a review of both the requirements and the design since Spacecraft 012 had been released for manufacturing. In reality it was both a PDR and a CDR.

b. Delta Critical Design Review (DCDR)

The intent of the Delta CDR for Spacecraft 012 was to insure that each level of spacecraft flight hardware and ground support equipment (GSE) end item was designed and built to meet all the requirements and was compatible with the planned mission. The review was also intended to determine the adequacy of the spacecraft checkout flow plans. It was held just prior to commencing


DEVELOPMENT/REVIEW PROCESS
(APO DEFINED)
PDR
PRELIMINARY DESIGN REVIEW
CDR
CRITICAL DESIGN REVIEW
FACI
FIRST ARTICLE CONFIGURATION INSPECTION
DCR
DESIGN CERTIFICATION REVIEW
FRR
FLIGHT READINESS REVIEW
DEFINITION
DESIGN
MANUFACTURING
OPERATIONAL
HAVE DESIGN REQUIREMENTS BEEN FULLY DEFINED?
DOES MANUFACTURING INFORMATION REFLECT CURRENT REQUIREMENTS?
DOES THIS MODEL AND SPEC. REPRESENT WHAT WE WANT TO BUY?
DOES DESIGN SUPPORT A MANNED MISSION?
ARE WE READY TO FLY?

systems testing on S/C 012. The Delta CDR utilized the CSM 012 End Item Specification, Part I, Performance Design Requirements Apollo dated 22 February 1965, classified Confidential (Reference 6-20).
6-20).

For S/C 012 the Delta CDR was held in two phases as discussed in the following paragraphs and is documented in S/C 012 Delta CDR Minutes, Part I, (Reference 6-21) and Part II (Reference 6-22).

(1) The scope of the first phase was limited to the nominal mission (Block I Design Reference Trajectory) and the "as built" configuration of the spacecraft ground support equipment (GSE). In addition, Spacecraft 008, (the thermal/vacuum test article) was reviewed concurrently with Spacecraft 012 primarily to determine the "as built" configuration differences between the two spacecrafts and to arrive at a final determination of the acceptable differences in the S/C 008 configuration. The testing of S/C 008 in the thermal-vacuum chamber at Houston was a constraint to the first Apollo manned mission S/C 012). This Delta CDR commenced on February 11, 1966, with the delivery of the NAA Data Package to NASA-Houston and was concluded with the publication of the Minutes on March 3, 1966. The data package contained 1) documents related to the Flight Mission such as AS-204A Mission Requirements and Design Analysis Report, S/C 012 End Item Specification, Measurement Requirements, Weight Report, Functional Integrated Schematics, Failure Mode and Effect Analysis and Reliability Problem Summaries for S/C 012, and 2) Ground Operations documents such as the Apollo Ground Operations Requirements Plan, Test and Checkout plans and Integrated Checkout Process Specifications. Additional documentation was available at NAA-Downey to support the Downey review. (For details see Reference 6-23, Appendix I)

After the receipt of the NAA Data Package and a technical briefing by NAA, NASA reviews were conducted at Houston, Texas, by five working groups, made up of NASA-MSC representatives. The purpose of these reviews was to identify existing and potential deficiencies, with respect to specific mission requirements, of the spacecraft design or the checkout philosophy and specifications. The Preliminary Requests for Changes (Pre-RFC's) resulting from these reviews were then submitted to a NASA-Houston Review Panel consisting of key management representatives from NASA-Houston.

As a result of the total NASA-MSC review, 137 Pre-RFC's were submitted to North American Aviation (NAA) for their consideration and then for further reviews by the same five working groups, with the addition of NAA representation on each group, at the NAA plant, Downey, California. During these reviews, many Pre-RFC's were resolved or deemed inappropriate primarily because NAA documentation showed that either design changes were in progress or, through additional information, the Pre-RFC was not valid and no change was required.

From the above five working group meetings, 37 Requests for Changes (RFC's) were submitted to the CDR Board for review. The disposition of each of these RFC's is documented in the Apollo Spacecraft 012 Delta CDR Minutes (Part I), dated March 3, 1966 (Reference 6-21). In summary 3 RFC's were rejected, 3 were not applicable, 19 were assigned for studies (10 NAA, 5 NASA, 4 joint) and the remaining 12 required immediate NAA action.

Concurrently with the working group reviews and prior to the CDR Board Review, a crew compartment review was conducted by crew members utilizing a mockup of the crew compartment. All of the Request for Changes (RFC's) resulting from this mockup review were satisfactorily resolved prior to the CDR Board Review on March 3, 1966.

(2) The Part II Delta CDR objectives were to verify compatibility of the S/C 012 design with the requirements of Mission AS-204A (Reference Trajectory) and to assure compatibility of the ground support equipment (GSE) for Launch Complex 34, at KSC, Cape Kennedy.

This activity began on March 22, 1966, and was completed on April 5, 1966, with the publicwtion of the Minutes of the NASA/NAA Management Review, Spacecraft 012 Delta Critical Design Review (Phase II) Mission Review (Reference 6-22). During the period from March 22 through March 25, 1966, a review was made at MSC by essentially the same five working groups but with primary interest by members from the APOLLO Program Office, the Flight Operations Directorate, and the Flight Crew Operations Directorate. On completion of the NASA Review on March 25, 1966, a total of 53 Review Item Dispositions (RID's) were transmitted to NAA by NASA letter PD2/L1501/66-319. (The Review Item Disposition forms are new NAA forms that have essentially updated and replaced the NAA Request for Change (RFC) forms. They accomplish the same purpose.) Thirteen of these RID's were identified as having significant program or mission impact. A NASA/NAA management review was held at NAA, Downey, on March 29, 1966, where agreements were reached and action items identified for each RID (Reference 6-22).

A second NASA/NAA Management Review was held at NAA Downey on April 5, 1966, where agreements were reached and action items assigned for the remaining 40 RID's, which consisted of requirements for data or revisions to documentation (Reference 6-22).

All of these action items were not closed out by July 19, 1966, for the Phase I of the CARR (SAR Meeting) as evidenced by the Phase I CARR report (Reference 6-24 for example, see page 3-65). They were, however, closed out by the CARR which was held on August 19, 1966, since no RFC's or RID's are reflected as open items. (In this regard, the CARR report is by exception and, therefore, reflects only open items.) The fact that they were closed out prior to the CARR has been confirmed by the NASA-Houston CSM Project Officer in his letter to Chairman of Panel 6, Historical Data. (Reference 6-25)

c. Customer Acceptance Readiness Review (CARR)

The CARR was a two phase review. Phase I was a System Assessment Review (SAR) held at NAA-Downey on July 19, 1966. The SAR was a working level, informal meeting held to assess spacecraft systems testing (all systems functioning for checking interfaces) and enabled the participants to evaluate the system performance and problems. The SAR is a constraint to performing integrated systems testing (mission simulation tests). The systems testing was documented by NAA-Downey in the Phase 1 CARR report (Reference 6-24) which was submitted by NAA-Downey to NASA-Houston on June 13, 1966.

The SAR meeting minutes and action assignments are documented in the Phase II CARR Report (Reference 6-26). As a result of the SAR meeting, one-hundred ninety-three (193)a action items were assigned. One-hundred twenty-seven (127) action items had program or mission impact while sixty-six (66) of the action items were requirements for data or documentation.

The Phase II of the CARR is a formal board meeting to review the results of spacecraft integrated systems testing, the open action items from the SAR, and the action items from the Crew Compartment Fit and Functions (CCFF) review. The CCFF is a review where the spacecraft crew enters the spacecraft and physically verifies the stowage and proper use of crew equipment. The CCFF was initiated prior to the CARR, but was incomplete at the time of the CARR and was completed after the CARR Board Review. The CARR Board Review. The CARR Board determines if the spacecraft is ready for shipment to the launch facility (KSC-Cape Kennedy).

The CSM 012 CARR Board was held in Downey on August 19, 1966. There were 66 items brought before the Board for discussion, 33 of which originated at the Phase I SAR. Sixteen (16) items were determined to have been adequately dispositioned and were closed for future action. Thirty-three (33) items were deferred for resolution at a later date and were not constraints to the shipment of the vehicle. These items fell into the general categories of: work or tests to be accomplished at KSC; resolutions to be made pending results of studies; investigations or qualifications tests; and furnishing NASA with data requested at the CARR meeting. The remaining 17 discussion items were required to be dispositioned at Downey prior to shipment to KSC. The CARR

action items are documented in "CARR Minutes and Action Assignments" and "CARR Action Response" (Reference 6-26).

The following summarizes the Downey ACTIONS AND DISPOSITIONS OF THE ABOVE REFERENCED ITEMS] Each item is identified by its respective item number in the Phase II CARR report minutes.

1.7.1 POWER LOSS ON CSM - INVERTER
Problem: During spacecraft testing, power loss occurred.

Resolution: Inverter 1 was determined to be faulty and was removed and replaced. The replacement inverter was installed, checked and determined to be acceptable prior to shipment.

3.6.14 FLIGHT QUAL INSTRUMENTATION STATUS
Problem: Four transducers were determined to not be operating properly.

Resolution: The transducers were replaced and the new transducers functionally verified prior to spacecraft shipment.

3.7.1 SUIT LOOP LEAKAGE
Problem: Leakage noted during Operational Checkout Procedure (OCP) 5051 was greater than the specification allows.

Resolution: It was concluded from evaluations that misinterpretation of data caused the out-of-specification statement. Re-evaluations were made of test data and it was concluded that leakage of the suit loop circuit at time of shipment was within acceptable limits. It was also noted that normal test flow at KSC would verify this conclusion.

3.7.2 DEMAND REGULATOR FAILURE (OXYGEN)
Problem: The demand regulator was determined during spacecraft testing to be inoperative.

Resolution: The regulator was replaced and the new regulator functionally verified prior to shipment.

3.7.3 WATER CYCLIC ACCUMULATOR FAILURE
Problem: During spacecraft testing, the water cyclic accumulator was determined to be inoperative.
inoperative.

Resolution: Two (2) new units were installed before the water cyclic accumulator would pass checkout. The units were installed and checked out and the final unit was determined to be acceptable prior to shipment.

3.7.10 OPERATIONAL CHECKOUT PROCEDURE (OCP) 5051, SUIT LOOP CHECKS
Problem: Checkout per OCP 5051 was not complete at the time of the CARR.

Resolution: OCP was completed prior to shipment. The following problems were transferred to KSC for final resolution. Squawks 54, 58, 59, 60, 61, 62, 63, and 908. (See Reference 6-27, Material Inspection and Receiving, DD Form 250, CF66-51922 numbers, 1,. 2, and 3.)

4.6.8 TV CAMERA CHECKOUT - PICTURE DISTORTION
Problem: The TV image was distorted during Crew Compartment Fit and Function Tests (CCFF).

Resolution: A reverification of the TV image was performed prior to shipment and found to be within acceptable limits.

5.6.17 CALIBRATION CURVES

Problem: The Flight Crew required the Spacecraft panel meter calibration curves.

Resolution: The calibration curves were transmitted to the crew prior to shipment.

5.7.1 FAILURE OF ECS MEASUREMENTS

Problem: The water-glycol pump package pressure measurements CF0025P was found defective. Measurements CF0484T and CF0135R were also faulty.

Resolution: The cause was found to be defective transducers. The transducers for measurements CF0484T and CF0135R were replaced and the new transducers reverified prior to shipment. The transducer for water-glycol pump inlet pressure measurement CF0025P was not replaced and NAA's request for waiver was granted (Reference 6-28).

12.6.3 HATCH DECALS

Problem: Installation of torque limit decals had not been completed.

Resolution: The decals were installed prior to vehicle shipment.

13.6.10 CO2 PARTIAL PRESSURE GAGE

Problem: When power was turned on, the gage went to full scale deflection and triggered the caution and warning system.

Resolution: Additional testing was accomplished prior to shipment and gage operation was determined to be satisfactory although Automatic Checkout Equipment (ACE) readouts did not correspond. Per CARR Board direction, calibration was to be validated at KSC.

13.7.1 RHEOSTAT FAILURE - FLOODLIGHTS

Problem: The rheostat failed to provide a smooth linear resistance change with shaft rotation.

Resolution: The rheostat was removed and replaced. The new rheostat was installed and operation verified prior to shipment.

13.7.2 EVAPORATOR STEAM BACKPRESSURE C&W INDICATION

Problem: The master caution and warning light triggered with no visible indication on the individual display when the glycol evaporator steam backpressure was operated.

Resolution: The problem was found to be a defective switch which was removed and replaced. A retest with the new switch was not performed and was transferred as open work to KSC. (Reference 6-27, Material Inspection and Receiving Document, DD Form 250, Squawk 62, CM Number 1, 2 and 3.)

14.7.1 PARTIAL CREW COMPARTMENT FIT AND FUNCTION CHECK (CCFF) SUMMARY

Problem: CCFF was not completed at the time of the CARR and numerous items were open for evaluation.

Resolution: The CCFF was completed prior to shipment. The following problems were transferred to KSC for final resolution: Squawks 12, 15, 20, 22, 23, 30, 33, 35, 38, 56, 925,

and 929 (Reference 6-27, Materials Inspection and Receiving Document, DD Form 250, CF66-51922, CM numbers 1, 2, and 3).

14.7.2 FLAMMABLE MATERIALS IN CM

Problem: Use of Velcro and other materials in the Command Module (CM) was not considered desirable and was unsatisfactory for flight.

Resolution: Investigation of the CM crew compartment was performed with identification of undesirable materials listed prior to shipment of the spacecraft. NASA participated in the investigation and the results of the investigation are documented in NAA IL 633-300-040-66-1009, dated 22 August 1966 (Reference 6-29). Further documentation is in the Materials Review, Panel 8 Final Report, Section C.8.b.

15.7.1 MDAS CHECKOUT

Problem: The Medical Data Acquisition System (MDAS) was not checked out during the Crew Compartment Fit and Function (CCFF) review.

Resolution: The checkout of the MDAS was performed satisfactorily during the Operational Checkout Procedure (OCP) 5051, prior to shipment.

15.7.2 16 MM CAMERA OPERATION

Problem: The camera was not operable at time of CARR.

Resolution: Camera operation was satisfcatorily demonstrated during the second run of OCP-P-5051 and CCFF, prior to shipment.

(1) Description of Material Inspection and Receiving Document, DD Form 250.

In conjunction with the CARR procedures and as a part of the CARR Board aActions, it is necessary to officially document the spacecraft configuration at the time of shipment as well as any items of open work to be transferred to KSC-Cape Kennedy for accomplishment. The DD Form 250 is utilized for this purpose and is the formal acceptance of the spacecraft by the government from the contractor.

The status is defined by listing those additions to, and those unaccomplished items from the major module configuration definition of record at the time of shipment (i.e., top level engineering drawings for the spacecraft). The DD Form 250 will normally contain the following information:

- Government Furnished Equipment (GFE) installed
- Field site installations that were installed at Downey
- Removals (normally to support shipment)
- Loose equipment with shipment (to support open work and removals for shipment)
- Actual part shortages
- Open work items (squawks, Engineering Orders, drawings)

On Spacecraft 012, there were four (4) DD Form 250's used (Reference 4-16) since four (4) separate shipments were made as follows:

- Spacecraft complete V14-000002-21 (DD Form 250 CF66-51968, 9 September 66). This form confirms shipment of the total spacecraft and the spacecraft data package.
- LES - V15-000002-221 (DD Form 250 CF66-51886, 22 July 1966).
- CM - V16-000002-191 (DD Form 250, CF66-51922, 1, 19 August 66; 2, 25 August 66; 3, 27 September 66).
- SM - V17-000002-131 (DD Form 250, CF66-51898, 8 August 66).

Two revisions were made to the original Command Module (CM) DD Form 250 (Ref-

erence 6-27). The first (original) DD 250 did not reflect the true status of the Command Module in that it did not include all of the actual part shortages nor did it list the equipment removed to facilitate shipment. To correct the status of the Command Module, the second CM DD Form 250 was written.

After shipment, additional discrepancies were discovered in the "as shipped" hardware configuration status. Additional shortages, Field Installation Items (FOI), equipment removals, Government Furnished Equipment installed on the CM or accompanying the shipment, and additional items of loose equipment were discovered. The third CM DD 250 was written to correct the status of the Command Module. In addition, the contents of third DD 250 were rearranged to provide a document which was easier to read and understand.

Those CARR items requiring Downey action which were not completed at NAA-Downey, were transferred to KSC, Cape Kennedy, on the DD Form 250 (Reference 6-27).

(2) Certificate of Flight Worthiness (COFW)

A COFW was initiated in accordance with Apollo Program Directive No. 6 for S/C 012 on August 24, 1966, at NAA-Downey. This was endorsement one and is included as Reference 6-17.

d. Design Certification Review (DCR)

The initial phase of the DCR was conducted for the Apollo 204 mission in accordance with the requirements of Apollo Program Directive (APD) No. 7 (Reference 6-18) during the period September 21-28, 1966, and concluded on October 7, 1966. The results of this phase of the DCR are documented in the attachment to an Apollo Program Director's letter dated October 12, 1966 (Reference 6-30). The Apollo Design Certification Board was chaired by the Associate Administrator for Manned Space Flight and the Board Members were as follows:

Director, NASA Manned Spacecraft Center
Director, NASA Marshall Space Flight Center
Director, NASA Kennedy Space Center

Presentations on the spacecraft were made to the Board jointly by NASA-Houston and NAA-Downey personnel. In addition, a memorandum for Design Certification Board (Reference 6-31 -sample) was submitted for the Board's consideration, certifying with contingencies the spacecraft for a manned mission. These memorandums were signed by the NASA-Houston Subsystem Managers and NAA-Downey Design Engineers.

There were a total of 89 action items resulting from the Board's review. In addition, each of the three Apollo Program Managers developed a Certification Contingency List and they are also included as Minutes. These Contingency Lists contain a total of 20 action items.

Action items resulting from all aspects of the review are as follows:

Launch Vehicle	- 29 (No. 11 combined with No. 19)
Launch Complex	- 10 (41 through 49 have no action)
Spacecraft	- 38
Other	- 12
Launch Vehicle Program Manager's Contingency List	- 5
Spacecraft Program Manager's Contingency List	- 8
Launch Complex Program Manager's Contingency List	- 7
TOTAL	- 109

On October 7, 1966, the Design Certification Board issued the AS-204 Design Certification Document (Reference 6-30, Attachment) which certified the design of the Space Vehicle for flight worthiness and manned safety and the capability of the Mission Support to support a manned mission contingent upon satisfactory resolution of the qualifications, tests, investigations and action items listed in attachments to the Design Certification Document.

The action close out processes continued from October 7 through December 20, 1966, however, during this period the Apollo Program Director made a decision to conduct a Recertification Review to be conducted during the month of December 1966. This action was deemed necessary in view of the large number of action items resulting from the initial review, with many remaining open. The selected date of December 21, 1966, for this second review was influenced by a slippage in the launch schedule caused by the delay in completion of the Environmental Control Sub-system water boiler test at the AiResearch Corporation to correct a previously identified deficiency wherein the water boiler became contaminated and blocked fluid flow (Reference 6-30, Attachment II, item 5.d.).

The status of action items as of December 20, 1966, is contained in the Apollo Program Director's report (Reference 6-32) on that date to the DCR Board Chairman. There were 14 items with incomplete responses and 9 to be closed prior to the FRR. The status as of January 27, 1967, as reported to the Apollo 204 Review Board on March 17, 1967 (Reference 6-33, shows 66 items closed, 4 not required for certification, 2 to be closed out at the AS-204 FRR, 4 with incomplete response and 13 with closure pending the Apollo Program Director's concurrence. There were no new action items as a result of the December 21, 1966 meeting. The updated Action Item Synopsis sheets are included in the Apollo Program Director's status report (Reference 6-32) and appropriately marked to indicate the status as of January 27, 1967.

e. Flight Readiness Review (FRR)

The Office of Manned Space Flight, Washington, D.C., had planned to conduct a two-part Flight Readiness Review for S/C 012 with the purpose as:

Part I - To determine that the space vehicle hardware and launch complex are ready to commence the mission period.

Part II - To determine the readiness of the operational elements for a manned space flight.

Part I would have been conducted by the Apollo Program Director; Part II by the Mission Director. The FRR is defined in Apollo Program Directive No. 8 OReference 6-19). The FRR would have been held approximately two weeks prior to launch.

MSC, Houston, in conjunction with KSC - Cape Kennedy, would have conducted a Pre-Flight Readiness Review (Pre-FRR) at KSC - Cape Kennedy approximately 3 days prior to Part I of the FRR. Upon completion of the Pre-FRR, a NAA prepared report would have been submitted to the Program and Mission Directors along with the Apollo Spacecraft Program Manager's report. The Apollo Spacecraft Program Manager would have orally summarized these reports at the FRR and provided an update of the spacecraft checkout, failure analysis and qualification status, implementation of Pre-FRR action items and DCR action items.

The basic objective othe Pre-FRR is to evaluate the readiness of the spacecraft, GSE hardware and ACE hardware to achieve the specified mission as documented in the MSC, Houston FRR Procedure (Reference 6-34). Specifically the objectives are to:

- Evaluate all work accomplished subsequent to the delivery of the spacecraft to KSC.
- Determine the status of the hardware with respect to all waivers, deviations, discrepancies, shortages, unresolved checkout problems, generic and spacecraft failures, limited life components, configuration changes, uncontrolled parts, and open work.
- Determine qualification/certification status of spacecraft hardware, including evaluation of test versus flight hardware differences.
- Determine the flight readiness and degree of engineering confidence in the reliability of the

hardware at the point in time of the review.

- Specify action to be accomplished as a result of the review.
- Release the hardware for final launch preparations.

The Pre-FRR review board consists of:

Chairman - Apollo Spacecraft Program Manager, or his designated appointee.

Members - Representative from Engineering and Development Directorate, MSC-Houston.

- Representative from the Flight Operations Directorate, MSC - Houston.
- Representative from the Flight Crew Operations Directorate, MSC - Houston.
- Representative from the Flight Safety Office, MSC - Houston
- Representative from the Medical Research and Operations Directorate, MSC-Houston.
- Representative from the Office of the Director, Plans, Programs, and Resources, KSC - Cape Kennedy.
- Representative from the Office of Assistant Director for Spacecraft Operations, KSC-Cape Kennedy.

Secretary - Representative from the Reliability, Quality and Test Division, MSC - Houston.

The Pre-FRR report (Reference 6-35) was completed by NAA on January 27, 1967, however fifteen (15) preliminary copies were delivered to MSC - Houston on January 25, 1967. The original masters were impounded on January 27, 1967, after the S/C 012 accident. With the Apollo 204 Review Board's approval, copies of the original masters of the Pre-FRR report were made and one copy delivered to the Apollo 204 Review Board Legal Counsel.

All hardware problems in the Pre-FRR report (Reference 6-35) were reviewed to determine which problems may have been related to the accident. These problems are listed in below along with the action taken:

- During Downey and KSC checkout of S/C 012, two inverters experienced "moly-Block" transistor failures. These failures cast suspicion on the conclusiveness of the "Moly-Block" transistor fix for a prior overheating problem. Analysis of the problem revealed no design inadequacies but did show the need for improved screening techniques of the transistors. Such techniques were developed and imposed on the transistors installed in S/C 012.

Action - Inverters to be removed from S/C 012 and analyzed per Review Board Action Items 0041, 0123, 0153, and 0182.

- The Environmental Control System, in particular the Environmental Control Unit (ECU), has experienced several significant problems that had impact on S/C 012. The majority of these problems occurred in qualification testing. The most serious problem was that the water evaporator (water boiler) blocked and would not accept water for evaporation to cool the water/glycol. This problem was eliminated by redesign of the distribution plates and making a filter change. With these and other changes incorporated, the ECU has successfully completed qualification testing. All of these changes were implemented on S/C 012.

Action - ECU to be analyzed per Review Board Action Items 0097, 0102, 0168.

- During the Combined Systems Test at Downey, several caution and warning light indications could not be verified. Troubleshooting isolated the problem to an open circuit within terminal block assembly No. 1 behind the Main Display Console (MDC) C&W Panel No. 11. An x-ray examination of the matrix terminal block assembly (TB-1) revealed seven pins not proerly inserted. The pin insertions in the remaining 31 similar TB assemblies installed in the S/C were examined. This examination revealed nine additional discrepant terminal block assemblies.

Action - Terminal Blocks to be analyzed per Review Board Action Items 0160, 0161, 0153.

- Several spacecraft electrical wire harness assemblies were saturated with water-glycol during KSC Checkout Operations. Subsequent investigations have proven that this solution in spacecraft wiring and connectors will support electrolytic corrosion particularly in the presence of a polarizing electric potential.

Action - Wire harness assemblies to be analyzed per Review Board Action Items 0160, 0161.

- Analysis of shielded and unshielded Environmental Control Unit (ECU) electrical harnesses

indicated that numerous connectors were improperly potted. S/C 012 was retrofitted with cables using ML wire and larger backshells. All of these cables have had dielectric testing. These cables have been tested under a corrosive contaminant oxygen and humidity environment and have satisfactorily passed the minimum acceptable insulation resistance requirement. The ECU with these new cable assemblies was installed in S/C 012.

Action - ECU electrical harnesses to be analyzed per Review Board Action Items 0161, 0168.

- Floodlights: Problems which occurred in S/C checkout, characterized by abrupt loss of light output and blowing of internal fuses, were traced to susceptibility to line transients within the floodlight power converter circuit. Circuit design and component changes were made to improve transient susceptibility margin, and units have since been subjected to a more rigorous acceptance test.

Action - Floodlights were analyzed per Review Board Action Item 0169 and it was determined the floodlights were not an initiator or propagator of the fire.

- Bio-Med parameter CJ0002 (Respiration) decreased in level when either crew member pressed Push to Talk (PTT) switch. Modulation was also present when crewman spoke.

Action - Bio-Med harness and Medical Data Acquisition System to be analyzer per Review Board Action Items 0155, 0156, 0165.

- Flexible Polyurethane Foam (FPF). The FPF has failed in the flammability test per MA0115-008 whch requires no flame at 400°F in 02. This foam is used in Crew Systems Design and Support, ECU, ECS, and Telecommunications.

Action - The FPF is discussed and future corrective action is outlined in the final report of Panel 8 - section C.8.b. Corrective action is to use a substitute, nonflammable material in future spacecraft.

The Apollo Spacecraft Program Manager's FRR report was approximately 60 percent complete at the time of the S/C 012 accident, but had not been reviewed by the Manager. The existing sections of the report were reviewed to determine if any problems discussed could be related to the accident. The following problems were a result of this review and are in addition to the problems discussed from the Pre-FRR report.

- Polyurethane foam is used as potting in the Electronic Control Assembly (ECA). This potting includes and surrounds printed circuit boards and electronic components. Polyurethane foam gives off a flammable gas at elevated temperatures. These units are installed in the crew compartment and are therefore exposed to an oxygen environment.

Action - The polyurethane foam is discussed in the final report of Panel 8 - Section C.8.b. Corrective action is to use a substitute, nonflammable material in future spacecraft.

- As the result of recent flammability tests, the Uralane Foam 577-1 was found to fail the flammability tests below 400°F. If this foam were used in close proximity to components whose normal or overload condition could reach excessive temperature, a fire could be started. Typical components falling into this category are electrical resistors, capacitors, or malfunctioning diodes.

Action - Corrective action is to use a substitute nonflammable material in future spacecraft as discussed in the final report of Panel 8 - Section C.8.b.

- Of the approximately 1300 nonmetallic materials identified as used in the Command Module, NAA has supplied the following status information:

300 Materials do not meet the criteria established by MC999-0058.

350 Materials are acceptable by these same criteria.

650 Materials have no status as to acceptability.

Due to the type of information, i.e., material lists, bill of materials, etc. used by NAA to compile the material usage list, exact location and amount used is not available in the majority of the cases. Such information is obtainable only by drawing review. This activity is not planned by NAA. In addition, subcontractor compliance has not been either imposed or obtained in all cases. Due to this lack of information, an engineering decision cannot be made on whether a serious problem does or does not exist nor can an assessment be made on the effect on the reliability from a toxicity and flammability standpoint. It is estimated at this time that the identification of the nonmetallic materials is approximately 85-90 percent complete.

Action - Corrective action is outlined in the final report of Panel 8 - Section C.8.b.

REFERENCES

6-12 Apollo Program Directive No. 6A MA009-006-1A, dated August 30, 1966, titled "Sequence and Flow of Hardware Development and Key Inspection, Review and Certification Checkpoints".

6-13 Apollo Spacecraft Program Office Configuration Management Plan, Revision B, dated March 15, 1966.

6-14 NAA-CSM Configuration Management Plan, SID 65-100. Section 10.0, Formal Reviews.

6-15 Project Apollo - Procedure for the Certification of Flight Worthiness (COFW) from NASA, MSC, Houston, Texas, dated June 20, 1966.

6-16 Apollo Program Manager's letter dated July 13, 1966, subject "Design Certification Review Support for Mission AS-204/SC 012".

6-17 Certificate of Flight Worthiness for Spacecraft 012, Endorsement No. 1, dated August 24, 1966.

6-18 Apollo Program Directive No. 7, dated April 21, 1966, titled, "Apollo Design Certification Review".

6-19 Apollo Program Directive No. 8, dated November 8, 1965, titled, "Apollo Flight Readiness Reviews".

6-20 CSM-012 End Item Specification SID 64-1080, dated 22 February 1965. Classified CONFIDENTIAL.

6-21 Apollo S/C 012 Delta CDR Minutes of the Meeting. Part I NAA-Downey, California, dated March 3, 1966.

6-22 Apollo S/C 012 Delta CDR Minutes of the Meeting. Part II NAA-Downey, California, dated March 29, 1966 and April 5, 1966.

6-23 Manned Spacecraft Center, Project Apollo, Plan for Phase I, Delta Critical Design Review, Spacecraft 012. dated January 28, 1966.

6-24 Customer Acceptance Readiness Review, Project Apollo, CSM 012, Phase I Report, dated June 1966.

6-25 United States Government Memorandum PF2/G-116-67, Subject: Disposition of S/C 012 Delta CDR Action Items, dated March 23, 1967.

6-26 Customer Acceptance Readiness Review, Project Apollo, CSM 012, Phase III Report from NNAA-Downey, California, dated 21 July 1966.

6-27 CSM Major Module Material Inspection and Receiving, DD Form 250's.

6-28 Apollo NAA/NASA Waiver Approval Request. CSM S0001 dated 3-24-66.

6-29 NAA Internal Letter dated August 22, 1966, Subject: Flammability Investigation S/C 012 CARR.

6-30 Apollo Program Director's Letter, dated 12 October 1966, Subject: AS-204 Design Certication Review.

6-31 Memorandum for Design Certification Board dated September 23, 1966, Subject: Service Propulsion Subsystem.

6-32 United States Government Memorandum dated 20 December 1966, Subject: AS-204 DCR Action Items

6-33 Datafax transmission from Apollo Program Office Action Center, dated 17 March 1967 supplemented by Letter from APO Action Center, dated 24 March 1967, Subject: AS-204 DCR Record Supplement.

6-34 Apollo Spacecraft Program Office Flight Readiness Review Procedure MSC-A-D-66-6, dated October 12, 1966.

6-35 Project Apollo, Flight Readiness Review Spacecraft Readiness Review, Spacecraft 012 Report, dated February 1967.

APOLLO REVIEW BOARD

APOLLO SPACECRAFT 012

HISTORICAL NARRATIVE

OF

PRELAUNCH OPERATIONS

AT

KENNEDY SPACE CENTER

Enclosure 6-7

INTRODUCTION

This report presents a brief historical narrative of the prelaunch operations performed on Apollo Spacecraft 012 at Kennedy Space Center. Each major test that was accomplished is briefly described in addition to significant problems and spacecraft rework required.

For additional clarification, an "as run" bar chart is included. Charts are also included to portray the relationship of spacecraft testing to scheduled and non-scheduled work as a result of design modifications and discrepancies during the prelaunch operations.

Apollo Spacecraft 012 prelaunch checkout at Kennedy Space Center was initiated on August 10, 1967, with arrival of the Service Module portion of the Spacecraft. After arrival at the Cape Kennedy Skid Strip, the Service Module was transported to the Kennedy Space Center industrial area warehouse for painting. Service Module painting is normally delayed until arrival at Kennedy Space Center to preclude abrasions during shipment. The condition of the Service Module paint is of concern since it is a thermal paint and performs a mission function in the environmental control of the Service Module.

With completion of painting, the Service Module was moved to the Operations & Checkout Building and installed in a workstand for installation of the Service Propulsion System engine nozzle plug. The nozzle plug was installed in preparation for accomplishing leak and functional testing of the Service Propulsion System.

After installation of the nozzle plug, the Service Module was moved into the adjacent altitude chamber on August 13. On August 15, the parallel tasks of

receiving inspection and preparations for Operations Checkout Procedure number 4074 were initiated. Receiving inspection is delayed until this point is reached since the required removal of various panels for testing provides better visibility to perform the inspection. Receiving inspection consists of a visual inspection to check the "as received" condition of the vehicle for possible damage incurred during shipment. Operations Checkout Procedure 4074 is a leak and functional test of the Service Module Propulsion System to verify the pressure integrity and functional operation prior to mating with the Launch Vehicle on the launch complex. The actual performance of Operations Checkout Procedure 4074 was started on August 17 and continued through August 27.

In parallel with Operations Checkout Procedure 4074, a Service Module radiator reflectivity test was accomplished per Operations Checkout Procedure 5116. This test confirms the capability of the radiators in the Service Module to remove the heat generated by the Spacecraft systems. In addition to

the accomplishment of these two parallel tasks, two design modifications were incorporated and five discrepant conditions were repaired on the Service Module during this time period.

The Command Module portion of Spacecraft 012 arrived at Kennedy Space Center on the 26th of August, three weeks after arrival of the Service Module. The Command Module was transported directly to the Pyrotechnic Installation Building for weight and balance and Launch Escape System thrust vector alignment checks. Command Module weight and balance checks are performed to determine the weight and center of gravity of the spacecraft. Launch Escape System thrust vector alignment consists of optically ascertaining the proper alignment of the Launch Escape System rocket engine nozzles with respect to the centerline of the CM after mating the Launch Escape System tower to the Command Module. With the completion of these two tasks, the Launch Escape System tower was removed from the Command Module and returned to storage to await reinstallation during final preparations for launch at the launch complex.

The Command Module was removed from the Pyrotechnic Installation Building and transported to the Operations & Checkout Building altitude chamber on August 29 for mating with the Service Module. The Command and Service Module mating operation was started on the 30th of August and required 64 hours to complete. Command and Service Module mating normally requires 16 hours. In this instance, the mechanical hardware utilized to attach the Command Module to the Service Module was of a new design and proved to be difficult to adjust with relation to the Command Module aft heat shield interface. Previous experience was not available since factory checkout plans did not require final installation of the aft heat shield prior to factory Command and Service Module mating. In addition, information (strain guage calibration curves) required to ascertain when the proper tension adjustment between the Command Module and Service Module was achieved, had inadvertantly not been shipped from the factory with the spacecraft, and was subsequently lost. Completion of mating was delayed until calibration curves could be generated locally.

After completion of Command and Service Module mating,

a receiving inspection was performed on the Command Module. With completion of receiving inspection, the accumulation of required design changes, and repair of discrepant conditions was such that a fifteen-day, "no test" work period was initiated. The spacecraft had arrived with 113 approved, but unincorporated design changes (EO's). During this period, thirteen major system design changes (MCR's, Master Change Record) were incorporated, the majority of which were wiring modifications. In addition, various removal and repair and rework activities were conducted. The incorporation of known modifications and repairs at this point in time was required prior to proceeding into Operations Checkout Procedure 0035, Combined Systems Testing, since rework of this nature and scope could invalidate the test. The objective of the combined systems test is to determine that all spacecraft systems perform properly and that no incompatibilities or interferences exist between systems.

On September 15, the Combined Systems Test was commenced and continued until September 17 when testing was stopped in order to determine the cause of two major malfunctions in the spacecraft Caution and

Warning System and Reaction Control System respectively. Investigation revealed that several pins within a Matrix electrical connector (TBI) on the caution and warning main display panel in the Command Module cabin had not been completely inserted during manufacturing. This resulted in a lack of electrical continuity. As a precautionary measure, seven cabin display panels were removed from the spacecraft and x-rayed to determine if a similar discrepancy existed on other Matrix electrical connectors. This activity required two days to accomplish. The Reaction Control System malfunction was determined to be two badly bent pins in an electrical connector resulting in a short circuit to ground. On September 19, Operations Checkout Procedure 0035 was again started and was completed on September 23; however, some additional unresolved malfunctions had been detected. At this point, spacecraft testing was discontinued for an eight-day period to resolve and repair the known malfunctions. In addition, this time period was utilized for various mechanical work and incorporation of two design changes.

With relation to the detected malfunctions, improper

operation of the fuel cell water-glycol coolant system was determined to be blockage of fluid flow due to installation of a blind (no hole) Voishan seal in a system line. After seal replacement, the system was purged, dried, and reserviced. Other malfunctions repaired during this period included replacement of an oxygen supply valve and resolution of problems in the Telemetry and Guidance and Navigation systems. Also during this work period, a leak developed in the Environmental Control System water-glycol loop due to a faulty soldered joint behind the Display Electronic Control Unit. This was subsequently repaired.

One area of considerable trouble during this time period was the crew couches which had been removed from the spacecraft for extensive mechanical rework. Some twelve separate major discrepancies had been detected and required factory design engineering personnel to travel to Kennedy Space Center to assist in the resolution of design deficiencies.

On October 1, spacecraft testing was reinitiated for a one-day period to demonstrate that the previous electrical malfunctions had been properly resolved

and repaired. At completion of this one-day period of testing, the Combined Systems Test was considered satisfactorily completed and was accepted.

On October 2, a work period was started for the purpose of preparing the Spacecraft for Operations Checkout Procedure 0034, Altitude Chamber Testing. This test involves testing the spacecraft under simulated altitude conditions with the flight crew onboard. Preparation for the altitude test included a leak test to verify pressure integrity of the spacecraft cabin, various crew equipment installations, flushing and servicing the environmental control water system, and the continued reservicing of the fuel cell water-glycol system. During reservicing of the fuel cell water-glycol system, additional leaks were detected and repaired. During the cabin leak test, improper operation of a cabin relief valve was detected. This unit was removed and replaced and the test satisfactorily completed. Also during this work period, a design modification was incorporated, which provided the flight crew with additional mechanical leverage to open the spacecraft hatch. With completion of a crew equipment stowage exercise by the flight crew, the spacecraft was considered ready

for the Altitude Chamber Test.

On October 10, the Altitude Chamber Test was started. This test consists of a sea level run, an unmanned run "at altitude", and two manned tests, or runs, "at altitude". The sea level run consists of testing all systems in a mission sequence to ascertain that systems perform properly and events occur at the correct point in time with relation to the planned flight. The flight crew participates as an integral part of the test. The unmanned run "at altitude" is accomplished to assure the capability of the spacecraft life support systems to sustain the flight crew "at altitude" prior to attempting the manned runs. Finally, the manned altitude runs (one for the prime crew and one for the backup crew) are for the purpose of evaluating the spacecraft systems operation at altitude; compatibility of spacecraft and crew under altitude conditions; and capability of the crew to perform various tasks with the crew stowed equipment.

During the sea level portion of the Altitude Chamber Test, a malfunction was detected in the spacecraft abort system. Investigation revealed three bent pins in the electrical umbilical connector between the Command

Module and Service Module. This problem was corrected and the sea level run was successfully completed on October 13. During the following two days, the unmanned run at altitude was satisfactorily completed.

With completion of the unmanned run, preparation for the initial manned run was initiated. This preparation consisted of servicing the spacecraft environmental control system with potable water; liquid oxygen loading, and fuel cell activation. These tasks were completed on October 17. On the following day the manned run was initiated and continued until a spacecraft electrical power system inverter failed during pump down of the altitude chamber. After replacement of the inverter, testing was again resumed and the run completed on the following day, October 19, with one equipment malfunction, failure of a spacecraft primary oxygen regulator.

Determination of the cause of the regulator failure proceeded with removal of the regulator from the spacecraft and subsequent disassembly of the unit. Disassembly of the unit and further investigation revealed a design deficiency existed in the regulator.

While awaiting a redesign decision on the spacecraft oxygen regulator, various miscellaneous spacecraft work items were accomplished such as replacement of all spacecraft circuit interrupters (improved design), additional x-rays of Matrix connectors, etc. On October 27 a decision was made to remove the Environmental Control Unit from the spacecraft and return to the factory for incorporation of a design change to the water boiler.

Meanwhile, a Spacecraft 017 Service Module propellant tank had ruptured during factory checkout at Downey, California. In view of the tank failure at the factory, it was decided to conduct some special testing on the Spacecraft 012 tanks at the Kennedy Space Center. In order to proceed with the Service Module special tank test and continue work on the Command Module in parallel, the Command and Service Modules were demated on October 29. The Command Module was moved out of the Altitude Chamber and installed in the adjacent integrated work stand and removal of the Environmental Control Unit was started. The Service Module remained in the altitude Chamber and preparation for removal of the Service Propulsion System propellant tanks was initiated. The rationale behind removal of the tanks prior to testing

was to prevent destruction of the Service Module in the event a tank rupture occurred similar to the Spacecraft 017 failure during factory checkout.

On November 2, removal of the Service Module propellant tanks was completed and the tanks were transported to Launch Complex 16 at Cape Kennedy for special pressure testing. During pressure testing, the tanks were serviced with liquid Freon to reduce the hazardous aspect of the test. Complex 16 is a remote area approved for hazardous testing. Tank testing was successfully completed on November 7 and on the following day the tanks were returned to the Operations & Checkout Building. By November 11, tank installation in the Service Module was complete. The following two days were utilized to incorporate an engineering modification on the Service Module propulsion fuel tank plumbing.

On November 13, the Service Module was transported to Launch Complex 16 at Cape Kennedy for Service Propulsion System pressure testing. This was necessary to reestablish overall system confidence at operational pressure after the tanks had been reinstalled in the Service Module

Pressure testing on the Service Module was completed on November 16 and the Service Module was returned and reinstalled in the Operations & Checkout Building altitude chamber. Two days of preparation and work followed and on November 18, the Service Module was ready for mating with the Command Module.

In parallel with the previously described Service Module activity, work had been progressing on the Command Module in the Operations & Checkout Building integrated workstand. The Environmental Control Unit had been removed and returned to the factory for modification. On November 8, a new configuration Environmental Control Unit was received and installation into the Spacecraft was started. Installation was complete on November 12 and a leak and functional test on the system was initiated. This was completed on November 18.

In additional to the Environmental Control Unit activity described above, other testing had proceeded on the Command Module. A reaction Control System leak and functional test had been performed per Operations Checkout Procedure 4070. This test would normally have been performed at the launch complex as a portion of Operations Checkout Procedure 0005. However,

since the capability to perform the test existed in the Operations & Checkout Building and time was available, the test was performed to alleviate testing and provide additional contingency time on the launch complex. It is noted that the Reaction Control System Test performed is only a small portion of the Operations Checkout Procedure 0005 that was utilized, and only the Reaction Control System portion was performed. In addition to the Reaction Control System Test, a calibration test on the Guidance and Navigation System was performed at this time as a normal periodic requirement.

Concurrent with preparation of the Service Module for mating, the Command Module was moved from the Operations & Checkout integrated workstand into the adjacent altitude chamber and mated to the Service Module on November 19. With completion of Command and Service Module mating, preparation for continuation of the manned altitude chamber test (second manned run for backup crew) was started. On November 25, a new configuration spacecraft oxygen regulator was installed.

On November 29, servicing of the Environmental

Control System water and water-glycol systems had been completed and power was applied to the spacecraft in preparation for the manned altitude run. During powerup of the spacecraft, evidence (a few drops) of water-glycol was observed on the spacecraft cabin floor under the aft right hand corner of the newly installed Environmental Control Unit. Three days of investigation failed to positively locate the source of the leakage. On December 3, a decision was made to remove the Environmental Control Unit and return it to the factory for further investigation and location of the source of leakage.

While awaiting return of the Environmental Control Unit from the factory, a reverification test was performed on two components (check valves) of the Reaction Control System. These units had failed during the previously described Reaction Control System leak and functional test and had been replaced. Also during this time period an additional leak was detected at a supply line solder joint (lower equipment bay) in the Environmental Control System water-glycol system.

On December 14, the Environmental Control Unit was returned to Kennedy Space Center from the factory.

Extensive testing on the unit at the factory had not confirmed any leakage associated with the unit. After Environmental Control Unit installation was completed, the Environmental Control System was serviced, and again an indication (a few drops) of water-glycol leakage was observed on the cabin floor under the aft right hand corner of the Environmental Control Unit. At this time extensive efforts were made to locate the source of the leak, but were unsuccessful. No leakage was ever noted or observed at this same location apart from the servicing operation. It was assumed that the leakage condition was due to a dynamic action by "O" ring seals and/or other seals as a result of prolonged vacuum during servicing operations and thus would not occur except during servicing. A decision was made to proceed with testing and continue to observe this condition.

Reverification testing of the Environmental Control System was successfully completed on December 20. The crew couches were installed on December 21 and the environmental control water system serviced the following day. The crew couches had been removed for access to remove and reinstall the Environmental Control Unit. Preparations for continuing the altitude chamber test

were continued until December 24 when work was discontinued for the Christmas holiday.

On December 27 and 28, the sea level and unmanned portions of the altitude chamber test were successfully completed. Although these tests had been previously completed, they were repeated to establish confidence for the manned run since a significant amount of spacecraft rework had been accomplished. On December 29 and 30, the second manned altitude run with the backup crew participating was performed and all test objectives were met. It is noted that the final manned run was very successful with all spacecraft systems functioning normally. At the post test debriefing, the backup flight crew expressed their complete satisfaction with the condition and performance of the spacecraft.

After completion of the altitude chamber test, the environmental control water and liquid oxygen systems were deserviced and the spacecraft was removed from the altitude chamber and placed in an adjacent workstand on January 3. The Service Propulsion System nozzle extension was installed and leak checked on the following day. On January 4, the spacecraft was mated to the spacecraft adapter and installation of ordnance devices was started.

On January 6, the spacecraft was moved to the launch complex and mechanically mated to the launch vehicle.

After mechanical mate with the launch vehicle, ground support equipment was connected in preparation for the spacecraft Integrated Systems Test, Operations Checkout Procedure 0005.

The basic objectives of this test are to verify that spacecraft electrical systems are compatible with the launch complex and ground support equipment prior to electrically mating the spacecraft to the launch vehicle and performing overall space vehicle testing.

Test preparations were completed on January 11 and the spacecraft was powered up for the integrated systems test on the following day. This test was completed on January 14. The Launch Escape System tower was mated to the spacecraft on the following day and preparation for the cryogenic loading test, Operations Checkout Procedure 4736 was started.

The cryogenic loading test involves servicing the spacecraft liquid oxygen and liquid hydrogen systems. The basic objective is to assure that servicing can be

performed and that no incompatibilities exist between the spacecraft and ground support equipment. This test also provides early verification of the test procedure and provides practice for the servicing exercise to be repeated later during critical portions of the launch countdown. The cryogenic loading test was completed successfully on January 17 and the spacecraft was deserviced.

With completion of the cryogenic loading test, the spacecraft was electrically mated to the launch vehicle. Verification that proper electrical connection had been made was verified by performing Operations Checkout Procedure 0004. This test was completed on January 18.

At this point the spacecraft was powered down for a one-day work period. Power had been applied to the spacecraft since the initial launch complex test was started (except during launch escape tower installation); as a result, various minor work items had accumulated, the majority of which were configuring the interior of the cabin for flight. In addition, detailed study of test results (data) from the spacecraft Integrated

System Test had indicated possible malfunctioning equipment in the guidance and navigation inertial measurement unit and the stabilization and control system. Further investigation of these two possible problems were continued during this period. The Inertial Measuring Unit (platform) was determined to be acceptable. The Yaw Electronic Control Assembly of the Stabilization and Control System was found to be unsatisfactory and was replaced at a later date.

On January 20, a decision was made to proceed with a practice run of the Space Vehicle Overall Test number 1, Operations Checkout Procedure 0006. The run was a practice run in that it would have to be repeated since the required participation of the Mission Control Center in Houston, Texas, was not available to support the test until some four days later. The prime objective of making a practice run was to identify at the earliest possible time any procedural or hardware compatibility problems. It is noted that up to this point testing had involved the spacecraft and launch vehicle individually except for the Electrical Mate Test. The opportunity to detect overall spacecraft launch vehicle hardware and procedural problems had not occurred.

It is noted that since initiation of the final manned altitude chamber test, operations had proceeded so well that testing was five days ahead of schedule even after completion of the overall test No. 1 practice run.

The objective of the Space Vehicle Overall Test Number 1 (plugs in) is to ascertain proper operation of the total Space Vehicle (launch vehicle and spacecraft) during a simulated mission sequence from liftoff to completion of the spacecraft reentry and recovery phase. The practice run was completed successfully on January 20. On the following day minor work items and repairs were accomplished with no work scheduled for January 22 (Sunday). On January 23 minor spacecraft work items and repairs continued in addition to preparation for the Houston Mission Control Center Software Integration Test.

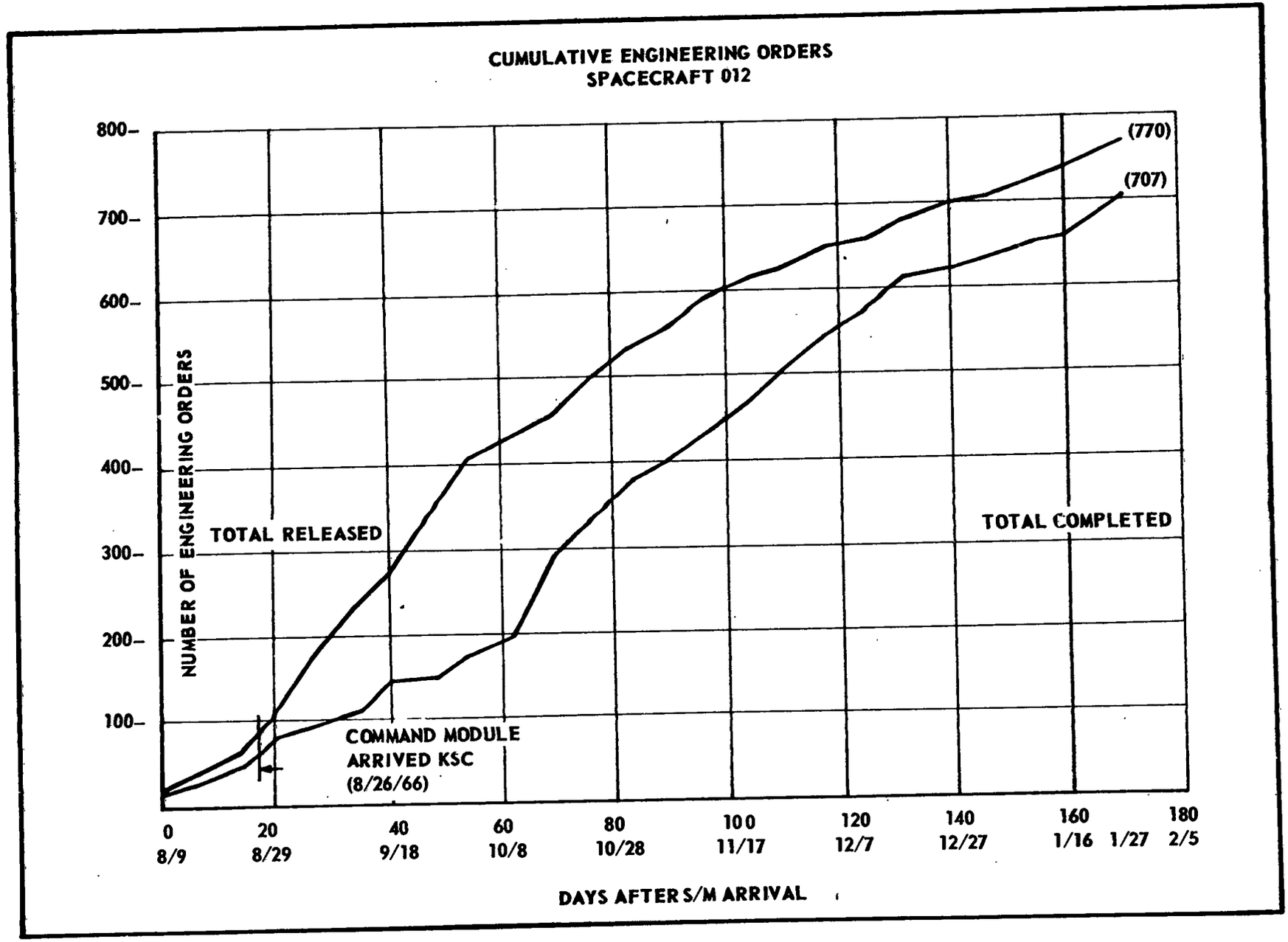
On January 24, the Houston Mission Control Center Software Integration Test was performed per Operations Checkout Procedure 0045. This test verifies that the Houston Mission Control computer programs and equipment performs properly with relation to the spacecraft. This test was successfully completed and the following day the "repeat" run of the Space Vehicle Overall Test Number 1 was made with the Houston Mission

Control Center participating. The test was completed and all test objectives met.

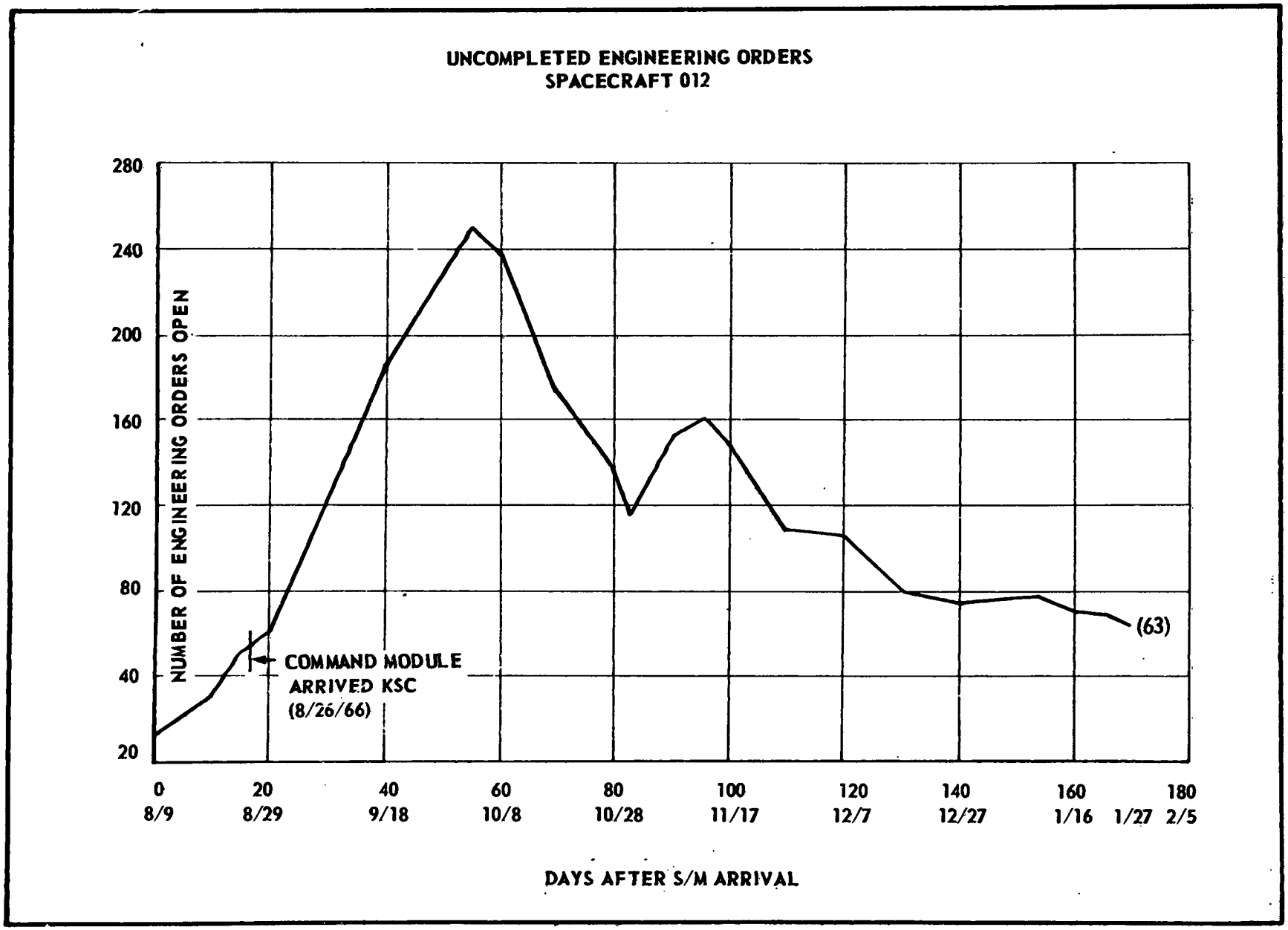
At the conclusion of the Space Vehicle Overall Test Number 1 (plugs in), spacecraft power was left on in order to perform a detailed system test on the yaw Electronic Control Assembly and the Guidance and Navigation System. These systems were suspected of malfunctioning due to a detailed data review of the Operations Checkout Procedure 0005, Integrated Systems Test. It was determined that the yaw Electronic Control Assembly was defective. The unit was replaced and retested satisfactorily. The Guidance and Navigation System was found to be functioning properly. Spacecraft power was removed and preparation for Space Vehicle Overall Test Number 2, Operations Checkout Procedure 0021, was started.

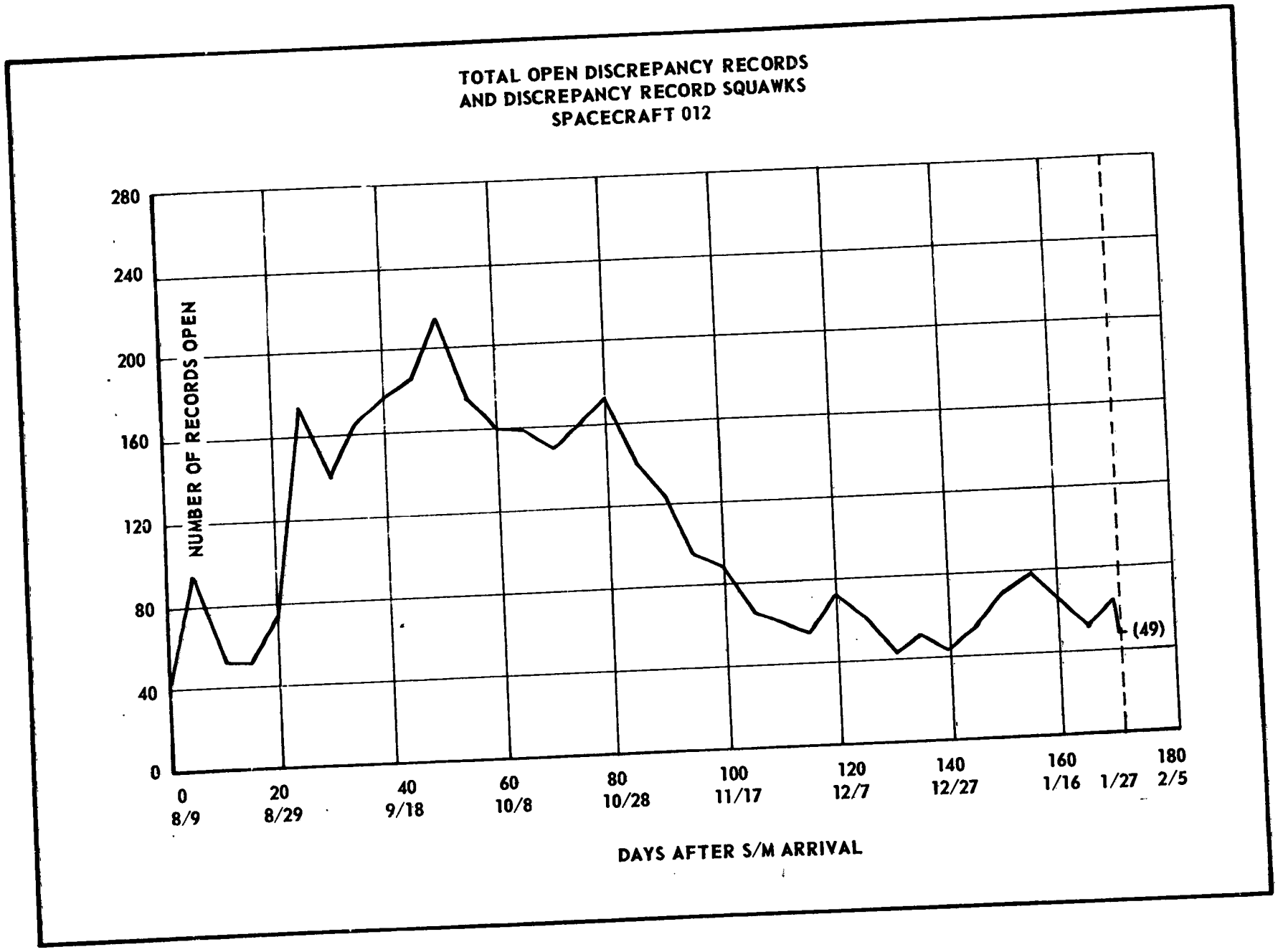
The prime objective of the Space Vehicle Overall Test Number 2 is to verify performance of the total space vehicle during a simulated mission sequence with the space vehicle as near launch and flight configuration as possible. This test was initiated on January 27, 1967.

ENCLOSURE 6-7
D-6-57



ENCLOSURE 6-7





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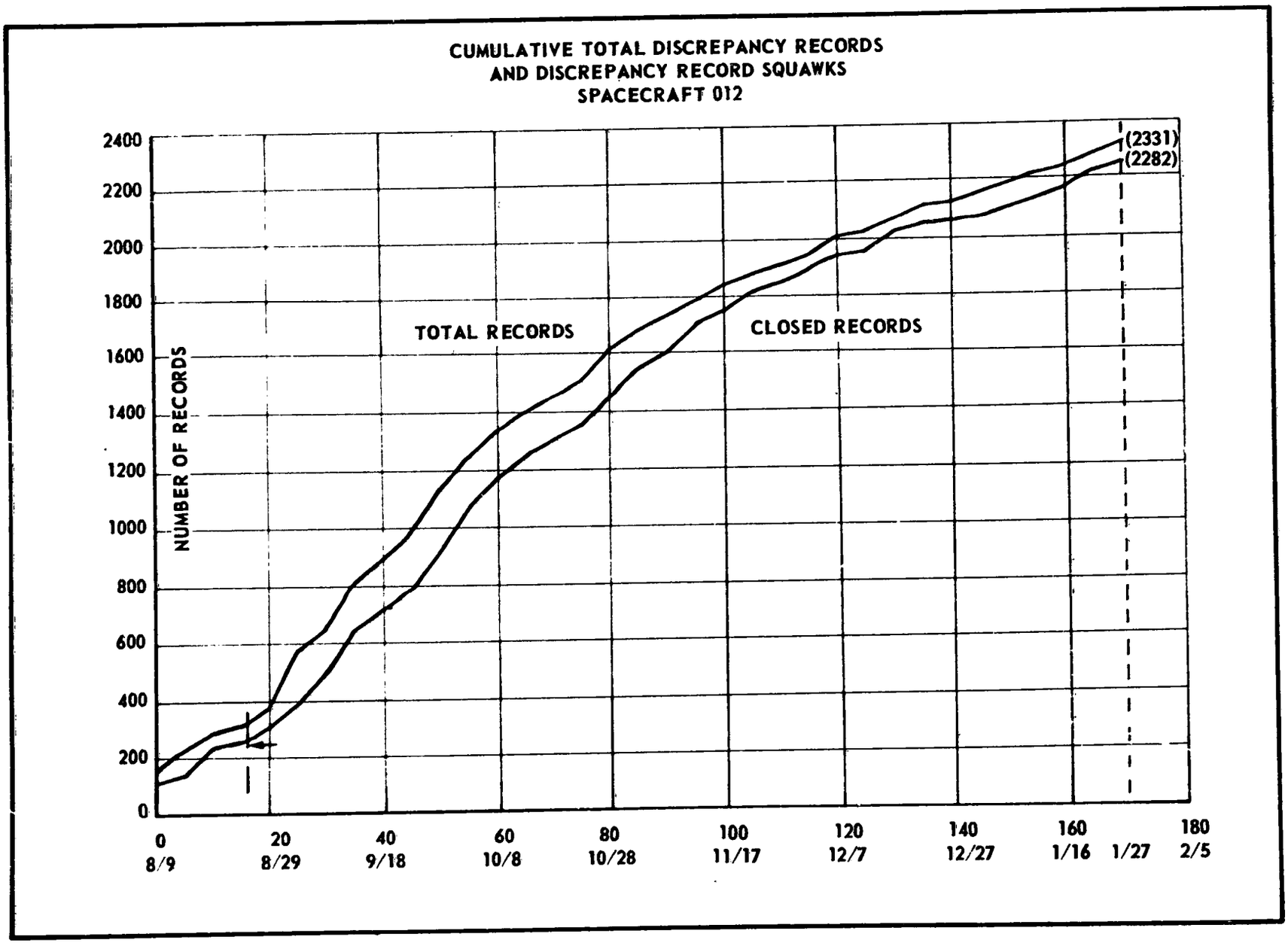
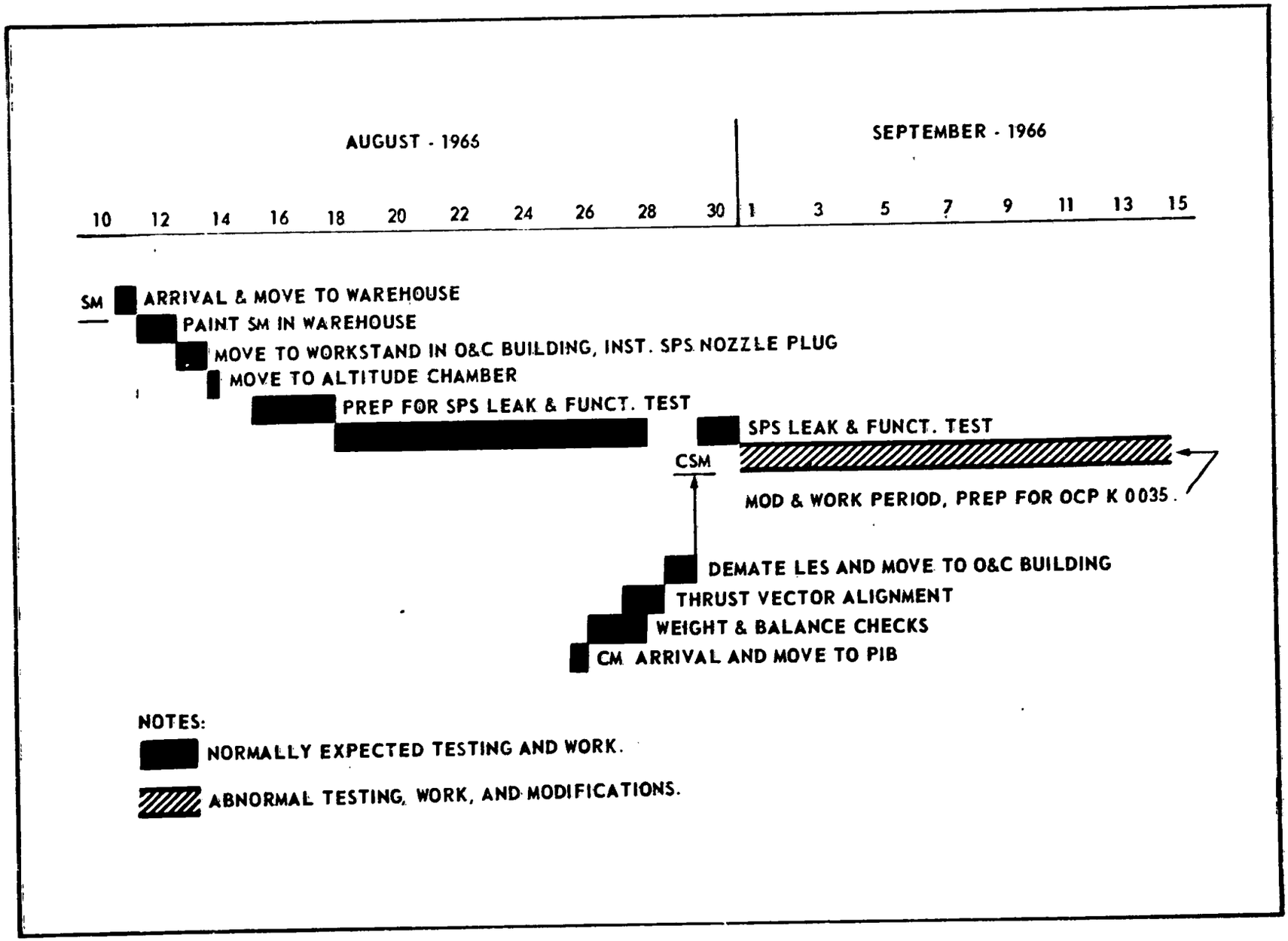
D-6-59

ENCLOSURE 6-7
D-6-60





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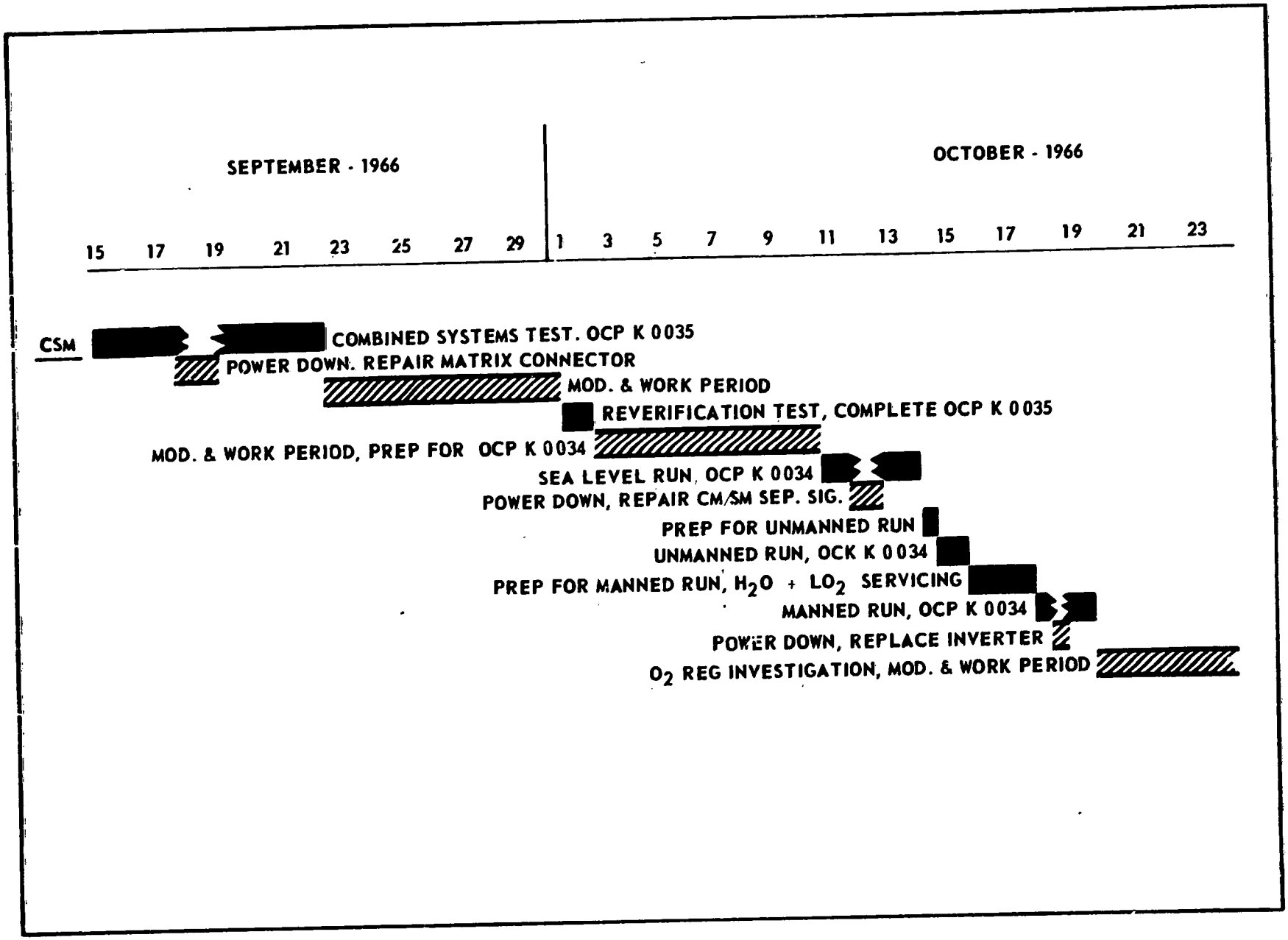
D-6-61



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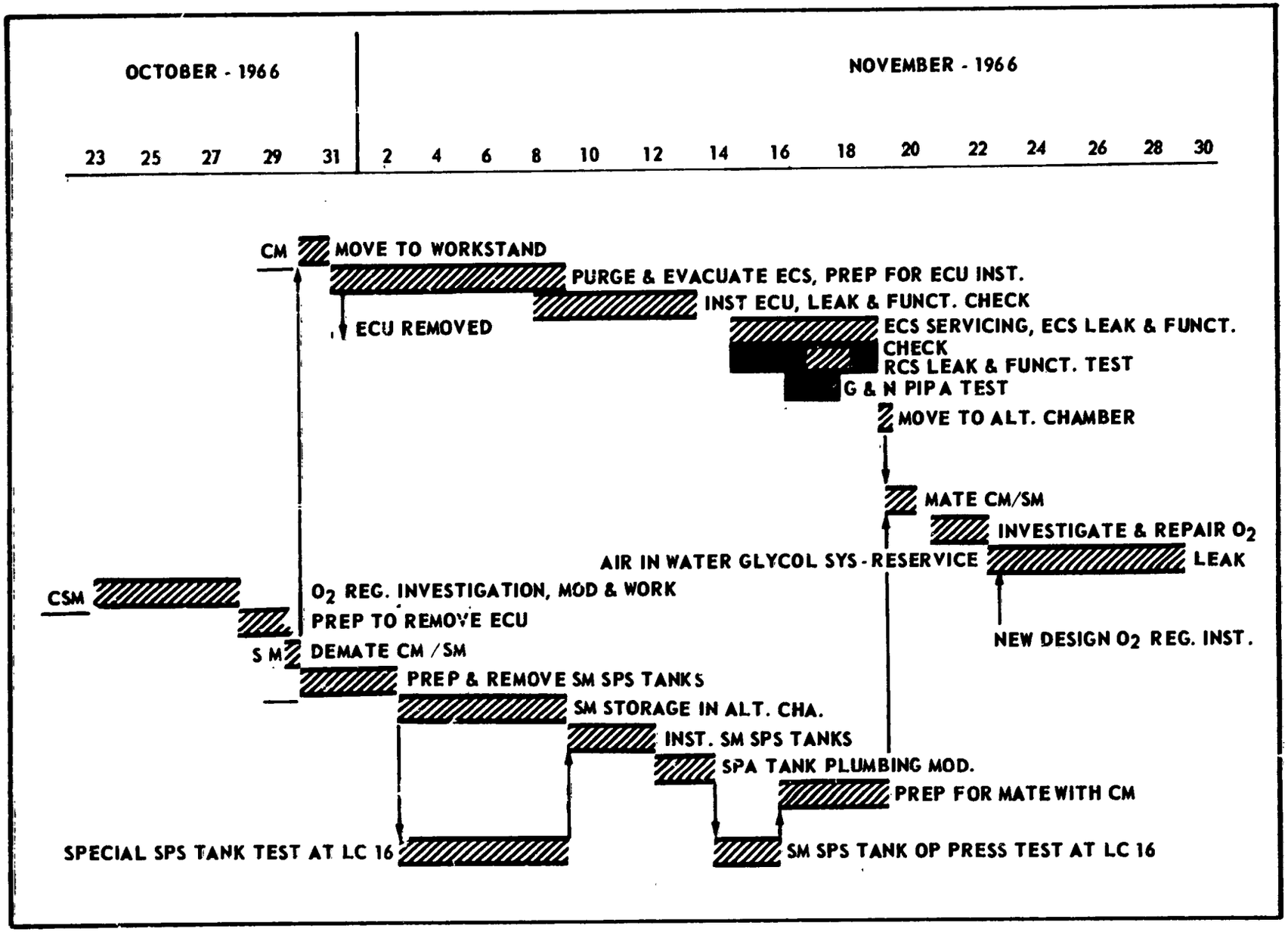
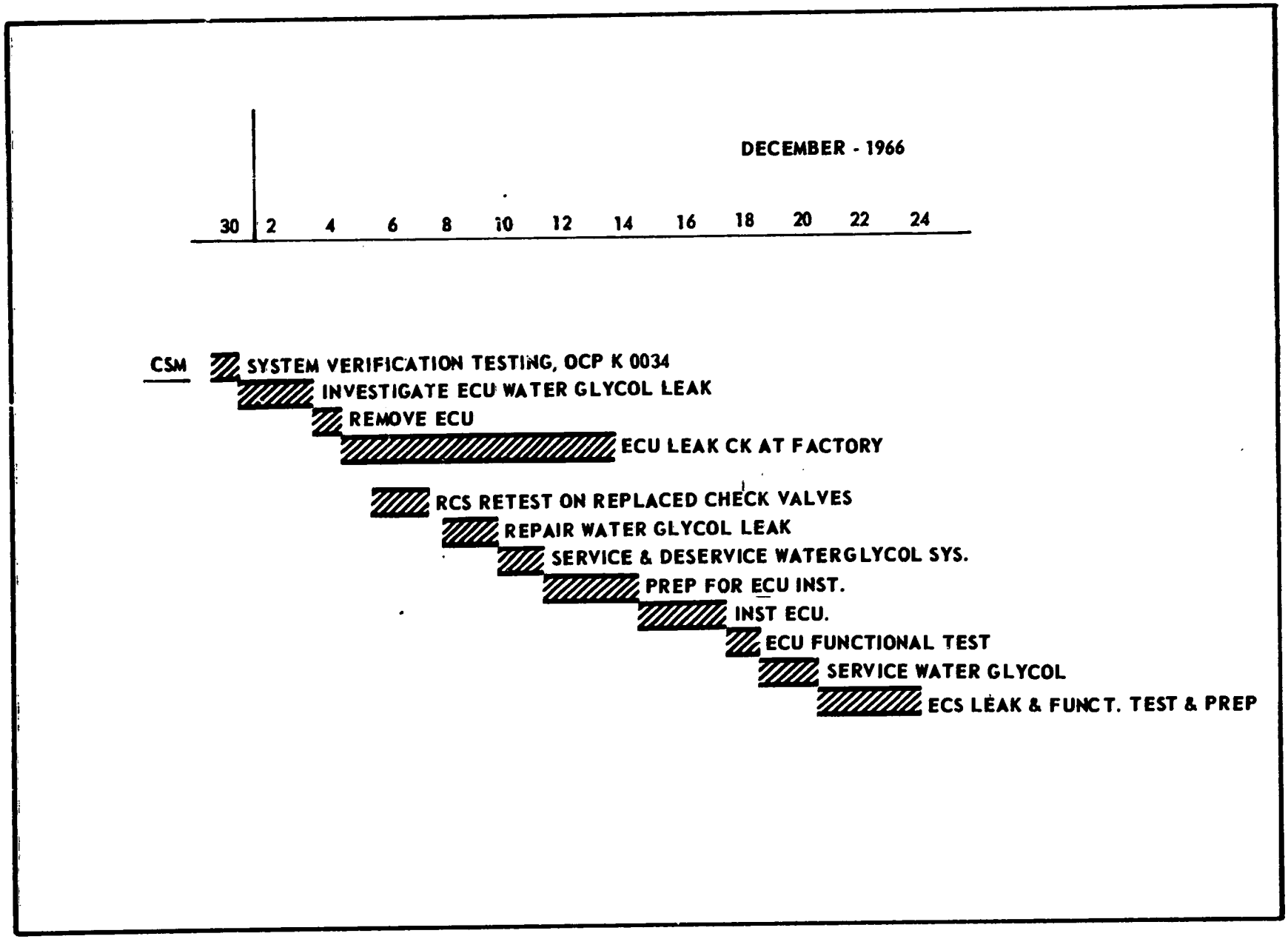
D-6-62

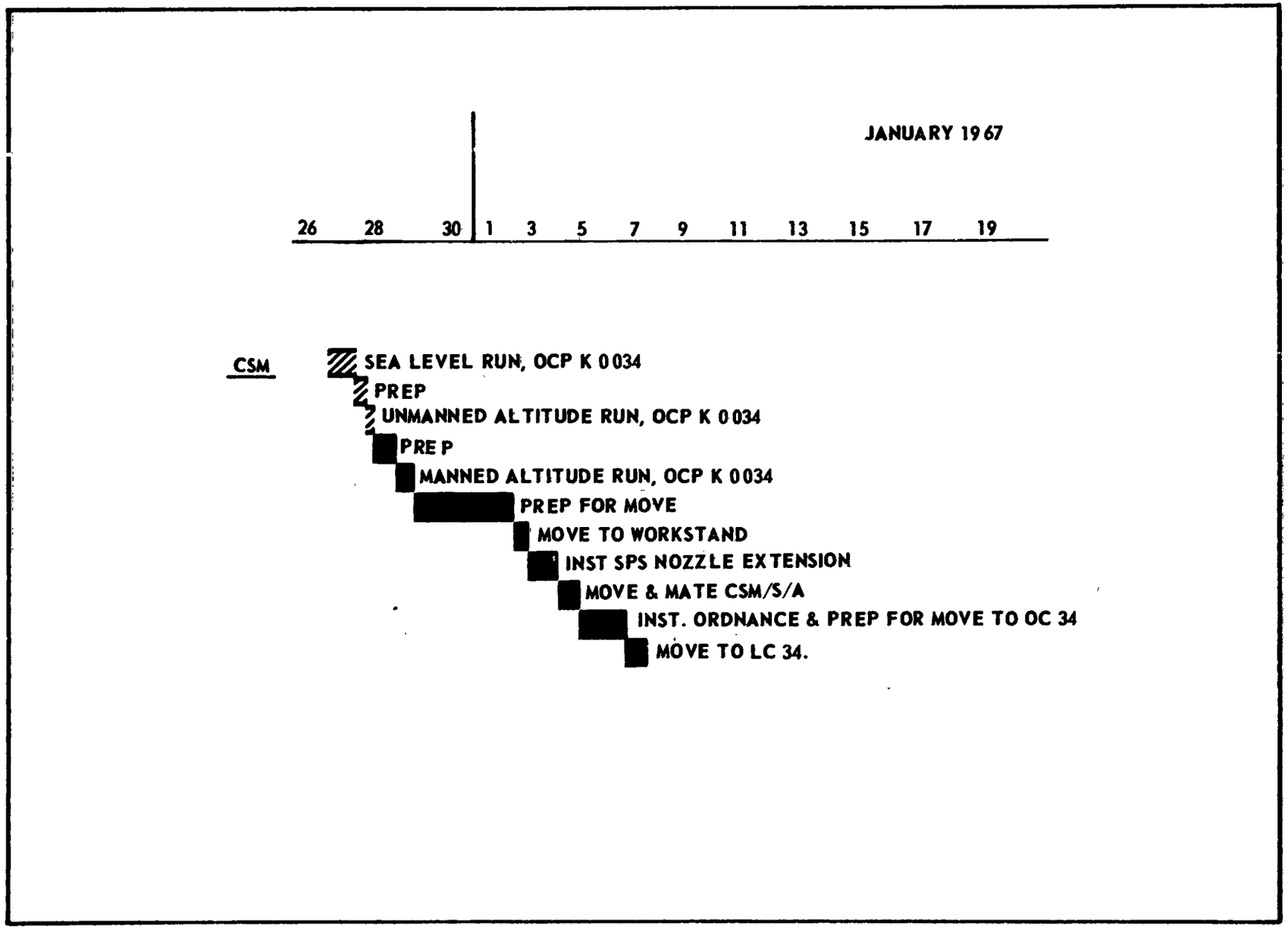


ENCLOSURE 6-7
D-6-63

ENCLOSURE 6-7

D-6-64

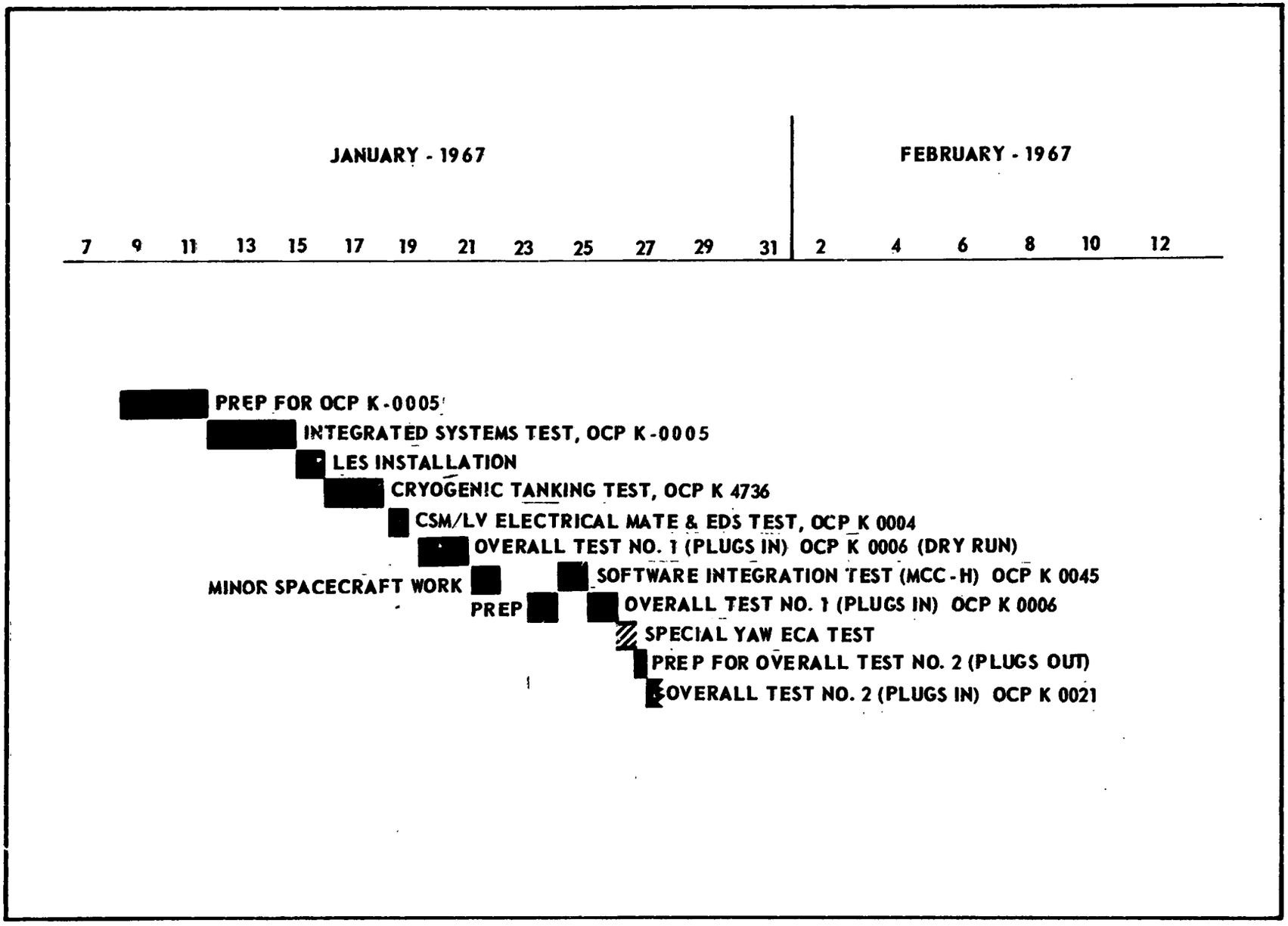




ENCLOSURE 6-7
D-6-65

ENCLOSURE 6-7

D-6-66



APOLLO SPACECRAFT 012

HISTORICAL NARRATIVE FOR PERIOD

OF

SPACE VEHICLE OVERALL TEST NO. 2 PREPARATION

ENCLOSURE 6-7

D-6-67

INTRODUCTION

This report presents a brief historical narrative of the period encompassing final preparation for the Space Vehicle Overall Test No. 2 (plugs out), Operations Checkout Procedure 0021.

The initial portion of the report describes the various types of operational meetings and procedural methods used during the period of checkout described. The final portion of the report includes a cronological listing of pertinent events that occurred in preparation for the plugs out test.

DESCRIPTION OF MEETINGS

Open Items Review

The purpose of an Open Item Review is to examine all paperwork that exists at that point in time depicting work that must be accomplsihed to the Spacecraft and Ground Support Equipment. The basic documents utilized in an Open Item Review are the NAA Spacecraft and Ground Support Equipment Status Reports. At an Open Item Review a constraints list is developed which indicates the work that must be accomplished prior to proceeding into the next spacecraft test. A test constraint is defined as that open work item which if not accomplished would interfere with, or prohibit, the successful completion of a spacecraft test.

Test constraints are normally broken up into two basic categories: constraints to powering up, and constraints to powering down. A constraint to applying power to the spacecraft busses normally indicates work which must be performed that would require modifications (removal and replacement) of spacecraft and/or Ground Support Equipment. Judgement is utilized to recognize hardware availability and work and retest time available in subsequent operations. A constraint to removing

power from the spacecraft busses normally indicates investigation and retest that should be accomplished at that point in the test operation but which would not prohibit the conduct of that test procedure.

Open Item Review Meetings are co-chaired by the NASA Spacecraft Test Conductor and the NAA Test Project Engineer. Functional groups represented at an Open Items Review are as follows:

NAA	NASA
Test Project Engineering	Spacecraft Test Conductor
Engineering (S/C & GSE)	Engineering (S/C & GSE)
Operations	Project Engineering (S/C & GSE)
Inspection	Operations
Shop	Inspection
Service Engineering	Flight Crew Representative
Operations Integration	

Open Item Reviews are normally conducted several days prior to a test in order that appropriate time will be available to work off the identified constraining items.

At the Open Item Review Meeting, the Spacecraft and Ground Support Equipment Status Reports are reviewed and those open items considered to be constraints for the forthcoming test are identified. The identified

constraints are compiled into a single "constraints list" and published shortly after the open item review meeting, usually within three hours. The constraints list identifies the tasks to be worked by system and indicates the responsible person to accomplish close-out of the item.

The constraints list cover sheet identifies the applicable spacecraft test constrained by the list and provides for NAA and NASA approval signatures. Two types of approvals are required. The initial approval signatures indicate that the list is official and are obtained prior to distribution of the list. The final approval signatures indicate that all constraints listed have been worked and closed out. This approval is obtained just prior to going "on station" to start the test. Constraints list approvals are provided by the NAA Test Project Engineer and the NASA Spacecraft Test Conductor.

After completion of the Open Item Review Meeting and subsequent distribution of the constraints list, new items of work are continuously assessed by the NAA and NASA operations engineers. As each new item of work is released, the operations engineer contacts the applicable system engineer to discuss disposition

of the item. The system engineer may or may not proceed to the spacecraft area at this time and actually write the disposition. The main object of the discussion is to maintain the operations engineer's knowledge of new constraints.

Regardless of the previously described discussion relative to the disposition all new items are added to the Spacecraft and Ground Support Equipment Status Reports. New spacecraft work items are reflected daily in the form of an addendum to the basic Spacecraft Status Report utilized at the Open Item Review Meeting. New ground support equipment work items are also reflected in addendums to the Ground Support Equipment Status Report. These addendums are issued weekly or more frequently as required by the amount of new items. Utilization of these status report addendums occurs in real time and at the daily 0800 Status Meeting and 1430 Scheduling Meeting described below.

It is noted that after initial generation of the official constraints list, newly identified constraints become a part of the list in two different manners. If time permits, a revised constraints list is generated. In the absence of appropriate time for revision, the appropriate sheets of the Spacecraft and Ground Support

Equipment Status Report addendums are attached to the original constraints list. The attached addendum sheets are marked to indicate the constraining additional items.

Daily Status Review Meeting

The daily 0800 Status Review Meeting is a general coordination meeting to review the work accomplished during the past 24 hours and to discuss new work items that any have been generated during that same period of time. The following personnel attend the 0800 meetings.

NAA	NASA
Sr. Test Project Engineer	Chief Test Conductor
Asst. Sr. Test Project Engr.	Spacecraft Project Engr.
Engineering Representative	Operations
GSE Representative	GSE Project Engr.
Inspection	Inspection
Shop	RASPO Representative
Service Engineers	Support Contractor Representative
Quality Engineering	
Downey Project Engineering	
Logistics	
Safety Engineering	

Following the 0800 meeting, new work items are scheduled on the Working Schedule Planning Sheet by NAA and NASA Operations personnel. This Planning Sheet is used to schedule all work that must be accomplished on the space

craft and projects three weeks into the future. The Planning Sheet is updated daily if required and is used in supplement to the overall spacecraft schedule. The Planning Sheet is not an official document (not signed by either NAA or NASA) but is given wide distribution throughout the NAA/NASA Test organizations.

In preparation for the 0800 Status Meeting, a complete review of the updated Spacecraft Status Report is conducted by the NASA and NAA operations engineers. This review is usually conducted at the spacecraft where all inspection logs are available to verify the status report.

Daily Scheduling Meeting

At 1430 each day a scheduling meeting is conducted at which the spacecraft work schedule for the next 24 hours is generated. Planning Sheets are utilized at this meeting for reference. At the 1430 meeting, the Spacecraft and Ground Support Equipment Status Report addendums are reviewed to determine if additional constraining work items exist which should be scheduled.

for work. The 1430 schedule meeting is attended by the following personnel:

NAA	NASA
Representatives from each system	Representatives from each system
GSE Representatives	GSE Representatives
Operations	Operations
Quality Engineering	NASA MSC Representative
Safety Representatives	Flight Crew Representative
Inspection	Inspection
Downey Project Engineering	NASA Headquarters Representative

Support Contractor Representatives and other personnel as required also attend this meeting to support the operation.

Note that the individual spacecraft systems are represented individually at the 1430 Daily Scheduling Meeting whereas at the 0800 meeting an engineering coordinator is the only engineering representative.

Pretest Briefing

A Pretest Briefing is a meeting conducted by the NAA Test Project Engineer and the NASA Spacecraft Test Conductor prior to each test to review various aspects of test with other members of the test team. Each

systems engineer presents a summary of his particular system status with relation to state of readiness for the test. Any open items (constraints) existing at that time are identified and anticipated problems associated with the closeout of same prior to the test are discussed. If the test is eminent, a "Go" is requested from each system engineer indicating his complete state of preparedness for the test.

All pertinent operational ground rules for the test are reviewed and past problems of an operational nature are discussed. Specific attention is directed to any hazardous aspects of the test and test discipline. The method of handling certain paperwork during the test, such as procedure deviations, is reviewed and the integration engineer responsible for writing deviations is identified.

A Bar Chart of the test is also reviewed on a system by system basis to briefly review the intent of the test and the manner of accomplishment. The meeting is normally concluded with an announcement of the "on station" time and time for initiation of GSE setup and spacecraft switch list accomplishment.

Personnel normally attending Pretest Briefing are as follows:

NAA	NASA
Sr. Test Project Engineer	Spacecraft Test Conductor
Test Project Engineer	Project Engineer
System Engineers	Operations Engineer
Operations Engineers	System Engineers
Shop Supervision	GSE Engineering
Quality Control	Quality Control
Safety	RASPO
Service Engineers	Flight Crew Systems
Downey Project Engineer	ACE Engineering
GSE Engineers	Flight Crew Representative
ACE Engineering	

It is noted that separate pretest briefings are held for the test team technicians. In this instance only those operational aspects of the test involving the technicians are discussed.

Post Test Debriefing

A Post Test Debriefing is a test team meeting held subsequent to a test for the purpose of determining if the test objectives were met. The Interim Discrepancy Record (IDR) log is reviewed on a system by system basis. Each system engineer explains any problems encountered during the test, the implication of same, and establishes

the post test status of his system.

At the completion of a test, spacecraft power is normally left on for troubleshooting if problems have been encountered during the test. In this event, the post test debriefing is not held until spacecraft power is removed. It is also noted that a complete review of test data is not available at the time of the post test debriefing and it is not uncommon for IDRs to be generated at a later date when a complete data review is available.

A post test debriefing concludes with the decision to perform additional troubleshooting, await further detail data review for analysis, or consider the test complete and proceed into the next test, as the situation warrants. Personnel normally attending post test debriefings are as follows:

NAA	NASA
Sr. Test Project Engineer	Spacecraft Test Conductor
Test Project Engineer	Project Engineer
Systems Engineers	Systems Engineers
Operations Engineer	ACE Engineering
Quality Control	Quality Control
GSE Engineers	Operations Engineering
Downey Project Engineer	Flight Crew Systems
ACE Engineering	RASPO
	Flight Crew Representative
	Flight Crew (if applicable)

CHRONOLOGICAL LISTING

1. January 23, 1967, 1030. Open Item Review Meeting for Operations Checkout Procedures 0006 (Plugs In) and 0021 (Plugs Out). A constraints list was developed with the following open items:

   Operations Checkout Procedure 0006 (Plugs In)

   Constraints to power up - 11 open items.

   Constraints to power down - 16 open items.

   Operations Checkout Procedure 0021 (Plugs Out)

   Constraints to power up - 26 open items.

   Constraints to power down - 2 open items.

   The power up constraints that were developed for Operations Checkout Procedure 0006 were also to apply to Operations Checkout Procedure 0045 (MCCH Software Integration Test) scheduled to be run prior to Operations Checkout Procedure 0006.

2. January 23, 1967, 1230. Pre-test Briefing for Operations Checkout Procedure 0045 and 0006. This meeting excluded the test team technicians.

3. January 23, 1967, 1430. Daily scheduling meeting.

4. January 23, 1967, 1530. Pre-test Briefing, Operations Checkout Procedures 0045 and 0006 for first shift test team technicians.

5. January 23, 1967, 2400. Pre-test Briefing, Operations

5. Checkout Procedures 0045 and 0006 for second and third shift test team technicians.
6. January 24, 1967, 0400. Power on for Operations Checkout Procedure 0045. The constraints list for Operations Checkout Procedure 0006 had been signed off prior to start of the test.
7. January 24, 1967, 0800. Daily status meeting.
8. January 24, 1967, 1430. Daily scheduling meeting.
9. January 24, 1967, 2030. Operations Checkout Procedure 0045 completed. Spacecraft power remained on to close out Operations Checkout Procedure 0006 (Plugs In) constraints. Those spacecraft systems which had no constraints were powered down. A post test debriefing was conducted "on station" on an individual system basis through review of real time recordings and all new Interim Discrepancy Reports (IDR).
10. January 25, 1967, 0400. Operations Checkout Procedure 0006 was started.
11. January 25, 1967, 0800. Daily status meeting.
12. January 25, 1967, 1430. Daily scheduling meeting.
13. January 26, 1967, 0300. Operations Checkout Procedure 0006 (Plugs In) completed. A post test debriefing was conducted on station on an individual systems basis through review of all new IDR's and real time records.

13. Spacecraft power was left on for troubleshooting associated with the Guidance and Navigation System and the Yaw Electronic Control Assembly. IDR's had been written on these systems as a result of detailed data review of the Integrated Systems Test, Operations Checkout Procedure 0005. IDR's were constraints to power up for Operations Checkout Procedure 0021 (Plugs Out).

14. January 26, 1967, 0800. Daily status meeting.

15. January 26, 1967, 0900. A meeting was held at Complex 34 to review the spacecraft readiness status for the Plugs Out Test with the following personnel in attendance:

NAA	NASA
Senior Test Project Engr	Chief Spacecraft Test Conductor
Asst Senior Test Proj. Engr	Spacecraft Test Conductor
	Senior Operations Engr

This meeting was held in order to verify that the spacecraft would be ready to proceed into the Plugs Out Test on the following day and that the NASA Spacecraft Test Conductor could commit the spacecraft for that test to the Test Supervisor. At that time, it was determined that the remaining constraints to the Plugs Out Test (accomplishment of which were required) was the retest of the Yaw Electronic Control Assembly, a spacecraft removals review, and completion of the test checklist.

Based on discussions with engineering personnel, it was agreed that several items that appeared on the constraints list could be waived for the Plugs Out Test, but that they must be accomplished prior to the Flight Readiness Test (Operations Checkout Procedure 0028). The results of this meeting were submitted to the NASA Spacecraft Project Engineer for evaluation. It is noted that a waiver is obtained when it is determined that a work item cannot be accomplished to meet a specific test schedule and that the particular work item is not an absolute test prerequisite, but rather preferential to that test. This procedure has been followed on each of the Apollo spacecraft operations at Kennedy Space Center.

16. January 26, 1967, 1000. Space vehicle post test debriefing. The NASA Chief Spacecraft Test Conductor, NASA Spacecraft Test Conductor, and the NAA Test Project Engineer attended the Plugs In Debriefing held by the NASA Space Vehicle Test Supervisor at Complex 34. At the conclusion of that meeting, the spacecraft status for the Plugs Out Test was summarized. A portion of this summary included the fact that all of the spacecraft data from the Plugs In Test had not been completely reviewed and that there were still final preparations and work items to complete before being ready to meet the scheduled power on time.

17. January 26, 1967, 1430. Daily scheduling meeting.

18. January 26, 1967, 1800. Spacecraft power removed. Power was removed from the spacecraft busses at 1800 on January 26 following replacement and successful retest of the Yaw Electronic Control Assembly. Additional Guidance & Navigation System testing had indicated that the system was operating satisfactorily. IDR constraint to these two systems were closed out.

19. January 26, 1967, 1900. Meeting to discuss revision to Operations Checkout Procedure 0021 (Plugs Out). On January 26 at 1900 a meeting was held to discuss the Operations Checkout Procedure 0021 to be utilized for the Plugs Out Test. A revision to the Plugs Out procedure had been issued earlier in the day at 1730. There was some concern with the timeliness of the revision and its possible affect on the time critical sequences of the test. It was concluded, however, that the revision had been properly reviewed and approved by the test team and a decision was made to proceed with the procedure and test as scheduled.

20. January 27, 1967, 0600. Operations Checkout Procedure 0021 (Plugs In) pre-test briefing.

21. January 27, 1967, 0635. Test Team on station for Operations Checkout Procedure 0021 (Plugs Out).

22. January 27, 0735. Spacecraft power on for Operations Checkout Procedure 0021 (Plugs Out). The test team went on station immediately after the pre-test briefing and the NASA Test Conductor and NAA Test Project Engineer received a "Go" from each Systems Engineer and the Pad Leader verifying readiness to proceed with the test. The Environmental Control Systems Engineer and the Pad Leader stated that they were running late with their preparations but that the remaining work could be completed in parallel with the power up operation. These preparations were required in order to establish the Environmental Control Systems Ground Support Equipment Test configuration required for gaseous oxygen servicing. These preparations were completed satisfactorily at 0900 at which time the Environmental Control System Test was initiated. The Stabilization and Control Systems Engineer gave a qualified "Go" based on incomplete data review. At the start of the test, the NASA Test Conductor and the NAA Test Project Engineer requested that an Interim Discrepancy Record (IDR) be written to document the fact that there was no signed off constraints list for

the Plugs Out Test. The status of each item not signed off on the operations engineers' master constraints list, in addition to those open items accumulated since the generation of the constraints list, were to be provided in the disposition of the IDR at the completion of the test. The Test Conductors chose to request an IDR rather than to sign the constraints list since it was not complete and "up-to-date". The disposition was never documented on the IDR since all documentation was impounded at the time of the incident. It is noted that the constraint list and all open items that were generated between the time of the constraints list generation and the incident had been reviewed (and determined satisfactory to proceed) by NAA/NASA Operations and Systems Engineering personnel.

23. January 27, 1967, 0800. Daily status meeting

Summary of Operations Checkout Procedure 0021
Unsigned Constraints List Situation

A. A constraints list was developed for Operations Checkout Procedure C021, but was not signed prior to proceeding into the Plugs Out Test since it did not represent an accurate picture of all open paper work due to the additional work generated from January 23 to January 27, 1967. The constraints list had not been formally updated due to the limited time available between tests.

B. The constraints and additional open work items generated after development of the constraints list were under constant review by the test team.

C. Two meetings were held daily between systems personnel (or their representatives) and operations personnel at which time the status of spacecraft open items was discussed.

D. A number of items on the constraints list were evaluated and deferred for accomplishment until after the Plugs Out Test, but prior to the Flight Readiness Test (Operations Checkout Procedure 0028).

E. The status of the spacecraft was known at the time of the test by systems engineering and operations personnel. Readiness reports were received from all operations and systems engineering personnel prior to power up and there were no open work items to constrain the running of the Plugs Out Test.

REPORT OF PANEL 7
TEST PROCEDURES REVIEW
APPENDIX D
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

TEST PROCFDURES REVIEW

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Test Procedures Review Panel, 7. The task assigned for accomplishment by Panel 7 was prescribed as follows:

Document test procedures actually employed during day of incident. Indicate deviations between planned procedures and those actually used. Determine from review potential changes that might alleviate fire hazard conditions or that might provide for improved reaction or corrective conditions. Review these changes with respect to applicability to other test sites or test conditions.

B. Panel organization

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Test Procedures Review Panel:

Mr. D. L. Nichols, Chairman Kennedy Space Center (KSC), NASA,
Mr. F. G. Bryan, Kennedy Space Center (KSC), NASA
Mr. J. M. Twigg, Kennedy Space Center (KSC), NASA
Mr. C. O. Brooks, Marshall Space Flight Center (MSFC), NASA
Mr. W. Petynia, Manned Spacecraft Center (MSC), NASA
Mr. W. F. Cahill, North American Aviation (NAA), KSC
Mr. R. H. Jones, North American Aviation (NAA), KSC
Mr. J. C. Wright, North American Aviation (NAA), KSC, Technical Assistant
Mr. J. W. Cuzzupoli, North American Aviation (NAA), Downey
Mr. E. E. Dale, North American Aviation (NAA), Downey
Mr. C. C. Harshberger, North American Aviation (NAA), Downey (Alternate)
Mr. R. L. Swanson, North American Aviation (NAA), Downey (Alternate)
Mr. H. H. Luetjen, Mc Donnell Company KSC

2. COGNIZANT BOARD MEMBER:

Mr. John J. Williams, Kennedy Space Center, NASA, Board Member, was assigned to monitor the Test Procedures Review Panel.

C. PROCEEDINGS

1. In response to the Apollo 204 Review Board, the Panel derived detailed objectives as follows:

a. Document test procedures actually employed during day of accident. Verify and cross-correlate following sources of information.

(1) Offical Operational Checkout Procedure (OCP) FO-K-0021-1, :Plugs Out Test, With Deviations, and associated procedures.
(2) Voice Tape of Test
(3) Cabin configuration as found vs. OCP
(4) GSE configuration as found vs. OCP
(5) Test Conductor's log
(6) Test Project Engineer's log
(7) Test Supervisor's log
(8) Pad Leader's Report
(9) North American Aviation (NAA) Test Monitor report

b. Research the relationship between hardware changes and retest thereof in the period between Altitude Chamber Test and Plugs Out Test.

c. Compare procedural difference between the Altitude Chamber Test as run and Plugs Out Test as run.

d. Document the development of the as run procedure used for the Plugs Out Test.

(1) Chronological development of test philosophy and of the actual OCP.

(2) Relationship between test as developed and MSC/NAA Downey tese requirements.
(3) Effect of philosophy changes on the test.
(4) Assess adequacy of the technical review of the OCP prior to its use.
(5) Assess adequacy of the safety review of the OCP prior to its use.
(6) Review late-change control.
(7) Review deviation control during test.
(8) Evaluate test discipline from voice tape.

e. Evaluate total procedural interface with respect to adequacy and complexity.

(1) OCP FO-K-0021-1
(2) GSE checklist
(3) Crew countdown
(4) What procedures did crew carry on board and use?
(5) What TPS's if any were used to supplement OCP's?
(6) Space Vehicle Plugs Out procedure
(7) Support documentation

f. Evaluate potential effect of automation upon safety of operation.

g. Review overall control of testing requirements with regard to timeless, level of control, and technical integration.

(1) Ground Operations Checkout Plan (GORP)
(2) Process Specifications and Test Specifications
(3) Vehicle Test Planning
(a) Downey
(b) KSC
(c) MSC
(d) Other test sites

h. Evaluate potential changes to vehicle hardware and test procedures to indlude experience gained from Apollo and other related Programs.

(1) Investigation areas in which minor design changes may allow significantly improved checkout capability and alleviate hazardous conditions.
(a) Solicit recommendations from contractor and NASA checkout personnel.
(b) Solicit recommendations from procedure writers.
(2) Review testing philosophy and specific procedures utilized.
(a) Other Apollo test sites
(b) Other Manned S/C programs
(c) Manned Launch Vehicles

2. TEST PROCEDURE EMPLOYED DURING DAY OF ACCIDENT

A master copy of the Space Veicle Plugs Out Integrated Test FO-K-0021-1 S/C 012/014 was developed documenting the procedure as run on the day of the accident. This master procedure used the Quality Control Record copy of the test as a starting point. Information obtained from the test engineers' copies of the Operational Checkout Procedure (OCP) was added.

Voice recordings of communication channels used during time of test were reviewed. Procedural functions performed were checked in the master procedure as they were verified by audio reply. Deviations from published procedures were noted and investigated.

Two (2) intercom channels, designated Black 3 and Black 4, were recorded throughout the test. These two channels were superimposed upon one track of recording tape. The recording was adequate to reconstruct the events immediately prior to the accident. During earlier periods of the Plugs Out Test, Spacecraft test activity took place on approximately half of the fifteen channels assigned to Spacecraft operations. Complete reconstruction of the activity during this period was not possible due to the lack of recording.

The Quality Control (QC) copy of the OCP, which Panel used as a baseline, was incomplete. Operating method did not require continuous QC monitoring of each communications channel in use during test.

Spacecraft switch positions specified in the OCP were compared with the as-found post accident positions. There were no functionally significant differences except for the main bus tie switches (2). Telemetry data indicates the bus tie switches were positioned by the crew subsequent to the detection

of the fire. The pocedural sequence in which each switch was last positioned was also identified. One significant circuit breaker (CB-116) position was noted. The closed circuit breaker, as specified by the OCP, applied power to gas chromotograph cable although the instrument had been removed and documented by approved procedures.

3. RELATIONSHIP BETWEEN HARDWARE CHANGES AND RETEST THEREOF

A. Records were researched to determine relationships between hardware changes and retest verification made during the period between the Altitude Chamber Test (OCP FO-K-0034-A) and the OCP run on the day of the accident. Appropriate modifications, rework, and discrepancy items were defined for more detailed review. The review included Interim Discrepancy Records (IDR), Discrepancy Records (DR), Test Preparation Sheets (TPS), and Engineering Orders (EO), which were worked between the Altitude Chamber Test (OCP-K-0034-A) and the Plugs Out Test (OCP FO-K-0021-1). Both of these tests were run with the spacecraft hatch closed and an oxygen (O_2) cabin environment. Emphasis was placed on review of electrical changes, such as modifications to spacecraft wiring, replacement of electronic boxes, and Ground Support Equipment (GSE). The required retest was performed for all spacecraft changes except for those noted in Enclosure 7-2.

Definition of retest required and the point at which it constrains subsequent testing, is determined by the responsible NASA and NAA System Engineers. Documentation of these requirements is defined by Apollo Pre-Flight Operations Procedure (APOP) Manual No. T-501, 5.1.

b. An open item review prior to starting any test is required by Apollo Pre-Flight Operations Procedure (APOP) No. 0-202. This was accomplished and a constraints list complied on January 23, 1967, four days prior to the implementation of the test. The review allowed lead time for accomplishment of the open items prior to the test. However, additional open items were accumulated on the daily Spacecraft status Report in the form of released Test Preparation Sheets (TPS), Discrepancy Records (DR's), Discrepancy Record Squawks Sheets (DRSS's), and Interim Discrepancy Records (IDR's). This accumulation of open items was not added to the constraints list. Systems engineers were expected to be aware of these items which were published in the Daily Status Report. The Panel requested clarification from the NASA Chief Spacecraft Test Conductor (CSTC). The response statement is included as Enclosure 7-2. According to referenced enclosure, the accumulation of open items was "under constant review by the test team." The enclosure indicates that certain items were evaluated and deferred until after Plugs Out OCP FO-K-0021-1 and prior to Flight Readiness Test (FRT).

The NASA Spacecraft Test Conductor (Organization Chart; Enclosure 7-1) normally gets a sign-off by each systems engineer verifying that no constraints to the test exists in his system. The Test Conductor can, therefore, affix his signature to the Constraints List verifying that all constraints have been resolved. The Test Conductor is required by APOP 0-202, paragraph 6.3.6, to sign the Constraints List prior to beginning the test.

The Test Conductor and NAA Test Project Engineer agreed to proceed with the test based upon the reasons listed in Enclosure 7-2. The available Constraints List was not signed off since it was not complete list of all open items due to the additional work generated from January 23 to January 27, 1967. Interim Discrepancy Record No. 001 was issued noting that the Spacecraft was powered up without the Constraints List formally signed off.

This Panel did not evaluate whether the open items, as discussed in the referenced enclosure, contributed to the indident. This item was referred to Panel No. 18 of the Review Board for analysis.

4. COMPARISON OF ALTITUDE CHAMBER TEST AND PLUGS OUT TEST

The differences between the OCP's were evaluated in an attempt to identify functions which may have been improperly performed in the Plugs Out Test. The procedural differences were attributable to required configuration differences with one exception.

During the Altitude Chamber Test only those functions required prior to altitude simulation were performed with cabin pressures greather than sea level, and an O_2 environment. During Plugs Out, all testing after hatch closeout was to be accomplished with the cabin at greater than sea level pressures and an O_2 environment. In the Altitude Chamber, the cabin was pressurized with O_2 four times (varying from 1 hour to 2 hours 30 minutes) for a total of 6 hours 15 minutes at pressures greater than sea level. This length of time is two and a half times as long as the cabin was pressurized with O_2 prior to the accident during Plugs Out Test.

The analysis of differences, and methods of implementation between the Altitude Chamber Test and Plugs Out Test, has not provided any discrepant conditions that could contribute to the cause of the accident. The Test Configuration differences are covered in the report of Panel No. 1.

5. DEVELOPMENT OF THE PLUGS OUT TEST

The Plugs Out Test procedure was reviewed to determine the adequacy of the system used in developing the OCP.

a. The chronological development of the Plugs Out Test philosophy and OCP was documented (Enclosure 7-3).

The Plugs Out Test was defined in preliminary form on July 12, 1966. In September, the crew emergency egress practice was added to the test procedure, to be performed at the conclusions of the Plugs Out Test. The preliminary OCP was released and reviewed in October. In November the OCP was modified to provide closed hatch operation during the test. The approved OCP was released on December 13, 1966. The revisions designated as dash one (-1), was released on January 26.

b. The relationship between the test as developed and MSC/Downey test requirements was reviewed.

The MSC test requirements document is the Ground Operations Requirement Plan (GORP). It is primarily a flow plan through the various test locations used to prepare the vehicle for flight. The definition of testing to be performed varies in detail from test to test While some specific testing requirements are defined, emphasis is more on sequence than on specific technical requirements. The NAA, Downey prepared test specification for the Plugs Out Test (Process Specification MAO-0201-3214, Revision B, dated August 19, 1966) is written in test procedure format. This document contained outdated pretest switch lists, and a GSE listing not compatible with GSE available at KSC. It lacked the detail of engineering specifications to which systems should be tested, and was not directly relatable to overall vehicle test planning at KSC. The process specification is an internal contractor document used to prepare test procedures for NASA approval.

NAA personnel at KSC (NAA, Fla) prepared an overall test plan for KSC covering operations from receipt of the vehicle to launch. SP 64, S/C 012 Test Outline, was published and presented to MSC for review containing the outline of the Plugs Out Test. Specific procedures for system operation were based on the Test Outline and NAA Downey Test Procedures. They were also extracted from previously run procedures at KSC. The Plugs Out Test Procedure meets the intent of both the MSC GORP and the NAA Downey Test Specification.

c. Effect of philosophy changes on the test was evaluated.

Major changes such as closed hatch, O_2 cabin environment, and crew emergency egress practice were generated and implemented subsequent to the preliminary Plugs Out OCP preparation. These changes were made with sufficient lead time to allow timely incorporation into the procedure.

d. The adequacy of the technical review of the OCP was assessed.

The technical review of the OCP was as adequate for initial release of the procedure. NASA and NAA engineering representatives for each system, participated in the review prior to approval of the Plugs Out Procedure. A detailed review of the subsequent revision showed that the percentage of changes attributable to technical error in the original procedure was approximately one percent.

e. The adequacy of the safety review of the OCP prior to its use was assessed.

The KSC Safety Office did not receive or review the procedure since it was not submitted as a hazardous test. (Enclosure 7-5.) All participants in the test failed to realize the extent to which hazard potential existed. This is evidenced by the following: (a) a Safety Office review of the procedure was not made, (b) Pad Emergency Procedures were not prepared, and (c) Fire fighting and ambulance equipment were not on the pad during the test. This procedure was handled in accordance with normal operating methods as shown in Enclosure 7-4.

f. OCP revision control was reviewed.

The basic procedure, OCP FO-K-0021-1, was released and distributed on December 13, 1966 and consisted of 275 pages. Following the release, there were many changes in the OCP. These changes were collected and incorporated into "flimsies" (preliminary copies), six (6) of which were circulated for systems engineering review two days prior to the test. The resulting revision, consisting of 209 replacement pages, was distributed at 5:30 p.m., January 26, 1967, 14½ hours before start of the test.

The technical changes to the OCP were not as great as the number of changed pages would indicate. The actual changed lines represented less than 25 percent of the revision with the remaining 75 percent being required to allow full page replacement. (If one side of a page is changed, both sides must be reprinted.) The reasons for these changes were researched. The basic causes for change were defined:

(1) To make the OCP compatible with the updated Flight Crew Checklist.

(2) To make the OCP sequences similar to the Spacecraft Launch Countdown which was first published on January 23.

(3) To perform the Emergency Detection System Test at a different time due to new Launch Vehicle requirements.

(4) To incorporate the experience gained from running the Plugs In Test (OCP-K-0006).

(5) To incorporate items existing in the Space Vehicle procedure.

(6) To delete the Guidance Computer erasable memory update since the Mission Control Center Houston (MCCH) was unable to support the test.

(7) To incorporate general operational improvement.

(8) To correct the OCP technical and typographical errors.

(9) To perform certain crew stowage operations transferred from the Altitude Chamber Test to the Plugs Out Test.

A copy of the entire revision has been annotated, with the reasons for the change, and submitted as reference material.

A number of the changes were not avoidable, considering the first-of-a-kind mission. However, the changes were not integrated into OCP revisions and released early enough to allow test personnel to become completely familiar with the test as it was to be run.

g. Review deviation control and documentation during test.

A review of the 106 OCP deviations written during the test showed that they were handled in accordance with requirements of APOP No. 0-202. This procedure permits performing deviations during the test with the documentation of the deviation to be coordinated subsequent to the test. The forms were not completed during the test in many cases and the impodunding of documents prevented their normal post-test completion. As a result, the Panel had to work from incomplete records.

h. Evaluate test discipline from voice tape

The overall test discipline displayed by the voice tape recordings was generally adequate, but was hindered by communications difficulties. There was considerable evidence of uncoordinated switching during the period of communications troubleshooting which left the Spacecraft Test Conductor in doubt as to on-board system configuration.

A contributing factor to this undesirable condition was the chronic difficulty which had been experienced with communications during previous tests.

During the period of difficult communications between the Flight Crew and Spacecraft Test Conductor, the procedures to isolate the problem appeared haphazard and uncoordinated. The troubleshooting did not isolate the cause of the poor communications, even though several hours were spent in trying various links and communications configurations. Troubleshooting at times was being run independently from three locations; the Spacecraft, Launch Complex 34, and the Manned Spacecraft Operations Building (MSOB). This occurred due to lack of a single controlling station to coordinate and direct the total troubleshooting effort.

6. REVIEW OF PLUGS OUT TEST SUPPORT DOCUMENTATION

A list of documents required in direct support of the Plugs Out Test was compiled (Enclosure 7-18). The purpose, scope and operational interfaces of these documents were evaluated to determine their overall technical and or operational adequacy and complexity.

a. Crew Checklist and OCP

One potential source of confusion was the overlap between the pre-launch switch configuration contained in the OCP (prepared at KSC) and that in the Apollo Crew Abbreviated Checklist (prepared at MSC). It was determined that no copies of the Apollo Crew Abbreviated Checklist were taken into the spacecraft. The crew had copies of the OCP Switch Checklist but no copies of the entire OCP.

b. The Ground Support Equipment (GSE) Checklist

The GSE Checklist adequately defines required pre-test setups. The procedure refers to other documents for the step-by-step installation of equipment but effectively retains control of overall test setup operation.

c. The Space Vehicle Plugs Out Procedure

The Space Vehicle Plugs Out Procedure was written as the overall control document for the Plugs Out Test. The intent of the space vehicle procedure was to provide the Test Supervisor with the interface points required to maintain overall control in the test. The space vehicle procedure also covers both launch vehicle and spacecraft interfaces with external organizations such as the Eastern Test Range, Mission Control Center, Houston, etc. The space vehicle procedure accomplished this function. Actual launch vehicle operations were performed from a launch vehicle procedure under the direction of Launch Vehicle Test Conductor. Similarly, the spacecraft team under the direction of The Spacecraft Test Conductor operated from the spacecraft OCP.

Each of the procedures provides specific data for performing independent operations usually by different groups of personnel. To combine or modify any of these documents would possibly increase the confusion and complexity of the end objectives. The documentation as defined fulfills its intent and no significant requirements for changes are noted by the Panel.

7. POTENTIAL EFFECT OF AUTOMATION UPON THE SAFETY OF THE OPERATION

Acceptance Checkout Equipment (ACE) system capability and the ACE to spacecraft interface was reviewed. While some computer program changes were proposed to aid checkout and improve safety (Reference 7-7), no significant area was found where additional automation could substantially increase safety without a significant enlargement of the ACE to spacecraft interface. ACE computer programs neither contributed to the accident, nor could they have been used in the existing ACE configuration to reduce or extinguish the fire.

Computer program and hardware design precludes the ground computer from operating the existing GSE and facility systems pertinent to extinguishing a fire. In addition, existing fire retardant or extinguishing systems are inadequate to cope with such an emergency. If active fire retardant or extinguishing systems are added in the future, a careful analysis should be made before automating these systems. Activating emergency systems such as nitrogen purge or pressure relief may present additional hazards to personnel.

In reviewing the existing method of activating safety systems on both the Spacecraft and GSE, it is evident that additional remote control capability should be considered for systems such as:

a. Service Structure Water Deluge
b. ECS Control
c. Electrical Power
d. GN_2 Deluge
e. Pressure Supply and Control
f. Cryogenic and Hypergolic Supply

8. CONTROL OF TEST REQUIREMENTS

A review of overall control of testing requirements with regard to timeless, level of control, and technical integration was accomplished. This task was treated in two basic parts. Part a. dealt with the review of Apollo S/C 012 pre-launch test and checkout documentation. Part b. of the task encompassed the review of pre-launch test and checkout documentation, planning and control as applied to other similar programs as related to Apollo Spacecraft.

a. S/C 012 Pre-launch Test and Checkout Documentation.

Documentation can be categorized into four major types:

(1) Pre-launch Checkout Requirements
(2) Test Specifications and Criteria
(3) Checkout Plan
(4) Checkout Procedures

The first two categories represent the requirements imposed upon the pre-launch operations and the last two, methods for implementing these requirements.

(1) Pre-launch Checkout Requirements

Pre-launch checkout requirements are established in the Ground Operations Requirements Plan (GORP). This document, as currently approved, establishes the contractual baseline for the sequential flow of the Spacecraft and for the tests to be conducted at each test station in the flow. The GORP is prepared by NAA, Downey as a contractual document for MSC-Houston, requiring joint NAA MSC approval (Class I). The GORP effectiveness as a test requirements document is

hampered by its original intent as a GSE provisionin document. The GORP also contains considerable detail not directly applicable as requirements. Because of this level of detail it is difficult to maintain the GORP current through formal contractual channels.

The GORP is a Class I document between MSC and NAA but in the case of CSM 012 it was not formally submitted to KSC by MSC. NAA releases the requirements through its internal document distribution system which constitutes formal direction to its field organization. Implementation of the GORP by NAA, Florida results in a situation whereby the contractor may, in fact, provide direction to KSC.

(2) Test Specifications and Criteria

The Test Specifications and Criteria for Apollo are contained in the NAA generated process specifications MAO-201-XXXX. For CSM 012 the document was written in a procedural sequence format, rather than by system, makeing determination of the actual engineering hardware performance values and tolerances difficult. The specifications were not updated to provide the latest configuration and tolerances. However, NAA, Downey personnel were assigned to Florida on a temporary basis to assist in interpreting the requirements. This information is made available to NASA-KSC by the NAA, Florida at KSC. The Process Specification documents do not require NASA, MSC approval and are not sent to MSC for information unless specifically requested (Class III). The requirements contained therein are not necessarily screened by MSC or KSC. These specifications are generated within NAA, Downey and forwarded to NAA, Florida to be implemented in the Operational Checkout Procedure.

(3) Checkout Plan

The Checkout Plan for Apollo is contained in the Florida Facility Test Flow Plan. This document is prepared by NAA, Florida for NSA-KSC approval. The Test Flow Plan establishes the flow of the vehicle through KSC, the sequence of tests to be performed, and the activities to be accomplished in each OCP at each test location. The plan implements the intent of the GORP but may not implement the operational requirements in the precise manner stated in the GORP. There is no formal requirement for the plan to be submitted to either MSC or to NAA, Downey for review or approval. It is used extensively by pre-launch and launch operations personnel of both NASA, KSC and NAA, Florida.

(4) Checkout Procedures

The pre-launch OCP's are written locally at KSC by NAA-Florida and approved by NASA-KSC. These procedures are forwarded to both MSC and NAA, Downey for review. However, because of the late release of the OCP's an acceptable before-the-fact technical review of the procedures, other than by local KSC personnel, has not been feasible. The OCP's provide a detailed step-by-step procedure for the accomplishment of an activity or task during the pre-launch and launch operations at KSC. The OCP's are related to a particular task or functional activity and are based on the GORP, the Florida Facility Test Flow Plan and the Process Specifications (Enclosure 7-4).

b. Control of pre-launch test requirements

A detailed review of the overall control and implementation of the pre-launch operational requirements and the test specifications and criteria was accomplished. This review was centered primarily around the type of documentation used on programs similar to Apollo and the type that was used specifically for S/C 012. The review also encompassed the adequacy of content and timeliness of the documents to support its intended use. The Panel interviewed representatives from the following:

Marshall Space Flight Center, Kennedy Space Center, for the Saturn IB and Saturn V Launch Vehicles

North American Aviation, Manned Spacecraft Denter and Kennedy Space Center, for the Apollo CSM Spacecraft

McDonnell Company Manned Spacecraft Center Resident Gemini Program Office at KSC, and Kennedy Space Center for the Gemini Spacecraft

The types of documentation used by the above programs were obtained and reviewed by the Panel for definition of requirements and the implementation of these requirements in pre-launch checkout operations at KSC (Enclosures 7-6 and 7-7).

(1) Saturn

Delegation of pre-launch checkout and launch implementation responsibility from MSFC to KSC was the significant feature of the Saturn Launch Vehicle Program. This relationship was complemented by the existence of detailed inter-Center agreements and by KSC controlled supplemental contracts with stage prime contractors to implement the delegation. The engineering pre-launch checkout requirements, specifications, and criteria are formally controlled by MSFC, Enclosure 7-7. This control is

accomplished by having the necessary documentation prepared by the respective stage contractors for MSFC. The documents, upon MSFC aaproval, are then levied upon KSC and its stage contractors for implementation. A formal response is required from the KSC stage contractor to MSFC via KSC. This response is in the form of checkout plans and procedures. A significant characteristic of this method of control is that formal contractor direction is accomplished only through MSFC/KSC channels. The stage prime contractor home/field relationship is one of informal technical coordination and communication.

(2) Gemini

The MSC Resident Gemini Program Office (RGPO) at KSC provided for rapid response to operational changes. This was primarily accomplished by after-the-fact contractual closure of open items, and changes on a quarterly basis.

Pre-launch checkout requirements were prepared by the contractor's field organization at the launch site with parallel feedback to the home plant, MSC-RGPO, and MSC-Houston.

(3) Apollo

The Apollo Spacecraft pre-launch operational requirements flow is characterized by a highly centralized control exercised by the MSC-Apollo Program Office at Houston. Since MSC approval is required prior to implementing detailed operational changes in pre-launch planning, there is an inherent slow response loop which constrains normal pre-launch activity. The lack of detailed inter-Center agreements relating to the delegation and control of spacecraft pre-launch operations at KSC is another factor. This lack of detailed agreement clouds the definition of MSC and KSC roles and missions and the interface involved, leading to misunderstandings.

The S/C Contractor at Florida is subject to technical direction from both KSC and its home plant. This direction may be conflicting. Clarification of S/C Contractor pre-launch direction at the field site would materially improve the implementation and control of pre-launch operations.

c. Improvements Currently in Progress

During the course of the investigation, it was determined that several significant changes are presently being made in the system of pre-launch checkout documentation and management control.

It was determined that the s/c Contractor (NAA) is in process of preparing a specification covering spacecraft checkout requirements applicable to factory acceptance (Contract End Item Specification, Part II). This document is Class I and requires approval sign-off by MSC-Houston. The S/C Contractor (NAA) has, since early January 1967, initiated action to develop a new type of checkout requirements and specification document to cover field operations. This document will represent a logical extension of the Contract End Item Specification, Part II, in that it will provide requirements and specifications tailored to field pre-launch checkout operations. The new specification will replace a multitude of existing subsystem, interface, and integrated system level specifications. It will be system-oriented and will take precedence over the existing specifications.

This type of document will satisfy the intent of the test specification and criteria document as required for testing at KSC. The authority for, and description of, the new format of specifications is stated in Enclosures 7-9 and 7-10.

Several major changes intended to improve the control of Apollo Spacecraft pre-launch operations requirements are also underway in response to the direction received from the Apollo Program Director in the NASA-OMSF memorandum of January 31, 1967, subject: Minutes of Meeting at KSC, January 26, 1967 (Enclosure 7-11).

9. POTENTIAL IMPROVEMENT IN CHECKOUT CAPABILITY

The panel investigated areas in which minor design changes may be made which will permit a significant improvement in checkout capability in the areas of safety and alleviation of hazardous conditions.

This task was treated in two basic parts. Part a. covered recommendations from contractor and NASA test and checkout personnel in the area of hardware changes. Part b. covered recommendations for improvements in the areas of operations and procedures.

a. Recommendations for Design Changes to Hardware

The Panel interviewed NASA, KSC and NAA, Florida system engineers with regard to recommendations for design changes affecting either spacecraft or GSE hardware. Their comments and recommendations were categorized by spacecraft subsystem with an explanation of the reason for the change and the advantages that will be gained if the change is incorporated. Panel 7 screened and evaluated the proposed changes on the basis that the change would provide increased margins of safety or that the improvement in the checkout operations will contribute to safer operations. The review included a comparison of the master measurement lists for Block I and Block II spacecraft. The system engineers submitted 110 recommendations for design changes. Of these changes 92 effect the Apollo, 1 the LM and 17 the GSE.

Results of this review were forwarded to Panels 9 and 18 for final review, disposition and closeout.

b. Recommednations for Changes to Procedures

The Panel evaluated potential changes to test procedures as a result of investigating areas in which such changes may allow significantly improved checkout capability to alleviate hazardous conditions. Interviews and briefings were conducted with procedure oriented engineers and management personnel from Apollo and other related programs. The methods and procedures are sound in concept for both administrative and technical direction and control of the preparation, publication, release, and revision of OCP. However, in post test evaluation, the content (and scope) of test deviations should be evaluated by test management to ascertain that test objectives have been met and that procedure preparation was adequate.

e. Review of Philosophy and Procedures

Review testing philosophy and specific procedures utilized on other manned programs and launch vehicles.

(1) This item was investigated by addressing a number of questions to the various programs and sites in order to understand the different test policies, operating standards, and test management structures.

Programs and sites considered were:

(a) Apollo - KSC
(b) Apollo - Houston (Space Environmental Simulation Laboratory)
(c) Apollo - Downey
(d) Gemini - KSC
(e) Saturn - KSC
(f) Titan - (Titan I, Gemini Launch Vehicle, and Titan III)
(g) LM - KSC (Planned Approach)

The questions asked were:

(a) Does Safety review all test procedures?
(b) Is there a formal work item review prior to each test?
(c) Does Q C monitor the operation and in what capacity?
(d) How are test deviations written and approved?
(e) How and to what extent does the Government monitor and control tests?
(f) Are tests run by engineers or technicians or by both?
(g) Who (Q C, Safety, Design Engineering, Operations Engineering) may stop or scrub a test?
(h) How thoroughly are procedure changes documented?
(i) Who determines if a procedure is hazardous?
(j) Does the local operations group have design change authority?

(2) By studying the answers to the questions provided by representatives of the sites, the Panel was able to compare those operations with Apollo-KSC operations to illustrate areas of possible improvement. These areas are listed below:

(a) Safety Review of Procedures - Martin Titan uses the policy of having Safety review all all procedures for possible hazardous operations, rather than giving the operations engineers the responsibility for deciding which operations are hazardous. This item is also discussed in Paragraph 5e of this Report. It was found that for Apollo operations Safety does not review all procedures.

(b) Formal Review of Work Items Prior to Tests - The three Apollo sites were all found to have similar procedures for reviewing open work prior to beginning major tests.

(c) Q C Monitoring of Test Operations - At all Apollo spacecraft sites the policy pro-

vides for Q C to monitor tests and provide an as run copy. The policy is not fully implemented since not all operations are monitored full time. This item is also discussed in Paragraph 2 of this Panel Report.

(d) Test Deviations - In the case of the Apollo operations at KSC and Downey, and the LEM operations at KSC, engineering supervision (one level above the operations systems engineer) does not approve procedure deviations. In the case of the two launch vehicles and the MSC Apollo operation the supervision approval is by signature during the test.

(e) Government Monitoring of Tests - The only significant difference noted is that the Saturn operation does not use NASA Q C to formally monitor test operations. The KSC Launch Vehicle Operations (LVO) systems engineers are required to monitor tests, and thus provide the required NASA surveillance.

(f) Procedures Not Run by Engineers - Tests are run by engineers inall cases except that of Martin Titan where technicians are used on a regular basis to run tests.

(g) Authority to Stop a Test - It was noted that Safety can stop a test in progress at all sites, either directly or through the Test Conductor depending on the type of test in process.

(h) Real Time Procedure Deviation Documentation - All sites had policies requiring that this be done.

(i) Determination of Hazardous Procedures - In four of the seven cases it was found that both Safety and Operations personnel made determinations as to whether a particular procedure was hazardous. In the remaining three cases only Operations personnel determined such. In all cases Safety personnel reviewed in detail those procedures declared hazardous regardless of who made the declaration.

D. FINDINGS AND DETERMINATIONS

1. FINDING:
The Panel documented the Plugs Out Test Procedure (FO-K-0021-1) as it had been performed.
DETERMINATION:
The Test Prodecure did not contribute to the accident. There was a defect in the procedure in that power was applied to the uncapped gas chromatograph power cable after the gas chromatograph had been removed from the spacecraft.
2. FINDING:
209 pages of the 275 page OCP were revised and released on the day before the test. Less than 25 percent of the line items, however, were changed. Approximately 1 percent of the change was due to errors in technical content in the original issue of the procedure. In addition, 106 deviations were written during the test.
DETERMINATION:
Neither the revision nor the deviations are known to have contributed specifically to the incident. The late timing of the change release, however, prevented test personnel from becoming adequately familiar with the test procedure prior to its use.
3. FINDING:
During the Altitude Chamber Tests the cabin was pressurized at pressures greater than sea level with an oxygen environment 2-½ times as long as the cabin was pressurized with oxygen prior to the accident during Plugs Out Test.
DETERMINATION:
The spacecraft had successfully operated at the same cabin conditions in the Chamber for a greater period of time than on the pad up to the time of the accident.
4. FINDING:
The Plugs Out OCP was not classified as hazardous.
DETERMINATION:
The hazard level was not recognized and consequently the procedure was processed through the review cycle as a non-hazardous procedure.
5. FINDING:
Only local control is provided for certain systems which may require remote control for safety reasons, such as service structure water and hypergolic supplysources.

DETERMINATION:
The full potential of the safety systems is not utilized due to the lack of remote control capability.

6. FINDING:
The open item constraint list was not formalized as required by APOP No. 0-202.

DETERMINATION:
Pretest constraints were evaluated informally on a system-by-system basis by the test team. (Enclosure 7-2)

7. Finding:
Troubleshooting of the communication problem was not controlled by any one person, and was at times independently run from the Spacecraft, Launch Complex 34 Blockhouse, and the Manned Spacecraft Operations Building. Communications switching, some of which was not called out in the OCP, was prformed without the control of the Test Conductor.

DETERMINATION:
The uncontrolled troubleshooting and switching contributed to the difficulty experienced in attempting to assess the communication problem.

8. FINDING:
KSC was not able to insure that the spacecraft launch operations plans and procedures adequately satisfied, on a timely basis, the intent of MSC. Changes to S/C testing by KSC could not be kept in phase with the latest requirements of MSC. Pre-launch checkout requirements (GORP) were not formally transmitted to KSC from MSC.

DETERMINATION:
Pre-launch test requirements control for the Apollo Spacecraft Program is constrained by slow response to changes, lack of detailed KSC-MSC inter-Center agreements, and by the lack of official NASA approved Test Specifications applicable to pre-launch checkout.

9. FINDING:
The Test Specifications for Spacecraft 012 were not written in a convenient to use format, did not contain field tolerances, were not NASA approved, were not maintained up-to-date, and were not transmitted to NASA/KSC.

DETERMINATION:
The lack of usefulness of the Test Specifications has been recognized by NAA, Downey and measures intended to correct the situation have been initiated (Enclosures 7-9 and 7-10).

10. FINDING:
The decision to perform the Plugs Out Test with the flight crew, closed hatch, and pure O2 cabin environment made on October 31, 1966, was a significant change in test philosophy.

DETERMINATION:
There is no evidence that this change in test philosophy was made so late as to preclude timely incorporation into the test procedure.

E. SUPPORTING DATA

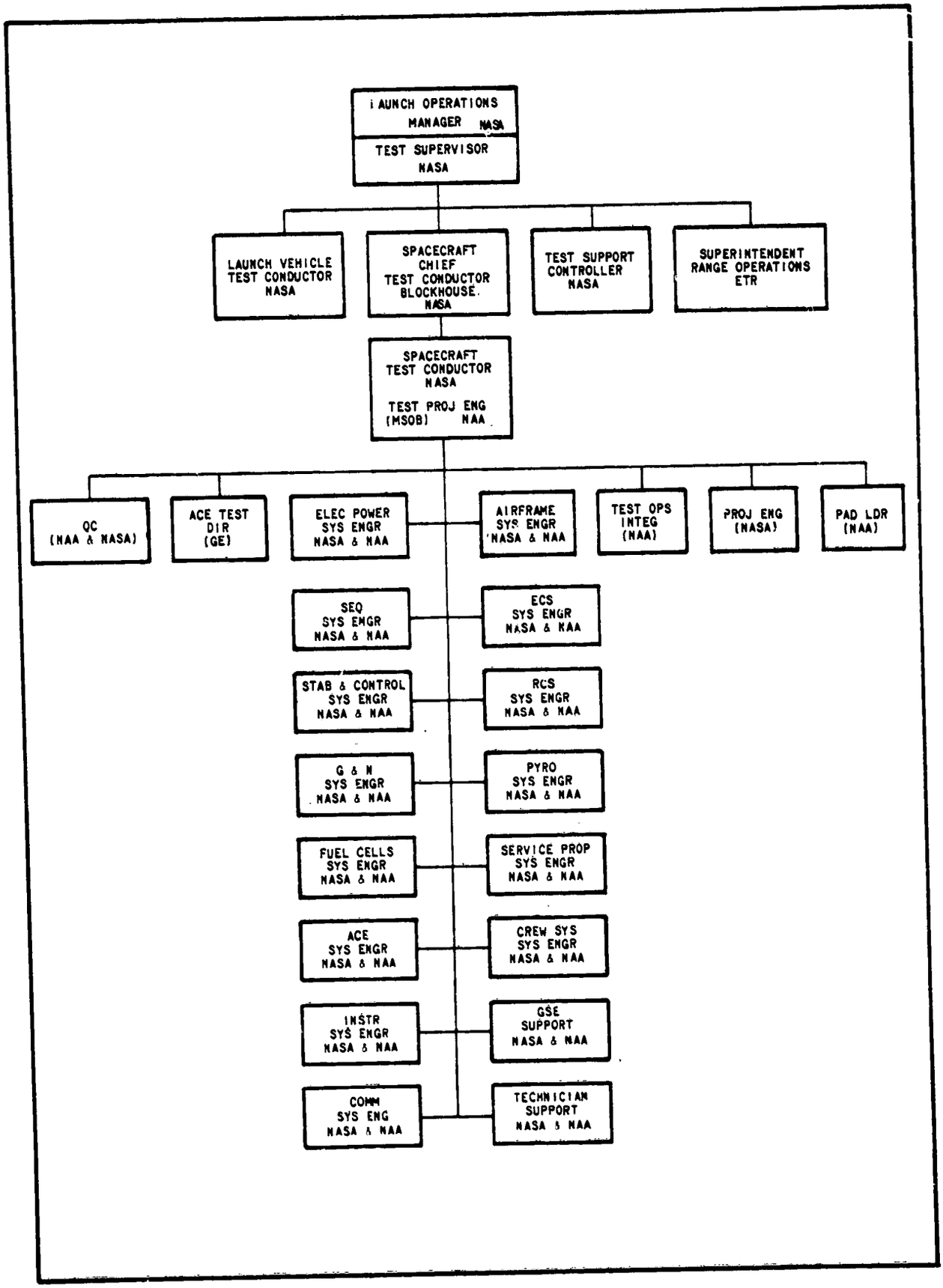
Enclosures

7-1	Test Team Organization
7-2	Memo for Record, Open Item Review
7-3	Plugs Out Test Development History
7-4	Procedure Development Flow Plan
7-5	Safety Office Memo, Procedure Review
7-6	Program Control of Prelaunch Test Requirements
7-7	Flight Vehicle Test Documentation
7-8	Plugs Out Test Support Documentation
7-9	NAA Memo, Test Specs & Outlines
7-10	NAA Memo, Process Specifications
7-11	Minutes of NASA Inter-Center Meeting
7-12	Spacecraft Configuration Comparison
7-13	List of References

GLOSSARY

AC	Alternate Current
ACE	Acceptance Checkout Equipment
AFETR	Air Force Eastern Test Range
AGC	Apollo Guidance Computer
APOP	Apollo Preflight Operations Procedure
BMAG	Body Mounted Attitude Gyro
B/P	Boilerplate
BPC	Booster Protective Cover
CCA	Contract Change Authorization
CDDT	Count Down Demonstration Test
C/M	Command Module
CMD	Command
C/O	Change Order
COMM	Communications
CRT	Cathode Ray Tube
CSM	Command Service Module
CSTC	Chief Spacecraft Test Conductor
CX	Complex
DC	Direct Current
DR	Discrepancy Record
DRS	Discrepancy Report Squawks
DSE	Data Storage Electronics
DSE	Data Storage Equipment
DSEA	Data Storage Equipment Assembly
DSKY	Data Storage Key Board
ECA	Electronic Control Assembly
ECS	Environmental Control System
EDS	Emergency Detection System
ELS	Earth Landing System
EO	Engineering Orders
EPS	Electrical Power System
FCS	Flight Control System
FCSD	Flight Crew Support Division
FCSM	Flight Combustion Stability Monitor
FEO	Field Engineering Order
FEO/FCA	Field Engineering Order/Field Change Analysis
FRT	Flight Readiness Test
FS	Full Scale
G&N	Guidance and Navigation
GAEC	Grumman Aircraft Engineering Corporation
GFE	Government Furnished Equipment
GMIL	Goddard Merritt Island
GN	Gaseous Nitrogen
GORP	Ground Operations Requirements Plan
GSE	Ground Support Equipment
IDR	Interim Discrepancy Record
IMU	Inertial Measurement Unit
INSTR	Instrumentation
KSC	Kennedy Space Center
L/C	Launch Complex

LEB	Lower Equipment Bay
LEM	Lunar Excursion Module
LM	Lunar Module
LO_2	Liquid Oxygen
LOS	Loss of Signal
LV	Launch Vehicle
LVO	Launch Vehicle Operations
MCC-H	Mission Control Center, Houston
MCR	Master Change Record
MDAS	Medical Data Acquisition System
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSOB	Manned Spacecraft Operations Building
NAA	North American Aviation
NAA-FF	North American Aviation, Florida Facility
OCP	Operational Checkout Procedure
OMSF	Office of Manned Space Flight
PCM	Pulse Code Modulated Data
PGNS	Primary Guidance Navigation System
PIRR	Permanent Installations and Removal Records
PLSS	Portable Life Support System
P/N	Part Number
PP	Peak to Peak
PSIG	Pounds per square inch - gage
PTT	Push To Talk
QC	Quality Control
RCS	Reaction Control System
RCS/SPS	Reaction Control System/Service Propulsion System
RGPO	Resident Gemini Program Office
S/C	Spacecraft
S/C AGC	Spacecraft Automatic Ground Control
SCS	Stabilization and Control System
SEDR	Specification
SEQ	Sequencers
SLA	Service-LM-Adapter
S/M	Service Module
SMJC	Service Module Jettison Controller
SPS PU	Service Propulsion System - Propellant Utilization
STC	Spacecraft Test Conductor
TAIR	Test and Inspection Record
TB	Terminal Board
TIRR	Temporary Installations and Removal Records
TPE	Test Project Engineer
TPS	Test Preparation Sheets
TVC	Thrust Vector Control
UDL/UHF	Up Data Link/Ultra High Frequency
W/G	Water-glycol
WMS	Waste Management System



ENCLOSURE 7-1

C-2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

TO: Chairman, Panel 1 & Panel 7

FROM: Deputy Manager, Operations Management, KE-2

SUBJECT: Memorandum for the Record

1. To clarify the records and provide an explanation of procedures followed to insure spacecraft readiness for OCP-K-0021-1, Plugs Out Test, the following information is submitted.

2. On 1/23/67 at 1030 an open item review was conducted with the S/C 012 NAA/NASA Test Team. Outstanding (open) items against the spacecraft were reviewed and a listing of 55 items was generated that were considered constraints in one of four categories. These four categories were:

a. Constraint to power up for OCP-K-0006 (Plugs In Test), 11 items.

b. Constraint to power down for OCP-K-0006, 16 items.

c. Constraint to power up for OCP-K-0021, 26 items.

d. Constraint to power down for OCP-K-0021, 2 items.

Names of the responsible NAA system engineers were assigned to each item and the cover sheet was signed by the NAA TPE and the NASA STC.

3. On 1/24/67 power was applied to the spacecraft at 0400 and OCP-K-0045, MCC-H Interface Test, was conducted. The test was completed at 2030 and power was maintained on the spacecraft.

4. On 1/25/67 at 0400 the Plugs In Test was started and was completed at 0300 on 1/26/67. Power was not removed from the spacecraft. The portion of the constraints list applicable to this test was signed off prior to the start of testing.

5. A review of the new work items (i.e., the delta accumulated since the creation of the constraints list) was conducted in the daily recap/review meeting held at Complex 34 on both 1/24/67 and 1/25/67 at 0800.

NOTE: Following this meeting the items are scheduled on the planning sheet by NAA and NASA operations personnel. These updated planning sheets are passed out at the 1430 daily scheduling meeting where the schedule for the next 24 hours is created. This meeting is attended by NAA/NASA S/C and GSE Engineering, NAA/NASA Operations, NAA/NASA Quality Control, plus support personnel safety representative, NASA-MSC and NASA-Headquarters personnel and others as required. The depth of engineering coverage is far greater at the daily scheduling meeting than it is at the 0800 meeting since the 0800 meeting is attended by the NAA Engineering Coordinator and the NASA S/C and GSE Project Engineers who represent their respective organizations in lieu of having all engineering disciplines present. At the daily 1430 meeting the S/C open items status report is once again reviewed for additional items that can be scheduled for work.

6. On 1/26/67 the S/C open items were reviewed at the 0800 meeting but there were so few changes since 1/25/67 that no new planning sheet was created.

7. On 1/26/67, at 0900, a meeting was held at Complex 34 to review the general S/C readiness for the Plugs Out Test. Participants in this meeting were:

C. Gay, Chief Spacecraft Test Conductor, NASA
C. Chauvin, Spacecraft Test Conductor, NASA
E. Reyes, Senior Operations Engineer, NASA
B. Haight, Senior Test Project Engineer, NAA
C. Hannon, Assistant Senior Test Project Engineer, NAA

It was the opinion of this group that the remaining open items from the constraints list could be accomplished prior to the scheduled power up time for the Flight Readiness Test. The remaining constraints for Plugs Out were retest of the Yaw ECA, review of the removals and completion of the checklist. The results of this meeting were passed on to Engineering for evaluation.

8. At 1000 on 1/26/67, Messrs. Gay, Chauvin, and Edson (NAA TPE) attended the Plugs In Debrieting held by DLO-1 at Complex 34 and at the conclusion of that meeting summarized the S/C status for the Plugs Out Test. A portion of this summary included the facts that all of the S/C data from Plugs In had not been completely reviewed and that there were still final preparations and work items to complete before being ready to meet the scheduled power on time.

10. Constraining test items, which were originally listed as open constraints to the test, were released by the NAA responsible systems engineer for each respective system by contacting the NAA Operations Engineer on duty at LC-34, who then signed off the respective item on the constraint list. In addition, those items which were completed and sold off were signed by the NAA Operations Engineer on duty.

11. Following replacement and retest of the Yaw ECA, the S C was powered down at approximately 1800 on 1 26 67. This was the first power down period since 0400 on 1 24 and power was off until approximately 0730 on 1 27.

12. On 1 27 67 at 0600, Pre-test Briefing was held with systems engineers, operational personnel, technicians and inspectors in the MSOB.

13. The test team then went on station and the STC and TPE received a "Go" from each Systems Engineer and from the Pad Leader verifying readiness to proceed with the test. ECS stated in their status report that they were running late with their preparations. SCS gave a qualified "Go" based on incomplete data review. The Pad Leader indicated he had additional ECS set-ups to complete and that they could be accomplished in parallel with power up.

14. An IDR requested by the STC and TPE was written at the start of the test documenting the fact that there was no signed off constraints list for the Plugs Out Test. Status of each item not signed on the Operations Engineer's constraint list plus the delta was to have been provided in the disposition of the IDR upon completion of the test. This was not accomplished as all documentation was impounded at the time of the incident.

15. On 1 27 67, the 0800 meeting was held at Complex 34 and the planning sheet for 1 25 67 was updated accordingly. Reference Enclosure #3.

16. The constraints list and the additional S C open items have been reviewed since the incident and their status reverified. The results of this review are included as a part of this report as Enclosures #1 and #2.

17. The constraints list that was being signed off by Operations Engineers upon work completion and or waiver was at the complex on level A8 of the service structure. A copy of this list is included as Enclosure #4

18. Summary

a. A constraints list was created for OCP-K-0021 but was not signed off since it did not represent a true picture of all open paper due to the additional work generated from 1/23 to 1/27.

b. The constraints and additional open items generated after development of the constraints list were under constant review by the test team.

c. Two meetings are held daily between systems (or their representatives) and operations personnel where the status of S/C open items is discussed.

d. Certain items were evaluated and deferred until after Plugs Out and prior to FRT.

e. The status of the S/C was known at the time of the test by systems and operations personnel. Readiness reports were received from all factions prior to power up and there were no open work items to constrain the running of the Plugs Out Test.

C.Gay, Deputy Opns Mgmt, NASA

Concurrence:

NASA		NAA	
STC		SR TPE	
SR OPS		ASST SR TPE	
S/C Proj Engr		TPE	
		Elect Sys Chief	
		Mech Sys Chief	
		Telecomm Sys Chief	

EVALUATION OF CONSTRAINTS LIST

DR RECAP FROM CONSTRAINTS LIST

DR#	SYSTEM	DESCRIPTION
923	RCS	No readout on panel 12 for S/M RCS He temp. Originated as IDR-035, OCP-0005, upgraded 1/19/67. EO 477825 - Ref - TPS S/C 012 C/M 008. Panel 12 temp installed on temp installation for 0006, 1/23/67. Was left installed to support OCP-0021. Step 5 of DR-S/C 923 specified to remove panel 12 for potting check. Item was left open because potting was not completely cured at installation. Measurement was replaced and retest was accomplished per OCP-0006.
858	ECS	a. Crew reported eyes smarting during first hour at altitude and discomfort (due to heat) periodically during remainder of test at altitude. b. Originated as IDR 079, OCP-0034A-1. Transferred to DR-S/C 858 1/4/67. c. Suit hose umbilical was removed from S/C and sent to malfunction lab for analysis of interior for LiOH and other eye irritants. Sample analysis report was attached to hose and sent to FCS lab. d. 2.5 micrograms of LiOH found in -71 suit hose. e. DR-S/C 858 - conclusions were left open for retest and evaluation during OPC-0021.
864		Communication problem that was corrected by working TPS S/C 493 (sold) and DR was open for retest in OCP-0021. VHF/AM communication was unintelligible when the crew was in pressure suits. Modified cables were evaluated during OCP-0006. Required further evaluation during OCP-0021 with suited crew.
916		a. When either crewman pushes PTT parameter CJ0002J(resp.rate) is modulated in negative direction approximately 20% full scale. b. Originated IDR-029 OCP-K-0034A-1. c. Was to be retested per OCP-K-0021. d. Problem could not be duplicated, therefore, was held open for evaluation during OCP-K-0021.
932		a. Seq. 04-048 measurement SS-01-20X (SLA Sep. Monitor) reads 0% at de-com. b. Originated as IDR-0008, during OCP-0006 (dry run). c. Troubleshooting per continuation sheet directed to remove defective separation monitors upon engineering direction. d. Defective separation monitor was not replaced prior to going into OCP-K-0021.

932 (Cont'd)		e. Portion of DR which was a constraint, i.e., CSM umbilical reinstallation, was accomplished. f. Replacement of separation monitor scheduled for 1/28 - required installation of SLA platforms.
684	EPS	a. Wire routing to LEB XX strut lights is unacceptable. Wire much too loose--should be routed so as to lie flush on upper bulkhead. b. Originated as P/A SQK #9. c. EO release was pending and in meantime TPS S/C 469 was partially worked to correct discrepancy. d. DR-S/C 684 was left open due to pending EO release.
714	EPS	Floodlight connectors left and right couches are not adequately protected or supported to preclude damage by crew when changing couch position. b. Originated as P/A SQK #11. c. DR-S/C 714 was partially corrected per TPS S/C 469 - Ref EO 586488. d. DR-S/C 714 was left open due to shortage of parts.
865	EPS	Sold 1/26/67.
878	EPS	Sold 1/27/67.
922	EPS	Sold 1/24/67.
884	G&N	Sold 1/24/67.
905	G&N	Results of fine alignment test were unsatisfactory. Was IDR-038 of OCP-0005, Fine Alignment Test. Was rerun prior to OCP-K-0021. Rerun reverified original discrepancy. Out of spec condition required waiver. Waiver had not been requested at this time. No constraint.
915	G&N	Sold 1/26/67.
908	F/C	Sold 1/25/67.
344		Was IDR-072 - OCP-0035-1. When AC inverter #2 to AC Bus 1 On, a master alarm occurred. A successful attempt to duplicate the problem was performed prior to power down from OCP-K-0006. The data was returned to Downey for engineering evaluation.
909	F/C	Electrical noise was evident on O_2 tank #1 temp measurement SF0041. Ref IDR-018 - OCP-4736 and IDR-0008 - OCP-0005. a. Noise was 8% FS of PP superimposed on normal reading - Ref IDR 018. Correction of problem (harness replacement) scheduled for 1/28. b. O_2 tank #1 (SF0032) measurement cycling between 23-48. Closed by OCP deviation (without cryos measurement was not meaningful). Part a. required additional input.

918	F/C	Was IDR 009 in OCP-4736. No pressure indication on panel 13 of H_2 tank pressure. Troubleshooting accomplished. (EO 467267 scheduled for 1/28) Scientific matrix block was intermittent. EO changed pin location. Not accomplished.
831	FCS	Was IDR-001 from OCP-8240B. Nepheolometer could not be removed from stowage compartment without excessive pull. Foam cusion was removed and returned to bond room. A new nepheolometer foam cushion was installed in spacecraft on evening of 1/26/67 per TPS S/C 547 and EO 565265. A portion of this task required a piece of foam to be bonded onto the door on the nepheolometer storage compartment. This was not accomplished and was considered no constraint to OCP-K-0021 since nepheolometer was not installed.
899	Biomed	Was IDR 027 of OCP 0005. Simulator voltage was 6.8VDC, should be 16 ± 4 VDC. Troubleshooting revealed improper designed "T" adapter. Disposition was that Downey was aware of the problem and a redesign was required. Relay in all but two "T" adapters draws more current that voltage divider is designed for. This causes low voltage because source is not regulated. Part No.V16-601396, S/N 06362 AAF 8453 of defective adapter sent to Downey. S/N 3603, Part No.V16-601396 was installed in SSRP position on 1/24/67. (not same design S/N 06362 above)
126	FCS	TV camera mount assembly spring could not be installed, spring broke while installing during OCP-K-0034A. Disposition was to redesign spring. The spring was to be replaced per an EO from Downey. As soon as new spring was received DR could be closed.
165	FCS	T-adapter, pin #2 ot P3 is protruding apporx 1/4" above other pins. Disposition was to remove pin as it was a spare and not required and was suitable for 0034A. DR held open until replacement adapter arrival. Above T-adapter sent back to Downey. The one in the S/C was S/N 3603 and the S/N of DR'd one is 8453.

(Sold Items on OCP-0021 Constraint List)

0865 Closed 1/26/67.

Problem: 12/27/67 OCP-0034A-1 IDR #034 Primary floodlight control rheostat causes lights to blink in the full on position.

Action: Floodlights were replaced per TPS S/C 485. Recheck completed per S/C DR 0865 during OCP-0006-1. New floodlights did not flicker. Floodlights emitted a low buzzing noise.

0878 Closed 1/27/67

Problem: PAS #92 LM DSEA splice cable makes 90° bend as it comes out of recorder.

Action: Remove straight backshell and install 90° backshell. Work complete 1/27/67. Cable stowed in S/C for OCP-0021.

0884 Closed 1/26/67

Problem: 10/21/66 OCP 0034-7 IDR #116 trans to OCP 0034-A IDR #012
Recorder 15 shows IMU temp CG 5006 IMU delay CG 5008, comp power fail CG 5030; CRT PG11 L14 shows mark error 1.

Action: Troubleshooting disclosed problem was caused by depression of check condition lamps push button on G&N GNIC panel with IMU operate power on and G&N in course align mode. No constraint to further testing.

0908 Closed 1/25/67

Problem: OCP 4736 IDR #0008 O_2 flow FC #1 will not shut off when O_2 purge valve is cycled.

Action: Valve was found to leak. Valve was replaced and retested per section B on continuation sheets this DR. Retest was acceptable.

0915 Closed 1/26/67

Problem: 1/17/67, dust on lens and mirror on G&N telescope and sextant optics.

Action: Remove dust covers and clean lenses.

0922 Closed 1/27/67

Problem: 1/18/67
1. Unable to verify I/D on pyro connectors E18SQ9 (P9) and E18SQ7 (P7) per TPS S/C 012 - 534.
2. Connectors A18SQ1 (P3) in SLA is IDed as A155Q1 (P3) and A18SQ2 (P1) in SLA is IDed as A15SQ1 (P1).
3. The following connectors are not connected per TPS-534: S1551 SQ2, S1552 SQ1, C19SQ14 (P480) and C19SQ12 (P77).

0922 (Cont'd)		Action: 1. ID the connectors. 2. Connector ID's as called out per the TPS in error. TPS corrected per mod. 3. TPS modified to disconnect only those connectors connected.
869	AF	Problem: Panel 312 is not identified as such and panel 313 has paint on the ID decal. Action: Identify panel 312 as panel 312 and remove paint from ID decal on panel 313. Sold.
891	RCS/ EPS	Problem: Connector C05WBP495 in RCS roll access has been disconnected without a PIRR being written and had been connected to GSE cabling. Action: Reverify connector and record on proper NAA documentation. Sold.
GSE-572-1-0026		Was IDR 070 (0005A) - could not establish two way communications over GSE intercomm, 1/18/67. Action: Repatch 572-J-box and return to original configuration after launch. 572-J-box was repatched and a satisfactory comm check was completed..

TPS RECAP FROM CONSTRAINTS LIST

TPS S/C	SYSTEM	DESCRIPTION
534	EPS	Inspection of pyro connector for correct P/N and correct keying and insert. Sold 1/23/67. Ref DR S/C 922 (sold).
537	SEQ	Support "Q" ball installation. TPS written to support activity required by IBM. Re-evaluated prior to test as no constraint.
555		Hand control removal and inspection and was cancelled by TPS 561.
561		TPS cancellation of TPS 555. Sold 1/24/67.

545	ECS	a. Waste management system and S/C H_2O system cleanliness level verification. b. Perform EO 548578. c. Flushed waste management system urine dump line. d. Originated IDR #1 - no sample analysis available for step 11 of EO 548578. A verbal report of a satisfactory sample was received by R. MacDonald of NAA from Pan Am Lab. e. Purge and dry urine dump. f. Step 2 TPS/545 was not performed because it wasn't scheduled to be done until OCP-0021 was completed. Step 2 is to perform an H_2O flush of potable, waste and supplemental subsystem to kill the bacteria present and should be done as close to launch as the schedule permits.
493	COMM	a. Reduce noise in mike to audio center. b. Sold 1/26/67. c. Installed noise limiters in aduio center.
225	EPS	a. Disable SPS PU sensor fail lights. b. EO 466789. c. Sold 1/23/67. d. Removed wire #K-348C20 from P3 and cap.
469	EPS	a. Wire protection in crew compartment. b. Ref EO 586488, MCR-1831. c. Installs protective covering over S/C interior TB's wire harnesses and connectors. d. Steps 5,6,7,9,10 (pending cure short stamp) (11,13,14,16) are sold. e. Not complete due to part shortage (17,15 12,8,4,3,2,1). f. Configuration considered acceptable for test.
543	EPS	Installation of SMJC batteries in S/M and pyro batts in C/M for 0006 and remove after test. Installation portion completed.
510	EPS	a. Circuit interrupter test. b. Mod #2 - retested all circuit interrupters because could not verify that travel limiters were not left installed on initial testing. c. Mod #1 - EO 602525, EO 566969-1&2, added connectors. d. Sold 1/26/67.
536	G&N	a. Sextant mirror housing plug. b. Applied Loctite primer and finish coat to mirror housing plug (14 hr cure). c. Sold 1/27/67.

400	FCS	a. Install temp plugs on G&N optics. b. Steps 1,2,3 bought off. c. Step 4 removes after flight items are installed. d. No sold until item "c." is complete.
511	FCS	Perform EO 582263, portable floodlight stowage bag installation. Sold 1/27/67.
021	FCS	a. Installation of cushion and container crew and scientific "G". b. Work EO 501694 - Install Scientific "G". c. Step #1 & #2 hex stamped because flag note 4 of V16-880168 not complied with. d. Intent of EO not complied with. e. Scheduled to be accomplished during stowage exercise 2/3 & 2/4. NOTE: Step #1 and #2 were hex stamped because intent of EO 501694 had not been fully accomplished as the GFE equipment called out in V16-880168 had not been installed and stowed.
079	FCS	a. Work EO 582206 b. Adds 2 spare -51 cobra cables. c. Cobra cables were on temp install. d. Per OPC-K-10011 deviation. This EO would be accomplished for launch.
505		Perform OCP-K-0006. Accomplished 1/26. No constraint.
506		Perform OCP-K-0021.

IDR RECAP FROM CONSTRAINTS LIST

OCP-0005

IDR-15 - Observed momentary LOS at time when cabin air fan, suit compressors (2) and glycol pump were switched on (individually) and off.

Results - AC buses were monitored and voltage transients were confirmed. Transients were within spec for inverter operation with full load on bus. IDR condition written with minimum load on bus. Additional testing to be accomplished prior to power down from OCP-K-0021.

IDR-48 - Problem with TV hardline from CX-34 to MSOB.

Results - Troubleshooting disclosed patching problem at MSOB. Not retested prior to OCP-K-0021. Retested during OCP-K-0021.

IDR-61 - GMIL reported poor quality of DSE reverse dump.

Results - Hardware design dictates that we should not dump in reverse direction. Evaluated as no constraint to OCP-K-0021. Test was performed in OCP-K-0006 and resulted in a forward dump mode only that was acceptable to FCS.

IDR-12 - While manually loading K-start tape, word error 1, sync error 3, and momentary PGNS were displayed at 01736E (just before tape listing stop).

Results - Results are normal. Close per OCP deviation.

IDR-13 - CH0413 reads - 0.1 and CH0613 reads - 2.199 and blinking, both should be zero.

Results - Troubleshooting indicated that problem is in ACE carry-on equipment. No GSE DR number available. ACE carry-on not utilized in OCP-K-0021.

IDR-66 - Non-verify received on K-start and TL fail indication observed in S/C.

Results - Troubleshooting disclosed that the S/C AGC had operated properly with erroneous information on uplink to the AGC. The failure indication was attributed to external noise, generated within the ACE uplink system, and responded to by the guidance computer as the first "one" bit into the computer. This spurious bit then caused a failure in the computer verification of the next legitimate data transmitted via the K-start. (The same problem was observed and verified on S/C 017 and the noise was found to originate in a R-start execution.)

IDR-72 - SCS executed C180, 184 and 172 and did not receive a confirm indication.

Results - This was transferred to GE software DR 322. The problem only occurred when using ACE uplink load 3. No change was made to software and a workaround was utilized by initiating and terminating from the same start. IDR was sold 1/25/67.

IDR-77 - When R-187 was executed, noise peaks appeared on recorder 26, GC1022, 1032, 1502, 1512, 1522 and 1532.

Results - Problem appears to be crosstalk between SCS and G&N systems. IDR still open for SCS and G&N further evaluation. Was considered no constraint to OCP-K-0021.

IDR-80 - Measurement CH1038 noisy when TVC power applied.

Results - Troubleshooting indicated bad Yaw ECA. IDR transferred to S/C DR 940. ECA was removed, replaced and retested successfully prior to OCP-K-0021 (with exception of frequency response test). Frequency response was scheduled for 2/1/67.

OCP 0006

IDR-2 - AC bus 2 phase C reads 112.4VAC on CRT and 117VAC in S/C. (within tolerance)

Results - No conclusion at this time. Signal conditioner appears to be drifting. Considered a S/C problem but requires further investigation to verify. Considered no constraint.

IDR-9 - Sold.

OCP 0034A-1

IDR-5 & IDR-37 - Did not receive He isolation #2 opening indication when thrust on was initiated.

Results - Troubleshooting (KSC & Downey) disclosed present GSE instrumentation is marginal with respect to providing positive readout of SPS He and pilot valve signals. IDR's were transferred to GSE DR GC484-7 -0041 & -0042. No constraint to OCP-K-0021.

MISCELLANEOUS ITEMS

1. SP113 is a test in which the meter readings in the S/C are compared against the PCM data. All system engineers were to compare their measurements and write an IDR against any reading out of tolerances established. Partially accomplished in OCP-K-0006 and further data was being obtained in OCP-K-0021.

2. This item was generated by DR 932 (Instr) in which measurement No.SS0120X read incorrectly. All engineers were advised as to what functions go through this connector and to write an IDR on any anomaly noted. Was monitored during OCP-K-0006 and no anomalies were noted.

EVALUATION OF ADDITIONAL OPEN ITEMS

The following items represent new work tasks that were entered into the S/C TAIR books between the completion of open items review and the start of OCP-K-0021. A status and/or explanation for each item is provided.

1. TPS 547 - Install nepheolometer cushion MCR 1875 logged 1/24/67. Item was partially worked third shift 1/27 but was not completed. It was not considered a constraint to the test.
2. TPS 548 - Markings on panel #23 MCR 1863 logged 1/24/67. Not considered a constraint.
3. TPS 553 - Remove ablator plugs; add pore seals, logged 1/23/67. Continuing exterior task which is accomplished NIB. No constraint.
4. TPS 556 - Assemble soft BPC in warehouse, logged 1/23/67. Completed for OCP-K-0021.
5. TPS 562 - Cover rough edges on crew couch, MCR 3563, logged 1/24/67. Scheduled for 1/31/67. No constraint.
6. TPS 563 - Change from 1 man rafts to 3 men raft, logged 1/24/67. Scheduled for 2/1/67. No constraint.
7. TPS 568 - Install BPC parts, logged 1/25/67. Accomplished 1/27 to support OCP-K-0021.
8. TPS 581 - Determine reflectivity of S/M coating, logged 1/27/67. Received after planning sheet dated 1/27 was originated. Planned for completion after OCP-K-0021. No constraint.

9. DR 0933 - Ding in CM floor, logged 1/23/67. Completed 1/26 - in cure - not sold. No constraint.
10. DR 934 - Valve markings on CM panel 307, 311 and 314 do not line up, logged 1/23/67. Scheduled for 1/31. No constraint.
11. DR 938 - Rain water in tower leg area, logged 1/24/67. Water dried out 1/24. No constraint.
12. DR 939 - Three dents in SM sector 6, logged 1/24. Sold 1/27.
13. DR 0944 - Washer dropped in F/C #1 sector 4, logged 1/25/67. Sold.
14. DR 949 - Scratches on SLA, logged 1/26/67. Under evaluation. No constraint.
15. TPS 554 - Ball valve #3 position potentiometer change, logged 1/24/67. Work accomplished. Required EO verification. No constraint.
16. TPS 570 - Monitor CM isolation valve temp, logged 1/26/67. Monitoring was being accomplished during OCP-K-0021.
17. DR 0947 - WMS blower on more than 24 hours, logged 1/26/67. ECS blower - not to be run during test. To be replaced after test. No constraint.
18. TPS 580 - Event timer checkout, logged 1/26/67. No constraint. Check on 8 day wind up clock.
19. DR 0936 - Panel 206 wind and set control stuck in the in position, logged 1/24/67. Completed 1/26. No constraint.
20. DR 0940 - Measurement Ch1038 noisy when TVC power applied, logged 1/24/67. Yaw ECA replaced 1/26. Retest accomplished, less frequency response, 1/26. No constraint.

21. TPS 552 - Wiring change EG-467267, logged 1/23/67. Ref DR 0918 on constraints list, changed position of wire in matrix block. Task deferred until after Plugs Out. Scheduled for 1/28.

22. TPS 565 - Transport 2 pyro batteries per OCP-K-0006, logged 1/24/67. Accomplished less post test removal.

23. TPS 569 - Install S.C ordnance, logged 1/25/67. Scheduled for 1 31 67. No constraint.

24. TPS 577 and 579 - Transport and install battery for OCP-K-0021, logged 1 26 67. Accomplished less post test removal.

25. DR 0937 - Bonding material used not acceptable inside CM, logged 1 24/67. Work done per B P. Used MA0106-70 - waiver letter #192-20-66 309 permits material usage. Area involved approximately 1 square inch. No constraint.

26. DR 0948 - Connector J-54 broken, logged 1/26. DR voided. Problem already covered on MR #250. Signal conditioner ACE carry-on connector.

27. DR 943 - Circuit breakers on panel 150 not in proper configuration per procedure, logged 1 24 67. Procedural problem circuit breakers closed in error caused draining of pyro batteries during OCP-K-0006 dry run. Batteries replaced prior to OCP-K-0006 sell run. DR sold 1/27/67.

28 DR 0945 - Panel 200 reads out H_2 regulator pressure. Should by O_2 regulator pressure, logged 1 25/67 System not involved in test. No constraint.

29. TPS 566 - Removal of hand controller, logged 1/24/67. Completed less post test removal of spare hand controllers. One spare rotational and one spare translation controller installed for test

30. TPS 573 - Install decals of computer codes, logged 1/26/67. No constraint.

31. DR 941 - Locking ball retainer ring for telescope flight cover missing, logged 1/24/67. GSE covers installed - no constraint.

32. DR 946 - LO_2 tank #2 exceeded replacement point by operating 90 hours, logged 1/25/67. No constraint - awaiting waiver.

33. TPS 528 - Determine stowage location for additional food, logged 1/26/67. Scheduled 2/3/67. No constraint.

34. TPS 538 - Installation of container V16-332131, logged 1/26/67. Sold 1/27. No constraint.

35. TPS 549 - Perform OCP-K-8240C section 2 part 2 of Crew System Stowage procedure, logged 1/23/67. Scheduled 2/3 and 2/4. No constraint.

36. TPS 564 - Fit check of octopus cable, logged 1/24/67. Accomplished 1/25 and 1/26.

37. TPS 570 - Install and checkout of crewman optical alignment sight, logged 1/26/67. Scheduled 2/3 and 2/4 - no constraint.

38. TPS 583 - Installation of stowage items to support OCP-K-0021, logged 1/27/67. Accomplished prior to crew ingress.

39. DR 0912 - Grommet damaged tee adapter, logged 1/24/67. Sent to lab - no constraint. This tee adapter was the second of two good ones. Had unused pins missing. Not used in S/C for OCP-K-0021.

40. DR 0950 - Cushion assembly for scientific "T" compartment has damage one edge of assembly, logged 1/26/67. No constraint.

41. DRS 878 - Fiberglass covers for gears (2) on docking mechanism were missing. Had not yet been scheduled. No constraint.
42. DRS 880 - Fiberglass covers P/N V16-531826-1 and -2 were not installed per print. Had not yet been scheduled. No constraint.
43. DRS 884 - Thermal shrink sleeving was not properly shrunk. No constraint.
44. DRS 886 - Transferred to DR 0945.
45. DRS 892 - Door #9, -Y axis on the SLA had a loose washer and there was dirt and other foreign material inside. Scheduled to work on a non-interference basis. No constraint.
46. DRS 894 - CMD position had two loose cobra cable clamp screws. Had been dispositioned to tighten the screws and had not been scheduled. No constraint.
47. DRS 895 & 896 - Written against the BPC during test preps. No constraint to test.

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23 January 1967

CONSTRAINTS LIST - OCP-K-0006/0021 (Reference 23 January Status Report)

All power-up constraints to OCP-K-0006 have been satisfied.

NAA _____ NASA _____

All power-up constraints to OCP-K-0021 have been satisfied.

NAA _____ NASA _____

This listing identifies all constraints to OCP's 0006 and 0021 S/C 012 tests per constraints meeting held 10:30 AM on 23 January 1967.

NAA 1-23-67 NASA

CATEGORY	TPS/DR	TASK DESCRIPTION	RESP. ENGR.	CONSTRAINT 0003 PWR UP	0003 PWR DN	0021 PWR UP	0021 PWR DN
Misc. (1)	TPS 505	PIRT's/TIRT's 10011 Checklist 10010 Placards	All	X			
	TPS 506	PIRT's/TIRT's 10011 Checklist 10010 Placards	All			X	
AFRM/PYRO (2)	TPS 534	Pyro connector keying Sold	Patterson	X OK C.P. Dannel R.J. Teh NASA			
	TPS 537	Support G-Cell Installation	Patterson				
ECS/EPS(3)	DR 0003	No readout on Panel 12 for C/W ECS temp.	Tribe	X OK to is R.J. Teh NASA			
	0031-1-1 TPS 535 & 537	Pontoon Helium isolation valve oper.	Tribe	Transfer To OSE Per Johnson			
ECS (4)	TPS 545	Vehicle Waste Management System checklist(s) level - Part I of TPS only	Griffith	R.J. Teh NASA			
	DR 0058	Fuel sparing	Griffith			X Will close 4-00 BC	
	0005A TPR 015	Momentary LOS	Griffith/ Warner		X*		
Comm (5)	TPR 483	Incorporate Mod Kit (ECR 1844) Sold	Ostiguy			X B.P. Warner	
	DR 0864	VHF/AM comm. unintelligible with pressure garments on	Ostiguy				
	DR 0916	C30602 is modulated when PTT is pushed	Ostiguy				

*Indicates Engineering resolution required.

CAT	TR3/DR	TASK DESCRIPTION	RESP. ENGR.	CONSTRAINT 0006 PWR UP	CONSTRAINT 0006 PWR DN	CONSTRAINT 0021 PWR UP	CONSTRAINT 0021 PWR DN
[illegible] (5)	CDCSA-1 ECR 063	TV system retest	Ostiguy		X		
	GSE DR 572-1-0025	Communication system retest	Ostiguy		X		
		Houston Communications Check			During 0045		
	TPS	C14-348 reinstallation		Signed off per LMTPE 21 Jan 0300			
		Availability of light weight headsets shell caps, and T-adapters	Ostiguy/ Corley				
INSTR. (8)	DR 0032	[illegible] should be 1023 - [illegible] for [illegible]	Sargent				
	CDCSA-1 ECR 061	[illegible]	Sargent		X		
EPS (7)	TPS 225	[illegible]	Vallin	Sold BP Ramon RJ/eh NASA			
	TPS 450	Wiring protection OK for test BP Ramon	Vallin			X	
	TPS 510 Cod 2	Circuit interrupter test	Vallin	No Constraint A. Wagner Peak Telec.			
	TPS 543	Battery installation ok for test BP Ramon	Vallin	INSTALLATION BP Ramon 2/82			
	DR 0081	Wiring routing to LEB OK for test BP Ramon	Vallin			X	
	DR 0714	Floodlight support OK for test BP Ramon	Vallin			X	
	DR 0755	Primary floodlight operation OK for test BP Ramon	Vallin		X		
	DR 0078	LEM DSEA splice cable	Vallin			X	

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CATEGORY	TP3/DR	TASK DESCRIPTION	RESP. ENGR.	CONSTRAINT 3 0006 PWR UP	0006 PWR DN	0021 PWR UP
EPS (7)	EPS 0002	Pyro connections (reference TPS 534)	Vallin	X Sold G.P. Hanson		
	0001-1 MER 002		Vallin			X
GNC (8)	GNC 536	Sextant mirror housing plug	Bennett ok for test G.P. Hanson			X
	GNC 0004	Shows 1 PV temp. 1 PV delay comp. pwr. fail 3 cmd. shows 4 mark error #1	Ferris		X	
	GNC 0005	IMU align anomalies	Ferris		X	
	GNC 0015	Sextant optics cleanliness OK Sextant G.P. Hanson				X
	0002-1 GNC 012	Secondary TCS	Ferris			X
	GNC 045	Non-verify on E-Start, TL fail in S/C	Ferris			X
SCS (8)	0003-1 SCS 013 → now DR S/C 042	SM C.13 valve improperly	Schultz/Buzz		X	
	SCS 072	C-Start actuation anomaly	Schultz/HACO			X
	SCS 070		Schultz		X	
	SCS	Hand Controller installation/inspec.	Schultz	X will repl G.C. Ramsey RJ Lt. NAID		
	0005-1 SCS 009		Schultz/Buzz		Prior to Mission Run	
FUEL CELL (9)	F/C 0008	O_2 Purge valve monitor - fuel cell #1 pressurization	Dvorak		X	
	F/C 009	SP 0041-2 is noisy	Dvorak			
	F/C 013	Panel 13 H_2 Tank #2 pressure indication Waiver granted for OCP-K-0021 G.P. Hanson	Dvorak	X Panel Instl Comp.	Will repl G.C. Ramsey RJ Lt. NASA	

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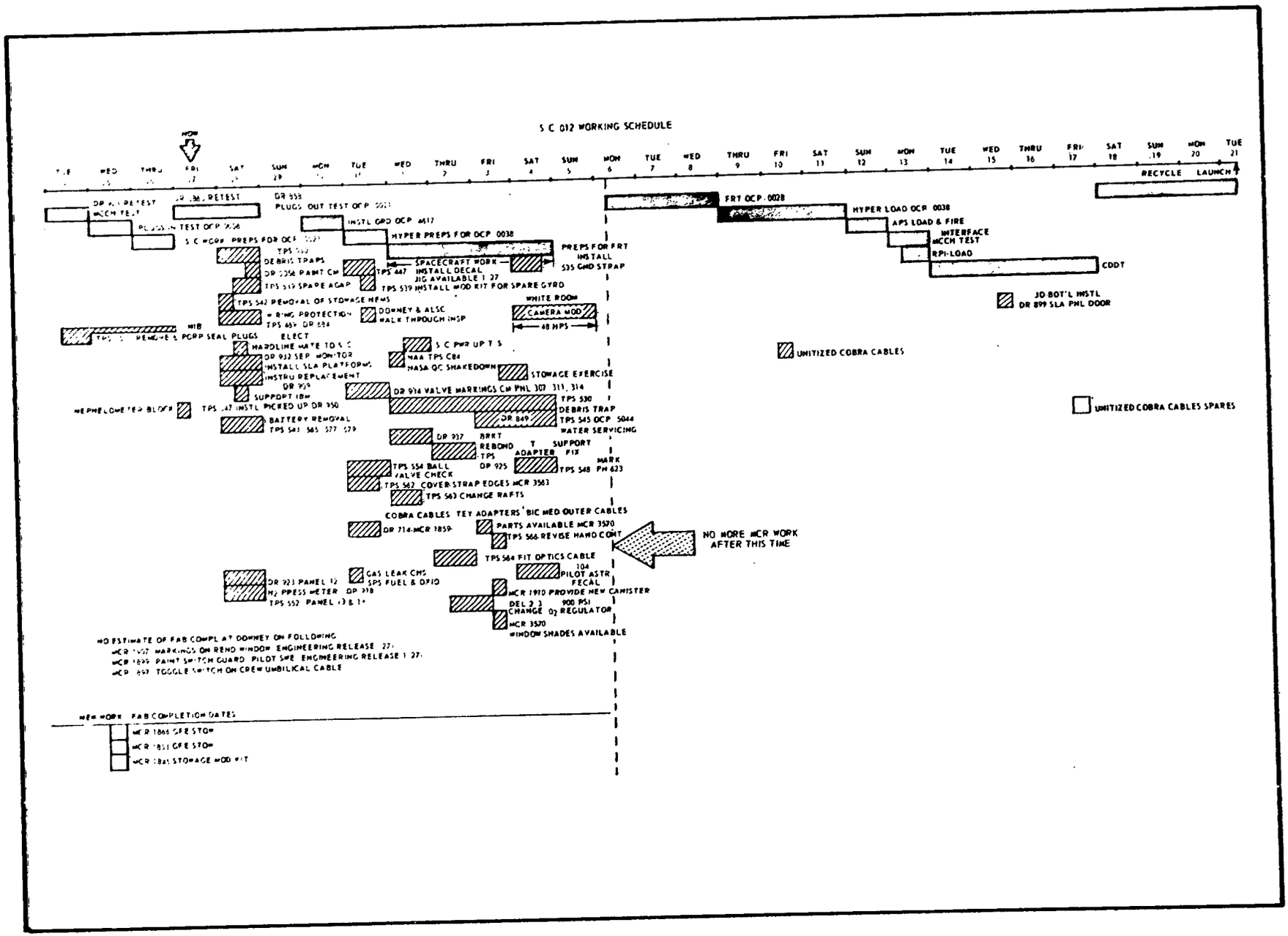
CATEGORY	TPS/DR	TASK DESCRIPTION	RESP. MNGR.	CONFIG 0005 PWR UP	CONFIG 0005 PWR DN	CONFIG 0021 PWR UP	CONFIG 0021 PWR DN
SIM (10)	DR 0344	When A/C inverter #2 was connected to A/C Bus #1 the master alarm came on.	Brandon		X		
	00054-1 IDI 077	R187 execution anomaly	Brandon		X		
FCS (11)	TPS 400	G&N option plugs installation	Corley Not required G.P. Hanson			X	
	DR 0331	Napholometer installation/removal	Corley Not required G.P. Hanson			X Stowage	
	TPS 511	Work PD 582263	Corley Not required G.P. Hanson			X Stowage	
	DR 0339	Sim. voltage is 6.8, should be 16	Corley			X Need T-Adapter	
	TPS 521 (Lab)	Installation of scientific "G"	Corley Not required G.P. Hanson			X Stowage	
	TPS 523 (Lab)	Work PD 582263	Corley			X Stowage	
	DR C1265 (Lab)	TV camera mount spring broken	Corley Not required G.P. Hanson			X	
	DR C1265 (Lab)	Pin #2 of P3 protruding	Corley			X T-Adapter	
ECS (12)	DR 339	Panel 312 and 313 ID	Griffith Not required G.P. Hanson			X	
	DR 381	Panel 307, 311 & 312 valve markings	Griffith Not required G.P. Hanson			X	
MISC. (1)		SP113 to be filled out and evaluated	All		X		
		Retest due to pulling of C3H umb. connector P15 and circuit interrupter actuation	All		X		


S C 012 WORKING SCHEDULE
RECYCLE
LAUNCH
FRT OCP 0028
HYPER LOAD OCR 0038
APS LOAD & FIRE
INTERFACE MCCM TEST
RPI-LOAD
CDDT
JD BOT'L INSTL DR 899 SLA PNL DOOR
UNITIZED COBRA CABLES
UNITIZED COBRA CABLES SPARES
HYPER PREPS FOR OCP 0038
PREPS FOR FRT INSTALL
SPACECRAFT WORK
INSTALL DECAL
JIG AVAILABLE 1 27
WHITE ROOM
CAMERA MOD
48 HPS
STOWAGE EXERCISE
DR 934 VALVE MARKINGS CM PNL 307, 311, 314
TPS 530 DEBRIS TRAP
TPS 545 OCP 5044 WATER SERVICING
DR 849
DR 937 BRKT REBOND
T ADAPTER
SUPPORT FIX
MARK PM 623
TPS 548
DR 925
TPS 554 BALL VALVE CHECK
TPS 562 COVER STRAP EDGES MCR 3563
TPS 563 CHANGE RAFTS
COBRA CABLES TEY ADAPTERS BIC MED OUTER CABLES
PARTS AVAILABLE MCR 3570
TPS 566 REVISE HAMD CONT
NO MORE MCR WORK AFTER THIS TIME
TPS 564 FIT OPTICS CABLE
104 PILOT ASTR RECAL
MCR 1910 PROVIDE NEW CANISTER
DEL 2 3 CHANGE O2 REGULATOR
900 PSI
MCR 3570 WINDOW SHADES AVAILABLE
DR 933 PANEL 12
H2 PRESS METER
TPS 552 PANEL 13 & 14
GAS LEAK CMS
SPS FUEL & OPIO
DR 918
NO ESTIMATE OF FAB COMPL AT DOWNEY ON FOLLOWING
MCR 1497 MARKINGS ON RENDEZVOUS WINDOW ENGINEERING RELEASE 27
MCR 1899 PAINT SWITCH GUARD PILOT SME ENGINEERING RELEASE 1 27
MCR 867 TOGGLE SWITCH ON CREW UMBILICAL CABLE
NEW WORK FAB COMPLETION DATES
MCR 1866 GFE STOW
MCR 1851 GFE STOW
MCR 1865 STOWAGE MOD KIT

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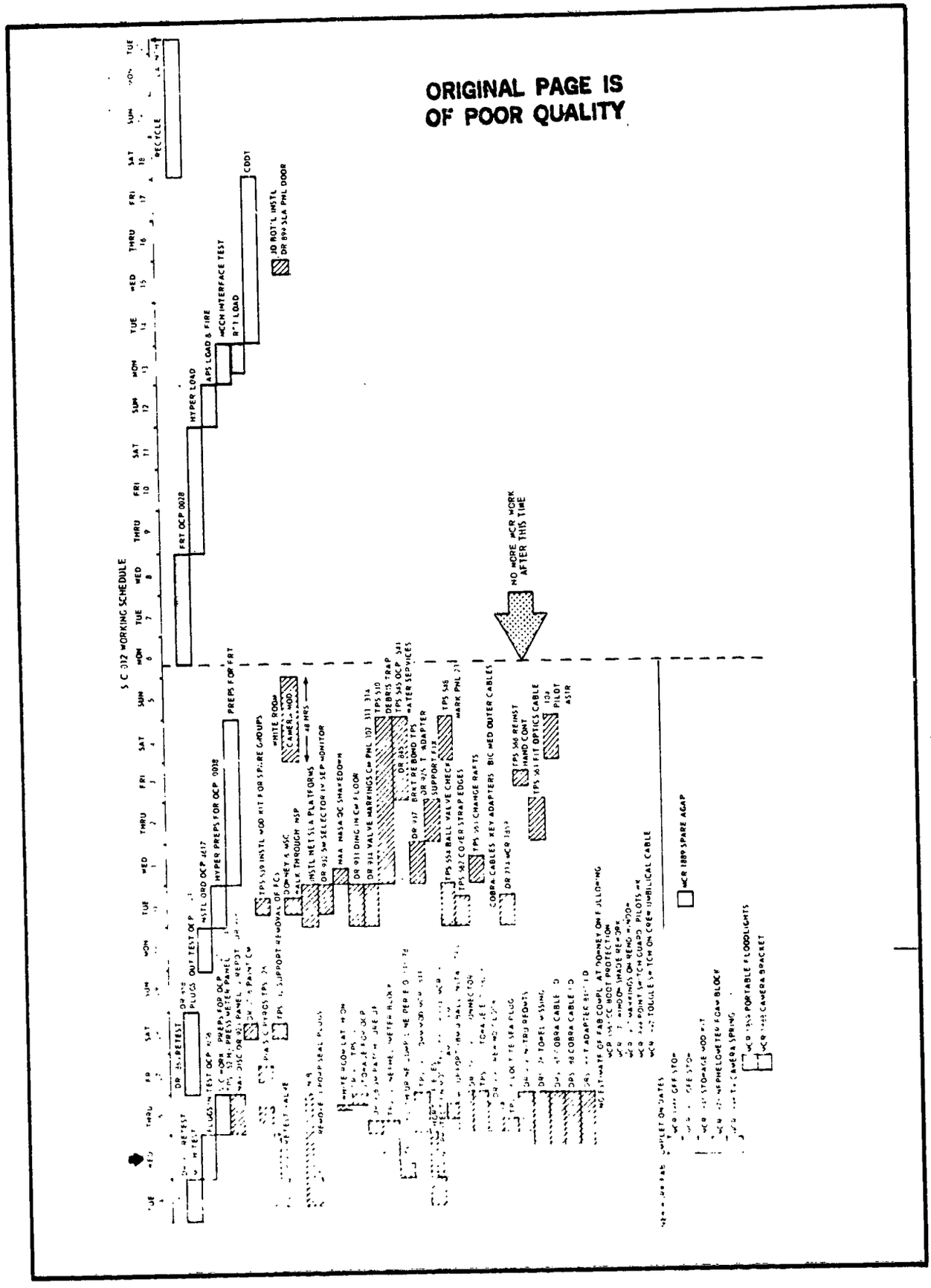


DEVELOPMENT HISTORY

PLUGS OUT TEST

OCP-K-0021

12 July 1966	- SP-64,, "S/C 012 Test Outlines". published for a preliminary review to be completed by 20 July 1966.
	- PURPOSE OF OCP-K-0021
	A. To verify overall S/C L/V compatibility and demonstrate proper function of S/C systems with all umbilicals and GSE disconnected.
	B. To verify no electrical interference at time of umbilical disconnect.
10 August 1966	- SP-64, retitled "S/C 012 - S/C 014 Florida Facility Test Flow Plan" was published.
	- PURPOSE OF OCP-K-0021 - No changes

- Presented to Checkout Management Panel #24, (MSC/KSC/NAA).

- No significant changes to L/C 34 testing were requested by the Checkout Management Panel.

- TEST CONFIGURATION

A. S/C and L/V were mechanically mated, and were electrically mated through fuse boxes.

B. S/C Internal Power Sources:

1) Pyro batteries (test) installed.

2) Entry and Postlanding batteries installed.

3) SM jettison controller (SMJC) batteries (test) installed.

4) GSE test batteries used to replace fuel cells.

5) GSE power to Spacecraft busses.

C. Installed Pyros disconnected and shorted.

D. Forward Heat Shield installed.

E. CM and SM RCS Simulators connected.

F. G and N Flight Ropes.

G. ECS CM W/G circulation.

H. Operational TV camera mounted.

I. LES installed and electrically and mechanically mated to CM.

J. Flight Qual and DSE Recorders loaded with Degaussed Tapes.

K. ACE Carry-on disconnected.

L. Physiological Simulators installed (MDAS connected).

6 September 1966 - Reviewed and redefined plus-time operation, specifically regarding the scope of G&N programs to be conducted during the altitude chamber runs and plugs out tests. This was done to adequately divide all the G&N checkout among the separate OCP's which have plus-time mission sequences.

19 September 1966 - Flight crew requested emergency egress practice prior to Countdown Demonstration Test due to hazardous conditions in the CDDT resulting from fully fueled Launch Vehicle.

20 September 1966	- Rough draft sent to keypunch for preliminary flimsy printout, delivered 21 September.
26 September 1966	- Flimsy copy of OCP to NAA Safety for electrical hazard review.
27 September 1966	- Decision made in NASA/NAA OCP Control Board Meeting this date to run emergency egress test after completion of the mission runs in OCP-K-0021. The following was then coordinated with the back-up crew Command Pilot: A. Back-up crew to participate in the test, then the prime crew would perform a normal ingress and the emergency egress test during L/V reset period. (See sequence 07-310, Page 7 - 56 of OCP-K-0021-1.) B. GSE air and open hatch for simulated mission by back-up crew. Full hatch close out (including Boost Protective Cover) for prime crew emergency egress test. C. Prime Crew wanted normal pre-T-0 ingress and closed hatch during simulated flight missions, but

	the ELS Sequencer Controller Pressure Stimuli Generator (C14-451) would have interfered with hatch close-out.
	D. The purpose of OCP-K-0021 was changed to add, "C. To verify astronaut emergency egress procedures (unaided egress)."
	E. On this date, review comments from 21 September were sent to keypunch for a second set of flimseys.
4 October 1966	-Third set of flimseys printed for mark-up.
19 October 1966	- Distributed printed preliminary hard copies of procedure for review. Had been submitted for printing on 14 October.
30 October 1966	- Formal review meeting held. Attended by all systems except G&N.
31 October 1966	- In accordance with Astronaut and checkout team desires, and following a technical investigation, it was agreed to delete the ELS Sequencer Controller Pressure Stimuli Generator from the test thus allowing the

following test philosophy changes:

A. Allow performance of normal flight crew countdown. (OCP-K-5117) (This is the astronaut procedure from wake-up to arrival at the launch complex.)

B. Back-up crew to perform their normal launch day functions.

C. Prime crew to ingress and run entire test as on launch day.

D. Emergency egress test to be performed by prime crew after simulated landing.

E. Normal cabin hatch close-out and running of the test on O_2 were results from these decisions

7 November 1966 - Crew Systems Stowage was added to be performed as part of the test set-ups per request of local MSC crew support personnel.

15 November 1966 - G&N information available. Coordination with L/V procedures in progress.

21 November 1966 - Received the mats for printing the basic issue of OCP-K-0021.

7 December 1966 - Six copies of the final master flimsy were presented to Systems Engineering for final review.

10 December 1966	- Final mats approved, cover sheet signed, sent to print shop.
13 December 1966	- Procedure published and released formally.
13 January 1967	- Meeting held at KSC attended by the prime crew Pilot (MSC), Lou DeWolf (FCSD), Tom Grier (FCSD), Don Nichols (KSC), and F. J. Powell (NAA), the following items were discussed and tentatively agreed to: A. Back-up crew was to perform a panel-by-panel check of all C/M controls during "Back-up Crew Pre-Launch Checks." (See sequence 8.5, 8.6, and 8.7 of OCP-K-0021.) These checklists were to be conducted on a switch-by-switch basis over the intercom. B. After ingress, the prime crew was to perform a panel sweep of the display console and associated panels which can be reached from couches (lower equipment bay not to be rechecked). This checklist was not to be called out over the intercom. C. The information to be contained in the switch lists in Items A and

and B above, were discussed and mutually agreed upon. This information was subsequently provided to FCSD for incorporation in Section 1 and Section 2 of the Crew Abbreviated Checklist.

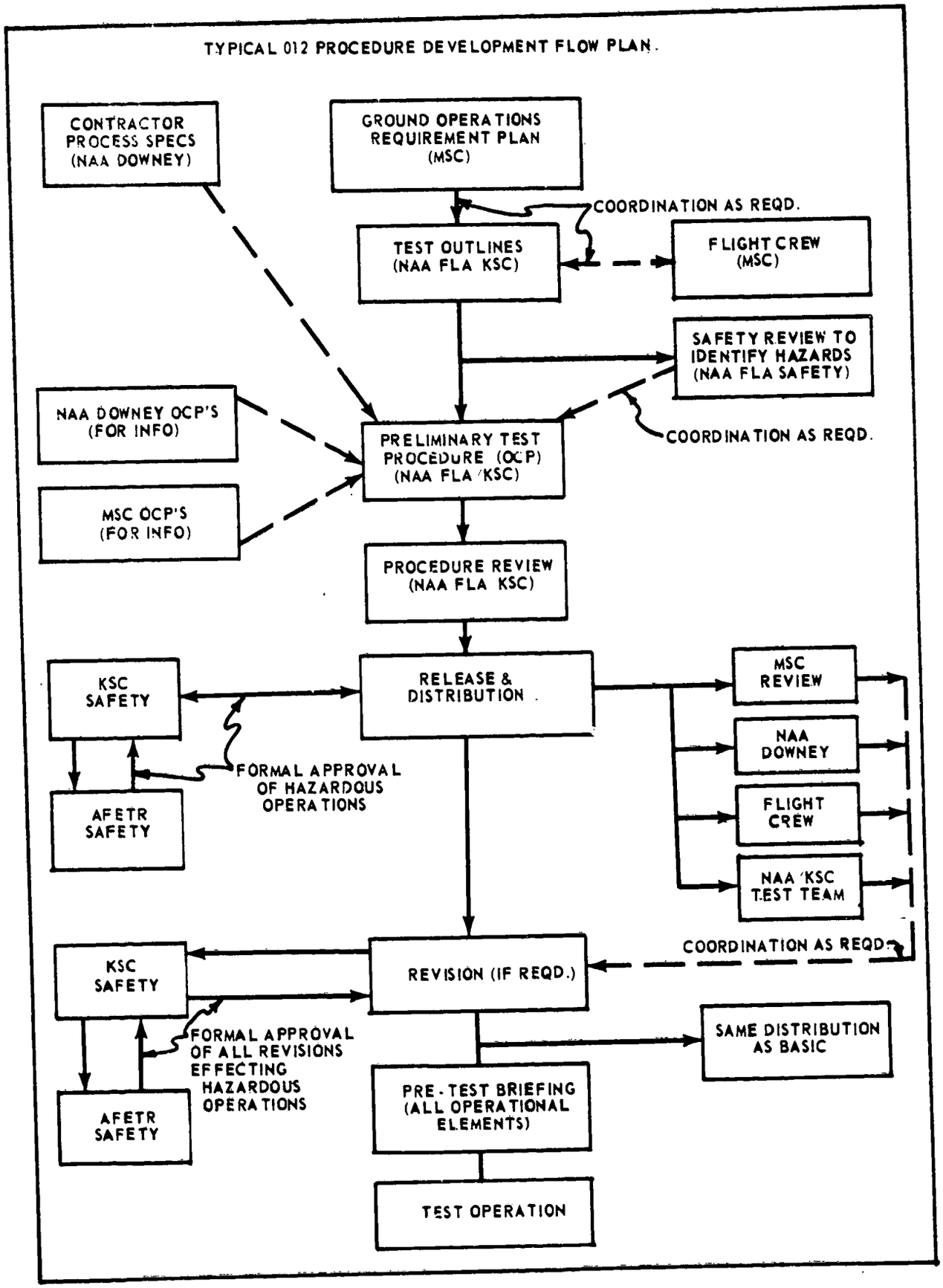
D. Panel nomenclature was called out in all switch lists. In a case where simplification of call outs could be made, the Test Conductor was to combine such call outs as "Main A", "Main B", and other similar switch nomenclatures.

E. Plugs In, Plugs Out, Flight Readiness, and Countdown test procedures were revamped to a standard minus time operation from approximately T-2 hours to liftoff.

F. All S/C 012 OCP's had been written utilizing the 14 November 1966, S/C 012 Crew Checklist (SM-2A-03) as a reference document.

From this date (1/13/67), NAA was in the process of updating procedures to the 5 January 1967, version plus

	the changes that would be supplied by FCSD in their 16 January 1967, revision.
23 January 1967	- Preliminary Launch Countdown, OCP-K-0007, was published. This procedure provided a baseline from approximately T-3 hours to T-Zero for use in the Plugs Out Test.
26 January 1967	- (5:30 p.m.) Rev. -1 consisting of 209 pages was released with update from OCP-K-0006, Plugs In Test experience, plus 4 weeks information accumulations and incorporation of agreements made in the 13 January meeting. See Attachment 7-3 for details and dates related to the reasons for the -1 Revision of OCP-K-0021.
27 January 1967	-(10:00 a.m.) -1 Revision A delivered. All changes affected plus time sequences only. (Four typed pages in lieu of having to write on-station deviations.)



ENCLOSURE 7-4

UNITED STATES GOVERNMENT

Memorandum

TO : Apollo 204 Review Board Panel - Task No. 7
Test Procedures Review/Attn: Nichols, Chairman

DATE: February 13, 1967

FROM : Chief, Safety Office, RE

RE-1/106/Barnett:mr
867-3973

SUBJECT: Test Procedures Review for Hazardous Operations

1. The requirement for the KSC Safety Office and the Air Force Range Safety review of test procedures for hazardous operations is specified in Section I, paragraph 3, page A-1 of KMI 1710.1, Attachment A, dated October 4, 1966, and Section C, paragraph 3, page C-5 of AFETRM 127.1 Range Safety Manual dated 1 November 1966.

2. Some operations that have been specified as hazardous in nature are as follows:

a. Propellant servicing

b. Pressure testing

c. Pyrotechnic (ordnance) work

d. Radioactive and toxic material operations

e. Operations with hazardous gases

3. The responsibility of submitting hazardous test procedures for Safety approval is with the contractor. A test to be conducted on Cape Kennedy requires 5 copies of the Test Procedure to be submitted to the KSC Safety Office. One of these copies is retained by the KSC Safety Office and one is sent to Bendix Systems Safety for comment; three copies are then forwarded through the Apollo/Saturn I-V Requirements Branch, DK-3, to Air Force Range Safety (ETOSH) for review and approval.

4. Comments from ETOSH and Bendix Systems Safety are submitted to the KSC Safety Office, who in turn transmits the comments to the contractor for incorporation into the OCP.

5. It should be noted that the AFETRM 127-1 Range Safety Manual requires a minimum of 30 days for review of documents. Apollo Procedure submittals have been very delinquent in meeting this time requirement. The late submittal of procedures has repeatedly been brought to the attention of North American and Spacecraft Operations in various meetings and correspondence. Some procedures have been submitted with as little as two days

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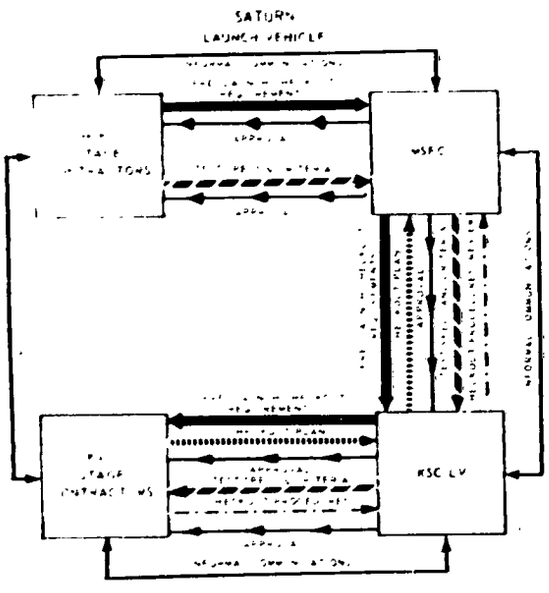
allowable Safety review time. Also, changes to an approved procedure have been published on the day of the test, thereby eliminating any allotted time for Safety review.

6. OCP-0021, S/V Plug Out Integrated Test was reviewed for S/C 009 and was classified as a non-hazardous test, thereby eliminating required Safety approval. This type procedure is not again submitted to KSC Safety for review unless it is changed in such a way as to make the Operating hazardous. OCP-0021 for S/C 012 was not submitted to the KSC Safety Office for approval.

for John R. Atkins

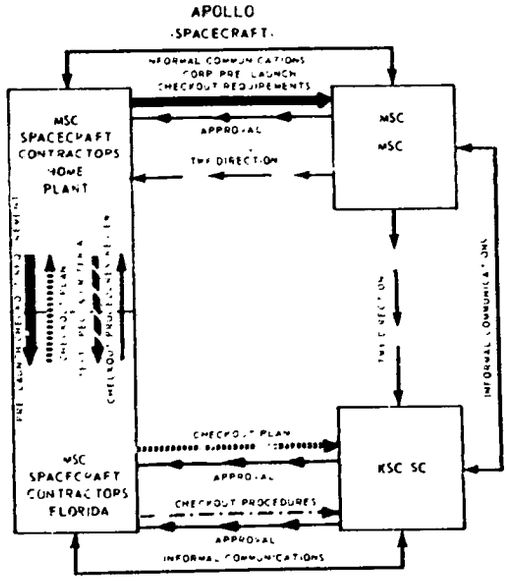
ENCLOSURE 7-6
D-7-59

PROGRAM CONTROL OF PRE LAUNCH TEST REQUIREMENTS



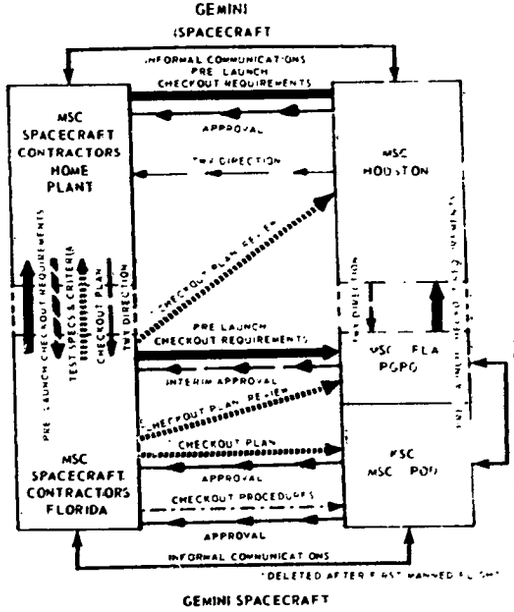
SATURN LAUNCH VEHICLE

- DELEGATION OF PRE LAUNCH CHECKOUT AND LAUNCH IMPLEMENTATION RESPONSIBILITY TO KSC FROM MSFC
  - A FORMAL INTER CENTER AGREEMENTS
  - B KSC CONTROLLED SUPPLEMENTAL CONTRACTS TO IMPLEMENT DELEGATION



APOLLO SPACECRAFT

1. CENTRALIZED AUTHORITY RETAINED AT MSC
   - A SLOW RESPONSE LOOP
   - B MSC APPROVAL CONSTRAINS NORMAL PRELAUNCH ACTIVITY
2. INTER CENTER AGREEMENTS NOT FORMALIZED
   - A INTERFACE OF CENTERS ROLES AND MISSIONS NOT CLEARLY DEFINED



GEMINI SPACECRAFT

1. LAUNCH SITE AUTHORITY WITH QUICK RESPONSE CAPABILITY TO MEET DYNAMIC NEEDS OF REAL TIME OPERATIONS
2. MSC CONTRACTUAL LOOP NON RESTRAINING WITH AFTER THE FACT CLOSURE ON QUARTERLY BASIS

FLIGHT VEHICLE TEST DOCUMENTATION

PRELAUNCH CHECKOUT REQUIREMENTS

PURPOSE: Defines and Levies General Checkout and Operations Requirements.

SATURN LAUNCH VEHICLE	APOLLO SPACECRAFT	GEMINI SPACECRAFT
PRELAUNCH TEST AND AND CHECKOUT REQUIREMENTS	GROUND OPERATIONS REQUIREMENTS PLAN	SEDR 9882
1. Class I Document (KSC) 2. Prepared by MSFC Stage Contractor for MSFC 3. Approved by MSFC Stage Manager 4. Content A. System Oriented B. Treats System Functions not Methods or Sequences C. Launch Site Oriented 5. Format – Tabular 6. Delivery Schedule A. Original – 1 to 2 Months Prior to Vehicle Delivery B. Revisions – as Required SUMMARY: Requirements are Levied without Restraining Sequence or Method of Implementation.	1. Class I Document (S/C Contractor) 2. Prepared by A. S/C Contractor (Home Plant) B. KSC Informal Inputs to MSC 3. Approved by MSC Contracting Officer 4. Content A. Operations Outlined in Detail B. Specific System Operation Defined C. Flow Oriented – Factory thru Launch Site 5. Format – Tabular 6. Delivery Schedule A. Original – 18 Months Prior to Delivery Due to Its Utilization as a GSE Provisioning Document B. Revisions – Continuous SUMMARY: Optimum Effectiveness not Achieved as a Test Requirements Document Due to its Utilization as a GSE Provisioning Document and the Excessive Level of Detail in its Contents.	1. Class I Document (S/C Contractor 2. Prepared by A. S/C Contractor (Florida) (with KSC Inputs for MSC) 3. Approved by MSC Contracting Office (after GPO Agreement) 4. Content A. Program Document with Table Showing Requirements per Vehicle B. Treats Test Objectives, not Methods or Sequences C. Launch Site Oriented 5. Format – Tabular 6. Delivery Schedule A. Original – 1 to 2 months Prior to Delivery B. Revisions – Updated at 3 month Intervals (Includes after the Fact Changes) SUMMARY: Prepared at Launch Site with Real Time Approval Allowing after-the-fact Contract Revision.

TEST SPECIFICATIONS AND CRITERIA

PURPOSE: To Furnish Specs and Criteria Applicable to System Performance During Prelaunch and Launch Operations.

PRELAUNCH CHECKOUT SPECIFICATIONS AND CRITERIA (KSC)

1. Class I Document (KSC)
2. Prepared by MSFC Stage Contractor for MSFC
3. Approved by MSFC
4. Content
   - A. Systems Information by System
   - B. Field Tolerances by System
5. Format - Tabular
6. Delivery Schedule 1 to 2 Months Prior to Vehicle Delivery

SUMMARY: One Integrated Document Per Stage Scoped to Cover Normal Testing, Troubleshooting, And/or Detailed Testing.

PROCESS SPECIFICATION MA0201-XXXX (BLOCK I)

1. Class III Document
2. Prepared by S/C Contractor (Home Plant) Engineering For External Use
3. Approved by Contractor Proj. Engr.
4. Content
   - A. Step-by-step Like a Checkout Procedure
   - B. One Integrated Document Per Test
5. Format - Written Like Launch Site Checkout Procedures
6. Delivery Schedule Four Months Prior to Test

SUMMARY: Scoped by Test in a Format Which Makes Its Use, As a Reference Document for Specific System Values, Difficult.

PERFORMANCE AND CONFIGURATION SPECIFICATION (MAC REPORT A-900)

1. Class I Document (S/C Contractor)
2. Prepared by S/C Contractor (Home Plant) for MSC
3. Approved by MSC Contracting Office
4. Content
   - A. Mission Performance Specification by System
   - B. Configuration by System
5. Format - Narrative/Tabular
6. Delivery Schedule Two Months Prior to Spacecraft Delivery

SUMMARY: One Integrated Document Per S/C, Scoped to Cover Normal Testing Level. Troubleshooting And/or Detailed Testing Required is Referenced to Lower Level Documents.

CHECKOUT PLAN

PURPOSE: To Provide an Outline of the Testing and Checkout to be Performed.

CATALOG OF LAUNCH VEHICLE TESTS

1. Class I Document (KSC)
2. Prepared by KSC Stage Contractor for KSC
3. Approved by MSFC Upon Submission
4. Content
   - A. Test Objectives
   - B. Brief Test Description
   - C. Test Support Requirements
5. Format – Narrative
6. Delivery Schedule
   - A. Original - 6 Months Prior to Vehicle Arrival

SUMMARY: KSC Response to the MSFC Prelaunch Test and Checkout Requirements.

FLORIDA FACILITY TEST FLOW PLAN

1. Class III Document
2. Prepared by MSC S/C Contractor (Florida) for KSC
3. Approved by
   - A. S/C Contractor (Florida)
   - B. KSC
4. Content
   - A. Test Objectives
   - B. Brief Test Description
   - C. Detailed SC/GSE Configuration Matrices
   - D. Detailed Outline of Each Test and Operation
   - E. Safety Requirements
5. Format – Narrative and Tabular
6. Delivery Schedule
   - A. Original - 2 Months Prior to SC Arrival

SUMMARY: Locally Generated at KSC To Define Scope and Method of Spacecraft Checkout at KSC.

TEST OPERATIONS PLAN (SEDR 301)

1. Class III Document (S/C Contractor)
2. Prepared by S/C Contractor (Florida) for KSC
3. Approved by
   - A. S/C Contractor (Florida)
   - B. KSC
4. Content
   - A. Test Objectives
   - B. Brief Test Description
   - C. SC/GSE Configuration
   - D. Brief Test Outline
   - E. Hazards (Safety)
5. Format – Narrative
6. Delivery Schedule
   - A. Original - 7 Months Prior to SC Arrival

SUMMARY: Document Replaced After First Manned Launch By Test Matrix Containing Similar Information.

CHECKOUT PROCEDURE

PURPOSE: To Provide Detailed Step-by-step Procedure for Performing Each Test and Operation.

DETAILED OPERATING PROCEDURE (DOP)	OPERATION CHECKOUT PROCEDURE (OCP)	SERVICE ENGINEERING DEPARTMENT REPORT (SEDR)
1. Prepared by Local Contractor for Local NASA		
2. Approved by Local Contractor and Local NASA		
3. Content – Detailed, Step-by-step Procedure	SAME	SAME
4. Delivery Schedule –		
A. Preliminary - 30 Days Prior to Use		
B. Final - 5 Days Prior to Use		
C. Revisions - As Required		

DOCUMENTS REQUIRED IN DIRECT SUPPORT ON THE PLUGS OUT TEST

1. Spacecraft Plugs Out Procedures FO-K-0021 S C 012 014
2. Launch Vehicle Plugs Out Procedure
3. Space Vehicle Plugs Out Procedure, T-20015-SA204
4. GSE Checklist FO-K-10011 S C 012
5. Crew countdown FO-K-5117 S C 012

AO-67-32

INTERNAL LETTER
North American Aviation, Inc.

Date: 23 February 1967

TO: Apollo Supervision
Address: 42-820, 818, 41-696/697

FROM: J. L. Pearce, 42-818 ZK1A
Address: S. M. Treman, 41-696-697 HC3

Phone: 867-6151
923-1121

Subject: Memorandum of Understanding - Coordination of Preparation of Engineering Test Specification and Major Test Outline Document for Florida Facility Block II Apollo Spacecraft Test Operations

The purpose of this memorandum is to record understanding of responsibilities for coordinated preparation between the Florida Facility and Downey Spacecraft Design of the test specification and criteria and FF Major Test Outline documents for Block II Apollo spacecraft operations at KSC.

Specifically, C/O Integration and Combined Systems (D/697-400) is responsible for the preparation of a document to provide requirements for Block II spacecraft functional test and servicing operations to be performed at KSC. The document is to be modular in form and generally system-oriented. It shall be consistent with the requirements of the applicable Block II S/C GORP.

The document will be prepared with the direct support of Florida Facility Apollo Engineering (D/820) and Apollo Operations (D/818). Active coordination channels will be established to assure that the form, content, and details of the document meet the needs of Apollo S/C operations as planned and scheduled by the Florida Facility organization.

Florida Facility Apollo Operations (D/818) is responsible for the preparation of the Major Test Outline document applicable to Block II S/C KSC operations in coordination with D/820. This document will meet requirements contained in the test specification and criteria document and will be in accordance with the applicable Block II S/C GORP. The document will be submitted to D/820 for review and concurrence. The document will simultaneously be provided to D/696 and 697 for review and comments. These comments will be provided to D/820. D/697-400 will provide technical support to D/818 as necessary during document preparation. A summary of the contents of the FF Major Test Outline document is enclosed (See Attachment 1).

D/820 is responsible for assuring that OCP outlines satisfy the requirements of the test specification and criteria document. D 820 will take necessary action to assure that these documents are compatible. D 820 will, in this capacity, directly support

D/697-400 in the timely on-the-spot assurance of test specification/OCP outline compatibility.

Following initial EO release of the test specification, Downey changes must be implemented utilizing existing Engineering procedures. Copies of EDC's will be supplied to FF for advance information. Changes initiated by FF must be implemented utilizing the FEO/FCA system.

A flow chart depicting the channels of communications and coordination is enclosed (See Attachment 2).

To facilitate coordination and implementation of the provisions of the memorandum, single point contacts will be named in Departments 818, 820, and 697-400. The prime coordination contact at KSC for interfacing with D/696 and 697 will be provided by D/820.

J. L. Pearce
Director CSM
Florida Facility

S. M. Treman
Director
Spacecraft Design

cc: G. W. Jeffs
R. L. Renner
A. B. Kehlet
G. R. Merrick
L. G. Rochester
M. Karp
J. P. Proctor
R. E. Barton

Attachment 1

DEFINITION OF SECTIONS OF THE FLORIDA FACILITY MAJOR TEST OUTLINE DOCUMENT

SECTION A .

Internal Power Configuration Plan

A chart showing usage of batteries, battery substitute units, fuel cells, fuel cell simulators and fuel cell substitute units as a function of various major KSC tests.

SECTION B

GSE Utilization Plan

A chart showing usage of GSE models and DTT's on a per test basis.

SECTION C

Spacecraft Test Plan

1. A chart showing types of missions and aborts on a per test basis.

2. A prose description of each test defining the test objectives and clarifying the goals of the days activities.

SECTION D

Test Limitations

1. References appropriate placards and limitations guide.

2. References appropriate KSC and ETR safety limitations.

3. Describes the limitations of the allocations of activities per test to insure that total KSC testing does not exceed limits.

SECTION E

Spacecraft Flow Plan

A sequential listing of the details of the test flow plan intended as a guide to checklist preparation.

Attachment 1

SECTION F

Plan of System Testing

Either a prose description or a matrix, as appropriate, showing the plan for all KSC test on a per system basis. It is intended to be a convenient guide to all parochial interests to examine the plot of each system in Florida. This section also includes a table of measurements tested and on-board display correlation with telemetry on a per test basis.

SECTION G

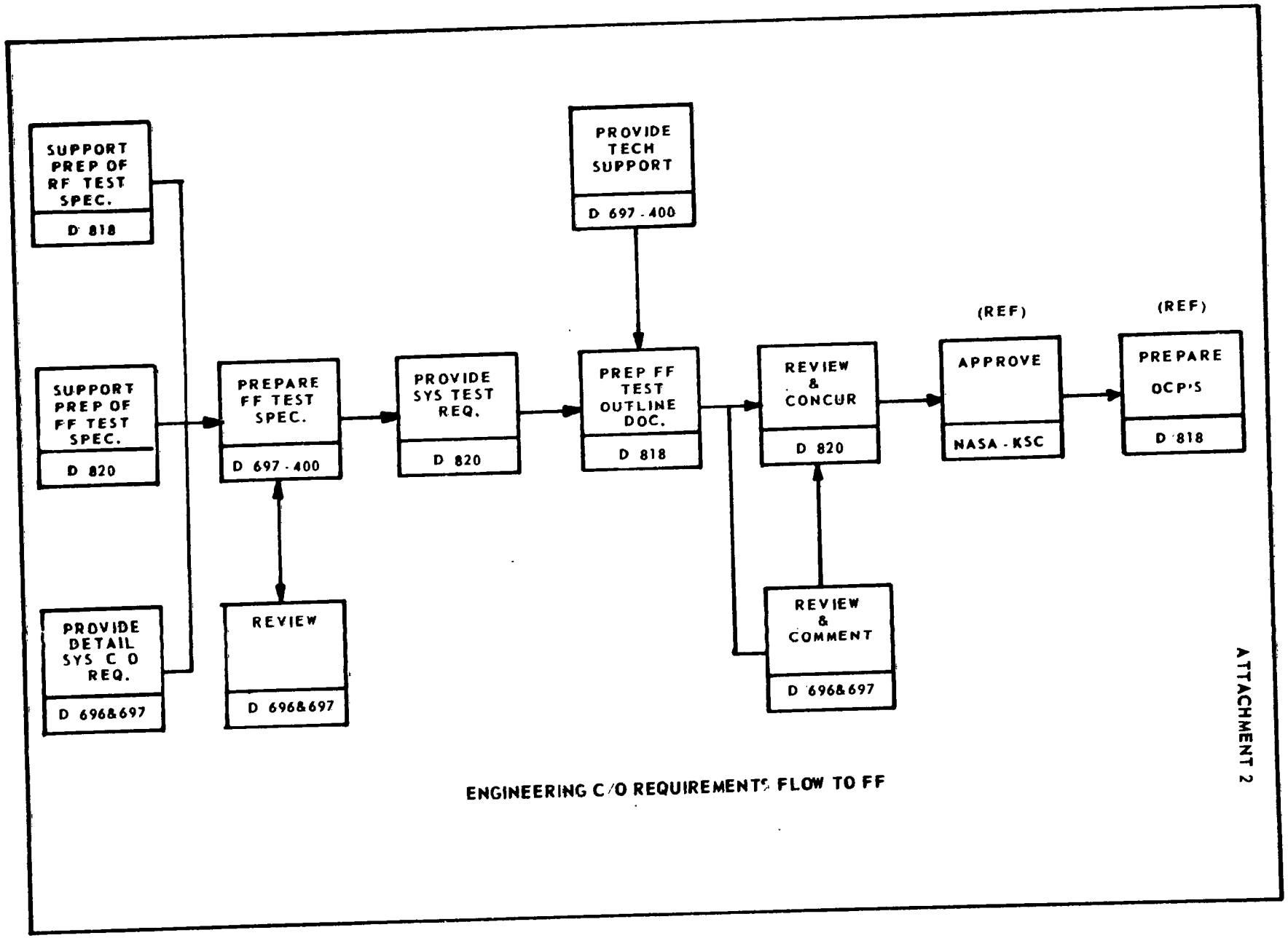
Mission Test Sequence

A sequential listing of all normal or backup event blocks. Does not conform to the flight plan. The intent is to detail all items occurring while going thru an exercise. Test outlines would then pick out selected blocks for performance as appropriate considering the primary test objectives.

SECTION H

Test Outlines

A detailed step by step outline of each OCP from beginning to end. Each item in the outline would be the same as a block title in either the Appendices or the Mission Test Outlines.



ENGINEERING C/O REQUIREMENTS FLOW TO FF

ATTACHMENT 2

INTERNAL LETTER
North American Aviation, Inc.

AO-67-34

Date: 2 March 1967

TO Address: Apollo Supervision 42-820, 818, 41-696/697

FROM Address: J. L. Pearce, 42-818 ZK1A
S. M. Treman, 41-696/697 HC30

Phone: 867-6151
923-1121

Subject: Memorandum of Understanding -
Concerning the Form, Content, and Intent of the Block II Florida Facility Engineering Checkout Process Specification

REFERENCES: (a) Memorandum of Understanding, J. L. Pearce and S. M. Treman, Coordinated Preparation of Engineering Test Specification and Major Test Outline Document for Florida Facility Block II Apollo Spacecraft Test Operations, dated 23 February 1967

(b) Meeting at Florida Facility, 28 February 1967, Attended by E. E. Dale, W. F. Cahill, W. L. Eckmeier, W. F. Edson, H. E. Heilman, R. H. Jones and T. H. Linsday

The purpose of this memorandum is to describe the format and objectives of Sections 4.0 and 5.0 of the CSM Checkout Process Specification being prepared for Florida Facility Block II spacecraft prelaunch checkout operations by D/697-400, Checkout, Integration and Combined Systems. This memorandum is an addendum to Reference (a) in order to provide the details of the Process Specification.

The proposed specification, in consonance with the Vehicle Plan (GORP) for Block II Apollo spacecraft, is the logical extension of Part II of the Contract End Item Specification in that the latter document contains only Downey located post-manufacturing checkout operations.

Florida Facility D/820 Systems Engineers and D/818 Operations Integration Engineers and Publications Analysts require firm, accurate, and timely engineering documentation from Downey Spacecraft Design in order to plan and prepare mission oriented Operational Checkout Procedures (OCP's) for those Apollo CSM spacecraft intended for checkout and launch from the KSC. The following stipulations and definitions defined at the Reference (b) meeting will produce a readily usable document to satisfy this requirement:

A. Stipulations -

1. The specification should provide Downey Engineering CSM checkout requirements; and these should be compatible with the applicable GORP. Tests subsequently identified at the Florida Facility as special or additional requirements will be coordinated with Engineering and EO's generated for permanent specification changes.

Form 131 R Rev 2 63

2. For KSC checkouts required, it should provide requirements and planning constraints in Section 4.0 and specifications and criteria including operational constraints in Section 5.0. These data should be in the form of hardware performance values and tolerances relative to a specific operating condition.

3. The specification should be subsystem oriented and must be approved by Subsystems Design Groups.

4. It should include a definition of relationship to other documents and will take precedence over subsystem level process specifications. Subsystem specs are not effective at F/F.

5. It should be controlled by the Engineering change system including field change procedures.

6. An EO on a subsystem process specification will not be effective on this specification. However, changes applicable to this specification must be generated immediately to keep the specifications compatible.

7. Initial issue of Section 4.0 should be five (5) months before CSM arrival at KSC. Initial issue of Section 5.0 should be four (4) months.

8. It should be updated 30 days before CSM arrival at KSC; subsequent updating at 30 day intervals should be accomplished until a final EO incorporation is accomplished after launch.

9. A tabular form should be used for stimuli and measurement tolerances, torque values, etc (with respect to system condition).

10. The Launch Mission Rules will take precedence for launch.

B. Definitions -

Section 4.0 - "Checkout Requirements" (Definition of the Engineering requirements per subsystem for checkout at KSC.)

Presents the following: (See Exhibit No. 1 attached)

1. Test code number

2. Brief description of the required subsystem checkout.

3. Statement of major checkout planning constraints (e.g. is a prerequisite to another checkout; time/cycle limitations).

Release date for this portion of the specification will be five (5) months prior to spacecraft delivery. Subsequent updating at 30 day intervals.

Section 5.0 - "Specifications" (A statement of hardware performance values per subsystem with respect to a specific input or operating condition.)

Presents the following: (See Exhibit No. 2 attached)

1. Brief system functional performance description.

2. Measurement number and title.

3. Stimuli characteristics (e.g. amplitude, frequency, duration, pressure, etc.).

4. Performance (output characteristics with tolerance expressed as nominal +/-XX, in engineering units; also may involve other characteristics such as acceptable leakage rate, as applicable and should be compatible with Launch Rules.)

5. Operational constraints affecting specified performance values.

6. Critical spacecraft configuration and interface requirements.

Release date for this portion of the specification will be four (4) months prior to spacecraft delivery.

This memorandum states the mutual agreement of the undersigned to the form, content and intent of a single checkout process specification for each Block II Apollo CSM that will receive a prelaunch checkout at KSC.

J. L. Pearce
Director CSM
Florida Facility

S. M. Treman
Director
Spacecraft Design

cc: G. W. Jeffs
R. L. Benner
A. B. Kehlet
G. B. Merrick
L. G. Rochester
M. Karp
J. P. Proctor
R. C. Burton

EXHIBIT NO. 1

EXAMPLE

CHECKOUT REQUIREMENTS

(Section 4.0 of C/O Spec for Florida Facility)

TF0001 ENVIRONMENTAL CONTROL SYSTEM
SERVICING, ACTIVATION, AND VERIFICATION

Perform an ECS servicing, activation, and verification of the primary and secondary water-glycol loops, oxygen system, and suit loop system..

Performance of this checkout is a prerequisite to CSM system activation and verification operations.

TH0012 STABILIZATION AND CONTROL SYSTEM
FREQUENCY RESPONSE

Perform an SCS frequency response checkout to demonstrate capability to gimbal the SPS engine, using both primary and seocndary gimbal motors, with the proper magnitude, rate, and direction.

Frequency and step response must be verified in both the LEM OFF and LEM ON operating conditions.

EXHIBIT NO. 2

EXAMPLE

CHECKOUT SPECIFICATIONS

(Section 5.0 of C/O Spec for Florida Facility)

ENVIRONMENTAL CONTROL SYSTEM

The specifications applicable to ECS servicing are as follows:

FF5026P	W/G Supply Pressure	55 +/- 15 PSIA
FF5027Q	W/G Flow	200 +/- 20 Lb/Hr
FF5028P	W/G Diff Pressure	35 +/- 15 PSID
FF5029T	W/G Return Temp	55 +/- 10 Deg. F
FF5030T	W/G Supply Temp	35 +/- 10 Deg. F

The above specifications apply after system stabilization.

STABILIZATION AND CONTROL SYSTEM

The specifications applicable to SCS/SPS engine frequency response are as follows:

INPUT AMP (Deg./Sec.)	FREQ. (CPS)	TIME (Sec.)	MEAS.	NOMEN.	VALUE (W/ TO L)
3.0	0.318	15	CH3517	Gimbal Pos, Pitch	(XXX+/-X)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

TO: NASA Manned Spacecraft Center
Houston, Texas 77058

Attn: Dr. Joseph F. Shea
Apollo Program Manager

John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

Attn: General John G. Shinkle
Apollo Program Manager

Mr. Rocco A. Petrone
Director of Launch Operations

FROM: MA/Apollo Program Director

SUBJECT: Minutes of Meeting at KSC, January 26, 1967

Attached for necessary action is a copy of the minutes of the meeting held at Kennedy Space Center on January 26, 1967 to consider possible improvements in spacecraft checkout based on experience of the past year.

/S/ Samuel C. Phillips
Major General, USAF

Attachments (3)

DISTRIBUTION:
See attached list

MINUTES OF MSC/KSC/OMSF MEETING AT KSC
JANUARY 26, 1967

1. In accordance with an OMSF TWX 362 2204, dated December 22, 1966, a meeting was held at KSC (attendees listed in Attachment 2) to review spacecraft checkout experience over the past year and discuss actions that might be taken to improve checkout of subsequent spacecraft. Items discussed were those submitted by MSC and KSC prior to the meeting (Attachment 3).

2. The discussion of the agenda items resulted in the following agreements or actions:

   a. MSC and KSC to continue to track the 7 configuration verification discrepancies found by KSC on a spot check of 30 odd pieces of hardware to assure that the configuration control paperwork eventually reflects the "as is" condition and review the time lag between the hardware reconfiguration and the time this reconfiguration is reflected in the paperwork. A similar type spot check will be made on S/C 020.

   b. MSC and KSC will review the Cape receiving inspection records on 017 and consider the preparation or modification of inspection criteria for those items where the presence of well written criteria would tend to reduce inspection variances among Quality Control personnel.

   c. KSC will provide a Quality Control inspector to participate in the final inspection of subsequent spacecraft at Downey through spacecraft 102. MSC will also provide a NASA Quality Control inspector to participate in spacecraft receiving inspections at the Cape through 102. Data collected during these inspections will be used to refine and improve inspection methods and criteria.

   d. MSC will provide direction to see that all contractor and GFE non-flight hardware is clearly marked and so identified in the spacecraft paperwork.

   e. KSC will bring to the appropriate Program Manager's personal attention any non-flight hardware that is installed on a space vehicle and not clearly marked.

   f. KSC and MSC will arrange a subsequent meeting to discuss the other actions recommended in the KSC handout to improve overall quality and review the use of the Engineering Disposition Book.

   g. MSC indicated that PAR closeout action by NAA reflects the engineering order number or other specific written corrective action that has been taken to correct the problem.

   h. MSC will check to determine why EO number E15-420603 and 604 were not incorporated in spacecraft 017 before delivery to the Cape.

i. MSC will check recurrence control applied to the cabin relief valve (part number ME-284-0149-0021) to assure that the system is operating as it should.

j. KSC will provide MSC a specific list of areas where it would be helpful to consolidate several process specifications into a single process specification which summarizes requirements.

k. MSC will review MSC and NAA non-metallic crew bay material requirements documents to update them and assure they are compatible.

l. MSC will review NAA documentation on functional checkout and/or PIA time cycles on spare components and provide written guidance to KSC.

m. MSC will review the list of hardware problems presented by KSC in discussing design problems (electrical switch, communications cables, bi-metallic interfaces, DSE recorder, signal conditioner fuses, hand controller cable covering, water glycol and O_2 line installation) and assure that appropriate corrective action is in process.

n. MSC is preparing a revised flow plan and is reviewing the technical requirements to which the system and subsystem is tested as it progresses from assembly through checkout at the Cape. This system will be implemented for Block 2 spacecraft and will provide a better overview of the total testing done on flight hardware before launch. It will also assist in providing better visibility into the test status of hardware when the DD 250 is signed.

o. MSC will recheck the list of items indicated under Part VI, Level of Testing, in KSC handout to assure that the problems indicated have been fed back into NAA for appropriate corrective action.

p. MSC and KSC will take action to arrange for a joint review of the classes of problems found during checkout of each particular spacecraft after it has flown and discuss corrective action that can be taken to reduce the same type of problem on subsequent spacecraft.

q. MSC is taking action to assure closer control over the listing of engineering orders in the Configuration Verification Records of the appropriate spacecraft in accordance with the effectivity point in the EO.

r. MSC and KSC will have a meeting the week of February 13 and formally coordinate the Block II CSM, the LEM and the integrated Ground Operation Requirements Plans (GORP). Any unresolved problems will be presented to the KSC Program Manager and the MSC Program Manager for decision or submission to higher management levels for resolution. KSC will formally sign the basic GORP documents and approve all subsequent changes in writing. Coordination and sign-off on the GORP will be binding on both parties. Additional testing of the type specified in the GORP will not be added at

the Cape without formal coordination. Changes recommended by either party will be officially submitted to the otherparty for approval. Contractual direction to the contractors will not be provided by CCA until coordination has been accomplished. As a part of the meeting during the week of February 13, MSC and KSC will develop a written change procedure to permit expeditious revision of the GORP. During this meeting consideration will also be given to reviewing a proposed system for controlling operational checkout procedures (OCP's) including the necessary interface with engineering orders.

s. MSC (Mr. Kapryan) and KSC (Mr. McCoy and Mr. W. Williams) will develop a proposed procedure for integrating into a single Board the present MSC Configuration Control Board at the Cape and the KSC Spacecraft Change Implementation Board. This proposal will include membership, responsibilities, appeal procedures, documentation, signatures, and other appropriate items. This proposal will be prepared for coordination and approval of the KSC Program Manager and the MSC Program Manager. After completion of FRT approval to remove or replace spacecraft flight hardware (components, panels, cables, etc.) will require approval of appropriate KSC and MSC personnel. KSC will develop written procedures to implement this basic policy, and coordinate it with MSC (Mr. Kapryan).

t. A discussion of the procedure for processing of failed hardware led to reconfirmation that MSC makes the decision as to where failure analysis is to be conducted.

u. MSC will review the paperwork associated with the expeditious return of failed hardware to a vendor for repair and return to the Cape and make appropriate changes to facilitate the process.

v. The return of ACE Station No. 5 from GAEC to the Cape will not take place before August 1, 1967. Therefore checkout at the Cape through the summer of 1967 will be limited to 4 ACE stations. KSC will review ACE program development verification, number and experience of maintenance personnel and other factors associated with utilization of their ACE equipment and will develop by March 1, 1967, any necessary recommendations to assure checkout schedule will support the OMSF official working schedule. MSC (Dr. Lanzkron) will provide necessary assistance in considering the use of MSC ACE equipment to assist in sofrware development.

w. The Apollo Program Office (OMSF) is developing revised schedules which will show a working schedule based on an earliest possible launch date and assuming clean hardware is delivered from the factory. These dates are to serve as objectives for everyone to work toward in an effort to launch as early as hardware will permit and still assure mission success. This schedule will receive further review and discussion during the time period February 8-10.

/S/ Samuel C. Phillips
Director, Apollo Program
OMSF

/S/ Joseph F. Shea
Manager, Apollo Spacecraft
Program Office, MSC

/S/ John G. Shinkle
Manager, Apollo Programs Office
KSC

/S/ Rocco A. Petrone
Director, Launch Operations
KSC

SPACECRAFT CONFIGURATION

Altitude Chamber (K0034A) Versus Pad 34 Plugs Out (K0021)

ALTITUDE CHAMBER

Umbilical In
Carry-on Disconnected
Water/Glycol - Internal Circulation
H_2 Tank Pressurized with GN_2
Cryogenic O_2 Supplied by GSE
Water Tanks Filled
Inner Hatch Installed
Outer Hatch Not Installed.
LV Simulator Attached
GSE Power Supplied Through S/C Umbilical
Boost Protective Cover Not Installed

PAD 34

Umbilical In
Carry-on Disconnected
Water-Glycol - Circulated Through Spacecraft From GSE
Gaseous O_2 Supplied by GSE
Water Tanks Empty
Inner Hatch Installed
Outer Hatch Installed
Mated to Booster
Fuel Cell Substitute Unit Utilized

GENERAL INFORMATION (ALTITUDE CHAMBER RUN)

During the altitude chamber run, the spacecraft was powered up and all systems verified prior to crew ingress. After crew ingress, suit integrity tests are made and the inner hatch is closed.

The following functions were performed in the listed order after inner hatch closure.

a. Cabin purge and leak check.
b. Sleep switches installed in cobra cables (not applicable to plugs out, pad 34)
c. Post ingress switch list performed.
d. Logic and pyro busses armed
e. VHF FM, C-band transponder and S band checked.
f. Coolant temperature lowered to 45 ± 5 degrees F and the water glycol trimmed
g. Gas chromatograph signal checked.
h. Battery bus ties placed from off to auto.
i. Battery relay bus, battery A and B, circuit breakers closed.
g. Guidance system put in gyro compassing mode
k. The spacecraft was taken up to altitude. All testing and mission functions from here on were performed under altitude conditions (cabin pressure 5.71 psia, suit pressure 6.14 psia).

This points out that during the altitude runs, minimum testing is accomplished at sea level pressures. Whereas during the pad operation all testing is accomplished at sea level pressure.

The following list itemizes system tests performed on K0034 and K0021 prior to hatch closure

	K0034	K0021
G&N		
AGC Operational Test	X	X
DSKY Pushbutton Check	X	X
Uplink Downlink Check	X	X
Bank Sum Check	X	
G-Relay Alarm Checks	X	X
G&N Operations Test	X	X
Optics Power-on Test	X	X
GMC Clock Alignment	X	X
Negative Delta T	X	
SCS		
SCS Activate	X	X
BMAG Warm up	X	X
RF		
RI System VHF FM Test	X	X
C Band Test	X	X
Recovery Beacon	X	
VHF AM Test	X	X
HF Test	X	
S Band and TV	X	X
UDL UHF	X	
UDL		
End to end	X	
INSTRUMENTATION		
DSE	X	X
Flight Qual Recorder	X	X
ECS (See General ECS Configuration)		

The following list itemizes system tests and general configuration deltas between K0034 and K0021 after hatch closure and prior to lift off for mission run. Coded (a) designates test is performed at altitude

	K0034	K0021
Cabin Purge and Leak Test	X	X
Auto Water Boiling	X(a)	
SPS Abort and Reset	X(a)	
EDS Test		X
Normal Mission Preps	X(a)	X
Sleep Switches Installed in Umbilicals	X	
SPS Engine Gimbaled (MTVC)		X
RCS Static Firing		X
Floodlights On		X
FCSM SCS in SCS Mode		X
FCSM G&N Mode	X	
RCS Prop Isolation Circuit Breakers Closed		X
EVC Power 1 and 2 On	X	
Direct RCS On	X	
SCS Channel A C Mode	X	
2 Engine Out in Auto Mode	X	

LV Rates in Auto mode	X	
Water Accumulator in Auto Mode	X(a)	X
Non-Essential Telecon on AC 1	X	X
Non-Essential Telecon on AC 2		
Cryogenic Quantity Amplifiers On	X	
Drinking Water Supply On	X	
Gas Chromatograph Panel On (Not Installed for K0021)	X	
Battery C to Main Bus A - Open	X	
Battery C to Main Bus B - Open	X	X
Battery Vent in Vent	X	
O_2 Heaters in Auto	X	
H_2 Fans in Auto		

ECS PREPARATION PROCEDURE AND SYSTEM TEST

Comparison of ECS configuration in the manned altitude chamber run OCP KOO34 and L/C 34 OCP KOO21 Plugs Out Test.

	K0034	K0021
GSE WATER GLYCOL ADJUSTMENTS		
ECS Prep (GSE)	X	X
Trim Unit No. 1 and 2 Verification (GSE)		X
Refrigeration Unit 1 and 2 Verification (GSE)		X
Adjust R1 on S14-140 (GSE)	X	X
Transfer Trim and Refr Units to ACE control		X
Transfer accum. quantity to remote (GSE)		X
Transfer Trim and Refr units to manual (GSE)		X
S/C SYSTEM VERIFICATION		
Cabin Air Fan Checks	X	X
Suit Compressor Checks	X	X
ECS Pump Check	X	X
ECS Coolant Loop Check	X	X
Pressurize H2 Tanks with N2	X	
Cabin Temp Control Checks	X	
Glycol Pump Deadhead Check	X	
O2 Tank Purge	X	
Suit Circuit Purge 98% O2 (Note 1)	X	X
Cabin Press Using S14-079 at Hatch Adap	X	X
O2 Press Relief Valve Crack Press	X	X
O2 Press Relief Valve Reseat Press	X	X
O2 Purge 20 Min at 14.7 psia	X	X
O2 Purity (Note 3) % in Cabin	X	X
Increase O2 Pressure to (Note 2) Press and Perform Leak Check	X	X
Install Hatch Plug	X	X
Install Outer Hatch		X
ECS CONFIGURATION PRIOR TO LIFT OFF		
ECS Radiators On	X	X
Battery Vent	X	X
Glycol Compressor Pump 1 on AC	X	X
Cabin Air Fans On	X	X
Suit Compressor Pump 1 on AC 1	X	X
Gas Chromatograph Cabin Auto	X	
Gas Chromatograph Start	X	
Waste Tank Inlet Auto	X	X
Potable Tank Inlet Open	X	X
Press Relief Both	X	X
Waste Tank Servicing Valve Closed	X	X
Cabin Repress Closed	X	X
Direct O2 Flow Reg Off	X	X
Pot H2O Heater Off	X	X

Cabin Temp Auto (R4) Full Decrease	X	X
Cabin Temp (S12) Manual	X	X
Steam Press (S23) Auto		X
Steam Press (S24) Incr/Decr Enter (OFF)	X	X
Temp in (S25) Manual (Note 4)	Auto	X
Glycol Evap H2O Flow (S22) OFF (Note 5)	X	X
H2O Ind (S10) Potable	X	X
Suit Evap (S8) Manual	X	X
Waste H2O Tank Refill (S36) OFF	X	X
H2O Accum (S26) Auto 1	X	X
H2O Accum (S22) OFF (CTR)	X	X
H2 Fans OFF	Auto	X
O2 Fans OFF	X	X
O2 Heaters OFF	Auto	X
O2 Pressure Ind Surge Tank (S28)	X	X
H2 Heaters OFF	X	X
Suit Ht Exch Gly-Evap	Note 6	X
Demand Reg Selector 1 and 2	Note 6	X
Demand Reg (Suit Test) OFF	X	X
Oxygen Surge Tank ON	X	X
O2 S/M Supply ON	X	X
O2 Entry ON	X	X
Glycol Reservoir Inlet Open	X	X
Water and Glycol Tank Press Regulator and Relief Normal	X	X
Glycol Reservoir Bypass Close	X	X
Glycol Reservoir Outlet Open	X	X
Glycol to Rad Open	X	X
Safety-Latch OFF	X	X
Cabin Press Relief Right (Boost Entry)	X	X
Emergency Cabin Pressure OFF	X	X
PLSS Fill Valve Closed	X	X
O2 Main Regulator Normal	X	X
Suit Evap OFF	X	X
Evap H2O Auto	X	
Glycol Reserve OFF	X	X
H2O Accumulator 1 and 2 Remote	X	X
Glycol Evap Temp in Full Cool	X	X
Suit Flow Relief OFF	X	X
Suit Evap Glycol ON	X	X
Glycol Accumulator ON	X	X
Glycol Evap H2O Control Bypass OFF	X	Bypass
Suit Circuit Return Air Manual Valve Close	X	X
Surge Tank Press Relief Valve Auto	X	X
Glycol Press Bypass 1 and 2 ON	X	X
Louvers Cabin Open	X	
Drinking Water Supply ON	X	No Info
Cabin Temp As Is Battery Vent	X	No Info

NOTES. 1. Suit loop purge is performed twice prior to crew ingress in 0034.
2. 3-3.5 PSIG OCT 0021 and 5±.2 PSIG in OCP 0034.
3. 75% O2 purity required OCP 0034 and 95% O2 purity required OCP 0021 prior to crew ingress.
4. Difference is at 180 K altitude performing water boiling.
5. On for 3 minutes and then off in OCP K0034.
6. Removed by deviation 13-01 to update OCP to latest SW list configuration.

LIST OF REFERENCES

Reference documents used in the preparation of this report are as follows:

References

7-1 Spacecraft Operational Checkout Procedure FO-K-0021 - S C 012 014, updated Jan. 25, 1967. Titled: "Space Vehicle Plugs Out Integrated Test", dtd Dec. 13, 1966

7-2 GSE Checklist FO-K-10011-S C 012. Titled: "LC 34 Checklist", dtd Oct. 25, 1966

7-3 Crew Countdown FO-K-5117-S C 012. Titled: "Flight Crew Countdown", dtd Jan. 26, 1967

7-4 Vehicle Plan for Spacecraft 012 & 011 Section II, Part 1, Ground ooperations Requirements Plan (NAS 9-150), SID65-304-2-1, dtd June 19, 1966

7-5 Process Specification MA 0201-3214. Titled: "Overall Test No. 2 with Plugs Out Checkout Requirements for Spacecraft 012 & 011, Florida Facility, Launch Complex 34", dtd August 19, 1966

7-6 Spacecraft Operational Checkout Procedure FO-K-0034-A-1. Titled: "CSM Altitude Chamber Test", dtd Dec. 20, 1966

7-7 Apollo Pre-Flight Operations Procedure T-501, Pages 4 & 5. Titled: "Work Authorization - TPS", dtd June 27, 1966

7-8 Apollo Pre-Flight Operations Procedure 0-202. Titled. "Operational Checkout Procedure", dtd May 13, 1966.

7-9 Interim Discrepancy Report (IDR) No. 001 for OCP-K-0021, dtd Jan. 27, 1967

7-10 Daily Status Reports, Titled: "Status Report Spacecraft 012", dtd Jan. 23, 1967 and Jan. 27, 1967.

7-11 S C 012 Test Outline, SP-64. Titled: S C 012 - S C 014 Florida Facility Test Flow Plan, dtd Aug. 10, 1966

7-12 Space Vehicle Plugs Out Procedure, I-20015-SA 204, Titled: "Space Vehicle Systems Plug Drop Test", dtd Jan. 18, 1967

7-13 Apollo Crew Abbreviated Checklist Mission AS-204, dtd Jan. 23, 1967

7-14 KSC Prelaunch Test and Checkout Requirements for S-IU-206 and Subsequent, NAS 8-14000, dtd Dec 5, 1966

7-15 Prelaunch Test and Checkout Requirements for Saturn S-IB Stages, SDES-66-424, dtd Aug. 12, 1966

7-16 Catalog of Launch Vehicle Tests, Saturn V, Apollo Saturn 501, Section III of III Sections, Standby Procedures, GP-307, dtd Jan. 15, 1967

7-17 Catalog of Launch Vehicle Tests, Saturn V, Apollo Saturn 501, Section I of III Sections, Test Procedures, dtd Jan. 15, 1967

7-18 Apollo Saturn V Checkout Plan (AS-500F), K V-041, dtd May 1, 1966

7-19 Test Specification and Criteria, KSC Prelaunch Checkout and Launch Operations, S-IVB-206, 1B67207, dtd Dec. 8, 1966

7-20 S-IVB-502 Stage End Item Test Plan, 1B63789, dtd Nov. 18, 1965

7-21 KSC Prelaunch Test and Checkout Requirements, S-IVB 1B, 1B66258, dtd May 24, 1966

7-22 Annotated Copy OCP FO K-0021-1

7-23 EDS Overall Countdown Test, FO K-0042

7-24 Spacecraft Launch Preparation Test Outlines, Report No. 9882, McDonnell Aircraft Corp., SEDR 9882, dtd Dec 14, 1964

7-25 Gemini Spacecraft Number 12 Performance Configuration Specification, A900-12, dtd July 30, 1965

7-26 Project Gemini, Production Spacecraft Test Plan for Spacecraft Number 2, SEDR 301-2, dtd Feb. 25, 1964

7-27 Test Operations Production Spacecraft at AMR Facility, SEDR 309-1, dtd July 26, 1963

7-28 Project Gemini Test Operations Production Spacecraft at AMR Facility, SEDR 309 N, dtd Aug 30, 1963

7-29 Titan III Test Procedure Manual, MC-66-2, dtd Feb 1, 1966

REPORT OF PANEL 8
MATERIALS REVIEW
APPENDIX D-8
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Materials Work Panel, 8. The task assigned for accomplishment by Panel 8 was prescribed as follows:

Assemble and summarize data and analyses related to flammability of spacecraft materials. Results of other programs as well as Apollo shall be considered. Requirements for additional testing shall be recommended. Review Apollo test conditions for adequacy. Make recommendations for materials or configuration changes to alleviate fire hazard. Perform analyses as appropriate to determine overall energy balance, correlations with temperature and pressure buildup, etc.

In addition to the above briefly summarized Work Statement, a detailed Work Statement was prepared and submitted to the Board on February 1, 1967, which contained the following salient features in keeping with above Work Statement:

1. Assemble, summarize, compare and interpret requirements and data describing the flammability of nonmetallic materials exposed to the crew bay environment of the spacecraft and in related applications.
2. Specify and authorize performance of tests and/or analyses to furnish additional information as to flammability characteristics of these materials alone, and in combination with fluids known or postulated to have been in the Spacecraft 012 cabin.
3. This panel, in support of Panel 5 - Origin and Propagation of Fire shall interpret and implement the requirements for analyses of debris removed from the spacecraft.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Materials Work Panel:

Mr. W. Bland, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. A. Busch, Kennedy Space Center (KSC), NASA
Dr. A. Staklis, Manned Spacecraft Center (MSC), NASA
Mr. W. Riehl, Marshall Space Flight Center (MSFC), NASA
Mr. A. Archer, North American Aviation, Inc., KSC
Mr. R. Olsen, North American Aviation, Inc., Downey
Mr. E. Welhart, McDonnell Company, St. Louis

2. COGNIZANT BOARD MEMBER

Dr. M. Faget, Manned Spacecraft Center (MSC), NASA. was assigned to monitor the Materials Work Panel.

C. PROCEEDINGS

1. APPROACH

The activities of the Materials Panel were divided into three major categories in implementing the panel work statement (Ref. 8-74, 8-75, and 8-76):

a. Determine the nonmetallic materials configuration of Spacecraft (S/C) 012.
b. Determine combustion characteristics and properties of these materials.
c. Conduct special tests and investigations.

The special tests and investigations conducted are separated into four broad areas:

a. Fire Initiation
b. Fire Propagation
c. Materials Criteria and Controls
d. Displays and Information

Within the fire initiation investigation, several studies were undertaken. These dealt with potential spark ignition sources, spontaneous ignition sources, and impact ignition sources.

The fire propagation investigation was divided into six subcategories. These included the usage and properties of flammable materials on S/C 012 and a theoretical analysis of materials combustion. Temperature mapping of S/C 012, the flammability of water/glycol, simulated mockup testing of materials configurations similar to S/C 012 and an evaluation of substitute materials for flammability were also included.

The criteria and controls investigation was directed to an evaluation of existing acceptance criteria for spacecraft nonmetallic materials located in the crew bay and to a determination of the effectiveness of controls of materials usage in design and fabrication.

The displays and information activity was directed to a determination of methods for presenting materials location and usage information, alternate nonflammable materials and materials properties and characteristics in graphical and usable form.

Status of the Materials Panel investigation program and special displays were maintained at KSC for use by Materials Panel Members and supporting personnel and by other Apollo 204 Review Board activities.

2. SCOPE OF THE REPORT

The scope of this report includes the following major categories of investigations:

a. Configuration of nonmetallic materials, including changes, in S/C 012.

b. Results of routine materials tests to determine combustion properties.

3. DETAILED TASK PROCEDURES

The following sections present technical results of Materials Panel investigations. The presentations include the objectives of the study, methods utilized and details of the results. The proceedings presented in this report are in general abstracted from more detailed reports referenced in Section E, Supporting Data.

4. NONMETALLIC MATERIALS CONFIGURATION OF S/C 012 COMMAND MODULE

a. OBJECTIVE

The nonmetallic materials configuration of S/C 012 was an essential element to evaluate materials combustibility data, potential ignition sources, propagation paths and intensity. A review of existing documentation was undertaken to develop a list of S/C 012 materials and test data.

b. APPROACH

A format containing required data was prepared. Data covering as-designed materials configuration, as-installed materials configuration from Discrepancy Report Squawks (DRS's) and Test Preparation Sheets (TPS's) and test data were included in compiling the S/C 012 nonmetallic materials list.

c. DATA FORMAT

The format is divided into four major sections: material description, location in the S/C, test information and quantity of material used. A sample data page is provided in Enclosure 8-2, Section E.

d. SOURCES OF DATA

(1) Design configuration data. Supporting References 8-1 through 8-13 were utilized.

(2) Test data. Supporting data References 8-14 through 8-27 were utilized. In addition, data available from the activities described in 5., "Routine Materials Tests", were added as they became available. Test data at oxygen (O_2) pressures to 21 psia covering the major combustible materials which contributed to the fire were available (Reference 8-91).

(3) Test conditions for existing data are shown in Table 1.

(4) Configuration changes. Documentation covering materials added to S/C 012 at KSC was reviewed. The documents reviewed included Discrepancy Reports (DR's), DRS's, and TPS's. The nonmetallic materials were identified and the amount used was noted. Photographs of the S/C as received at KSC and photographs of the S/C shortly before the fire were also reviewed for materials location and quantity.

(5) The crew bay materials usage lists of all contractors and suppliers were assembled into a master usage list. This list contains all of the materials that could have been used on S/C 012 but is not an as-built configuration list. This means that some of the materials on the list may not have been used and others may appear more than once. (Reference 8-28). See Enclosures 8-11 to 8-17 for location.

TABLE 1. SOURCE AND TEST CONDITIONS FOR EXISTING MATERIALS DATA

Note: All vertical tests are downward.

Source	Test	O_2 Pressure (psia)	Number of Tests
Collins (5-64)	Flash	15	
	Fire	15	
	Autogenous Ignition	15	
			61
Mass. Inst. of Tech. (1-67)	Flash	5	
	Fire	5	
	Combustion Rate (Vertical)	5	
			31
Hamilton Standard	Flash	5	
	Fire	5	
	Autogenous Ignition	5	
	Combustion Rate (Horizontal)	5	
			200
NAA (Hughes) (to 1-67)	Spark Ignition to 400°F	15	
			102
NASA (to 12-66)	Combustion Rate (Vertical)	5	
			112
Brooks	Combustion Rate (Vertical) (Horizontal)	5	
			66
Grumman	Autogenous Ignition	5	
	Combustion Rate (Horizontal)	5	
			48

e. MATERIALS USAGE SUMMARY

A summary of the nonmetallic materials used or suspected of being used in the Command Module (C/M) of S/C 012 is presented in Table 2 (Ref. 8-28).

TABLE 2. MATERIALS USAGE SUMMARY

Generic Type	Products Identified
Solvents	18
Lubricants	86
Foams	82
Thermal Insulations	7
Fabrics	395
Tapes	123
Encapsulants	164
Electrical Insulations	185
Plastics	394
Elastomers/Rubbers	238
Paints and Coatings	222
Laminates	78
Adhesives	322
Glass	39
Command Module, Coolant	1
Miscellaneous	174
Total	2,528

f. MATERIALS ADDED AT KSC

Of the listing in Table 2, the following materials shown in Table 3 were added at KSC. (Ref. 8-55 and 8-64).

TABLE 3. MATERIALS USED IN THE C/M AFTER DELIVERY

Material Category	Number of Material Types	Quantities (Approximation)
Adhesives	9	32 ounces
Lubricants	8	10 ounces
Paint and Coatings	6	9 ounces
Encapsulants	6	12 ounces
Tapes	13	80 square inches
Solvents	4	Unknown
Miscellaneous	29	Several instances of large quantities, Ex: 960 in^3 polyurethane foam, 7 lb. Velcro, etc.

The complete documentation of all DR's, DRS's, TPS's used in preparing this compilation are available and were bound into volumes by categories.

g. ESTIMATED TOTAL QUANTITIES OF MATERIALS

In addition to the document review a determination was made of the appropriate mass of major combustible materials which were directly exposed to the cabin environment (not in closed boxes or stowage compartments) in S/C 012 at the time of the accident (Ref. 8-57, 8-64) see Table 4.

TABLE C-4, ESTIMATED QUANTITIES OF MAJOR COMBUSTIBLES EXPOSED TO CABIN ENVIRONMENT ON S/C 012 AT THE TIME OF PLUGS OUT TEST

Material	Function	Total Weight (lbs)	Portion Installed at KSC (lbs)	Portion which was non-flight (lbs)
NON - GFE MATERIALS				
Velcro Pile	Zero-G attachment mechanism	3.9	1.1	
Velcro Hook	Zero-G attachment mechanism	5.9	4.5	
Uralane 577	ECU Insulation	5.2	2.4	2.4
	Pads on floor			
Trilock	Couch Pads	2.7		
Green Nylon	Covering for O_2 suit hoses	0.2		
Raschel Knit (nylon)	Debris Net	2.4	1.3	
Cotton Cloth	Remove-before-flight tags	0.5	0.5	0.5
Plexiglas	Display panels	1.8		
	Flood lamp covers			
Nylon Webbing	Tie-down straps	3.9		
	Couches			
	Storage Compartments			
Nylon oxford cloth	GSE Window covers	1.0	1.0	1.0
Nylon cord	Electrical cable tie wrap	9.1		
Nylon tape	Crew provisions equipment	5.7		
	Binding for debris nets			
Paper (non-flight)	OCP, Note paper	6.9	6.9	6.9
Paper (flight)	Flight/Preflight checklists	1.0	1.0	
Velostat	Covering for Uralane floor pads	0.1	0.1	0.1
Silicone foam	ECS Line insulation	5.0		
GFE MATERIALS				
Cotton cloth	Garments	4.3		
Lexan	Visors	3.0		
Nomex fabric	Garments	6.4		
Nylon Oxford	Garments	3.5		
	TOTAL	72.5	18.8	10.9

Displays have been prepared showing the location of Velcro, Uralane Foam, Raschel Knit and Space Suits used in S/C 012 and their location (See enclosures 8-11 to 8-17).

h. Nonmetallic Materials Status

A review of the acceptability and test status of materials identified on this list to the NAA MC999-0058 criteria was accomplished. The approved and waiver status of materials in Government Furnished Equipment (GFE) to MSC-A-D-66-3 (Ref. 8-85), was also determined. The results are reported in a subsequent section on Criteria and Controls.

i. SUMMARY

The nonmetallic (potentially combustible) materials configuration for the major elements of the as-designed configuration of S/C 012 and for the modifications actually installed at KSC was obtained (Ref. 8-28). Results have been tabulated in a standard format and reviewed for status. Tests have been initiated where data were not available. (See Paragraph 9). The precise nonmetallic materials configuration of S/C 012 was not obtained. There is some uncertainty about the materials used in the black boxes and materials applied during assembly at Downey.

5. ROUTINE MATERIALS TESTS

a. OBJECTIVE

As the compilation of data described in Section 4, "Nonmetallic Materials Configuration of S/C 012 Command Module" proceeded it became evident that test data were not available on the majority of materials used. A routine testing program was implemented to develop test data on some of these materials at one atmosphere or 16.5 psia oxygen (Ref. 8-31).

b. PROCEDURE

Procedures for testing were prepared and accuracies determined using Nomex cloth as a standard (Ref. 8-80). The following procedures were prepared:

Nonmetallic Materials Combustion (Propagation) Rate Test
Autogenous Fire Point Determination
Flash and Fire Point Determination of Nonmetallic Material
Combined Thermogravimetric Analysis and Spark Ignition Test
Electrical Wire Insulation and Accessory Spark Ignition Test
Electrical Wire Insulation and Accessory Flammability Test

c. STATUS OF MATERIALS TESTING AS OF MARCH 8, 1967 (Ref. 8-80 and 8-98)

2,527 Materials identified and tabulated
665 Materials determined to require testing
474 Materials orders
446 Materials shipped by supplier
429 Materials received at MSC
280 Tests in progress
245 Tests completed

d. REPORTS

Additional test results applicable to this Section of the report will be contained in Appendix G. Test data are logged in to the Materials List (Ref. 8-28) as they are reported.

e. RESULTS

Results obtained on several samples of materials used in large quantities in S/C 012 are listed in Table 5. Prior test data at 5.0 psia oxygen are also shown for comparison (ref. 8-33 and 8-91).

TABLE 5

Average Downward Flame Propagation Rates (In/Sec)			
Material	Oxygen Pressure		Ratio of Burning Rates
	5.0 psia	16.5 psia	
Raschel Knit (Blue)	0.4	1.0	2.5:1
Velcro Hook (Blue)	0.5	0.8	1.7:1
Velcro Pile (Blue)	1.4	2.5	1.8:1
Trilock	1.1	1.8	1.7:1
Polyurethane Foam	2.1	4.5	2.2:1

As stated, the above data are downward rates, i.e., the slowest rate possible at 1 g in 16.5 psia oxygen pressure. Upward rates are much higher. The average overall rate for materials as installed in S/C 012 will be much greater than those shown above.

f. SUMMARY

The materials which probably contributed heavily to the fire burned at least twice as fast at the accident conditions (16.5 psia) than that at which they were evaluated for space flight (5 psia).

6. SPECIAL INVESTIGATIONS AND TESTS - FIRE INITIATION

Early tests were primarily concerned with materials (solvents and liquids) that might ignite with electrostatic sparks or with low energy arcs.

The extremely low energy reported to ignite solvents and gases in 15 psia of oxygen prompted a search for possible presence of solvents in the spacecraft especially as they might be absorbed on flammable solids thereby sensitizing them to ignition and promoting propagation. The approximate spark ignition thresholds of flammable solids with and without absorbed solvents and glycol coolants were evaluated in laboratory tests. The electrostatic charging of materials and the space suit were studied. Arcing of audio circuit connectors in various concentrations of a solvent in 16.5 psia oxygen atmosphere were also tested.

Impact ignition in gaseous 16.5 psia oxygen was suggested from liquid oxygen experience and is being tested.

Water/glycol spillage and cleanup simulations on wire bundles and connectors are in progress to study corrosion-induced short circuits and electrical heating or arc ignitions.

Spontaneous ignition was also evaluated as a potential source mechanism (Ref. 8-33).

a. RETENTION OF SOLVENTS

OBJECTIVE

Investigate the contribution towards the fire of any solvent absorbed by the more widespread non-metallic materials in the cabin by evaluating solvent evaporation data and analysis.

PROCEDURE 1

Air-dried samples were weighed, saturated with liquid solvent, and allowed to air-dry until essentially free of solvent while being weighed.

RESULTS 1

Velcro hook samples soaked in methyl-ethyl-ketone (MEK) for ten minutes absorbed 3.2×10^{-5} lb in^2 of solvent. When evaporated into 50-percent relative humidity 75°F room air, they retained as much as 40-percent of the solvent for 5 hours (Ref. 8-103).

PROCEDURE 2

Tests with samples of Velcro pile, Uralane, Velostat covered Uralane, and couch material saturated with MEK for approximately ½ minute, air-dried for either 15 minutes or for 1 hour and then covered so that evaporation from the material had to take place by diffusion under the edge of an inverted 20 cc conical cover were conducted as described in Ref. 8-41. These tests were designed to determine the likelihood of vapor entrapment by equipment placed on saturated materials.

RESULTS 2

Diffusion of MEK and air under the edge took place rapidly. Vapor concentration fell below the 1.9-percent lean limit of flammability in less than 1 1/2 hours (Ref. 8-103). However, the results would be modified (1) if the edges of the material were sealed, (2) if the materials were not allowed to dry or (3) if the ratio of edge area to volume were very small. In these cases evaporation would be reduced and trapped pockets and/or heavy film layers of flammable mixture solvent vapors could have existed at the time of the fire.

SUMMARY

Velcro hook material can become saturated (after 10 minutes) with small amounts of MEK (3.2×10^{-5} lb./in^2). When exposed to a 50-percent relative humidity, 75°F environment the solvent retention in the sample decreases after 5 hours to 40-percent of the total amount absorbed.

Combustible concentrations of MEK solvent were not released into air from wetted Velcro pile, Uralane foam and couch material except for a short 1 1/2 hour period under conditions which restricted diffusion of vapor and air through the material to an area under the edge of the covering object.

The presence of significant volumes of concentrated solvent vapor in the spacecraft is unlikely. However, the retention of solvents in the surface layers of solid flammable materials could possibly contribute to their ignition (Ref. 8-103).

b. MATERIALS ODOR EVALUATION

OBJECTIVE

Odors resembling "sour milk" and MEK (see Materials Time Line, Enclosure 8-8) were reported. The objective of this analysis was to identify potential sources of these odors.

RESULTS

The evaluation of the "sour milk" odor involved the review of the K-bottle O_2 analyses, the Beckman Analyzer analyses, a gas sample taken at the crew mouthpiece and earlier sample analyses from August 29, 1966 to January 23, 1967. The review of the K-bottle analyses revealed no unusual impurities and the gas analyses met specifications as required. The analysis of gas from the two Beckman Oxygen Analyzers revealed no significant information on "sour milk" odor.

The gas sample taken at the crew mouthpiece on January 27, 1967 revealed approximately 400 ppm of unidentified hydrocarbons which could contribute to an odor condition (lab report Number TS75381 indicated odor to be of human origin).

A summary of previous analyses including earlier manned altitude testing samples revealed no significant information to identify any "sour milk" odor.

Re-Interrogation of witnesses revealed the following:

(1) There were no reports to the contrary that "only very minor amounts of solvent were introduced to the cabin on January 27, 1967" and these were by way of slightly dampened, wiping materials. No "spillage" or "dripping" of solvents was recalled.

(2) There was agreement that no one smelled anything of significance in the cabin during hatch closeout activity.

(3) There was general agreement that the strongest odors were detected at initiation of the first (20 minutes) cabin purge operations, approximately 3:32 pm EST, and decreased toward a "slightly detectable" level at completion of the second (10 minute) cabin purge operation approximately 4:18 pm EST. The odor was detected both within the white room and outside on Level A-8. There is also evidence which tends to indicate that this odor was was emitting from the steam duct just below the lower edge of the cabin hatch. An on-site review revealed that the configuration could allow some of the flow of gas from the steam duct to be deflected up into the white room and some of it could also be deflected downward into the general area of Level A-8. The other emission points of this odor were at the gas analyzer inlet bleed port and at the analyzer squeeze bulb exhaust port. Odors were detected at these points during environmental sample extraction.

(4) Description of the odor by the persons interrogated was that it was (1) MEK, (2) smelled "like" MEK, or (3) smelled like a solvent.

It appears that a fair degree of uncertainty is associated with identification of odors. Data indicate that the first threshold of smell for solvents such as MEK and isopropyl alcohol is approximately 0.01 percent to 0.03 percent by volume. The concentration that might be described as strong, irritating, and/or sickening is in the range of 1 percent to 4 percent by volume.

Samples of gas taken from the Ground Support Equipment (GSE) prior to the accident and also from the reassembled GSE system at the site provided negative results on significant hydrocarbon content. Solvents initially in the GSE would have been purged dry in the process of cabin purging. There is no reason to expect that further investigation will uncover a proof of solvents introduced by the GSE system.

SUMMARY

No particular suspect item was identified as emitting a "sour milk" odor although some of the Room Temperature Vulcanizing (RTV) potting compounds have distinct, pungent odors that probably come closest to fitting this odor description.

It is possible that accumulated solvent vapors could have been expelled through the steam duct during cabin purge.

Since the Command Pilot opened his faceplate for approximately 4 minutes at 6:19 pm EST and did not report significant odor concentrations it is likely that there were no solvent mixture concentrations in open areas (areas where the cabin fan produced reasonable flow). It should be noted that outward flow from the faceplate opening does not preclude cabin odor detection.

There is no evidence that significant concentrations or organic vapors existed in the spacecraft at the time of the accident (Ref. 8-54).

c. ELECTROSTATIC SPARK IGNITION

OBJECTIVE

The objective was to investigate the possibility of generation of sufficient electrostatic energy by movement of a suited astronaut to ignite combustible fuel-oxygen mixtures and materials of the type found in the S/C. Solid materials with remnant solvent had to be evaluated to determine required energy for ignition (Ref. 8-29).

PROCEDURES AND RESULTS

(1) Nylon fabrics, Raschel knits, polyethylene and neoprene were tested by rubbing with nylon. Only the nylon materials had appreciable charges generated on them at 50 percent relative humidity. Those that did not develop charges at 50 percent were tried again at 8 percent relative humidity and found to be still without appreciable charge (Ref. 8-32).

(2) In the laboratory a suit on a subject was charged by rubbing with nylon. He sat and then reclined on a linoleum covered metal table used to simulate spacecraft couches. Volt-

ages and energies induced were somewhat higher than the values later obtained in the spacecraft itself.

Capacity measurements were made using a 60 cps capacitance bridge and a radio frequency capacity meter. For the reclining subject they ranged from 500 to 600 picofarads. For the metal parts of the suit an increase over the theoretical values is explainable by coupled capacity of other objects such as the suit neoprene bladder and other metal parts.

TABLE 6

Maximum Voltages Induced and Energies Calculated		
Item	**Potential, KV**	**Energy, Millijoules (mj)**
Neck ring	2.1	1.36
Exhaust fitting	2.2	0.15
Inlet fitting	2.2	0.15
Zipper	1.7	0.56
Wrist ring	1.9	1.1
Subject and EKG lead	3.3	3.75

Resistances to ground which were measured at 10^9 to 10^{11} ohms would result in some loss of electrostatic energy during the process of measurement.

(3) A suited subject in C/M 014 at 8 percent relative humidity showed it was possible to obtain comparable capacitances to ground as in the laboratory. The subject's motion on the couch resulted in the generation of one (1) KV (Ref. 8-104 and 8-105).

(4) Capacitance spark tests showed that certain materials are ignitable by spark energies as follows (Ref. 8-79):

Material	Dry	Damp
Uralane foam	190 mj	40 mj (MEK and isopropyl alcohol)
Cotton (constant wear garment)	▪	210 mj (dampened with face oil)
Velcro	▪	200 mj (ethylene glycol)

▪ No ignition up to 300 mj

SUMMARY

Sufficient electrostatic energy (about 4 mj) can be stored on a suited astronaut to ignite MEK vapor and methane in 14.7 psia O_2 (0.002 to 0.004 mj required) (Ref. 8-42). Samples of suit and other spacecraft materials were not ignited by this energy level even when soaked in combustible fluids which were then allowed to evaporate for about 5 hours in a laboratory environment before being subjected to the spark test.

d. COBRA CABLE SPARK IGNITION TEST

OBJECTIVE

Reports of Cobra Cable connect-disconnect actions immediately prior to the fire were received. A test was designed to investigate the possibility of igniting flammable MEK mixtures in high con-

centrations of gaseous oxygen. This was accomplished by breaking and mating spacecraft connectors with power applied. For the test, two cables were fabricated using spacecraft approved materials and spacecraft qualified Deutsch Connectors.

PROCEDURE

The test setup consisted of three power circuits routed through the Deutsch Connectors in the pressure chamber to loads outside the chamber. The loads were identical to the circuit loads used in C/M 012. The communications load was an identical impedance (600 ohms) to that of a pressure suit helmet headset. The biomedical load was a physio-simulator. The simulator has a DC-DC converter which is flight-qualified and identical to the three used by astronauts in S/C 012. The converter had an input impedance of 300 ohms when loaded.

The spacecraft microphone amplifiers were powered from a 28-volt DC battery through a series-dropping resistor. Therefore, the spacecraft power source did not present any significant inductance. The test power supplies did present some inductances, since no dropping resistor was used. This test, therefore, presents a more severe arcing condition than the spacecraft system which was simulated.

Three separate AC to DC rectifier/transformer power supplies were used, one for the right microphone 16.8 VDC, one for the left microphone 16.8 VDC and one for the biomedical converter 28.2 VDC (Ref. 8-48 and 8-49).

RESULTS

With the circuit previously described increasing concentrations of solvent were established in the pressure chamber. During the first test the chamber was filled with air at ambient conditions. In the ambient condition the Deutsch Connectors were separated three times under circuit load. During the connector breaks 200-frame-per-second 16 mm pictures were taken to record any sparks or ignition. No sparks or ignitions were noted either visually at the time or on the film.

The second test setup was run with 97-percent oxygen at ambient in the chamber. The oxygen concentration requirement was 96-percent or greater. Chemical analysis revealed the oxygen concentration to be greater than 97-percent. With power on the circuit the connectors were separated a minimum of two times. No sparks were generated with sufficient energy to ignite the connector.

Other tests were performed with MEK concentrations of 2.0-percent, 4.0-percent, 8.0-percent, and saturated (less than 15.4-percent with the remaining atmosphere having an oxygen concentration of greater than 97-percent. A minimum of three separations and remates were performed at each mixture level. No sparks were initiated with sufficient energy to ignite the mixtures.

Modification No. 1 reconfigured the circuitry so that the current was increased to 150 ma. This is 2.5 times maximum operating current which approximates the worse case. Namely, the maximum current drain encountered if the biomedical power were shorted in the spacesuit umbilical. The connectors were separated several times with 4.0-percent gaseous volume of MEK in the chamber. No sparks were generated of sufficient energy to ignite the mixture.

Modification No. 2 configured the circuitry so that single wired pins could be pulled at 60 ma, 28 VDC (normal operating conditions). The pins were pulled twice at MEK concentration of 4.0-percent and once at 15.0 percent. No sparks were generated with sufficient energy to ignite the mixture. No sparks were seen by an observer or recorded on the high speed film (Ref. 8-48 and 8-49).

SUMMARY

Separating simulated Cobra Cable audio and biomed 16-volt circuits produced neither visible arcs nor ignition. Separations of connections at maximum nominal power with MEK-saturated O_2

and at 2.5 times nominal power in MEK concentrations to 4 percent, all in 16.4 psia oxygen produced no ignition. Tests using flight type Cobra Cables with audio center loads and battery power supply will be reported in Appendix G.

e. IMPACT SENSITIVITY OF MATERIALS IN GOX

OBJECTIVE

It is known that many materials in contact with liquid oxygen (LOX) are capable of exploding or igniting when subjected to mechanical shock or some other sudden energy surge. Organic materials of the type used in S/C 012 such as netting, lubricants, foams and Velcro are examples of ignitable substances.

Whether such materials form impact-sensitive hazards in low-pressure gaseous oxygen was unknown. Thus it was decided to investigate the feasibility of this method of fire initiation in gaseous oxygen at 16.5 psia and with typical flammable materials in S/C 012.

RESULTS

A standard method of evaluating the compatibility of materials with LOX has been used by Marshall Space Flight Center. The test equipment is shown in Reference 8-30. The test equipment was modified to permit impact of materials in contact with gaseous oxygen at slightly above atmospheric pressures. This corresponds to spacecraft conditions. Impacts are applied by a 20 lb plummet falling 43 inches and delivered through a 1/4-in. diameter striker pin face (less than 72 foot-pound). The chamber was purged with sufficient oxygen to maintain a 5 psig differential for fifteen minutes then bled off to 16.7 psia prior to impact.

The following materials were tested under impact in contact with gaseous oxygen (GOX). Each was applied to a 1-inch diameter disc of aluminum for test purposes:

Velcro Hook (pressure-sensitive adhesive backing)
Velcro Pile (pressure-sensitive adhesive backing)
Velcro Hook and Pile together (pressure-sensitive adhesive backing)
Velcro Hook - Cross-cut grooves to expose adhesive
Velcro Pile - Cross-cut grooves to expose adhesive
Velcro Hook - Creased intentionally during application
Velcro Pile - Creased intentionally during application
Raschel Knit

Six Velcro hook samples were run. No fires resulted but in two of these burnt odors resulted. Three samples of Velcro pile on the hook were run. In these one burnt odor was detected and one sample ignited and burned vigorously. Of three samples of Raschel Knit impacted to date two ignited and burned (Ref. 8-30).

SUMMARY

These tests have shown that mechanical impacts on Velcro or Raschel Knit in contact with 16.5 psia 0_2 can produce ignition and burning. A survey of spacecraft loose and movable objects revealed no possible high-impact condition on flammable materials.

f. AUTOGENOUS IGNITION SCREENING TEST OF S/C 012 MATERIALS

OBJECTIVE

Tests were undertaken to determine if combinations of solvents and materials could lead to unusually low spontaneous ignition temperatures in the oxygen atmospheres used in the S/C 012 test.

PROCEDURES

The tests were run in stainless steel pressure vessels equipped with a viewing port, thermocouple and a method of maintaining a 16.5 psi 0_2 atmosphere together with a heat source. All samples were exposed to programmed heating, culminating at 400°F for ten minutes. They were then examined. Samples for gas chromatographic analysis were taken.

Materials which have a significant capacity for absorption of solvents such as foams and fabrics were tested in the as-received condition. This was done after soaking in methyl-ethyl-ketone, isopropyl alcohol, 50-50 ethylene glycol/water and in various combinations of these fluids. Samples were allowed to dry for approximately 5 hours prior to testing. Materials exposed to these tests were as follows:

Uralane Foam
Velostat
Velcro (various colors), Hook and Pile
Raschel Knit
Trilock

Materials tested without solvents were as follows: (Ref. 8-46 and 8-93)

Epon 828	Minn Hon 6745A Oil
Mystic Tape	Bray Oil Lube 812
DC 4 Lubricant	PR 240 AC Lubricant
Rayclad Sleeving	Versilube 300
EC 1469 Adhesive	DC 33 Lubricant
Aero Shell Grease	NOPCO Foam A 206
AiResearch Grease	3M, No. 27 Tape
DC 30-121	Nomex-HT-1 Suit Fabric
Epon 828 + Versamid 115	RTV 90 Encapsulant
	RTV 577 Encapsulant
Stycast 1090	RTV 560 Encapsulant
Epon 934	Organoceram
EC 1469	--

SUMMARY

No autogenous ignition of materials tested was detected at or below the 400°F test limit even samples treated with cleaning solvents.

g. EFFECT OF WATER/GLYCOL ON WIRE BUNDLES

OBJECTIVE

This task was undertaken to determine the effects of spacecraft cabin environment on electrical wire bundles of S/C 012 types which had been exposed to water/glycol at some previous time.

It has previously been observed that flammable aircraft wire insulation such as polyvinylchloride (PVC) and nylon may burst into sustained flames in air even though adequately protected with circuit breakers. This can occur provided the following conditions are present:

(1) Insulation on adjacent wires is damaged to the conductors.

(2) Sufficient moisture is present to bridge the damaged areas.

(3) An electrical potential exists between the conductors of the damaged wires. (Ref. 8-38, 8-39 & 8-78).

These wet-wire fires were observed without tripping circuit protective devices because the current through the wires may be as low as 10 percent to 20 percent of the regular wire current at the time of ignition. The above results were recorded in a Lockheed Company film (Ref. 8-92 and 8-94).

The present task was undertaken to determine whether spacecraft wire bundles were susceptible to fire initiation and propagation as observed in the Lockheed tests.

PROCEDURE

Tests are in progress at NASA Manned Spacecraft Center on wire bundles. The test procedure includes a method for keeping the wire bundles moist with the water/glycol solution. Several wires in each bundle have intentionally-damaged wire insulation. The tests will be continued for at least several months to verify whether or not the effect of the water/glycol is appreciable.

In a special test Teflon covered shielded wire that had been purposely cut through to the conductor and exposed to ECS coolant caught fire. The fire occurred after about 8 hours in ambient atmosphere with less than 5 amperes passing through the conductor. The coolant was applied as droplets into the damaged area (Ref. 8-107).

SUMMARY

Initial test results show that fire initiation is possible. Additional test results applicable to this section of the report will be contained in Appendix G.

h. EFFECT OF WATER/GLYCOL ON CONNECTOR ASSEMBLIES

OBJECTIVE

Water/glycol coolant spillage occurred on a number of wire bundles and connectors used in S/C 012. The objective of this test program is to evaluate the effect of water/glycol and of the cleaning procedures used on S/C 012 on connectors similar to those used in S/C 012.

PROCEDURE

A series of tests have been defined to determine the effects of water/glycol spillage on wire bundle assemblies with connectors. A total of twenty-nine harness assemblies were ordered from NAA Downey for this testing. The assemblies are as follows:

V16-420337, CO5W5-P91	5 assemblies
V16-420303, CO5W5-P167	5 assemblies
V16-420308, CO3W15-P50	5 assemblies
V16-420307, CO3W15-P58	5 assemblies
V16-420316, CO1W1-J94	5 assemblies
836598-1-1	1 assembly
836600-1-1	1 assembly
836602-1-1	1 assembly
836599-1-1	1 assembly

These wire harness assemblies were selected since they represent harnesses that have been subjected to water/glycol (MBO 110-006, Type II) spillage on S/C 012. These harnesses are ECU cable harnesses, SCS-ECA cable harnesses and spacecraft harness assemblies located under the ECU.

The test environment is 75°F, 100 percent oxygen at 14.7 psia. These types of tests will be carried out as follows: (Ref. 8-83)

(1) Test A - Dip the cables and connectors in water/glycol for 30 seconds and allow to drip dry. Disassemble the connectors and clean per the procedures used on S/C 012. Rejoin the connectors and apply spacecraft voltages and currents and monitor the results.

(2) Test B - Test B is the same as Test A except the connectors are not cleaned and dried.

(3) Test C - Immerse the cables and connectors in a bath of water/glycol in the 0_2 atmosphere. Apply spacecraft voltage and currents and record all readings. Allow the wire bundles and connectors to remain immersed in the water/glycol solution and continuously record circuit resistances.

Tests A and C will be run at KSC while Test B will be run at White Sands Test Facility.

SUMMARY

Test results applicable to this section of the report will be contained in Appendix G.

i. REVIEW OF KSC CONNECTOR TEST WITH WATER/GLYCOL

OBJECTIVE

A test conducted during October and November 1966 at KSC on a connector which had been subjected to ethylene glycol in which shorting occurred under DC load came to the attention of the Panel. This test was investigated for applicability ot the fire investigation.

RESULTS

A review as contained in Ref. 8-66 and 8-67 of test requirements, objectives, test techniques and results related to the special test show that test personnel were properly concerned about the effects of water/glycol spillage on spacecraft electrical equipment. To evaluate the effect of water/glycol on S/C connectors they chose to apply a worse-case condition to a worse-configuration spacecraft-type electrical connector in a set of laboratory tests to check the effectiveness of a proposed vacuum-environment cleaning technique. Accordingly, a spacecraft-type connector partially equipped with pins and wires but without plugs in unused pin holes or potting applied to the exposed ends of the connector was dipped in a water/glycol solution of the type used in the C/M. This resulted in water/glycol being introduced directly into the components of the connector. After a number of operations involving resistance measurements, vacuum drying, room air storage, disassembly, cleaning, washing in water/glycol solution, reassembly and "drip drying," the connector was tested with active AC and DC circuits. The DC circuit failed because of an internal short. A later test at less voltage (28 compared to 35) was run for about the same length of time without failure.

SUMMARY

In analyzing test techniques, test results and statements made by the main participants in this test, it appears that the environment and the hardware were not representative of spacecraft equipment or environment but represent an extreme set of conditions which have not been known to exist in S/C operation. Thus, the results are not directly applicable to Apollo S/C equipment. Currently planned laboratory tests of real spacecraft connectors and cables wetted with water/glycol constitute a better source to judge the hazard of such events.

7. RESULTS OF SPECIAL INVESTIGATIONS AND TESTS - FIRE PROPAGATION

This section of the report deals with investigations and tests to evaluate the propagation of the fire.

The effect of foam insulation burning in 16.5 psia oxygen on aluminum oxygen supply lines in causing failure to these lines was evaluated. Investigations of the leakage of water/glycol solutions and residue were also undertaken. Temperature mapping of S/C 012 based on the condition of materials in various locations was investigated. The correlation of Command Module mockup tests with the S/C 012 configuration and condition was also investigated.

An analysis of combustion characteristics of materials was undertaken to evaluate the S/C 012 nonmetallic materials configuration from a combustibility standpoint.

a. EFFECT OF BURNING FOAM INSULATION ON OXYGEN LINES

OBJECTIVE

The objective of these tests was to determine if burning foam insulation on aluminum oxygen supply lines in 16.5 psia oxygen could cause failure of these lines.

PROCEDURE

Uralane foam insulation was placed in separate tests on and under oxygen lines and ignited in 16.5 psia oxygen. Foam thickness and weight was selected to duplicate the amounts used on S/C 012. The oxygen lines were selected to represent lines used in S/C 012 (1/4-inch outer diameter, .035-inch wall thickness).

Normal oxygen flow was maintained in these lines throughout the test. The following specific tests are planned:

(1) Foam insulation around a 100 psia aluminum line.
(2) Foam insulation placed under a 100 psia aluminum line.
(3) Foam insulation near a soldered joint of a 100 psia aluminum line.
(4) Foam insulation placed under a 900 psia aluminum line.
(5) Insulation and lines configured as in S/C 012 per test request.

RESULTS

Tests number 1 and number 2 are completed. No failure of the aluminum lines occurred when the foam insulation was burned (Ref. 8-98).

SUMMARY

Foam insulation representative of a single insulated line as installed in the S/C 012 ECU when burned in a 16.5 psia oxygen does not cause failure of a 1/4-inch, .035-inch wall thickness, 100 psia aluminum oxygen line.

Results from the remainder of the tests pertinent to this section of the report will be reported in Appendix G.

Additional tests are planned to determine the effect of a burning foam on soldered joints and 900 psia oxygen lines and lines configured as in S/C 012. These additional test results applicable to this section of the report will be contained in Appendix G.

b. WATER/GLYCOL LEAKAGE IN SPACECRAFT

OBJECTIVE

It was postulated that water/glycol (Ref. 8-96 and 8-97) leakage in S/C 012 could have contributed to the propagation or initiation of the fire. This study was initiated to determine the instances of water/glycol spillage in S/C 012, 009, 011, 017, and BP 014.

RESULTS

General: A review of documentation was conducted to determine the extent of water/glycol leakage in S/C 008, 009, 011, 012, 017, and BP 014. The records disclose that the water/glycol was MB0110-006 Type II. The following summary is a result of the review:

Vehicle Number	Instances	Total Leakage (Oz.)
S/C 008	1	16
S/C 009	1	2
S/C 011	6	52
S/C 012	6	90
BP 014	14	96 - 160 (est)
S/C 017	7	Unknown

No failures of spacecraft or boilerplate cables, harnesses, components or connectors have been attributed to the effects of water/glycol leakage.

S/C 012 The following instances of water/glycol leakage have been recorded against the ECS of S/C 012.

(1) ECU Removal at Downey - 2 pints. Approximately 2 pints of water/glycol leaked during ECU removal at Downey on August 12, 1966.

(2) Glycol Diverter Valve at KSC - Few tablespoonsful. On September 15, 1966 the glycol diverter valve was noted to be leaking at the rate of "approximately one drop/minute" (DR S/C 0188). This situation was corrected by adjusting the valve mounting bracketry to relieve the side loading effects which apparently were causing the leak. The DR was closed on September 26, 1966. The leakage had not caused other components or wire bundles to become wetted with water/glycol.

(3) Cold Plate IMU Supply Line, Weld Joint at KSC - 1 pint. On September 28, 1966 "three water/glycol leaks" were noted to be in existence "behind inverters - Lower Equipment Bay" (DR S/C 0289). The leakage was corrected by the replacement of existing solder unions with B-nuts and union. Following leak check and re-insulation of the affected lines the area exposed to water/glycol, including electrical connectors, was wiped with distilled water applied from a squeeze bottle, blown dry with GN_2, flushed with "denatured alcohol" from a squeeze bottle and dried again with GN_2. The electrical connectors were cleaned "inside and out". The subject DR (0289) was closed on September 30, 1966. DR-0305 was initiated against the water/glycol contamination to electrical connectors and wire harnesses which resulted from the leak documented on DR-0289. DR-0305 was closed by referencing the cleaning steps which were taken on DR-0289.

(4) Transducer CF0550 Removal/Rotation at KSC-2 pints (Oct. 11, 1966). The spillage of water-glycol which occurred during the operations documented on DR S/C 0436 was controlled to the extent that no water/glycol contamination of components or wire bundles was incurred.

(5) Pump Leak (1st) ECU Servicing at KSC - 1/2 cup (Nov. 30, 1966). Following ECU removal and subsequent investigation at AiResearch it was found that some evidence of leakage existed on the water/glycol pump flanges. Although leakage at this point in the system could not be verified the isolation of the leakage point to the pump flange area was the "best guess" available. (Reference DR S/C 0737).

TPS S/C 418 documents the tests which were performed on the ECU at AiResearch. The only leak source which could be determined was in the area of the pump filter housing. The observed leak was very minor (documented as "one drop" IDR 001, TPS S/C 418).

(6) Pump Leak (2nd) Servicing at KSC - 1/4 cup (Dec. 20, 1966). DR S/C 0811, which is still open, documented a water/glycol leak which "seeped down I-beam and extended to the wire harness on the C/M floor". The area was dried and the water/glycol did not reappear. The DR was to remain open until after the FRT (OCP-K-0028) at which time it would be closed.

The leak source was documented as being "exclusively associated with (water/glycol) servicing". Through 1830 on January 27, 1967 no failures on S/C 012 cables, harnesses, or connectors were attributed to the effects of water/glycol leakage. Total leakage 90 ounces (estimated).

From a review of the referenced documentation it may be concluded that the only water/glycol leak which wetted nearby electrical connectors and components was the leak at the solder joint at the IMU coldplate water/glycol supply line. The other leaks apparently did not contaminate electrical components or wire bundles. The water/glycol from the IMU coldplate leak wetted several connectors. These connectors were demated and cleaned to eliminate the possibility of water-glycol contamination inside the connector. The affected connectors were:

Yaw ECA: J-96, J-95, J-94, J-93, J-92
Auxiliary ECA: J-97, J-98, J-99, J-100
Pitch ECA: J-101, J-102, J-103, J-104, J-105

Each of these connectors was cleaned by water flush-gaseous nitrogen (GN_2) dry-denatured alcohol flush-GN_2 dry method. Each of the referenced connectors was potted.

During the inspection of the area in the C/M which could have been contaminated by the coldplate leak, black boxes were removed in sequence until the inspection of connectors and cables revealed that water/glycol had not reached the specific area being inspected. At that time the ECA units noted were determined to be the only units affected by the leak (Ref.8-70).

SUMMARY

There have been 35 instances of water/glycol leakage on the Spacecraft listed with a total leakage of approximately 320 ounces including the 6 instances and 90 ounces on S/C 012. There have been no failures of cables, harnesses, connectors or components attributed to water/glycol leakage. The 14 connectors which were wetted with water/glycol on S/C 012 were demated and cleaned.

c. FLAMMABILITY OF WATER/GLYCOL RESIDUES

OBJECTIVE

It was desired to determine whether a thin film of water/glycol on a surface (from a drip or stream along the floor or wall) could be ignited at room temperature or slightly above by a flame impinging directly on the liquid surface.

PROCEDURE

Tests were made in which a flame was applied directly on the surface of a thin film of water/glycol/inhibitor mixture, pure glycol and films of the C/M coolant mixtures after exposure to vacuum. All flammability tests were conducted in 14.7 psia oxygen.

RESULTS

(1) Fifty drops of C/M coolant spread onto a 3-inch x 3-inch glass plate and a 1/8-inch x 3-inch x 3-inch aluminum plate would not propagate a flame in 14.7 psia 0_2 when ignited by a 1/2-inch diameter 1-1/2-inch long paper cylinder. Burning of the coolant immediately adjacent to the paper produced small flashes and sparks for about a one-inch radius around the fire.

(2) The same test using C/M coolant fluid was performed using stainless steel plate with a 1/16-inch deep "V" groove. Ten drops of coolant were placed in the groove and five drops on the paper cylinder. The paper burned for 90 seconds and there was some progression along the groove as the plate heated.

(3) A test similar to (2) but using pure ethylene glycol took 3 to 5 seconds to propagate along the groove.

(4) The same test using C/M coolant fluid was performed on aluminum and stainless steel plates after 18, 24, 46, and 48-hour storage in room air. The fire burned out in both cases in about 10 seconds leaving about two thirds of the coolant on the plate. There was some sparking around the flame in all cases.

(5) When the 50 drops of standard coolant fluid on an aluminum plate was held under reduced pressure about 80 hours and then ignited the fire spread to the residue and was visible over the entire surface. The residue burned completely within 15 seconds after ignition. The same test on a stainless steel plate with a coolant exposed to dynamic vacuum for 9-1/2 hours shows partial burning of the coolant film.

(6) Tests performed by Raychem Corporation also showed that the evaporation residue from water/glycol will propagate a flame (Ref. 8-100).

(7) A test was conducted to determine if Teflon insulated wire soaked with water/glycol would propagate a flame. This test simulated the wiring in the SCS junction box which was burned in S/C 012. None of the samples would propagate a flame when ignited (Ref. 8-40 and 8-77).

SUMMARY

In 14.7 psia oxygen:

(1) A pure ethylene glycol film on a stainless steel plate will propagate a flame at room temperature.

(2) Water content in the C/M coolant will prevent flame propagation on thin films. Air drying for 48 hours does not produce a combustible mixture.

(3) Films of C/M coolant placed on horizontal stainless steel or aluminum plates and exposed to vacuum for extended periods at room temperature will propagate a flame if ignited.

(4) Residues from previous C/M coolant spills in S/C 012 could have provided a fuel.

(5) Single wires and three-wire bundles were soaked with water-glycol and either air-dried or vacuum-dried and did not propagate a flame.

d. TEMPERATURE MAPPING OF S/C 012

OBJECTIVE

A study was initiated to determine the major heat zones in S/C 012. Samples of nylon Velcro were used which had been heated to various temperatures. As part of this study the materials in the S/C were evaluated to determine which ones would allow ready comparison of hot and cool zones in the spacecraft.

PROCEDURE

Combustible materials were used throughout the spacecraft including nylon Raschel Knit and some plastic buttons or knobs on panels. Some of these were damaged but not entirely consumed. The reference material selected was Velcro. Samples of nylon Velcro were heated in an oxygen atmosphere at 16 psia at the White Sands Test Facility Laboratories. Each specimen was stopped at its assigned temperature, preserved, and photographed for degree of damage and color. Specimens were obtained for each 50°F increment between 300°F and 600°F.

RESULTS

The evidence that the fire was more intense on the left side than on the right side is summarized as follows:

Material	Type/Degree of Damage	
	Left Side	Right Side
Aluminum Panels	Blistered and whitened	No blistering. Some panels almost undamaged.
Velcro	Mostly burned off. Some of the patches are only partially burned.	Largely surface burning. Patches melted and dripped more than they burned.
Teflon Insulation	Extensive damage. On some wires the insulation is completely burned.	Mostly surface damage.

In general combustible materials were burned throughout the spacecraft particularly on the floor and around the sides. The materials listed subsequently which were in the S/C at the time of the fire were evaluated and an estimate of their role in the fire is as follows:

DEBRIS NETS - Virtually consumed or melted. These were probably instrumental in propagating the fire around the S/C.

VELCRO - This was another major material for flame propagation. Combustion varied from complete burning to only surface burning.

VELOSTAT PLASTIC SHEETS - These were consumed in nearly all areas. The material was a fuel but did not appear to be instrumental in spreading the fire.

FOAMS - A major fuel in the fire. The foam on the floor and on the ECU was nearly consumed.

COUCH MATERIALS - These pads and cover materials were partially consumed in the fire.

TEFLON WIRE INSULATION - It did not appear to act as a fuel for the fire by itself and was intact in most areas of the spacecraft. The wire insulation was damaged by the fire in those areas where flame impinged directly on the insulation. Areas where the wire

were bare of Teflon reached temperatures in excess of 800°F.

The data from the above summary were combined with the condition of the Velcro observed in the S/C to obtain the temperature chart presented in Enclosures 8-4 and 8-5 (Ref. 8-43). It was observed that the number of conditions in the S/C fire were not all reproduced in the test plan. As a result the temperature ranges in the diagram are approximate (Ref. 8-34, 8-35, 8-36, 8-37, 8-43, and 8-44).

SUMMARY

An estimate was made of temperatures attained at various locations in S/C 012. This was based on burning, melting, and other effects observed on aluminum alloys, Velcro and Teflon wire insulation coupled with calibration type exposures of Velcro materials to various temperatures and times. The most intense heat was in the lower left front area. Over 1000°F was attained on surfaces on the left side. However, in some isolated pockets temperatures did not exceed 400°F.

e. CORRELATION OF C/M MOCKUP TESTS

OBJECTIVE

These tests were made to (1) evaluate the integrated combustibility of materials as they interact in a fire representative of the S/C 012 accident, (2) to correlate test results with observations made on materials in S/C 012 after the accident, and (3) to compare the observation of (1) with tests at lower partial pressures of 0_2.

RESULTS

Test	Description	Status
1	Engineering Simulation of S/C 012 16.5 psia 0_2	Complete Feb. 26, 1967
2	All-Up Simulation of S/C 012 16.5 psia 0_2	Complete Mar. 4, 1967
3	S/C 012 Materials Configuration 5 psia 0_2	Complete Mar. 8, 1967
4	New Materials Configuration 14.7 psia Air	Scheduled Mar., 1967
5	New Materials Configuration 5 psia 0_2	Scheduled Mar., 1967 (Ref. 8-98)

Comparison of the measured rate of pressure rise and the minimum rate calculated from materials characteristics is discussed in the subsequent section 7 g. "Thermochemical Adiabatic Analysis of Fire Development". The test results are available in documented form. A test report covering material usage and placement forms a portion of the backup data for this report (Ref. 8-11 through 8-17, and 8-28), and in the form of motion picture films (Ref. 8-87 and 8-88). Additional information is contained in film (Ref. 8-99).

The 5 psia tests utilized approximately the same nonmetallic materials configuration except that Velostat-covered foam and nylon coverings on the suit hose were not included. Also, no oxygen was added during the 5 psia tests as was done in the 16.5 psia tests.

SUMMARY

Judging from an initial review of test results and comparing the external appearances of materials from S/C 012 and the mockup tests an effective reproduction of the S/C 012 accident was accomplished.

Review of the films of the 16.5 psia test indicates that after about a 10-second period the fire was propagated very rapidly by the Raschel Knit. Velcro and Uralane foam also were major fuels in the conflagration.

Fire simulation mockup tests at 5.0 psia resulted in a much lower fire propagation rate, less extensive fire damage before 0_2 supply exhaustion and a cabin pressure rise from the fire that was limited by the cabin pressure relief valve. The intensity of the fire in 5 psia 0_2 although less than at 16.5 psia was still incompatible with crew safety and could be fatal to an unsuited crewman.

The results of additional tests applicable to this section of the report will be contained in Appendix G.

f. FIRE PROPAGATION TEST OF RASCHEL KNIT AS INSTALLED.

OBJECTIVE

Determine fire propagation rate for Raschel Knit material in a configuration as installed in C/M 012 along the floor and side wall intersection near the ECU.

PROCEDURE

Raschel Knit was installed in the test chamber with the long dimension (about 2 feet) horizontal and the narrow dimension (about 8 inches) aligned about 20 degrees from the vertical. Ignition was accomplished by a Nichrome wire element touching the Raschel Knit at about the midpoint of the vertical dimension and a measured distance from the end point. The chamber atmosphere was about 100 percent 0_2 and near ambient pressure.

RESULTS

Preliminary results from two tests, reference 8-106, obtained with a visual observation and stop watch technique gave average rates of about 2 inches per second.

SUMMARY

Horizontal flame propagation rates of fairly large pieces of Raschel Knit material as used in C/M 012 below the ECU in oxygen at ambient pressure have been measured at about 2 inches per second. This rate is about twice as fast as the downward rate obtained with small samples in nearly the same environment during materials screening tests. This large increase shows the importance of testing materials in the intended-use arrangement.

g. THERMOCHEMICAL ADIABATIC ANALYSIS OF FIRE DEVELOPMENT

OBJECTIVE

The objective of this analysis is to correlate S/C 012 and boilerplate temperature and pressure changes with time. This will establish energy balance correlations with the combustion characteristics of materials.

SUMMARY

A supporting task showed that the total energy available from complete combustion of the Raschel Knit, Velcro, Trilock, and Uralane foam present in S/C 012 was over 300,000 Btu. Only about 3300 Btu (based on an adiabatic process) would be required to raise the interior pressure of the C/M from 16.5 psia to 36 psia. Thus many times more fuel was available than necessary to provide sufficient heat on burning to reach estimated burst pressure (approximately 20 psi positive differential). The minimum energy (approximately 3300 Btu) could be obtained from only about 4 ounces of Raschel Knit, Velcro, or polurethane foam, or 1/2 pint of Command Module water glycol coolant (ref. 8-61).

Limited theoretical calculations indicate that burning of either Raschel Knit or Velcro alone would probably release a sufficient quantity of heat to raise the cabin pressure from 16.5 to estimated burst pressure (36 psia) in less than fourteen seconds from initiation. By this time a quantity equivalent to a hole of over 14 in. radius would have been burnt in the Raschel Knit and approximately 11 in in the Velcro consuming at least 3.8 ounces of either material and less than 2 percent of the available oxygen.

Based upon a number of known and estimated conditions and assumptions the minimum rate of pressure rise as a function of time was calculated (enclosure 8-6). This curve is based primarily on the slowest rate of combustion of Raschel Knit, i.e., in the vertical downward direction and its heat of combustion. For reference purposes pressure measurement from S/C 012 and the estimated curve (from Panels 3, 5, and 10) are also shown for comparison on the same plot. Pressure measurements during the 16.5 psia mockup test (SMD-2B) at MSC (normalized to a zero time base and 16.5 psia starting conditions) are also plotted.

Fire development characteristics vary with initial starting conditions. Thus, similar theoretical analyses were made for space conditions, i.e., assuming external vacuum and internal 5 psia pure 0_2 and using Teflon and Raschel Knit materials as limiting cases. The maximum or most favorable conditions were assumed for the burning of the Teflon.

The approach consisted of calculation of the minimum amount of heat necessary to raise the crew bay pressure from 5 psia to that under consideration. The amount of Teflon or nylon necessary to produce this amount of heat and the times necessary to consume these amounts were then calculated. The baseline burning rate of Teflon (5 mil film) was taken as 0.38 in/sec measured in the upward direction and burning in a semicircular fashion in 1 g. Admittedly, such a favorable condition for Teflon burning probably will never occur. However, even under such conditions at least 80 seconds would be required to reach the estimated burst pressure. In this time frame normal adiabatic expansion of the gas would not occur because the heat sink capability of the structure would be utilized partially. This heat sink capability would give additional time to take corrective action. For example, it would take in excess of 25 seconds to heat the cabin gas to 160°F (assuming that the ECS was inoperative). Thus, the burning of Teflon sheets is not likely to cause overpressurization and structural failure of the Apollo C/M. (Ref. 8-56, 8-59 and 8-47). However, as indicated proviously Teflon can propagate a flame so that its use over wide areas of the S/C should be limited.

h. THEORETICAL COMBUSTION ANALYSIS

OBJECTIVE

The objective of this investigation is to evaluate combustion processes and data from other fire incidents to acquire further insight into initiation and propagation of fire in spacecraft. A second objective is to evaluate proposed remedial approaches involving materials selection and placement.

PROCEDURE

These analyses are being carried out by the Atlantic Research Corporation.

RESULTS

In preparation.

SUMMARY

Test results applicable to this section of the report will be contained in Appendix G.

8. RESULTS OF SPECIAL INVESTIGATIONS AND TEST - DESIGN AND INSTALLATION CRITERIA AND CONTROLS OVER MATERIALS

This action presents investigations undertaken to evaluate design and installation criteria and controls over materials used in S/C 012.

a. NAA CRITERIA AND MATERIALS PROCEDURES

OBJECTIVE

The objective of this investigation was to evaluate existing criteria and controls covering flammability of materials in effect by the prime contractor.

SUMMARY

With respect to the S C 012 fire, the NAA Specification MC999-0058 (Ref. 8-84) and MAO 155-008 covering the selection and usage of nometallic materials for flight had the following inadequacies

(1) The criteria did not require any combustion rate testing.

(2) There were no restrictions on total quantities of combustibles which could be placed in the cabin.

(3) The criteria did not require any restriction on quantities or location of particular materials.

(4) Material selection flammability criteria were not stringent enough.

(5) Requirements for flammability control of nonflight materials, including the usage of flammable solvents, were not established.

With respect to the implementation of controls, the following inadequacies were determined:

(1) The existing system for controlling installation and usage of materials to the established criteria was not effective.

(2) Controls were design-oriented but were not restrictive.

(3) Control and documentation of subcontractor materials usage was not adequate (Ref. 8-71, 8-72, 8-89, 8-55 & 8-63).

b. NASA/MSC CRITERIA AND MATERIALS CONTROL PROCEDURES COVERING THE SELECTION AND USAGE OF NONMETALLIC MATERIALS FOR FLIGHT OBJECTIVE

The objective of this investigaton was to evaluate existing criteria and controls in effect for government furnished equipment.

SUMMARY

With respect to the S/C 012 fire, the NASA MSC-A-D-66-3 and MSC-A-D-66-4 criteria had the following inadequacies:

(1) The criteria did not require evaluation of ignition and combustion rate at 16.5 psia oxygen. The criteria were oriented toward flight conditions of zero g and 5 psia oxygen.

(2) The criteria which specified combustion rate tests (downward) yielded results at the lowest rate possible in a one-g environment.

(3) The total quantity of combustible materials which could be used in the cabin was not limited.

(4) The materials selection flammability criteria and restrictions on individual quantities and locations were not stringent enough (Ref. 8-85 and 8-86).

(5) Requirements for flammability control of nonflight materials, including usage of flammable solvents were not established.

With respect to the implementation of controls, the following inadequacies were determined:

(1) Many materials used were qualified only by successful usage on prior programs.

(2) The existing system for controlling installation and usage of materials to the established criteria was not effective.

(3) Control of flammable materials installation was exercised by several organizations which tended to act independently.

(4) Control and documentation of contractor materials usage was not adequate. (Ref. 8-8, 8-9, 8-73 & 8-90).

(5) NASA criteria was not contractually imposed on the S/C contractor.

A physical "walk-through" inspection of S/C 012 was conducted at Downey on August 20, 1966 as part of the CARR activity. As a result of that inspection, nylon-Velcro chafe guards were removed from the electrical harness assemblies on the S/C floor and those around the sides and beneath the crew insertion hatch.

Subsequent to that inspection and after delivery the materials identified in tables 3 and 4 were added. Materials added included Raschel Knit debris nets, a large amount of Velcro, and Velostat plastic sheets and foam pads.

A "walk-through" inspection for S/C 012 was schedule for January 29, 1967 to review the arrangements of the large usage materials in the crew bay. (Ref. 8-89). While the results of this planned but not accomplished inspection can only be speculated, it is anticipated that the team made up of the same experienced people who had previously inspected S/C 012 at the factory and S/C 008 at MSC would have been concerned with the extensive use of Velcro and Raschel net (Ref. 8-60).

A similar inspection was made of the S/C 008 crew bay area before the altitude chamber tests were conducted in the Space Environment Simulation Laboratory at MSC. This inspection resulted in a number of changes including removal of the nylon-Velcro chafe guards, polyvinyl bags, a wooden wire bundle stiffener and the rework and qualification testing of a sealed Teflon and beta cloth for the polyurethane floor pads.

"Walk-through" inspections of spacecraft with NASA/NAA personnel have been utilized to perform a check of the installation of the nonmetallic materials visible in the cabins. During such inspections it has been possible for the team to judge on the basis of the NAA criteria and NASA criteria.

As noted the NASA effort to update the existing NAA Nonmetallic Materials criteria and control procedures had not been completed prior to January 27, 1967. Some of the more significant milestones on the updating efforts are listed in Ref. 8-101. Many of the contractor responses to NASA requests were in the form of status reports presented at regular NASA/NAA management meetings. The NAA responses culminated in a January 10, 1967 letter (Ref. 8-102) which was not acceptable to the NASA. Later, agreement was reached as confirmed in NASA TWX's of January 17, 1967 in item 15 and 18 of Ref. 8-101. This resulted in the January 27th revision of MC999-0058(E) which reflected the adoption of NASA criteria (Ref. 8-50 and 8-51).

The adoption of the NASA criteria through change to the contractor's nonmetallic materials criteria (MC999-0058) would not necessarily have prevented this accident because the cause has not been identified and because the NASA criteria also had some shortcomings as noted. However, the relative effectiveness of these two criteria is shown in Enclosure 8-27 by a comparison of the status of the major flammable materials attached to the spacecraft relative to these criteria. The two most significant differences were the restrictions given to the application of Velcro and the Uralane foam in the NASA criteria. Such restrictions would have prevented the installation of these materials any closer than 12 inches to electrical leads. This would have made a significant difference in the amount of both of these materials installed in the spacecraft at the time of the accident. The difference in the amount of permissible Velcro on and by the hatch and on the floor is shown by comparing the Velcro installation in Enclosures 8-17, 8-8 and 8-9. Only the Velcro shown in red in Enclosures 8-8 and 8-9 would have remained. Much of the Velcro used to support the Raschel would have been prohibited. Under the same enforcement assumption, most of the foam would have been removed.

c. REVIEW OF WIRE BUNDLE TESTING

OBJECTIVE

The objective of this analysis was to review the results of government and industry tests on the subject of ignition and flammability of spacecraft wires.

PROCEDURE

Available test and evaluation data on spacecraft wire bundles were reviewed (Ref. 8-95).

SUMMARY

Although flammability by itself may not be in every case the deciding factor, silicone rubber and polyolefin are so flammable that they appear to have limited usefulness at least in an oxygen atmosphere. On the other hand, H-film appears to be relatively fire resistant. Teflon insulation on electrical wiring propagates a flame in high concentrations of oxygen only when heated.

d. AVAILABILITY OF ALTERNATE MATERIALS

OBJECTIVE

The more prevalent flammable materials in the cabin are nylon debris netting, nylon Velcro, polyolefin couch padding, polyurethane foam and suit material. The objective of this task was to determine if nonflammable or less flammable alternate materials are available for replacement of combustible materials in the spacecraft.

RESULTS

The following materials are suitable for strengthening, insulating, cushioning and filling to reduce combustion rate of a bonded product. They are documented in various government, industry and manufacturers' reports as being nonflammable:

Fiberglass	Potassium Titanate
Beta Fabric	Eccospheres
JM Microfibers	Asbestos
Q felt	Silica
Min-K	Cabosil.

Government and industry documents present a great deal of data concluding that fluorinated plastics and elastomers have a very slow burning rate and are difficult to ignite in 5 psia oxygen. It is known that fluorinated polymers will produce harmful gases when subjected to temperatures over 600°F. Gases produced during flaming are not as harmful. The following are candidate fluorinated plastic and elastomeric matrix materials:

Teflon (TFE)	Kynar
Teflon (FEP)	Fluorel
Kel-F (CTFE)	Viton A
Fluorosilicones	

Typical commercial materials with low burning rates comparable to Teflon or which are nonflammable are presented in the following table (Ref. 8-58, 8-59, and 8-69).

Material	**Type**
Kel-F	n-CF2-CFCl
Aluminum Screen	Silicate coated
Metal Net	
Fluorocarbon Elastomers	n-CF2-CF2Cl-n
Fiberglass	
Armalon Felt (PBX-7700B)	Teflon
J.M. Microfiber Felt	
Min-K Felt	Ceramic
H-Film	Aromatic Polyimide
Sellev	
Inorganic Paper	Ceramic
Crystal M, MP, or MG	
Saucreisen Cement No.'s 28, 29 or 51	Ceramic (Cold Set)

Displays of available materials are shown in Enclosures 8-18 and 8-19. Attachment methods as replacements for Velcro are shown in Enclosure 8-20.

SUMMARY

Nonflammable (or significantly less flammable) materials which probably will meet the use requirements for most of the flammable materials used in S/C 012 were determined to be available

from commercial sources (Ref. 8-59). For example, fiberglass screens or fabrics are essentially nonflammable items which probably can serve as debris traps. Ceramic fiber batts in nonflammable covers are available for use as cushions, insulations, etc. Final choices of materials should be verified by test approximating their applied configurations.

e. CREW COMPARTMENT PROCESSING AND ENVIRONMENT TIME LINE

OBJECTIVE

The objective of this analysis was to determine the history of the materials processes and environment time line for S/C 012 crew compartment during January 1967.

PROCEDURE

A detailed review of certain C/M related documentation, including DR's, DRS's, and TPS's, was undertaken to define those nonmetallic materials, which were installed or utilized within the crew compartment of the C/M since its receipt at KSC. Interviews with personnel who were in attendance during the performance of OCP FO-K-0021-1 (Plugs-Out Test) were undertaken to further describe the actual C/M nonmetallic configuration at the time of the accident. Cabin environment conditions, i.e., 0_2 partial pressure, temperature, flow rate of circulating air were determined and plotted to display a profile of these parameters from the end of OCP FO-K0034a (Manned Sea Level Test) December 30, 1966 to 6:31 pm EST on January 27, 1967.

RESULTS

The tabulation of materials added by DR, DRS, and TPS action in January 1967 (Ref. 8-45, 8-62, 8-63 & 8-64) is shown below:

Water/glycol (leakage)
Pressure-sensitive adhesive-backed aluminum foil
Freon (cleaning)
RTV 560 (potting)
Methyl-ethyl-ketone (cleaning)
Sealing Compound (MBO 130-019) and primer (MBO 125-038)
Napthalene - Carbon tetrachloride mixture (cleaning)
White Paint (MBO 125-019)
Epon 828 with Versamid 125 (potting)
Glass fabric tape
Epon 954 (bonding)
Teflon tape
Naptha (cleaning)
PRC 1538 (potting)
Teflon heat shrink sleeving
RTV 577 (potting)
Loctite Grade HV, primer (sealing)
Isopropyl alcohol (cleaning)
Leak check soap solution
Acid paste

Review of these materials against the NAA control specification MC999-0058 showed that 6 were accepted, 4 were rejected but waived, and 10 did not appear (Ref. 8-55).

Solvent usage in S/C 012 is estimated as follows for this time period:

methyl-ethyl-ketone	2 quarts[a]
Freon	1 quart
Leak check soap solution	1 pint
Isopropyl alcohol	1 quart[a]
Acid Paste	0.1 pint

[a] Used as a basis for analysis reported in Section 6.a.

A graphic time line on solvent usage was prepared based on the preceding data. Pertinent excerpts are included in Enclosure 8-7, which depicts the last utilization of solvents, the detection of odors and the basic environmental parameters in the spacecraft cabin. (See "Materials Odor Evaluation", 6.5.). Although etchants were not used in the crew compartment a summary study of the potential effects of various etchants was compiled and is presented in References 8-52 and 8-53. Evaluation of the results reveals that many process materials were added in January, 1967. The process materials noted were either installed in such a manner or in such minute amounts that their contribution to the fire intiation even though possible is considered remote.

Approximately 4.5 quarts of solvent were used in the spacecraft through January, 1967. However, results of a cabin environment air sample taken at 10:15 pm EST on January 26, 1967, indicated less than 1 ppm total hydrocarbons. This result tends to reduce concern that solvent vapors could have been a fuel for the fire.

9. RESULTS OF SPECIAL INVESTIGATIONS AND TESTS -TECHNICAL DATA AND INFORMATION AVAILABILITY

This section deals with investigations of the feasibility of methods for improving technical information availability to primary activities having materials selection, installation and control responsibilities.

a. MATERIALS MAPPING AND CREW BAY DISPLAY OBJECTIVE

The objective of this analysis was to develop S/C 012 materials usage displays and to evaluate the feasibility of maintaining displays of nonmetallic materials usage with the LM and C/M crew bay. The purpose of this display was to locate the nonmetallic materials that may become flammability hazards due to their close proximity to ignition sources. The intent of this display was to graphically. illustrate the individual materials, location, approximate amounts, identity of the materials and their status.

RESULTS

The types of displays that were considered are as follows:

(1). Photographs for schematics.
(2). Overlay on schematic.
(3). Display board of actual material samples.
(4). Scale model of crew compartment interior.

A system that worked well during the Apollo 204 accident investigation has been to photograph the interior of the crew bay exhibiting by color photographs the location of the various pieces of associated equipment. This system involved one overall crew bay enlargement with individual "closeup" color photos of pieces of equipment and localized areas (Ref. 8-65 and 8-68).

SUMMARY

Maintenance of spacecraft nonmetallic materials usage displays is feasible and useful.

Preparation of the full-scale mockup of S/C 012 revealed the continuous fire propagation path presented by the placement of Raschel Knit and/or Velcro in the crew bay.

b. MATERIALS INFORMATION CENTER

Objective

The activities of the Materials Panel illustrated the need for:

(1) The rapid availability of materials information including usage and property data.

(2) The availability in graphic form of location and usage of nonmetallic materials in manned spacecraft.

(3) Increased awareness of personnel at all levels of characteristics of nonmetallic materials.

(4) Provide test data and means for getting new materials tested to appropriate criteria.

The objective of this study was to evaluate the feasibility of implementing a more active information interchange system.

RESULTS

An objective review of the materials information program has resulted in a plan for its reorientation toward a more active role in acquiring and distributing vital materials information. The targets for receipt of this information are program management, contractors, and field sites.

Displays covering materials usage in S/C 012 have been prepared. A feasibility study of maintaining individual spacecraft usage data in graphical form has also been prepared.

The existing computerized materials file maintained at MSC was reviewed. The expansion of this system to accommodate test data, usage locations and spacecraft effectivity and material status, including waivers is feasible and is being implemented. The target date is June 1, 1967 (Ref. 8-68, 8-81 & 8-82).

SUMMARY

The results of this study indicate the feasibility of a central data source for acquisition, storage, display and distribution of materials information.

Materials configuration can be maintained in a centralized document. This can be accomplished on each vehicle and reviewed during each Customer Acceptance Readiness Review (CARR), and Flight Readiness Review (FRR). During fabrication and test of each vehicle, configuration control and status can be maintained. Materials information on the use and applications of hazardous materials can be distributed to Program Management, Apollo contractors and field sites. This can be accomplished through workshops, film strips and formal presentations.

10. UNFINISHED BUSINESS

The following items of unfinished business are open.

ITEM	SECTION	EST. COMP. DATE
Routine Materials Testing	5	May 26
Electrostatic Spark Ignition - Suited Man in Spacecraft Tests	6.c	April 15
Effect of Water/Glycol on Wire Bundles	6.g	June 23
Effect of Water/Glycol on Connector Assemblies	6.h	April 21
Effect of Burning Foam Insulation on O_2 Lines	7.a	April 15
Command Module Mockup Tests	7.e	April 15
Theoretical Combustion Analysis	7.h	April 7

D. FINDINGS AND DETERMINATIONS

1. MATERIALS CONFIGURATION

a. FINDING:

Complete documentation which identified potentially combustible nonmetallic materials used in S/C 012 is not available in a single readily usable format. A total of 2,528 different potentially combustible nonmetallic materials which were probably used on S/C 012 were found by a review of available documentation.

DETERMINATION:

The program for identification and documentation of nonmetallic materials used in the S/C, including their weights and surface areas, was not adequate.

There is no system in effect through which nonmetallic materials configuration changes are tracked, reported, evaluated, and controlled in an integrated manner.

b. FINDING:

Test data providing individual combustion properties in environments of 5 psia to 21 psia oxygen were available for 550 of the potentially combustible nonmetallic materials identified as possibly being used. Data on higher pressure testing were available only on suit materials, Velcro and K-10 flight paper.

DETERMINATION:

Flammability test requirements were not standardized at the time the referenced tests were accomplished.

Large numbers of potentially combustible nonmetallic materials were used in the fabrication of S/C 012 without specific correlated combustibility test data. Test data were available at high O_2 pressures (to 21 psia) to define the combustion characteristics of some of the major materials which contributed heavily to the fire.

c. FINDING:

Installation records including photographs and redlined drawings were maintained at KSC which contained descriptions of materials added to S/C 012.

DETERMINATION:

Methods for identifying configuration changes related to materials were operational at KSC.

2. ROUTINE MATERIALS TEST

FINDING:

Raschel Knit, Velcro, Trilock and polyurethane foams burn about twice as fast (in the downward direction) in 16.5 psia as in 5 psia O_2.

DETERMINATION

The primary fuels for the fire burned over twice as fast in the early stages of the fire in accident conditions (16.5 psia) than in space flight atmosphere for which they were evaluated (5 psia).

3. FIRE INITIATION SPECIAL INVESTIGATION

a. Retention of Solvents

FINDING:

Laboratory analyses indicated that solvent retention by test specimens was significant. The analyses also indicate that the evaporation characteristics of the solvent is such that vapor concentration fell below the lean flammability limit after 1½ hours.

DETERMINATION:

The presence of significant volumes of concentrated vapor in the spacecraft is unlikely. However, the retention of solvents in the surface layers of solid flammable materials could possibly contribute to their ignitability.

b. Materials Odor Evaluation

FINDING:

Odors similar to that of sour milk and methyl-ethyl-ketone were reported before the fire during suit and cabin purge operations.

Thresholds of methyl-ethyl-ketone and isopropyl alcohol detection by smell are approximately .01 percent to .03 percent by volume and concentrations described as strong, irritating or sickening range from 1 percent to 4 percent by volume.

DETERMINATION:

There is no evidence that significant concentrations of organic vapors were present in S/C 012 at the time of the fire.

c. ELECTROSTATIC SPARK IGNITION

FINDING:

The maximum electrostatic spark energy generated and measured on a man suited in a space suit was about 4 millijoules.

FINDING:

Ignition of the more flammable S/C 012 solid materials tested required spark energies of 190 millijoules or greater.

FINDING:

Ignition of solvent vapors in oxygen can take place at spark discharge energies as low as 0.002 millijoules. Ignition of methane vapors in oxygen can take place at spark discharge energies as low as 0.004 millijoules. Ignition of solid materials damp with solvents can take place at spark discharge energies as low as 40 millijoules.

DETERMINATION:

Ignition of solid materials by electrostatic discharge is not a probable cause of the S/C 012 fire.

DETERMINATION:

It is possible from an energy consideration that methane and solvent vapor can be ignited by electrostatic discharge. Nevertheless, this is not believed to be a possible cause of the fire.

d. COBRA CABLE SPARK IGNITION

FINDING:

Connecting and disconnecting of spacecraft qualified Cobra connectors at normal loads did not create sufficient energy to ignite concentrations up to saturation (approximately 12 percent) of methyl-ethyl-ketone in 16.4 psia oxygen. An increase in loading to 2.5 times operating amperage in 4.0 percent of MEK yielded no ignition.

DETERMINATION:

Ignition of flammable concentrations of solvent vapors by connecting and disconnecting Cobra connectors is an unlikely ignition source for the S/C 012 fire.

e. IMPACT SENSITIVITY OF MATERIALS IN GOX

FINDING:

Preliminary high energy impact tests on Velcro and Raschel Knit in 16.5 psia oxygen produced ignition and burning.

FINDING:

A survey of similar spacecraft and mockup failed to disclose the possibility of any high impact conditions.

f. SPONTANEOUS IGNITION OF S/C 012 MATERIALS .

FINDING:

Results of tests on S/C 012 materials considered to be most flammable with and without solvents (methyl-ethyl-ketone, isopropyl alcohol) and coolants (water/glycol) did not result in spontaneous ignition at or below 400°F in any case.

DETERMINATION:

Spontaneous ignition is an unlikely ignition source for the S/C 012 fire.

g. EFFECT OF WATER/GLYCOL ON WIRE BUNDLES

FINDING:

Conditions required for wet-wire fire ignition through electrolytic action are damaged wire insulation, presence of an electrolyte and electric potential between damaged wires and a flammable substance in the proximity. A test has shown that ECS coolant applied to a purposely damaged wire of a type used in the C/M caused a fire .

DETERMINATION:

The required conditions could have been present in S/C 012.

h. REVIEW OF KSC CONNECTOR TEST WITH WATER/GLYCOL

FINDING:

An unpotted connector with some unused pin channels subjected to water/glycol and placed under DC stress developed a short circuit.

DETERMINATION:

Water/glycol electro-corrosion products and residue are conductive and capable of acting as an electrolyte.

4. FIRE PROPAGATION SPECIAL INVESTIGATION

a. WATER/GLYCOL LEAKAGE IN SPACECRAFT

FINDING:

There have been 35 instances of water/glycol leakage on Block I Spacecraft involving approximately 320 ounces.

DETERMINATION:

The water/glycol distribution system requires corrective action to eliminate leakage.

FINDING:

Prior to the accident there had been no electrical system failures attributable to the water/glycol leaks.

DETERMINATION:

The electrical system has some tolerance to water/glycol spillage.

FINDING:

There is no standard cleaning procedure in effect to remove water/glycol spills or residue.

DETERMINATION:

There is a probability that water/glycol residue is present in areas of all Block I Spacecraft.

FINDING:

Six instances of water/glycol leakage were recorded for S/C 012. Of these, one soaked several SCS connectors and wire bundles. Some corrective action was taken to clean all known spills in S/C 012.

DETERMINATION:

Water/glycol residues may have been present in areas of S/C 012 including on wire bundles and connectors.

b. FLAMMABILITY OF WATER/GLYCOL RESIDUES

FINDING:

Tests in a 14.7 psia oxygen atmosphere on horizontal surface show films of C/M coolant will not propagate a flame before or after air drying for up to 48 hours. Films of coolant will propagate a flame after exposure to reduced pressure for periods of 60 to 80 hours. Pure ethylene glycol will propagate a flame in a similar atmosphere.

DETERMINATION:

Residues from previous standard coolant fluid spills in S/C 012 might have provided a path for flame propagation on materials that were wetted. Spills or leaks in the early stages of the fire would burn when heated.

c. TEMPERATURE MAPPING OF S/C 012

FINDING:

Surface and bulk damage of materials in S/C 012 varied from melting and blistering of aluminum alloys, combustion of Velcro and melting and burning of Teflon wire insulation to slight surface damage and melting of nylon fabrics.

DETERMINATION:

The fire filled the S/C interior. The most intense heat was in the lower left front area around the ECU. Surface temperatures in excess of 1000°F were reached in areas such as the front and left side of the spacecraft. Surface temperatures were less than 400°F in isolated pockets above the right-hand couch.

d. CORRELATION OF C/M MOCKUP TESTS

FINDING:

The condition and appearance of individual materials after the 16.5 psia oxygen boilerplate test approximated materials conditions observed in S/C 012. The pressure rise measured in the boilerplate test approximated that in the S/C 012.

DETERMINATION:

A reasonable simulation of the S/C 012 accident was achieved by the boilerplate tests.

FINDING:

The rate of flame propagation, the rate of pressure increase and the maximum pressures achieved and the extent of conflagration in 5 psia oxygen boilerplate tests was much less severe than observed in the 16.5 psia oxygen boilerplate tests. Burning or charring was limited to approximately 29 percent of the nonmetallic materials by oxygen depletion.

DETERMINATION:

The conflagration which occurred in S/C 012 at 16.5 psia would be far less severe and slower in a spacecraft operating with an environment of 5 psia oxygen if additional large quantities of oxygen are not fed into the fire.

DETERMINATION:

A fire in a spacecraft configured as S/C 012 operating with a 5 psia oxygen environment could be fatal.

FINDING:

The early stages of fire propagation in the boilerplate tests were observed to be dependent upon the combustion rate and location of the materials. The observed rates appeared to have been much greater than the factor of two increase measured downward in the laboratory tests when the oxygen pressure is increased from 5 psia to 16.5 psia. The additional increase in rate in the boilerplate tests most likely occurs because of the combined effect of burning upward and along the continuous paths provided by flammable materials. This is substantiated by preliminary results referenced in 8-106.

DETERMINATION:

The spread of fire at 16.5 psia operating pressures is too rapid for effective remedial action in spacecraft with combustible materials arranged as in C/M 012. The spread of fire at 5 psia operating pressures is probably too rapid for effective remedial action by an unsuited crewman.

e. THERMO-CHEMICAL ANALYSIS OF FIRE DEVELOPMENT

FINDING:

The energy available from about four ounces of Raschel Knit or Velcro could raise the pressure in a closed C/M from 16.5 psia to 36 psia in less than 14 seconds after ignition. (Calculations assume complete combustion and adiabatic conditions).

FINDING:

Teflon materials did not burn appreciably in S/C 012. Calculations based on laboratory data indicate that Teflon could not have contributed appreciably to the rate of pressure rise. The total energy available from the Raschel Knit, Velcro, foam, Trilock and polyurethane materials was much greater than necessary to raise the cabin pressure from 16.5 psia to 36 psia.

DETERMINATION:

Teflon provides an insignificant fire risk.

DETERMINATION:

There was considerable excess combustible material available with which to raise the C/M pressure to the estimated burst pressure.

5. MATERIALS INSTALLATION CRITERIA AND CONTROLS

a. NAA CRITERIA AND MATERIALS CONTROL PROCEDURE

FINDING:

The NAA materials selection specification MAO 155-008 requires only that a material pass a 400°F spark ignition test in 14.7 psia oxygen.

DETERMINATION:

The NAA criteria for materials flammability control were inadequate.

FINDING:

A system for control of nonmetallic materials usage existed at NAA during the design, fabrication and assembly of C/M 012. The NAA materials control system is design oriented.

DETERMINATION:

The system is permissive to the extent that controls over the installation or use of flammable materials are not adequate.

FINDING:

There were nonflight items containing combustible materials in C/M 012 during this test.

FINDING:

No flammability criteria or control existed covering nonflight items installed in C/M 012 for test.

DETERMINATION:

Lack of control of nonflight material could have contributed to the fire.

b. NASA-MSC CRITERIA AND MATERIALS CONTROL PROCEDURES

FINDING:

The NASA materials selection criteria MSC-A-D-63 and MSC-A-D-66-4 requires that a material pass a 400°F spark ignition test and a 0.5 in/sec combustion rate (measure downward in 5 psia O2). Raschel Knit and Velcro (hook) pass this test.

DETERMINATION:

The NASA criteria for materials flammability control are not sufficiently stringent.

FINDING:

The system for control of nonmetallic materials usage at MSC during the design and development of government furnished equipment used in C/M 012 depended on identification of noncompliance with criteria by the development engineers.

DETERMINATION:

The NASA materials control system is permissive to the extent that installation or use of flammable materials were not adequately reviewed by a second party.

FINDING:

The NASA criteria were intended to limit the use of Velcro and Uralane foam to distances greater than 12 inches from wire bundles.

FINDING:

Nonmetallic materials selection criteria utilized by NAA and NASA are not consistent. The NASA criteria, although more stringent, were not contractually imposed on the S/C contractor.

DETERMINATION:

Materials were evaluated and selected for usage in C/M 012 using different criteria. Application of the NASA criteria to the C/M would have reduced the amount of the more flammable

C-3

materials (Velcro and Uralane foam).

FINDING:

Visual "walk-through" inspections had resulted in removal of combustibles in the proximity of wire bundles on C/M 012 before delivery and on C/M 008 before manned testing. Such inspection had not been made before OCP FO-K 0021-1

DETERMINATION:

Visual inspections have resulted in removal of combustible materials from potential ignition sources (wire bundles).

c. AVAILABILITY OF ALTERNATE MATERIALS

FINDING:

Alternate materials which are nonflammable or significantly less flammable than those used on C/M 012 are available for many applications.

DETERMINATION:

The amount of combustible material used in Command Modules can be limited.

6. TECHNICAL DATA AND INFORMATION AVAILABILITY

MATERIALS INFORMATION CENTER

FINDING:

Current information and displays of the potentially flammable materials configuration of S/C 012 was not available prior to the fire.

FINDING:

A centralized source for materials data was established for the Board Panel 8 (Materials Review).

DETERMINATION:

Maintenance of data and displays at central locations and test sites for management visibility and control of flammable materials is feasible and useful.

E. SUPPORTING DATA

This section contains references to supporting data in the form of reports, lists and other documents. Also included are photographs, tables and graphs essential to provide completeness of this final report.

Items are numbered 8-1, et. seq., for those displays enclosed in this section. Supporting reports and references not included in this report are numbered consecutively.

Supporting data included are listed below:

Enclosure	Description
8-1	Not used
8-2	Sample page from C/M 012 Materials Configuration, March 6, 1967
8-3	C/M 012 Temperature Mapping and Materials Usage Display - Prior to Fire (Neg. No. 166-238C-2)
8-4	C/M 012 Temperature Mapping and Materials Usage Display - After Fire (Neg. No. 166-238C-3)
8-5	C/M 012 Temperature Mapping Overlay (Neg. No. 283-198C-1)
8-6	C/M 012 pPressure vs Burning Time - Velcro or Raschel Knit
8-7	C/M 012 Materials Time Line
8-8	Exposed Nonmetallic Materials Location - Velcro and Wire Bundles 12 Inches Apart on Floor (Neg. No. 329-713C-3)
8-9	Exposed Nonmetallic Materials Location - Velcro and Wire Bundles 12 inches Apart on Aft Bulkhead & Hatch (Neg. No. 329-713C-4)
8-10	Major Exposed Nonmetallic Materials in C/M 012 (Neg. No. 166-238C-1)
8-11	Exposed Nonmetallic Materials Location - Command Module Outline (Neg. No. 216-468C-1)
8-12	Exposed Nonmetallic Materials Location - Velcro (Neg. No. 216-468C-4)
8-13	Exposed Nonmetallic Materials Location - Velcro and Uralane Foam (Neg. No. 216-467C-6)

8-14 Exposed Nonmetallic Materials Location - Velcro and Uralane Foam and Raschel Knit (Neg. No. 216-467C-3)
8-15 Exposed Nonmetallic Materials Location - Velcro and Uralane Foam and Raschel Knit and Trilock/Raschel Covering (Neg. No. 216-467C-2)
8-16 Exposed Nonmetallic Materials Location - Suits Added (Neg. No. 216-466C-5)
8-17 Exposed Nonmetallic Materials Location - Aft Bulkhead Added (Neg. No. 216-466C-1)
8-18 Candidate Nonflammable Materials - Cushions Insulation, Velcro, Debris Net and Miscellaneous (Neg. No. 233-485C-3)
8-19 Candidate Nonflammable Materials - Felts, Coatings, Lubricants, Adhesives and Coolants (Neg. No. 238-487C-2)
8-20 Possible Equipment Attachment Substitutions (Neg. No. 233-485C-2)
8-21 Candidate Nonflammable Materials - Command Module Outline (Neg. No. 221-470C-3)
8-22 Candidate Nonflammable Materials - Velcro Substitutes (Neg. No. 221-470C-4)
8-23 Candidate Nonflammable Materials - Substitutes for Velcro, Foam, and Trilock Raschel Covering (Neg. No. 221-470C-5)
8-24 Candidate Nonflammable Materials - Substitutes for Raschel Knit and Suits Added (Neg. No. 221-470C-2)
8-25 Candidate Nonflammable Materials - Substitutes on Aft Bulkhead (Neg. No. 221-470C-1)
8-26 List of References
8-27 Status of Major Nonmetallic Materials Used in CSM 012

ENCLOSURE 8-2

SAMPLE PAGE FROM C M 012 MATERIALS CONFIGURATION LIST

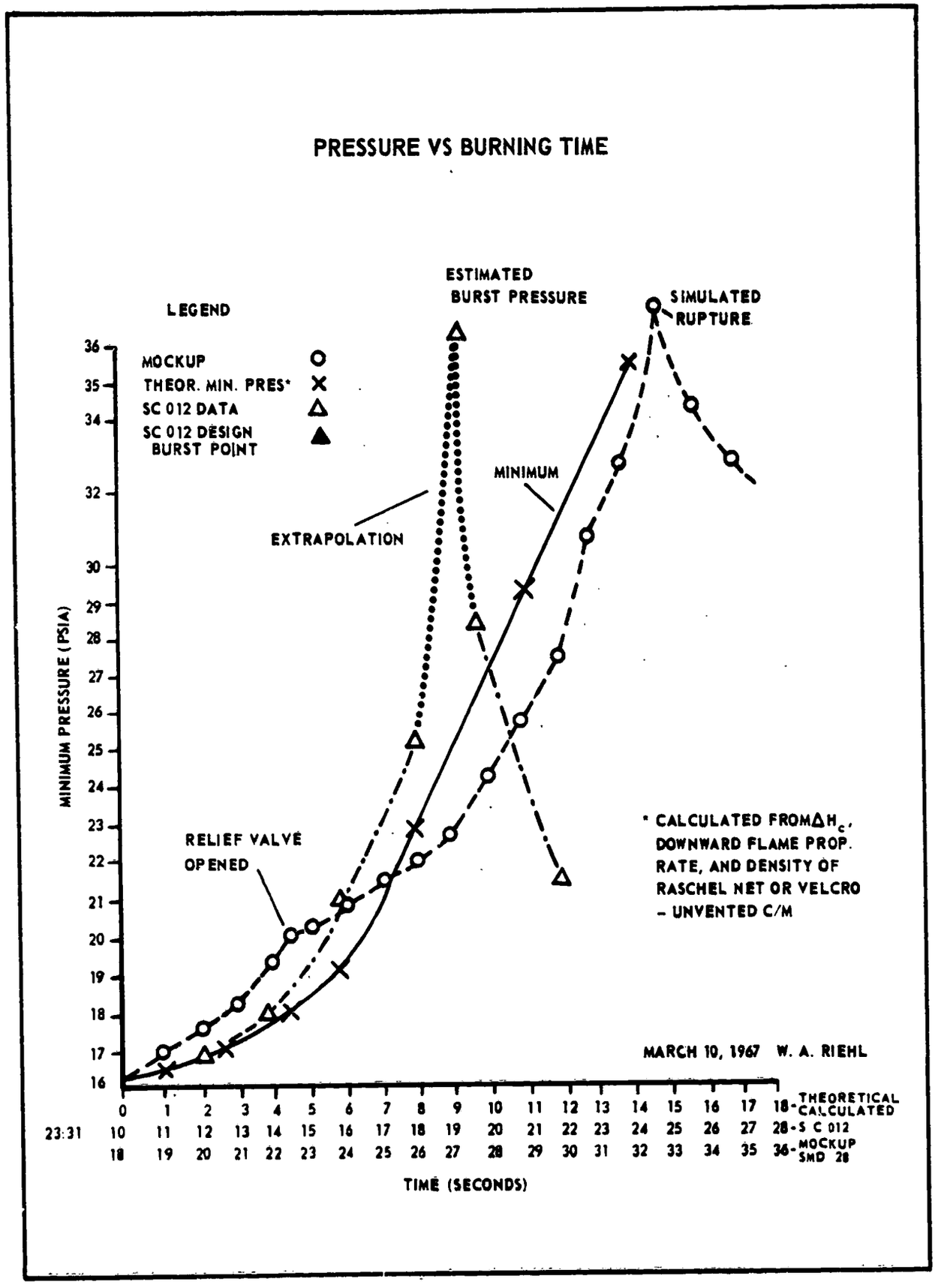
APOLLO CREWBAY MATERIALS

05 FABRIC

MATERIALS				LOCATION					PRIORITY	TESTS				TEST RESULTS				QUANTITY USED		WAIVER	MSC-A-R-64
NAME	MFGR DESIG	MFGR	SPEC NUMBER	SUB SYST	CONTR	SUB CONTR	INSTL SITE	USE		SPEC.	FACILITY	DATE	O_2 psi	FIRE PT.°F	FLASH PT.°F	COMB. RATE in/min	AUTO IGNT. °F	WEIGHT (LBS)	AREA IN^2		
																		.014	21.		
									4	AP SIM Spe 26.		1964		424	424		791				
	#594								6	MSCA D-66-5	MIT	1967		500	500	.36	N.R.				
										MSCA D-66-5	MIT	1967		500	500	.36	N.R.	.028 gm.	3.74	123 D	
																		.08	169		
																		.01	2.1		
									5												

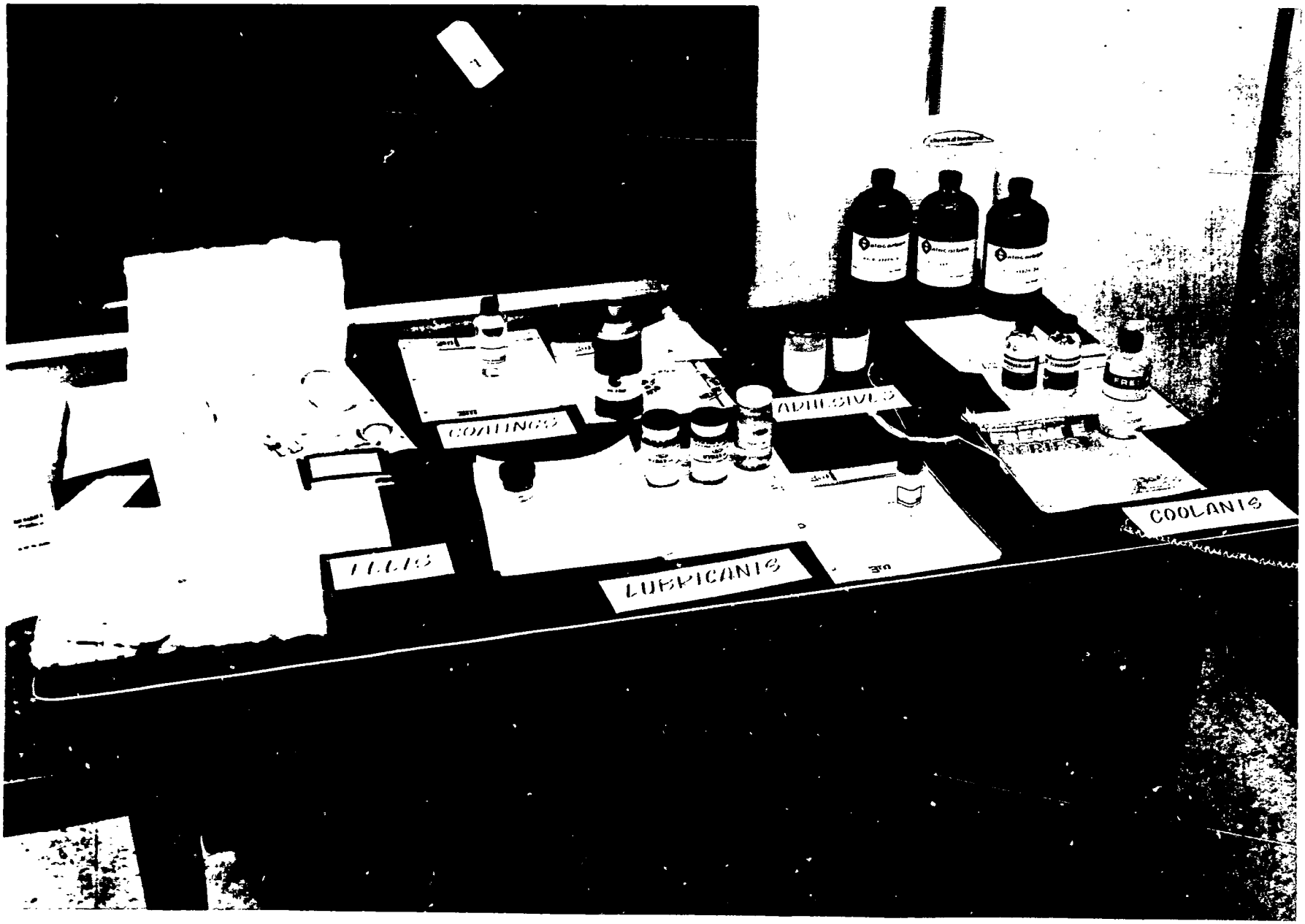
REMARKS:

D-8-3



ENCLOSURE 8-6

ENCLOSURE 8-19



CANDIDATE NON-FLAMMABLE MATERIALS – FELTS, COATINGS, LUBRICANTS, ADHESIVES AND COOLANTS

LIST OF REFERENCES

	TITLE	IDENTIFICATION SOURCE
8-1	Nonmetallic Materials Used in the Interior of the Apollo Command Module, September 1, 1966	Unidentified (30 pgs. 881 materials)
8-2	Subcontractor Material Use List	Unidentified (53 pgs)
8-3	Updated Tab Run of Nonmetallic Materials	NO ID Number
8-4	Stabilization and Control System, Honeywell Inc., Material List, October 25, 1964	A64769A (2)
8-5	Partial List of Materials on S/C 012 by Drawing Number	Unidentified (48 pgs)
8-6	Material Usage G&N 12/50, February 5, 1967	Unidentified (86 materials plus hand-written update of KSC added)
8-7	Apollo Materials Master File Index, December 28, 1967	RPT-X50-98-915
8-8	GFE Equipment - Nonmetallic materials (Addendum to TRIS 020580)	TRIS 020583
8-9	GFE - Flight Crew Support Division Hardware Onboard, January 27, 1967	Unidentified (Survey of cognizant FCSD personnel)
8-10	Acceptable S/C 012 GFE Materials List - Tab Run, February 6, 1967	TRIS.020585
8-11	Bills of Materials, Space Suit Assembly S987-000 Part I	TRIS 020590
8-12	Bills of Materials, Space Suit Assembly, S978-000 Part II	TRIS 020591
8-13	Bills of Materials, Helmet Assembly, A1920-000	TRIS 020592
8-14	Collins Test Data	AR-518-1, January 1965
8-15	Hamilton Std. Test Data	SVHSER 4024,3886.
8-16	KSC Data	February 14, 1967
8-17	MSC Data	February 2-9, 1967.
8-19	MSC Data	Tech. Note S136, 1966
8-18	MSC Data	February 7-8, 1967
8-20	WSTF Data	February 2, 1967
8-21	GAEC Data	LED-520-3A, January 1966
8-22	S. A. M. Data	TR-65-78, 1965
8-23	MIT G&N Data	Not published, 1967
8-24	NAA, Hughes Data	P64-53, June 1964
8-25	NAA, Hughes Data	P66-06, January 1966
8-26	NAA Hughes Data	P67-32, February 1967
8-27	NAA Hughes Data	2748, 06, 56, February 20, 1967
8-28	S/C 012, Materials Configuration	Apollo 204 Review Board Panel 8 Materials Review March 6, 1967
8-29	Spark Ignition Tests	Apollo 204 Review Board Panel 8 Materials Task 2.1
8-30	Determination of Impact Sensitivity of Materials to GOX	Apollo 204 Review Board Panel 8 Materials Task 2.29
8-31	Material Cataloging and Routine Testing	Apollo 204 Review Board Panel 8 Materials, Tasks, 1.1, 1.2 and 1.3
8-32	Electrostatic Spark Generation in Selected Nonmetallic Materials	Apollo 204 Review Board Panel 8 Materials, March 8, 1967
8-33	Flammability of Materials in O_2 (Preliminary)	Apollo 204 Review Board Panel 8 Materials Task 2.3
8-34	Temperature Mapping in S/C 012	Apollo 204 Review Board Panel 8 Materials Task 2.4
8-35	Preliminary Temperature Survey of S/C 012	Apollo 204 Review Board Panel 10, February 28, 1967

8-36	Temperature Changes in S/C 012	Apollo 204 Review Board Panel 3, February 28, 1967
8-37	Temperature Changes in S/C 012	Apollo 204 Review Board Panel 1, February 20, 1967
8-38	Wire Bundle Insulation Test Exposed to Water/Glycol	Apollo 204 Review Board Panel 8, Materials Task 2.5
8-39	Studies Underway on Water/Glycol Solutions	Apollo 204 Review Board Panel 8, Dr. A.A. Staklis
8-40	Flammability of Type II Water Glycol Coolant	Apollo 204 Review Board Panel 8, W. A. Riehl
8-41	Absorption - Evaporation Tests	Apollo 204 Review Board Panel 8, Materials Task 2.6
8-42	Data on Flammability Limits and Ignition Energies for Certain Substances	Datafax to A. Busch from W. T. Olson, Lewis Research Center February 2, 1967
8-43	Development of the Maximum Temperature Profile of C/M 012 Inner Cabin	Apollo 204 Review Board Panel 10, February 22, 1967
8-44	S/C 012 Temperature Profile	Apollo 204 Review Board Panel 10, February 18, 1967
8-45	Concentrations of MEK in S/C 012	Apollo 204 Review Board Panel 8, February 18, 1967
8-46	Autogenous Testing of Nonmetallic Materials in the C/M	Apollo 204 Review Board Panel 8, Materials Task 2.7
8-47	Updating of Thermochemical Plots of Pressures vs. Time for S/C 012	Memo to W. M. Bland, Panel 8, from W. A. Riehl March 10, 1967
8-48	Final Report - Preliminary Cobra Cable Spark Test, TPS-MA 014	Apollo 204 Review Board, Panel 8 March 7, 1967
8-49	Investigation Report - Preliminary Cobra Cable Spark Test (TPS-MA 014)	Submitted to Panel 8 by J. C. Van Hooser, March 1, 1967
8-50	Approved Nonmetallic Materials for C/M Interior	Apollo 204 Review Board, Panel 8 February 22, 1967
8-51	Materials Comparison and Reconcilliation Between NAA Spec. 0058 and MSC Spec. 66-4, March 1, 1967	Apollo 204 Review Board, Panel 8 Materials Task 2.11
8-52	Deleterious Effects of Etchants in S/C and Wire Bundles	Apollo 204 Review Board, Panel 8 Materials Task 2.13
8-53	MSFC Tests of Teflon Etchant	Apollo 204 Review Board Panel 8, February 15, 1967 W. A. Riehl
8-54	Material Odor Evaluation for S/C 012 (Ref. Action Item no. 78)	Apollo 204 Review Board Panel 8, March 7, 1967, Materials Task 2.15
8-55	S/C 012 Crew Bay Configurations Time of Delivery to Time of Accident	Apollo 204 Review Board Panel 8, Materials Task 2.16
8-56	Thermochemical Analysis of Fire Development in S/C 012 Based on Materials Characteristics	Apollo 204 Review Board Panel 8, March 9, 1967
8-57	Estimates of the Mass of Materials in S/C 012 at Time of Accident	Apollo 204 204 Review Board Panel 8, Materials Task 2.18
8-58	Flammable Materials Substitution Program	Apollo 204 Review Board Panel 8, Unissued
8-59	Alternates for the More Prevalent Nonmetallic in the Cabin, March 1, 1967	Apollo 204 Review Board Panel 8, Materials Task 2.19
8-60	Comparison of Nonmetallic Distribution in S/C 008 and 012	Apollo 204 Review Board Panel 8, Materials Task 2.21
8-61	Calorimeter Bomb Tests of Selected Materials to Determine Fuel Energy Available	Apollo 204 Review Board Panel 8, Materials Task 2.23
8-62	S/C 012 Materials Oriented Timeline Backup Material	Apollo 204 Review Board Panel 8, Materials Task 2.31
8-63	Summary of Solvents, Bonding Agents, Etchants, etc. Usage in S/C 012	Apollo 204 Review Board Panel 8, Materials Task 2.32
8-64	Quantities of Nonmetallic Materials Installed in CSM 012 at KSC	Memo to W. M. Bland, Panel 8, from A. Lorenz, March 9, 1967, re Task 2.16

8-65	Reconciliation of Materials Usage Geometry in PIB Mockup and Panel 8 Display	Apollo 204 Review Board Panel 8, Materials Task 2.38
8-66	A Special Assessment on Materials Analysis Branch Report of 12, 2, 66 on Hughes Co. Connector Assembly	Apollo 204 Review Board Panel 8, February 28, 1967
8-67	Materials Evaluation, Connector Assembly Hughes Aircraft Co. P, N 1004250 and P/N 1004251 - MAB-1392-66	Materials Analysis Branch Technical Services Division
8-68	Materials Information Service Plan	Apollo 204 Review Board Panel 8, Materials Task 2.41
8-69	Alternate Materials Follow-up Information Display	Apollo 204 Review Board Panel 8, Materials Task 2.44
8-70	Water/Glycol Leakage History of S/C 009, 011, and 012	Apollo 204 Review Board Panel 8, Materials Task 2.50
8-71	NAA's Criteria and Materials Control Procedures Prior to Jan. 27, 1967	Apollo 204 Review Board Panel 8, Materials Task 2.51
8-72	Contractor Nonmetallic Materials Waiver Status	Apollo 204 Review Board Panel 8, Materials Task 2.52
8-73	GFE Nonmetallic Materials Waiver Status	Apollo 204 Review Board Panel 8, Materials Task 2.54
8-74	Interim Summary Report	Apollo 204 Review Board Panel 8, February 16, 1967
8-75	Responsibility and Schedule for Accomplishment of Panel 8 Materials Tasks, Rev. A	Apollo 204 Review Board Panel 8, February 28, 1967
8-76	Responsibility and Schedule for Accomplishment of Panel 8, Materials Tasks, Rev. B.	Apollo 204 Review Board Panel 8, March 2, 1967
8-77	Study of Flammability Properties of Water Glycol Mixtures	Apollo 204 Review Board Panel 8 Materials Task 2.27
8-78	Testings of the Effect of Water Glycol on Apollo S/C Wire Insulation	Apollo 204 Review Board Panel 8, February 27, 1967 Dr. A. A. Staklis
8-79	Activity Report as of February 27, 1967, Spark Ignition Tests per February 6, 1967, Letter by A. Busch	Memo to W. Bland from J. D. Jeter, Chief, Materials Analysis Branch, KSC, February 27, 1967
8-80	Input to Panel 8 - Materials Final Report, Routine Materials Test Status and Boilerplate Test Status	Memo to W. M. Bland, Panel 8, from J. N. Kotanchik, MSC, March 8, 1967
8-81	Selection Control of Nonmetallic Materials in S/C (Preliminary Outline)	W. M. Bland, ASPO, R. Q&I, March 8, 1967
8-82	Materials Information Service Program Plan	Apollo 204 Review Board Panel 8, Materials, March 6, 1967
8-83	Testing of Water Glycol Treated Wire Bundles (Connectors) at KSC	Apollo 204 Review Board, Panel 8, Materials, March 10, 1967 (Task 2.12)
8-84	Approved Materials for Use in the Apollo S/C, General Specifications	North American Aviation, Inc., Specification No. 99-0058

8-85	Procedures and Requirements for the Evaluation of Apollo Crew Bay Materials	NASA-MSC, R: Q&T Div. May 13, 1966, MSC-A-D-66-3
8-86	Crew Bay Nonmetallic Materials Status Report of Unacceptable, Acceptable Materials Rev. F	NASA-MSC, R. Q&T Div. December 30, 1966, MSC-A-D-66-4
8-87	Boilerplate Flammability Tests in 5 psia oxygen	NASA-MSC (Film)
8-88	Boilerplate Flammability Tests in 16.5 psia Oxygen	NASA-MSC (Film)
8-89	Hazardous (Nonmetallic) Materials Control Program	H. M. Lampert, GE-ASD February 17, 1967
8-90	Acceptable S C 012 GFE Materials List, Tab Run, 2.16 67	TRIS 028075
8-91	Flammability Characteristics of Materials in Oxygen	Apollo 204 Review Board, Panel 8-Materials, February 22, 1967
8-92	Investigation Report - Aircraft Wire Harness Fire	Lockheed Film No. 3 (4-1963)
9-93	Spontaneous Ignition of S C 012 Materials	Apollo 204 Review Board, Panel 8, Materials-Task 2.7
8-94	The Lockheed Aircraft Corporation Film on Wet Wire Fire	Memo to PD Chief, Systems Engineering, from PD4 Engineering Branch, February 9, 1967, PD4 M864
8-95	Materials Literature Survey of Wire Bundle Tests Having Application to Apollo 204 Accident Investigation	Apollo 204 Review Board, Panel 8, Materials-Task 2.24
8-96	Flammability of the Higher Boiling Liquids and their Mists	Industrial and Engineering Chemistry, December 1947, p. 1607 - -
8-97	Physical Properties of Ethylene Glycol	GLYCOLS, Carme and Johnston, ACS Monograph 114 Reinhold Publ. Co.
8-98	Test Activities by Structures and Mechanics Division, Manned Spacecraft Center	Apollo 204 Review Board, Panel 8, March 19, 1967
8-99	Boilerplate Flammability Tests in 16.5 psia Oxygen (1st Test)	NASA MSC (Film)
8-100	"Some Experiments on Coolant Mixture"	Raychem Corp. Memo to R. M. Halperin from Heslop & Frisco dated March 11, 1967
8-101	List of Some Significant Correspondence Relative to Nonmetallic Materials Control at NAA	Apollo 204 Review Board, Panel 8 March 17, 1967
8-102	Contract NAS9-150, R&D for Project Apollo S C Toxicity and Flammability Program	Letter to R. W Williams, MSC from G. W. Jeffs, NAA, January 10, 1967
8-103	Final Report-Solvent Evaporation Rates from nonmetallic materials in an ambient environment	Letter to Panel 17 from Chairman, Panel 8, Material Review, Task 2.6
8-104	Results of Electrostatic Ignition Investigation, March 31, 1967	Memo from E. . Litchfield to Chairman, Panel 18, with attachment

8-105	Summary of Suit Electrostatic Measurement Data	Memo to Chairman, Panel 8, from KB-6, Whittaker
8-106	Results of Special Tests on Raschel Knit	Preliminary Report, March 31, 1967, W. M. Bland, Panel 8, Materials
8-107	Wet Wire Fire Test No. 1	Apollo 204 Review Board, Panel 8, March 31, 1967

STATUS OF MAJOR NONMETALLIC MATERIALS USED IN S/C 012 CREW BAY

Introduction

The objective of this evaluation was to determine the status of the major combustible materials used in the S/C 012 crew bay.

Results

The table below lists materials status as determined from a review of NAA MC 999–0058 and MSC-A-D-66-4 documents which list acceptable and unacceptable materials.

TABLE
STATUS OF MAJOR NONMETALLIC MATERIALS USED IN
S/C 012 CREW BAY

MATERIAL DESIGNATION	MATERIAL TYPE	STATUS PER NAA-MC-999-0058 Rev. D	STATUS PER MSC-A-D-66-4 Rev. F
Nylon Rachel Knit	Polyamide	Acceptable	Acceptable
Nylon Velcro	Polyamide	Acceptable	Restricted – 12 inches from electrical leads
Trilock Cushions	Woven Cushion. Rubber Based Thread.	Acceptable	Unacceptable
Uralane 577-1	Polyurethene Foam	Acceptable	Restricted – Not to exceed 18 inches lengths or closer than 12 inches from electrical leads

REPORT OF PANEL NO. 9
DESIGN REVIEWS PANEL
APPENDIX D-9
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

DESIGN REVIEW PANEL REPORT

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Design Review Panel, 9. The task assigned for accomplishment by Panel 9 was prescribed as follows:

Conduct critical design reviews of systems or subsystems that may be potential ignition sources within cockpit or which might provide a combustible condition in either normal or failed conditions. Consider areas such as glycol plumbing configuration, electrical wiring and its protection, physical and electrical, as well as other potential ignition sources such as motors, relays, and corona discharge. Other areas of review include egress augmentation and basic cabin atmosphere concept (one versus two-gas). Document where applicable pro's and con's of design decisions made.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Design Review Panel:

Mr. R. W. Williams, Manned Spacecrft Center (MSC), NASA, Chairman
Mr. J. Janokaitis, Kennedy Space Center (KSC), NASA
Mr. Aaron Cohen, Manned Spacecraft Center (MSC), NASA
Dr. John F. McCarthy, North American Aviation (NAA), Downey, California
Mr. R. Pyle, North American Aviation
Mr. F. Sanders, McDonnell Company, St. Louis, Missouri

2. COGNIZANT BOARD MEMBER:

Mr. G. White, NASA Headquarters, Board Member, was assigned to monitor the Design Review Panel.

C. PROCEEDINGS

1. APPROACH:

Panel 9 effort has encompassed the four major sub-divisions as follows:

a. Review of subsystems for sources of ignition or flammable materials.
b. Review of the selection of the cabin atmosphere.
c. Review of the egress process.
d. Review of the flight and ground voice communications.

The object of the review was to:

a. Identify problems and potential problem areas that may provide guidance in determining the cause of the fire.
b. Identify potential problem areas in the design for which design changes may be required.

The review process has been expedited by informal assignment of subtasks to knowledgeable groups of people (Reference 1).

It must be noted that the contemplated spacecraft configuration for the next manned flight (Spacecraft 101, Block II) is different to a significant extent from spacecraft (S/C) 012 (Block I) in which the fire occurred. As a consequence both configurations are involved in the design reviews; the Block I configuration as an aid to determining possible sources for the fire, and the Block II to evaluate the system design characteristics and potential design change requirements to prevent recurrence of fire.

2. DETAILS OF INVESTIGATION

A description of the process leading to the results of the detailed analyses of each of the four major subdivisions listed in Item 1 is presented herein.

a. Ignition and Flammability

(1) SUMMARY

A team of NASA and NAA Subsystem Managers and Systems Engineers conducted a thorough review of the subsystems housed in Block I and II Command Module (C/M) crew compartments. The purpose of the review was (1) to ascertain if any of the subsystems con-

tained ignition sources that might have contributed to the Apollo 204 incident and (2) to identify similar anomalies that might exist in the Block II S/C and document them for input to the overall spacecraft design review activity.

This extensive review culminated in the compilation of a final report (Reference 2) to the Chairman of Panel 9 substantiated by the Design Review summary sheets (Reference 3). Results of the review delineate ignition sources (Blocks I and II) and contiguous non-metallic materials (Block II) for each subsystem. The type of packaging and qualification history was examined and is listed for each component (Block II). A summary of this review is included as Enclosure 9-1 to this report.

(2) CRITERIA FOR REVIEW

(a) IGNITION SOURCES

Search for and identify possible ignition sources of the following types:

Corona discharge

Electrical arcs or sparks from damaged insulation, motor brushes, exposed relay contacts, switches, etc.

Overheating caused by circuit failures

Overheating due to inadequate or improper lubrication

Chemical sources

Miscellaneous (impact, etc.)

(b) COMBUSTIBLE MATERIALS

Identification and location by subsystem of all flammable materials within the crew compartment.

(3) SYSTEM/SUBSYSTEMS FOR REVIEW

(a) Guidance and Navigation (G&N) (including Block II rendezvous radar)
(b) Stabilization and Control System (SCS)
(c) Electrical Power System (EPS) and Sequential Events Control System (SECS)
(d) Controls and Displays
(e) Caution and Warning System (C&WS)
(f) Environmental Control System (ECS)
(g) Emergency Detection System (EDS)
(h) Telecommunications (T/C)
  Operational instrumentation
  Spacecraft communication
  Crew communication
  Television (TV)
  System instrumentation
(i) Experiments and Scientific Equipment
(j) Crew Personal Equipment

(4) METHOD OF OPERATION

The task was executed in two phases. The first phase consisted of concurrent independent reviews of the C/M subsystems by Subsystem Managers and Systems Engineers at Manned Spacecraft Center (MSC) and by contractor personnel at the North American Aviation (NAA) plant in Downey, California. These independent reviews were conducted in the time period February 6-16, 1967. The second phase consisted of working sessions, involving both MSC and NAA personnel, conducted at MSC during the period February 17-20, 1967. During these sessions, the MSC and NAA inputs were combined to constitute the subpanel report. The two-phase method of task execution was used for many reasons, the principal being optimum utilization of personnel and facilities at both the contractor's and MSC plants, and thoroughness afforded by two independent reviews of the subsystems which separately reflect the contractor and customer rationale.

(5) SPECIAL DESIGN CONSIDERATIONS

The configurations of both Block I and Block II vehicles were examined with a view

toward identifying deficiencies in design and compatibility of design with criteria (specified requirements). Many deficiencies in the design could be traced to criteria which changed in the course of the program. The deficiencies can be categorized into those affecting wiring and ECS plumbing.

A number of criticisms of the wiring and ECS plumbing joints for Block I vehicles have resulted from examination of S/C 012, 014, and 017. The criticisms include instances of:

Interference with access for maintenance
Insufficient physical protection
Undesirable routing and terminating
Lack of flexibility for change
Frequent leakage of water, glycol joints
Poor workmanship
Lack of neatness and craftsmanship

The process of spacecraft manufacture, test, and maintenance, which results in the above criticisms, derives from the designs to which the spacecraft are built. The criteria establish the requirements for the design. These criteria continued to evolve after the design had been started and in some instances changed after release of design to manufacturing. Some significant examples follow:

(a) WIRING

(1) Unmanned flights were introduced which required retrofit of the Mission Control Programmer and associated wiring, and interconnecting with C M flight control and other subsystem circuits. This additional complexity applies to S/C 017 but not to S/C 012 and 014.

(2) Because of the experience of water condensing on electrical equipment during the flight of a Mercury spacecraft, the electrical and electronic components were required to be qualified in a combined environment of water, oxygen and salt instead of oxygen alone. As a result, the environmental-seal concept was introduced which changed the packaging design of the electronic equipment.

(3) The in-flight maintenance concept, on which the initial design was based, was dropped in favor of built-in redundancy after design completion on Block I but prior to the initiation of the design of Block II.

(4) The requirements for in-flight scientific experiments were added after designs were released to manufacture or test.

(5) Additional development and operational instrumentation requirements were introduced after the wiring design was released and in manufacture or test.

(6) The design of displays and controls was based on requirements established by a flight-crew group. Subsequently, minor changes were made to meet the requirements of the assigned flight crew.

(7) The audio communication control equipment on S C 012 suffered from a series of changes in performance requirements resulting in a number of fixes. The final configuration contained many changed and interrelated switch functions which resulted in a complex matrix of switch positions for proper selection of the different modes.

The initial design for the Block I vehicles failed to accommodate growth and changes typically experienced in research and development programs. The result was that the flexibility for change was quickly saturated, and it was necessary to improvise at the expense of the factors exposed by the criticisms above. (However, the initial design of Block II allowed for a 50 percent growth in wiring.) The Block I wiring runs were laid out without the use of an engineering mockup and wire harnesses were fabricated in two-dimensional rather than three-dimensional fixtures.

Post-fire inspection of S C 012 revealed deficiencies in the wire installation demonstrating poor practices in design, manufacturing and quality control. The wiring in the spacecraft survived the fire with a small degree of damage overall. The Teflon insulation was found to be damaged only in localized hot spots. The majority of the damage consisted of insulation loss due to heat; however, in practically all instances there remained sufficient insula-

tion or distance between the affected wires, that shorting was not apparent. All enclosures pertaining to this section are photos of S/C 012 after the accident.

During the wire inspection, the following design deficiencies were noted:

(1) The wiring in the Lower Equipment Bay (LEB) was routed through narrow channels having many 90 degree bends. This could cause mechanical stress on the Teflon insulation. Some wiring in these areas was found with damage to the sleeve which covers the shielded wire (Enclosure 9-4).

(2) Wire color coding practices were not always adhered to as evidenced by Enclosure 9-5.

(3) Some areas of wiring exhibited what would be referred to as "rats nests" because of the dense, disordered array of wiring. In some instances excessive lengths of wires were looped back and forth to take up the slack. Also, there were instances where wires appeared to have been threaded through bundles which added to the disorder (Enclosures 9-6, 9-7, 9-8, 9-9 and 9-10).

(4) A circuit breaker panel was pressed so close to a wire harness, that wiring indentions were left in the circuit-breaker potting (Enclosure 9-11).

(5) There were wires routed across and along oxygen and water/glycol lines.

(6) The floor wiring and some connectors in the LEB were not completely protected from damage by test personnel and the astronauts. This is evidenced by mashed 22-gauge wires found in some of the wire harnesses.

The following Manufacturing and Quality Control deficiencies were noted:

(1) Lack of attention during manufacture and/or rework is evidenced by foreign objects found in the spacecraft harnesses. Enclosure 9-12 shows a wrench socket in one of the connector channels, and Enclosure 9-13 shows a metal washer inside a wire bundle.

(2) Some wiring did not have identification tags.

(3) A Hughes connector on communications equipment was broken prior to the fire as evidenced by soot in the crack, Enclosure 9-14.

(4) A chipped Hughes connector was found in a condition exposing female inserts (Enclosure 9-15).

(b) ECS PLUMBING JOINTS

(1) The ECS design criteria, emphasizing minimum weight, resulted in the selection of aluminum piping with soldered joints (Enclosure 9-3). The design approach utilized accounted for the normal operating stresses but failed to account for the loads and stresses introduced by handling and installation.

(2) The proper fabrication of joints requires that the initial alignment of the tubes to be soldered must be established without stress and without benefit of a holding tool. The tool provides support to the joint only during the heat-up and cool-down phase.

(3) The couplings were made too short to provide the joint with strength greater than the tubing. As a result, unanticipated axial, bending or torsional loads cause the joint to develop leak paths.

(4) The installation design does not permit adequate inspection and does not protect the plumbing and the joint from accidental damage, or from use as hand holds. In some areas access of tools is difficult without stressing or springing joints already made.

The development and qualification testing of the ECS extended beyond the original schedule. Units were produced and installed in spacecraft which required modification to eliminate problems later identified during qualification tests. The design failed to provide easy access for removal and replacement of components in the assembled condition. Consequently, the process of rework is difficult, and the design criteria for soldered joints is violated under rework conditions. The leakage of soldered joints in the C/M cabin is traceable primarily to these conditions.

b. CABIN ATMOSPHERE

(1) INTRODUCTION

The process of selection of the cabin atmosphere has been reviewed and a comprehensive bibliography (Reference 4) of all material leading to the decision to use oxygen O_2 in space and at the pad has been compiled. A summary of this material is contained in Enclosure 9-2 to this report. The references contain a retracing of all the steps and considerations leading to the choice of the cabin atmosphere for the spacecraft. Pertinent data are included from cognizant NASA organizations, other government agencies, Mercury, Gemini, and Apollo contractors and subcontractors, other aerospace companies, the medical community, universities, and other research organizations.

(2) DISCUSSION:

Selection of a spacecraft cabin atmosphere involves human physiology constraints, spacecraft and space suit design considerations, flammability characteristics of materials, ground considerations, and considerations of fire extinguishing and suppression.

(a) HUMAN PHYSIOLOGICAL CONSTRAINTS

Human physiology imposes a requirement for a minimum partial pressure of oxygen for respiration, a minimum absolute-pressure environment for respiration and control of body water-vapor partial pressure, and limits to the rate of depressurization to prevent bends from gases emanating from solution in the body. A one hundred percent oxygen atmosphere is physiologically acceptable for continuous use up to thirty days.

NASA physiologists specify that a minimum oxygen partial pressure of 3.5 psia and a minimum absolute pressure of 5 psia be maintained as spacecraft cabin atmosphere. Reduced levels are acceptable for short periods of time (up to eight hours). One hundred percent oxygen pre-breathing is specified for a minimum of three hours prior to launch.

Dysbarism (bends) is avoided by a minimum partial pressure of diluent gas in the spacecraft. The desirable partial pressure of nitrogen in a mixed-gas spacecraft atmosphere has not been formally established. It has been established that the disadvantages will more likely exceed the advantages at nitrogen partial pressures greater than 3.5 psia.

Oxygen toxicity is prevented by avoiding oxygen partial pressures significantly greater than those experienced at sea level (3.5 psia).

Consequently, from the physiological standpoint, acceptable cabin atmosphere ranges from a 5 psia oxygen single-gas environment to a mixed-gas environment with 3.5 psia oxygen and 3.5 psia nitrogen partial-pressures.

(b) SPACECRAFT AND SPACE SUIT DESIGN CONSIDERATIONS

The design parameters for spacecraft involving cabin atmosphere are concerned with the strength of the structure to contain the cabin pressure and the varying complexities of atmosphere-control systems for one hundred percent oxygen or mixed gases. The design parameters for space suits are the same as for the spacecraft with the addition that the effort associated with movement increases with increasing differential pressure.

The Apollo spacecraft atmosphere control system design is based on providing a one hundred percent oxygen environment. Duplication of the atmosphere-control components as well as addition of a mechanism for oxygen partial-pressure control is required to provide diluent gases. These additions introduce additional crew-safety failure modes into the flight systems.

The state-of-the-art in space suit design establishes 3.8 psi as the desirable maximum differential pressure. Freedom of movement is constrained with further increases in differential pressure.

(c) FLAMMABILITY CHARACTERISTICS OF MATERIALS

The flammability characteristics of materials involve interrelationships with chemical and physical properties of the material, the total pressure of the atmosphere and partial pressure of atmospheric constituents, the temperatures of the material and the atmosphere, and the process of ignition utilized to initiate combustion.

There are three flammability characteristics that are generally measured to determine relative flammability of materials:

(1) Linear burning rate in inches per second.

(2) Temperature at which self-ignition occurs.

(3) Temperature at which ignition by spark is achieved.

The tests are performed in the atmospheres of particular interest. These have included oxygen alone at various pressures and oxygen mixed with nitrogen at various pressures with various ratios of partial-pressure.

The linear burning rates and auto-ignition temperatures measured in tests are shown in the tables below:

Relative Propagation Rates (inches/sec, downward)

Atmosphere psia/gas	Material			
	Cotton	Velcro	Nomex	Teflon
3.5/O_2	.49	.4	.3	
5.0/O_2	.5	.48	.34	
16.0/O_2	.55	.7	.43	.003
3.5 O_2 1.5/N_2	.4	.33	.22	
Air	.1	.3	.1	

Auto-Ignition Temperature (°F)

Atmosphere psia/gas	Cotton
3.5/O_2	1160
5.0/O_2	1180
16.0/O_2	1280
3.5/O_2 1.5/N_2	1040
Air	1000

Downward burning rates of the same material are shown to vary over a range of only 1.4 to 1 with atmosphere changes from 5 psia oxygen to a 7 psia atmosphere of 3.5 psia oxygen and 3.5 psia nitrogen. Downward burning rates in a particular atmosphere vary over a range of 1000 to 1 with material changes from cotton to Teflon. Consequently, the potential for fire in the C/M is much more strongly influenced by the selection of materials than by acceptable variations in atmosphere.

It may be concluded that the selection of 5 psia oxygen as a cabin environment for space flight operations was a reasonable choice. The physiological requirements are totally fulfilled. The requirements on spacecraft structure and systems are minimized. Based on tests of downward-burning propagation, the difference in fire potential between various physically acceptable atmospheres is not large, particularly if easily combustible materials are eliminated.

(d) GROUND CONSIDERATIONS

At any pressure the suitloop must contain only oxygen to avoid the "bends". If cabin atmospheric constituents other than oxygen are used, they should be isolated from the suitloop and expelled from the cabin prior to crew emergency from the suited conditions to avoid anozia. These requirements were fulfilled for Apollo 204 by the use of oxygen without diluents.

Downward burning rates of some materials vary by a factor of 1.3 to 1 for an atmosphere of 16 psia oxygen compared to a 5 psia oxygen atmosphere. If the decision had been made to use the extreme atmosphere for space operation of 3.5 psia oxygen and 3.5 psia nitrogen partial pressures, the burning-rate ratio between 16 psia oxygen and this environment would be only 1.8 to 1.

Tests carried out subsequent to the Apollo 204 accident with full-scale mockups at both 16 psia and 5 psia, one hundred percent oxygen atmospheres have demonstrated that differences in downward burning rates of materials are not indicative of actual fire hazards. Propagation rates and overall fire damage were much greater at the higher pressure. Thus, it appears that the geometric arrangement of the combustibles in their actual installations are much more significant than tests on isolated samples.

If air were used instead of oxygen on the ground (recognizing that spacecraft design changes would be required) a ratio of burning rates of 1 to 2 over 5 psia or 1 to 4 over 16 psia oxygen would be achieved. This reduction in burning rate would provide a reduced hazard for ground operation over space operation, except within the suit loop where 15 psia oxygen is required. These relations are based on downward burning rates for isolated specimens under controlled conditions. The conclusions have not been verified by tests in air with full scale mock-ups.

It must be concluded that burning rates of materials are significantly reduced only when large amounts of diluent are used. The limited quantity of diluent acceptable by physiological criteria contributes very little to the reduction of burning rate over that in pure oxygen.

(e) FIRE EXTINGUISHING AND SUPPRESSION

The established process for extinguishing a cabin fire in space is to evacuate the cabin of oxygen by venting to space. Limited flammability tests indicate that burning generally ceases when oxygen pressure is reduced to a half (0.5) psia. The cabin-venting mechanism design results in cabin pressure reducing from 5.0 psia to 0.5 psia in approximately one minute forty-five seconds.

Cabin depressurization requires that the crew be in their space suits. The donning time is 10-15 minutes.

Alternative extinguishing techniques have been examined, but no really satisfactory technique has so far been found. Effort in this area is continuing. Recent experiments have shown only water to be effective. A better understanding of the burning and extinguishing phenomena is required to properly assess the adequacy of the present and alternative extinguishing processes.

Elimination of contaminants in the cabin by means such as suit purge and cabin venting must be provided. Prior to the venting process, crew protection should be provided by some means such as oxygen masks supplied by a separate fire-proof oxygen supply.

c. REVIEW OF THE EGRESS PROCESS

(1) INTRODUCTION.

A critical review of the egress situation investigated the elements of both Launch Com-

plex (LC) 39 and Launch Complex 34, including the environmental chamber, access arm, elevator, personnel carrier (M-113) (Launch Complex 34 only), escape chute and hardened room (Launch Complex 39 only), lighting, communications, and fire suppression. This review was supplemented by conferences and responsive written reports on suggested design criteria from the following permanent Apollo Saturn Inter-Center Coordination Panels: Apollo Launch Operations Committee (ALOC) Emergency Egress Working Group, Apollo Launch Operations Panel (ALOP) Emergency Egress Subpanel, and Crew Safety Panel, as well as the Ground Emergency Provisions Review Panel No. 13 of the Apollo 204 Review Board.

The Panel No. 9 review and the reports of these associated organizations are contained in the supporting data which has been transmitted to the Apollo 204 Review Board files (Reference 6). This review utilized time lines, simulations, review of drawings, inspection of the Ground Support Equipment (GSE), and a methodical analysis of the egress process all the way from C/M exit to safety.

(2) DISCUSSION:

Based on tests in mock-up configurations, the following times for crew egress were measured. (Average times are used; best times are in parentheses.) Sixty (41) seconds are required for unaided crew egress from the Command Module. Ten (7) seconds are required for all three crewmen to disconnect and for the center crewman to turn around and face the hatch prior to opening. Forty (26) seconds are required for the center crewman to release and stow the inner hatch and release and open the outer hatch and boost-protective-cover hatch. Ten (8) seconds are required for all three crewmen to exit. The hatch cannot be opened with positive cabin pressure above approximately 0.25 psi.

The access arm to the Command Module contains flammable materials, and the doors are not designed to accommodate rapid emergency egress. Correction of these conditions would significantly improve emergency egress capabilities.

Removal of the access arm to allow the escape mode changeover from crew egress to Launch Escape System (LES) pad abort is necessary for maximum flight-crew safety just prior to launch. In the event of a C/M fire in this time period, the access arm could be returned to the C/M in time for safe crew egress if reduced flammability characteristics of the Command Module would greatly increase the allowable time for the egress escape process.

d. REVIEW OF THE FLIGHT AND GROUND VOICE COMMUNICATIONS

(1) INTRODUCTION:

Since the Operational Checkout Procedure (OCP) Plugs-Out Test during the Apollo 204 accident (OCP FO-K-0021-1) experienced communications difficulties, an examination of the design and performance of the total communications network was undertaken. This effort included: a comprehensive review to establish the configuration and operating characteristics of the Apollo 204 system; a system and circuit analysis, a test of the total ground system utilizing detailed measurements (February 21-24, 1967), and analyses of recordings made during the OCP FO-K-0021-1 test.

The supporting data (Reference 7) transmitted to the Apollo 204 Review Board files contain: a description of the on-board system, its test performance, and a discussion of the problems encountered; description and conclusions concerning the ground network; and detailed findings and determinations.

(2) DISCUSSION:

During the OCP FO-K-0021-1 test (Plugs-Out Test during Apollo 204 incident), difficulties were experienced maintaining voice communications. These difficulties included the following:

(a) Voice unintelligible due to very low levels at the listener's position.
(b) Voice unintelligible due to distortion, or "garbling."
(c) Syllables or words not received.

(d) Inability to contact another individual.

(e) Inability to communicate because of noise or other interference, including undesired voice.

These problems did not occur at all stations, or at any one station all the time; however, there were instances when several of the troubles occurred simultaneously. The source of the problems can be divided into two parts, viz., spacecraft and ground.

SPACECRAFT:

The spacecraft experienced a "live mike" situation, first noticed by the crew approximately one hour and five minutes before the accident. The records indicate that the VHF and S-band RF downlinks (exclusive of spacecraft audio and control circuit wiring) from spacecraft to ground operated satisfactorily during the OCP FO-K-0021-1 test.

GROUND:

The Communications Astronaut Console (CAST) on the ground was configured to patch the three voice links together (Astro 1 - Unified "S" Band, Astro 2 - VHF, and Astro 3 - Umbilical). With this configuration any downlink transmission is retransmitted back to the spacecraft on all three links.

The Spacecraft Test Conductor (MSTC) in the Automatic Checkout Equipment (ACE) Control Room in the Manned Spacecraft Operations Building (MSOB) was unable to contact the Command Pilot, Senior Pilot or Pilot at one time because of the Voice Operated Relay (VOX) in the ground link. The back-to-back VOX circuits lock out operation in the reverse direction when a signal appears in the unit.

Any signal coming from the Cape Kennedy Air Force Communications Terminal Building, Eastern Test Range, such as the MSTC or Superintendant of Range (AFETR), going into Launch Complex 34 has priority, with interrupt capability, over a signal originating in the Complex. However, even though it gets into the Complex Operational Intercommunication System (OIS) and the CAST console, it still has no priority to the spacecraft on any link.

System and circuit analyses showed that the difficulties experienced were due to system design deficiencies in the ground communications system, unfamiliarity with the system limitations and unsatisfactory procedures.

The ground communication system is one that has evolved during a series of modifications and additions. Rather than establishing an overall system design, hardware was merely added as new requirements were identified. The result was an overloaded system, with different types of subsystems which were inadequately interfaced.

D. FINDINGS AND DETERMINATIONS

1. A listing of findings and determinations from the information generated in the processes described in in Section C above are listed in Section D.2.

2. To be compatible with Section C above, the findings and determinations are listed according to the major classifications; viz., Ignition and Flammability, Cabin Atmosphere, Review of Egress Process, and Review of the Flight and Ground Voice Communications.

a. IGNITION AND FLAMMABILITY

(1) FINDING:

Flammable, non-metallic materials are used throughout the spacecraft. In the Block I and Block II spacecraft design, combustible materials exist contiguous to potential ignition sources.

DETERMINATION:

In the Block I and Block II spacecraft design, combustible materials are exposed in suf-

ficient quantities to constitute a fire hazard.

(2) FINDING:

Malfunctions and failures can produce ignition sources in the Command Module.

DETERMINATION:

An ignition source in the presence of a combustible in the cabin atmosphere constitutes a fire hazard.

(3) FINDING:

Packaging design for Block II components differs from Block I in that nearly all components in Block II are hermetically or environmentally sealed.

DETERMINATION:

The Block II packaging design practice reduces the probability for the coexistence of an ignition source and flammable material.

(4) FINDING:

The space suit contains power wiring to electronic circuits; also, the astronauts could be electrically insulated.

DETERMINATION:

Both the power wiring and potential for static discharge constitute possible ignition sources in the presence of combustible materials. The wiring in the suit could fail from working or bending.

(5) FINDING:

Eighteen electrical circuits in Spacecraft 012 did not adhere completely to wire size/load/circuit protection design criteria.

DETERMINATION:

The condition was examined from the standpoint of overheating, and no problem was found to exist.

(6) FINDING:

Residues of RS89 (inhibited ethylene glycol/water solution) after drying are both corrosive and combustible. RS89 is corrosive to wire bundles because of its inhibitor.

DETERMINATION:

Because of the corrosive and combustible properties of the residues, RS89 coolant could in itself provide all of the elements of a fire hazard if leakage occurs onto electrical equipment.

(7) FINDING:

Water/glycol is combustible, although not easily ignited.

DETERMINATION:

Leakage of water/glycol in the cabin increases the risk of fire.

(8) FINDING:

Deficiencies in design, manufacture and quality control were found in the post-fire inspection of the wire installation.

DETERMINATION:

There was an undesirable risk exposure which should have been prevented by both the Contractor and the Government.

(9) FINDING:

The environmental control system is plumbed with aluminum tubing in both the water/glycol and oxygen circuits. Joints in the plumbing are made by nickel plating the aluminum and joining the nickel-plated surfaces with a tin-lead solder. Leakage of ECS coolant from these joints has been experienced in the Apollo spacecraft.

DETERMINATION:

The design of the soldered joints is inadequate to cope with all the conditions experienced in the spacecraft.

b. CABIN ATMOSPHERE

(1) FINDING:

NASA physiologists specify that a minimum oxygen partial pressure of 3.5 psia and a minimum absolute pressure of 5 psia be maintained as spacecraft cabin atmosphere.

DETERMINATION:

Acceptable cabin atmosphere ranges from a 5 psia oxygen single-gas environment to a mixed-gas environment with 3.5 psia oxygen and 3.5 psia nitrogen partial pressure.

(2) FINDING:

The spacecraft atmosphere control system design is based on providing a pure oxygen environment.

DETERMINATION:

The complexity of the technology is such that, to provide diluent gases, duplication of the atmosphere-control components as well as addition of a mechanism for oxygen partial-pressure control is required. These additions introduce additional crew-safety failure modes into the flight systems.

(3) FINDING:

Flammability characteristics of non-metallic materials are varied by only a factor of 3 or 4 by diluents in atmospheres containing oxygen at 3 to 5 psi partial pressure.

DETERMINATION:

Previous analyses leading to the decision to use 5 psia pure oxygen cabin environment in space are still valid.

c. REVIEW OF THE EGRESS PROCESS

(1) FINDING:

Sixty seconds are required for unaided crew egress from the Command Module. The hatch cannot be opened with positive cabin pressure above approximately 0.25 psi. The vent capacity was insufficient to accommodate the pressure buildup in the Apollo 204 Spacecraft.

DETERMINATION:

Even under optimum conditions emergency crew egress from Apollo 204 Spacecraft could not have been accomplished in sufficient time.

(2) FINDING:

The access arms to the Command Module in Launch Complexes 34 and 39 contain flammable materials, are removed thirty minutes prior to launch, and their doors open the wrong way for easy egress.

DETERMINATION:

The access arm could constitute a fire hazard and imposes delays to emergency crew egress.

d. REVIEW OF THE FLIGHT AND GROUND VOICE COMMUNICATIONS

(1) FINDING:

The control circuit from the Command Pilot developed a condition of continuous keying during the test.

DETERMINATION:

An anomaly existed in the spacecraft communication system.

(1) FINDING:

During the Apollo 204 test, difficulty was experienced in communicating from ground to Spacecraft and among ground stations.

DETERMINATION:

The ground system design was not compatible with operational requirements.

E. SUPPORTING DATA

The following is a list of enclosures to this section of the report.

Enclosures

9-1	Summary of Ignition and Flammability Review
9-2	Spacecraft Atmospheres
9-3	Examination of Soldered Joints for Aluminum Tubing
9-4	Wiring Assessment
9-5	Wiring Assessment
9-6	Wiring Assessment
9-7	Wiring Assessment
9-8	Wiring Assessment
9-9	Wiring Assessment
9-10	Wiring Assessment
9-11	Wiring Assessment
9-12	Wiring Assessment

9-13 Wiring Assessment
9-14 Wiring Assessment
9-15 Wiring Assessment
9-16 List of Reference Material

ABBREVIATIONS USED IN APPENDIX D-9

ALOC	Apollo Launch Operations Committee
ALOP	Apollo Launch Operations Panel
AS	Apollo Saturn
C&WS	Caution and Warning System
CM	Command Module
ECS	Environmental Control System
ECU	Environmental Control Unit
EPS	Emergency Detection System
ECP	Electrical Power System
EVA	Extravehicular Activity
G&N	Guidance and Navigation
T/C	Telecommunications
KSC	Kennedy Space Center
LC	Launch Complex
LES	Launch Escape System
LH_2	Liquid Hydrogen
MC	McDonnell Company
MSC	Manned Spacecraft Center
NAA	North American Aviation
0_2	Gaseous oxygen
OCP	Operations Checkout Procedure
OCP-0021	Space Vehicle Plugs Out Overall Test
RF	Radio Frequency
RS89	Inhibited Ethylene Glycol/Water Solution (AiResearch Specification)
S/C	Spacecraft
SCS	Stabilization and Control System
SECS	Sequential Events Control System
SM	Service Module
TV	Television
VHF	Very High Frequency

SUMMARY OF RESULTS OF IGNITION AND FLAMMABILITY REVIEW

This enclosure contains the significant findings of the Ignition Source Review Team for both Block I and Block II equipment installed in the Command Module interior. The possible ignition sources are grouped by subsystem. The information which follows was derived from a detailed review of the approximately 2000 pages contained in the basic ignition source report.

It is important to bring out the fact that neither the MSC, nor the NAA review teams nor the integration team were able to locate any possible sources of ignition in the subsystems under normal operating conditions. In all cases in order to have an ignition source, there must first be some type of failure of the component in question.

When a single failure mode for each component was postulated, twenty-one and fourteen potential ignition sources were identified for the Block I and Block II crew compartment subsystems, respectively. The number of ignition sources noted above does not represent a tally of total individual compartment subsystems, respectively. The number of ignition sources noted above does not represent a tally of total individual components that are suspect because all identical components such as switches and indicators on the display and control panels, all electrical connectors, and all harnesses or cable runs, etc., were treated generically; i.e., each group of suspect items in a category was considered as one potential ignition source. Delineation of ignition sources identified in Block I and II subsystem follows.

BLOCK I
ELECTRICAL POWER SUBSYSTEM

The following components of this subsystem are considered possible sources of ignition under a failure condition:

- General Usage Connectors
- Special Purpose Connectors
- Modular Terminal Boards
- Electrical Wiring

The above listed possible sources are generally generated by procedural and human error problems such as broken wires, damaged insulation, bent connector pins, damaged or lack of, conformal coating on terminal boards, etc. Evaluation of the detailed data in the basic report revealed that there were several cases on S/C 012 where there were deviations taken to the basic criteria for circuit-breaker compatability with wire size. The basic ignition source report contains an analysis of each of the cases of deviation, and evaluation of these analyses reveals a very low probability that these deviations could have been contributory to the S/C 012 accident.

DISPLAYS AND CONTROLS SUBSYSTEM

The following components of this subsystem are considered possible sources of ignition under a failure condition:

- Main Display Console (MDC) Panels
  - (Wiring and Terminal Strips)
- Lower Equipment Bay (LEB) Panels
  - (Wiring and Terminal Strips)

Excessive handling and human error problems associated with these components can lead to damage of wiring and conformally coated terminal strips. This damage could, in turn, lead to an arcing or shorting failure mode.

CAUTION AND WARNING SUBSYSTEM

The following component of this subsystem is considered a possible ignition source under a failure condition:

- Elapsed Time Indicator

This device is removed prior to flight and is, therefore, only a potential ignition source during ground operations. The Block I program has experienced one problem with this indicator on S/C014 during Downey checkout that could have led to it being an ignition source. Smoke was observed in this particular case when over-heating of a spike-suppression capacitor occurred.

ENVIRONMENTAL CONTROL SYBSYSTEM.

The following components of this subsystem are considered possible ignition sources under a failure condition:

Glycol Evaporator Back Pressure Controller
Cable Assemblies
Waste Management System Blower
Valve Seats in Oxygen Lines

The Controller was considered as a potential source only in that there is some probability that overheating of the controller under an internal failure condition could ignite the encapsulating material. It is not known, whether such a condition could result in ignition of the insulation, so it must be classified as suspect.

The cable assemblies are listed since breakage or abrasion could provide a source of ignition in that some harnesses are in direct contact with the Environmental Control Unit (ECU) foam insulation. The foam insulation was not covered with silicone rubber and thus did not meet the Apollo criteria for ignition temperature characteristics of nonmetallic materials.

The Waste Management System Blower is considered suspect because failures of a shorting or arcing nature within the blower motor have been experienced during the program.

Overheating of regulator and valve seats can occur in high-pressure oxygen lines due to compression waves. Because of this phenomenon, ignition of flammable plastic seats is possible.

GUIDANCE AND NAVIGATION SUBSYSTEM

The following components of this subsystem are considered possible ignition sources under a failure condition:

Display and Keyboard (DSKY) Electroluminescent Panels
Guidance and Navigation (G&N) Interconnecting Harness
Inertial Measuring Unit (IMU) Control Panel Switches
Eyepiece Heaters

A failure of the sealing for the Electroluminescent lights on the DSKY Panel could allow moisture to provide a shorting path for 250 volts used to excite the luminescent material. These seals did experience failure in qualification testing during low-temperature storage.

Breakage or abrasion of the G&N harness could lead to a possible ignition source.

The IMU Control Panel pushbutton lighted switches which contain bulbs do not constitute an hermetically or environmentally sealed device. These are possible ignition sources in the case of cracked bulbs or poor contact due to corrosion.

An equipment or component is considered hermetically sealed if it is sealed, either via a bonded-metal cover, or a gasketed cover (a molded-in-place elastomer gasket) which is designed to be capable of remaining pressurized or evacuated for the specification life of the equipment or component.

An equipment or component is considered environmentally sealed if it is not hermetically sealed, and is potted, foamed and/or conformally coated such that it will withstand the Apollo qualification environments, particularly with regard to the humidity and salt fog environments. This type of packaging generally "breathes" and is normally enclosed in a metal package.

The Eyepieces contain resistance heaters which operate at 28 volts and 0.1 amps. These eyepieces are subject to much handling before and during flight and are therefore subject to a greater probability of damage than fixed electrical components. Such damage could result in arcing or shorting.

STABILIZATION CONTROL SUBSYSTEM

The following components of this subsystem are considered possible ignition sources under a failure condition:

Rotational Control
Velocity Change Indicator (Delta V)

These two components of the Stabilization Control Subsystem contain non-hermetically sealed switches. If a failure occurs in the arc-suppression diodes, there could be a short to ground causing arcing of the contacts.

SPACECRAFT COMMUNICATIONS SUBSYSTEM

The following components of this subsystem are considered possible ignition sources under a failure condition:

Radio Frequency (RF) Connectors
Overheating of Equipment due to Loss of Cooling
Elapsed Time Indicators (See Caution and Warning Subsystem)
Hughes Connectors

Arcing of RF connectors and pin-to-pin shorting of the Hughes connectors are potential ignition sources under a failure condition. There is a general concern with regards to potential ignition sources if all communications system cooling should be lost. Whether or not ignition temperatures of adjacent non-metallics could be attained is not known.

TELEVISION SUBSYSTEM

The following components of this subsystem are considered possible ignition sources under a failure (procedural) condition:

Television Bulkhead Connectors and Cable Assemblies

If the TV power switch is left in the "on" position during connection or disconnection of the TV power cable, arcing could occur thereby providing an ignition source.

SUBSYSTEM CONTAINING NO PROBABLE IGNITION SOURCES

Based on the ground rules established for this evaluation, the following subsystems are considered non-suspect from a probable ignition source standpoint:

Sequential Events Controller
Mission Control Programmer
Crew Communications
Instrumentation
Experiments and Scientific Equipment

BLOCK II

The number of Block II components considered to be possible ignition sources under failure conditions is fourteen. This is seven fewer components than were listed in the Block I subsystems. The reduction in number is due in all cases to either one of two conditions:

(a) The Block I component is not used in Block II or

(b) The Block II components have been redesigned to eliminate the problem that existed in the Block I component. In many cases non-hermetically sealed components in Block I had been previously redesigned to incorporate hermetic seals due to concern over moisture penetration.

The following is a listing by subsystem of the Block II components that are considered possible ignition sources under failure conditions. The reasons that these are suspect can be found under the previous Block I susystem discussion of the component

ELECTRICAL POWER SUBSYSTEM

General Usage Connectors

Special Purpose Connectors
Modular Terminal Boards
Electrical Wiring

DISPLAYS AND CONTROLS SUBSYSTEM
MDC and LEB Panels (Wiring and Terminal Strips)

ENVIRONMENTAL CONTROL SUBSYSTEM
Glycol Evaporator Back Pressure Controller
Cable Assemblies

GUIDANCE AND NAVIGATION SUBSYSTEM
G&N Interconnecting Harness
Eyepiece Heaters

STABILIZATION CONTROL SUBSYSTEM.
Rotational Control

SPACECRAFT COMMUNICATION SUBSYSTEM
RF Connectors
Overheating of Equipment due to Loss of Cooling

TELEVISION SUBSYSTEM
Television Bulkhead Connectors and Cable Assemblies
The following lists subsystems in which there exists no probable source of ignition:
Caution and Warning
Sequential Events Controller
Entry Monitor
Crew Communications
Instrumentation
Experiments and Scientific Equipment

Table I of this Enclosure is a convenient listing of the ignition sources and identifies changes from Block I to Block II.

The type of packaging and qualification history was examined for the components which were reviewed for possible ignition services. The components were treated categorically so the total number portrayed is greatly reduced from the total number actually reviewed (i.e., switches, circuit breakers, terminal boards, etc.)

Total number of components	188
Number environmentally sealed	95
Number hermetically sealed	78
Number not protected by either hermetic or environmental packaging	15

Table II of this Enclosure is a listing of all the Block II components which are neither hermetically nor environmentally sealed.

Table III of this Enclosure is a listing by subsystem of non-metallic materials contiguous to the components in Block II which have been identified as possible single-failure ignition sources.

TABLE I OF ENCLOSURE
SUMMARY OF POSSIBLE SOURCES OF IGNITION UNDER A FAILURE CONDITION
- BLOCK I & BLOCK II -

BLOCK I ITEM	DESCRIPTION	STATUS IN BLOCK II
General Usage Connectors	Cabling	Same
Special Purpose Connectors	Cabling	Same
Modular Terminal Boards	Cabling	Same
Electrical Wiring	Cabling	Same
Main Display Console (MDC) Panels (Wiring and Terminal Strips)	Cabling	Same
Lower Equipment Bay (LEB) Panels (Wiring and Terminal Strips)	Cabling	Same
Elapsed Time Indicator	Component	Eliminated
Glycol Evaporator Back Pressure Controller	Component	No Change
Cable Assemblies	Cabling	Same
Waste Management System Blower	Component	Fixed
Display and Keyboard (DSKY) Electroluminescent Panels	Component	Fixed
Guidance and Navigation (G&N) Interconnecting Harness	Cabling	Same
Inertial Measuring Unit (IMU) Control Panel Switches	Component	Fixed
Eyepiece Heaters	Component	No Change
Rotational Control	Component	No Change
Velocity Change Indicator (Delta V)	component	Fixed
Radio Frequency (RF) Connectors	Cabling	Same
Overheating of Equipment due to Loss of Cooling	Condition	Same
Elapse Time Indicators	Component	Eliminated
Hughes Connectors	Cabling	Eliminated
Television Bulkhead Connectors and Cable Assemblies	Cabling	Same

TABLE II OF ENCLOSURE I
BLOCK II COMPONENTS NOT HERMETICALLY OR ENVIRONMENTALLY SEALED

COMPONENT	SUBSYSTEM	TYPE OF PACKAGING	REMARKS
DSC Panel Assemblies (Twenty-eight for Block I) (Fifteen for Block II)	Displays & Controls (D&C)	Conformal Coating	Terminals are potted or conformally coated. All current carrying contacts are within sealed enclosures. Incandescent filaments are doubly sealed within glass bulbs inside sealed envelopes
Eyepiece Stowage	Guidance & Navigation	Stowage	Qualified
Video Coaxial Connector Cable Assemblies	Communications	No seal	These assemblies have been qualified. Voltage and power levels are not considered to be high enough to pose a threat of fire. There are no known failures which have indicated that a fire hazard exists in the video connector cable assemblies

TABLE II OF ENCLOSURE I (Continued)

COMPONENT	SUBSYSTEM	TYPE OF PACKAGING	REMARKS
Bulkhead Receptacle	Communications	Metal housing with plastic dielectric around terminals. No seat	The receptacle has been tested in 100% O at 1.5 psia with simulated cameral load. No failure has occurred.
Stadimeter	Experiments & Scientific Equipment	Not packaged	Non-electrical component
Data Reduction Tables	Experiments & Scientific Equipment	—Not packaged	Non-electrical component
D009 Container	Experiments & Scientific Equipment	Not packaged	Non-electrical component
Ultraviolet (UV) Stellar Spectrograph Support Structure	Experiments & Scientific Equipment	Not packaged	Non-electrical component
Lens Cover	Experiments & Scientific Equipment	Not packaged	Non-electrical component
UV, X-Ray Solar Spectrograph Cable	Experiments & Scientific Equipment	Connectors Potted	No history of failure
Scientific Airlock	Experiments & Scientific Equipment	Not packaged; provides spacecraft seal	Non-electrical component
Film Magazine for Camera	Experiments & Scientific Equipment	Combustible film is totally enclosed, but not sealed, in metal magazine	No history of failure
1.2 Litre Contingency	Experiments & Scientific equipment	Not packaged	Non-electrical component
Urine Receiver	Experiments & Scientific Equipment	Not packaged	Non-electrical component
Scientific Junction Box	Experiments & Scientific Equipment	Potted internally	No history of failure

TABLE III OF ENCLOSURE 9-1

BLOCK II NON-METALLIC MATERIALS CONTIGUOUS TO COMPONENTS IDENTIFIED AS POSSIBLE SINGLE-FAILURE IGNITION SOURCES

SUBSYSTEM	NON-METALLIC MATERIALS
Electrical Power	Teflon Tetrafluoroethylene (TFE.) Silicone Rubber

TABLE III OF ENCLOSURE 9-1 (Continued)

SUBSYSTEM	NON-METALLIC MATERIALS
Stabilization & Control	Phenolic Molding Compound
	Diallylisophthalate (DAIP) Molding Compound
	Epoxy Primer
	Acrylic Enamel
	Epoxy-Syntatic Foam
	Polyurethane Varnish
	Silicone Lubricant
	Silicone Rubber
Sequential Events Control	No Ignition Sources
Mission Control Programmer	Not Applicable
Entry Monitor	No Ignition Sources
Communications	Class A Foamed Polypropylene
	Irradiated Polyolefin
	Irradiated Polyvinylidene Fluoride
	Teflon
Instrumentation	No Ignition Sources
Experiments and Scientific Equipment	No Ignition Sources

TABLE III OF ENCLOSURE 9-1 (Continued)

SUBSYSTEM	NON-METALLIC MATERIALS.
	Teflon Tetrafluoroethylene Fluoro Ethylene Propylene (TFE FEP)
	Polyvinylidene Fluoride
	Nomex Acrylic Coated
	Nylon
	Epoxy Polyamide Resin
	Epoxy Adhesive Epon 929
Displays & Controls	Silicone Rubber Grommets
	Room Temperature Vulcanized (RTV) Conformal Coating
	Teflon
	Polyvinylide Fluoride
	Nomex, Acrylic Coated
	Nylon
	Polyurethane
	Fiberglass
	Neoprene
	Epoxy Polyamide Resin
Caution & Warning	No Ignition Sources
Environmental Control	Compounds, Airesearch SPEC Nos 219 081 9001, 219 049 9001, S84711.22, S8952 20 9 008 223 022 9047 219 109 9001
Guidance & Navigation	Polyurethane Foam
	Viton
	Irradiated Polyethylene
	Polytetrafluoroethylene

SPACECRAFT ATMOSPHERES

BACKGROUND

The use of 100% oxygen for spacecraft atmosphere in the U. S. manned space program has been based on extensive research and development in both the fields of biomedical science and engineering. The selection of a pure oxygen atmosphere at a pressure of 5 psia for the Mercury, Gemini, and Apollo Programs resulted from careful consideration of the physiological, safety, and reliability requirements of manned space flight.

The engineering, medical, and safety aspects of the one-gas (100% oxygen) atmosphere have been the subject of widespread investigation in the United States and abroad, by government, university, and industrial research. While the bulk of the research has been over the past ten years, considerable work relating to the use of 100% oxygen in aircraft was done much earlier. Probably one of the most authoritative compilations of this research is contained in a four-part series on "The Selection of Space-Cabin Atmospheres," prepared for NASA by Dr. E. Roth of the Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico. The series, which was prepared under NASA contract, is comprised of four volumes: (1) "Oxygen Toxicity," (2) "Fire and Blast Hazards," (3) "The Physiological Factors of Inert Gases," and (4) "Engineering Trade-offs of One-Versus-Two-Gas Systems." Volumes (1) and (2) have been published; Volumes (3) and (4) are in the publication process. These studies have been further expanded by the work of the Douglas Company for NASA contained in, "Engineering Criteria for Spacecraft Cabin Atmosphere Selection," Douglas Missile and Space Systems Division, Douglas Report DAC-59169, November 1966.

GENERAL CONSIDERATIONS IN THE SELECTION OF SPACECRAFT ATMOSPHERE

Before discussing the specific aspects of the spacecraft atmospheres used in Mercury, Gemini, and Apollo, the general considerations relating to spacecraft atmosphere should be reviewed. Selection of the atmosphere must consider at least the following factors:

1. Sufficient oxygen content to support life. This requires a minimum partial pressure of oxygen equal to or greater than 3.5 psia.
2. Dysbarism (bends) caused by pressure decreases in a multi-gas system, or in transitions from normal atmosphere to pure oxygen environment at reduced pressures.
3. Total operating pressure, which affects spacecraft structural design as well as dysbarism potential in event of spacecraft decompression in normal or emergency operations.
4. Space suit operating pressure (gauge) which has significant effects on suit design, crew mobility in unpressurized cabin and extra-vehicular activity (EVA) physiological stress levels. In general, suit pressure levels exceeding 3.5 psia result in increasingly severe space suit rigidity.
5. Difference in cabin atmosphere constituents and suit atmosphere constituents which affect the possibility of dysbarism in decompression, or would dictate extended time for crew purging for EVA activities as well as potential leakage problems between suit and cabin atmospheres in redundant operating modes.
6. Pulmonary atelectasis (collapse of lung tissue), which could be caused by inhalation of pure oxygen for extended periods of time which is a function of absolute oxygen pressure level.
7. Differences between cabin atmosphere and suit atmosphere constituents which could produce the possibility of hypoxia! lack of sufficient oxygen! in the event of minor system malfunction or interaction.
8. The hardware complexity of the environmental control system design which is a function of its atmosphere constituents. This extends to consideration of oxygen uses for purposes other than life

its atmosphere constituents. This extends to consideration of oxygen uses for purposes other than life support.

9. The reliability of measuring and controlling the partial pressures of constituent elements of a multigas system. In general, more complex measurement and control systems must be used for a two-gas atmosphere as compared to simply controlling the pressure of an oxygen atmosphere.

10. Crew comfort on a long mission which is significantly affected by continued suit operation in either a pressurized or an unpressurized cabin. This consideration is also a function of confidence in cabin integrity and expected emergency decompression rates.

11. Effect of the atmosphere chosen on ignition temperatures of cabin materials. In general, the ignition temperatures for solids vary only slightly with oxygen partial pressure.

12. Effect of the atmosphere on combustion propagation rates after ignition has begun. Again, in general, the propagation rate is affected by oxygen partial pressure. However, at the relatively low pressures used in spacecraft, this effect appears to be of no significance.

MERCURY AND GEMINI FLIGHT ATMOSPHERES

The guideline for the selection of the atmosphere used in the Mercury Spacecraft was to employ the least complex and lightest approach consistent with reasonable safety. The 5 psia, 100% oxygen environment was selected as the best compromise to preclude anoxia and oxygen toxicity. Another consideration was the selection of a pressure level which, in the event of a cabin decompression, would result in a minimum decrease to the suit pressure, and therefore, the least incidence of dysbarism [bends!. It should be noted that prior to the inception of the Mercury Program, aviators flying high-performance aircraft were breathing 100% oxygen. This aircraft experience was the natural predecessor to the Mercury environment; in effect it constituted the "state of the art" within the aerospace medical community.

Early in the Mercury Program, a NASA Life Sciences Committee, chaired by Dr. W. R. Lovelace, II, reviewed the medical requirements and approved the approach taken by the program.

As a part of the development of the Mercury Environmental Control System (ECS) manned altitude chamber tests were conducted in a boilerplate spacecraft. The first of these manned tests was conducted at McDonnell Aircraft Corporation on April 21, 1960, with Mr. G. B. North, a McDonnell test pilot, as the test crewman.

Mr. North was prepared for the test by pre-breathing oxygen before ingress to the test vessel. The pressure suit circuit had already been purged with oxygen. After the ingress operation was completed, the suit circuit was again purged with oxygen for a time period and rate previously determined to assure an essentially pure oxygen environment in the suit circuit. The hatch was closed and sealed. No oxygen purge of the cabin was conducted, since the space suit was isolated and the Environmental Control System design provided an 80% cabin purge during spacecraft ascent by adding oxygen to the cabin as the cabin relief valve permitted total pressure to reduce from one atmosphere to space operating level.

The altitude chamber was evacuated to 27,000 feet equivalent altitude, and the Environmental Control System operation during the chamber pump down (simulating launch ascent) was as planned.

After approximately forty (40) minutes of operation at 5 psia, the test was aborted because Mr. North became unconscious. This condition was attributed to hypoxia (lack of sufficient oxygen).

Subsequent investigations revealed that leakage of nitorgen from the spacecraft air into the pressure suit circuit had gradually decreased the partial pressure of oxygen below physiologically acceptable limits. This decrease in oxygen partial pressure could occur since certain portions of the suit circuit were at negative pressures relative to the cabin pressure.

Three additional manned tests were conducted on June 2, 2, and 6, 1960. All three tests were aborted because of rapid decreases in the suit circuit oxygen levels.

As a result of these incidents, the prelaunch procedure for all Mercury spacecraft, both astronaut and chimpanzee, was changed to require that the cabin be purged with oxygen prior to launch. This change eliminated the possibility of nitrogen concentration in the suit circuit.

The requirement for purging the cabin with pure oxygen at approximately 15 psia during the

prelaunch period of several hours has been continued for all manned spacecraft launched in this country. This same procedure has been used also on all manned spacecraft vacuum chamber tests in the Mercury, Gemini and Apollo Programs.

The Gemini spacecraft atmosphere was selected to be the same as Mercury (5 psia, 100% oxygen). This selection allowed the Gemini program to develop an environmental control system largely based on the Mercury design, and to benefit from the years of previous experience in procedures, specifications, and standards. The Gemini system proved extremely reliable, and performed successfully in 10 manned flights, and in a large number of manned and unmanned altitude chamber tests and prelaunch operations.

APOLLO FLIGHT ATMOSPHERE

Early studies based on NASA's own research and also on a large body of other experimentation on artificial atmospheres, e.g., aircraft and submarine, resulted in a recommendation for a 7 psia oxygen-nitrogen atmosphere for Apollo. This first recommendation was in 1961. The primary reason for this recommendation was concern by physiologists that two-week Apollo missions in a 5 psia 100% oxygen environment (used in the Mercury Program) could cause pulmonary atelectasis (collapse of lung tissue). This condition had been observed after extended inhalation of pure oxygen prior to that time. However, a counter-balancing physiological question concerned dysbarism (bends) in the recommended two-gas system if a rapid cabin decompression should occur.

An extensive test program was, therefore, initiated to resolve these physiological questions for both the Apollo and Gemini atmosphere selections. (5 psia, 100% oxygen) atmosphere was planned for the Gemini spacecraft). The tests showed that a preoxygenation period of at least three hours was required to prevent bends in the event of cabin decompression during, or immediately following launch. Testing in the 5 psia 100% oxygen atmosphere indicated that atelectasis would not be a problem in the two-week Apollo or Gemini missions. (Satisfactory crew performance has not been demonstrated for 30-day periods in 5 psia 100% oxygen atmosphere, including dynamic and static conditions). Based on the results of this test program, NASA decided in 1962 that the Apollo spacecraft would also use the 5 psia 100% oxygen atmosphere used in the Mercury and Gemini Programs. This selection of cabin atmosphere in space has enabled:

1. Continuation of the Mercury and Gemini experience.
2. Avoidance of potential dysbarism problems in avrious modes of space operation.
3. Relatively simple environmental control system hardware with attendant high reliability.
4. A "shirt-sleeve" cabin environment which has enhanced crew comfort and effectiveness.
5. Minimum operational restraints to EVA initiation.
6. Maximum crew mobility within the constraints of present space suit design by utilizing lowest practical absolute pressure.

ELIGHT ATMOSPHERE FOR THE APOLLO APPLICATION PROGRAM

The Apollo Applications Program (AAP) presently plans to use a 5 psia two-gas atmosphere (60% oxygen; 31% nitorgen) only in the airlock module (S-IVBspent stage workshop) for planned mission durations in excess of 30 days. The 5 psia pressure level selected for the long duration missions was dictated by present Apollo pressure vessel capability and system compatibility considerations.

Present program plans continue the utilization of the standard Apollo pure oxygen environment in the Command Service Module and Lunar Modules, which may be associated with AAP missions. While the airlock module will have the capability for a two-gas system on the first AAP mission, present plans are to utilize the two-gas system for the second mission (45 days). Pure oxygen atmosphere would be used on the first mission (30 days).

The primary consideration in utilization of the two-gas system for long duration missions is a desire to avoid physiological uncertainties and the possibility of atelectasis.

FIRE HAZARDS IN THE SPACECRAFT ATMOSPHERE

The possibility that fire could occur in any atmosphere capable of life support has been understood throughout the program. In general, neither ignition temperature nor combustion rate is a strong function of oxygen partial pressure in the range from 3.5 psia to perhaps 7 psia. Mixed gas systems operating with a minimum of 3.5 psia oxygen partial pressure apparently do not have significantly different fire hazard potentials as compared to a pure oxygen atmosphere at the same pressure.

Limited zero-G aircraft testing has indicated that there is a tendency for combustion in a low-pressure pure-oxygen environment at zero-G to be self-limiting. This may occur because of the lack of natural convection to remove products of combustion which no longer contain oxygen from the vicinity of the flame source. However, forced convection in the cabin could nullify this effect.

In orbit, fire on board the spacecraft could be extinguished by venting the cabin to space. This mode of operation would require the crew to be suited prior to the decompression period because physiological constraints dictate that a minimum body pressure of 3.5 psia be maintained. Suit-donning times are on the order of 10-15 minutes. Since the probability of fire was considered sufficiently remote, this mode was not given strong consideration because crew comfort and crew effectiveness in long-duration missions require that the suits be off for extended periods.

Attempts to design fire extinguishers for cabin deluge systems have not been particulary successful. The "fire pockets" between instrument panels and structures complicate the design of any effective fire-extinguishing system for spacecraft use. In addition, there is the potential interaction with crew safety, e.g., toxic fumes. The difficulty of timely detection of a fire and reliable operation of an extinguishing system must be carefully weighed against the potential dangers when considering such a system for spacecraft use.

SUMMARY REMARKS

In summary, the selection of a 100% oxygen atmosphere for manned spacecraft has resulted from the careful consideration of all factors relating to crew safety and mission success. This choice has been based on extensive research, which has included single and multi-gas atmospheres with their attendant advantages and disadvantages.

The 100% oxygen atmosphere has been used successfully in all U.S. manned flights to date, and is considered suitable for missions of 30 days or less.

EXAMINATION OF SOLDERED JOINTS FOR ALUMINUM TUBING

A. Design Selection Rationale

The decision to use aluminum tubing in the Environmental Control System (ECS) for both the water/glycol and oxygen circuits was made on the basis of stringent mission requirements and design limitations (weight, vibration, fluid compatibility, pressure, ect.). These required that:

(1) All joints were to be essentially leak free. The maximum leak rate allowed was 5.6 x 10-6 std. cc of helium/sec.

(2). The joints were to be compatible with the various spacecraft fluids without a loss in strength, particulate formation, or fluid degradation.

(3). The joints, and the lines, were to withstand an acoustic environment sustained at a sound pressure level above 143 decibels for 150 seconds.

(4). The joints were to sustain a dynamic in-flight environmental stress of 17,000 psi for 5,000 cycles.

(5). The maximum design pressure was not to exceed 900 psi in the ECS aluminum lines.

Another consideration was that the plumbing system be of minimum weight. The aluminum tube wall thickness was established at .035 inch for strength and to facilitate handling, 304L stainless steel lines would also require 0.035 inch tube wall. On this basis, assuming the various joint configurations would be similar for both steel and aluminum, the steel system would weigh approximately 3 times the aluminum system, a weight penalty of approximately 103 pounds.

Welding of the aluminum joints was also considered, but early in the program it was evident that an extensive and costly development program would be necessary. Therefore, aluminum tube welding was limited to manual welding on the bench and in readily accessible areas on the spacecraft.

Mechanical fittings were utilized, but limited in number for obvious reasons. Mechanical fittings are susceptible to loosening under vibration, and generate the greatest amount of particulate matter during tightening. Therefore, these joints (B-nuts and quick disconnect fittings) were limited to dissimilar metal joining, closeout lines, equipment connectors, etc.

Based upon these considerations, a metallurgical joint was indicated and a soldered union for joining aluminum tubing was considered. The soldered tube-union joint permits the assembly of a plumbing system of minimum weight generates the minimum contamination, has adequate strength to withstand system pressures, is compatible with system fluids, and will sustain spacecraft environments.

When the decision to use solder joints was made in 1962, a program was immediately initiated to select a soldering alloy. This alloy was required to be compatible with the spacecraft fluids, readily available, and applicable to existing processing techniques. This phase of the program involved an intensive literature search, mechanical property determinations, flow and compatibility testing.

The literature survey resulted in 31 candidate alloys from which twenty were selected for fluid compatibility testing. These tests screened out all but two potential alloys. These two alloys were subjected to the following tests:

[1]. Compatibility with N_2O_4
[2]. Alloy wetting and flow characteristics
[3]. Optimem plate thickness (nickel base for solder)
[4]. Optimum gap for capillary flow
[5]. Peel resistance
[6]. Metallurgical analysis (diffusion, erosion of tube)
[7]. Mechanical properties (shear, stress rupture)
[8]. Effects of reheating

Subsequent to these tests, containment of N_2O_4 was not required by the aluminum tubing. This

necessitated a re-evaluation of the soldering alloy. Based upon prior development testing, production experience, strength, availability and exceptionally good corrosion resistance, it was decided to test and use the 60 Sn - 40 Pb solder alloy. This solder conformed to Federal Specification QQ-S-571, Type SN 60 RARP2 (activated rosin cored flux). This alloy was subjected to the following tests:

[1]. System and Material Compatibility Tests

a. Exposure and weight loss
b. Metallographic examination
c. Salt spray - 240 hours at 95°F in 20% NaCL
d. Humidity - 240 hours at 120°F in 95% humidity
e. Simulated system exposure to water-glycol for periods up to 8 months
f. Leak tests prior to and subsequent to exposure
g. Joint strength change prior to (control specimen) and subsequent to exposure.

[2]. Mechanical Property Tests

a. Joint shear strength
b. Stress rupture under tensile loading (38% to 90% of joint shear strength).
c. Creep (35% to 95% of joint shear strength)
d. Burst pressure (Hydrostatic)
e. Flexure - Impulse fatigue - Impulse fatigue (pressure 40-60 psi, 17,000 psi fiber stress for 5,000 cycles minimum).

[3]. Structural Environmental Tests

a. Acoustic vibration (143 decibels minimum for 150 seconds).
b. Vibration-flow (Sinusoidal and random vibration - time 5 minutes, Orientation: Both orthogonal axis perpendicular to the longitudinal axis of the tube).

[4]. Leak Testing

a. Mass Spectrometer

1. Internally pressurized joints
2. Evacuated lines and joints

[5]. Effect of Resoldering Joints

PROCEDURE

a. Solder up to 3 times (joints pulled apart between each resolder operation).
b. Check joint by X-Ray for presence of voids.
c. Leak rate with mass spectrometer
d. Determine change in joint strength.

[6]. Alignment

Where required, a tube alignment fixture shall be attached in such manner that the tubes are held together with a maximum allowable gap of 0.060 inch. The maximum premissible axial misalignment shall be three degrees, and displacement of either tube end from the center of the union shall not exceed 0.060 inch.

TEST RESULT SUMMARY

[1]. Corrosion and Compatibility Testing

a. No evidence of deleterious corrosion or corrosion products were noted in simulated partial ECS systems with inhibited water, glycol after eight months exposure. Aluminum soldered joints removed from SC 011 after flight and recovery revealed only a slight white deposit in

the joint area, but no evidence of tube or solder alloy corrosion. The white deposit is believed to be an anhydrous Al (OH)e, but is not considered detrimental in an active system as it is present as a gel and does not clog the system.

b. No deleterious corrosion was evident due to the salt spray and humidity testing. The leak integrity of the joint was maintained with no appreciable loss of strength as measured by the burst tests.

[2!. Mechanical Property and Environmental Stress Testing

a. The joint shear strenght (tensile) is more than adequate for the low pressures used on the Apollo. The tensile load applied by the system pressure is only a fraction of the joint strength. Avg joint strength [1/4 dia.! - 681 pounds Axial load due to pressure [900 psi! - 36 pounds

b. The vibration, flexure-impulse, and burst-test results indicate that the joints do withstand the environmental stresses by at least a factor of 10.

(3). Structural Environmental Testing (Spacecraft Test Sections)

Several test sections of the service module containing numerious soldered joints of all sizes and configuration were acoustically tested with only one leak (out of 51 joints) in a water/glycol tube tee assembly. This test was part of the auxiliary plumbing and not a test item This joint was repaired and the test repeated successfully.

[4!. Leak Testing

The leak tests were performed with a mass spectrometer sensitive to 10-6 std. cc of helium/second using helium as the detectable gas. The leak checks were performed prior to and subsequent to vibration, flexture-impulse, and resoldering tests. Out of 47 joints tested, five leaks were observed. Two of the leaks were in the tubes at the fixture, two did not exceed the allowable limits (3.54 x 10-7 and 1.27 x 10-7 st. cc of helium/sec.) and the fifth had a leak rate of 8.9 x 10-6 std. cc of He/sec.

(5). Burst Testing

The average hydraulic fluid pressure required to burst the aluminum soldered joints ranged from 13,000 psi for the 1/4 inch lines to 5,300 psi for 5/8 inch lines. These fluid pressures are more than adequate for the maximum system pressure of 900 psi. Based on these results the factor of safety at operating pressure is at least six.

(6). The selection of solder for joining aluminum tubes was evaluated further by establishing the magnitude of the midspan deflection of a simply-supported tube specimen stressed in bending to 17,000 psi. This stress was considered to be a minimum safe allowable value. The span was selected by assuring that the natural frequency would be greater than 120 cps. Based on the outer fiber stress of 17,000 psi achieved during the test, the following midspan deflections were obtained.

Tube Diameter (In.)	Span (In.)	Midspan Deflection (In.)
1/4	13.5	0.239
3/8	16.5	0.226
5/8	22.0	0.232

It was assumed that in normal manufacturing and assembly handling these deflections would permit assembly without any undue problems in tube alignment and line movement during equipment installation and removal. These deflections were substantiated by the vibration test which imposed a fiber stress of 17,000 psi for a minimum of 61,200 cycles.

Based upon the foregoing data, the implementation of soldering for joining aluminum tubing is considered to a sound decision provided the procedures for alignment are met, good design practice is exercised, and appropriate criteria for system installation and field maintenance are generated.

B. Program Experience

(1). Union on coupling design.

The union, as presently used in the program, has been designed to minimize weight. In practical use and especially in conjunction with the use of the 6061-T6 hardened aluminum tubing, these unions have proven to be unsatisfactory. Considerable number of leaking joints have been found on all spacecraft. Substantial improvement of this union is required in order to accept normal handling associated with spacecraft checkout and field repairs.

(2). Joint Assembly

Initially, considerable difficulty was experienced in the nickel plating process; however, this problem has apparently been resolved by establishing and maintaining rigid cleaning process specifications.

The present specification allows an additional heat if the joint is unsatisfactory. Criteria for a satisfactory joint has been reduced to leakage only. Joints not meeting the other criteria are often accepted as a result of engineering action if they meet the leakage requirements.

In spite of the allowable reheat and reduced criteria, a ten percent rejection rate still exists.

LIST OF REFERENCE MATERIAL

The supporting data for this report have been transmitted to the Apollo 204 Review Board files. These data are contained in the following references:

REFERENCE

9-1. Williams, R. W., DETAILED INSTRUCTION TO WORKING GROUPS, February 5, 1967.

9-2. Hamblett, E. B., et. al., COMMAND MODULE CREW COMPARTMENT IGNITION SOURCES AND CONTIGUOUS NON-METALLIC MATERIALS, March 15,-967.

9-3. Hamblett, E. B., et. al., DATA SHEETS, BLOCK I AND BLOCK II COMMAND MODULE IGNITION SOURCE AND CONTIGUOUS NON-METALLIC MATERIAL REVIEW.

9-4. CABIN ATMOSPHERE, SUMMARY AND BIBLIOGRAPHY.

9-5 Joslyn, A. W., et. al., OXYGEN SUMMARY, March 15, 1967
Hazards Evaluation, Bibliography
Engineering Tradeoffs [State of the Art! - General, Bibliography
Material Selection, Bibliography
Physiological Considerations - General, Bibliography
MSC Supporting Data [Atmospheric Selection, Safety Considerations!, Bibliography
New Releases, Bibliography.

9-6. Jaderlund, W. W., et. al., APOLLO 204 PANEL 9 REPORT ON PAD EGRESS, March 10, 1967.

9-7. Beers, C. A., et. al., VOICE COMMUNICATIONS ANALYSIS REPORT, PANEL 9, APOLLO 204 REVIEW BOARD, March 21, 1967.

REPORT OF PANEL 10
ANALYSIS OF FRACTURE AREAS
APPENDIX D-10
TO
FINAL REPORT TO
APOLLO 204 REVIEW BOARD

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Analysis of Fracture Areas Panel, 10. The task assigned for accomplishment by Panel 10 was prescribed as follows:

Inspect spacecraft for structural failures resulting from the fire. Analyze these failures from standpoint of local pressure, temperature levels, direction of gas flow, etc.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Analysis of Fracture Areas Panel:

Mr. P. C. Glynn, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. N. Koenig, Kennedy Space Center (KSC), NASA
Mr. R. E. Johnson, Manned Spacecraft Center (MSC), NASA
Mr. S. Glorioso, Manned Spacecraft Center (MSC), NASA
Mr. L. J. Korb, North American Aviation, Inc. (NAA)
Mr. D. Root, North American Aviation, Inc. (NAA)

Technical support was provided by the Manned Spacecraft Center (MSC) Structures and Mechanics Division (SMD) and North American Aviation structural analysis personnel. The major portion of the on-site task consisted of detailed metallurgical inspection and laboratory analysis. Metallurgists Korb, Glorioso, Root, and Johnson performed the majority of the inspection while Koenig monitored or performed all the laboratory analyses.

2. COGNIZANT BOARD MEMBER:

Mr. E.B. Geer, Langley Research Center (LaRC), NASA, Board Member, was assigned to monitor the NAnalysis of Fracture Areas Panel.

C. PROCEEDINGS

In response to the direction of the Apollo 204 Review Board, the Panel derived detailed objectives. These objectives were:

Inspect the spacecraft structures to determine the extent, origin, mode, and failure sequence of significant structural damage.

Estimate the cabin environment during the fire. Analyze all applicable data and examine the spacecraft for evidence of local temperature and pressure extremes.

Provide metallurgical support to the systems engineers during spacecraft disassembly. Define metallurgical test requirements to determine the cause of system damage.

1. PANEL ACTIVITY

The inspection of the spacecraft structures was conducted in a systematic manner starting with the Command Module (C M) and Service Module (S M) while located at Launch Complex 34 and continued through C M heat shield removal. Structural damage reports were made coincident with the spacecraft disassembly phases. As major sub-systems were removed from the spacecraft, they were visually inspected. Buckles, fractures, cracks, melted areas, localized arcing or pitting in metal components, and obvious direct wire-shorts were noted and documented. Those items which required laboratory analyses were identified and detailed test requirements were defined. Equipment removed from the spacecraft following heat shield removal was inspected in detail at the request of the applicable system engineer. Analyses of results of the monitored laboratory work were provided to Panel 18 Integration Analysis. Metal degradation due to extreme structural temperatures was documented and analyzed. An estimate of the temperature attained in local areas as determined from examination of the metallic components was provided to Panel 8 Materials Review. Support concerning the spacecraft strength and structural configuration was provided to Panel 4, Disassembly Activities Panel. Structural and mechanical subsystem support was provided to the Equipment Screening Committee.

2. INTRODUCTION

The crew compartment of C/M 012 was a pressurized shell fabricated of bonded aluminum honeycomb sandwich structure. The cabin structure was pressurized to a positive pressure of approximately 2 pounds per square inch differential (psid) pressure at the time of the fire. As a result of the fire, portions of the interior and exterior were burned and the primary cabin structure was ruptured.

At the time of the accident, all components of the structural and mechanical subsystem were inactive. No evidence was found which would support a hypothesis of mechanically induced ignition of combustibles within the C/M. The crew equipment subsystem contained combustible material which burned. Examination of film and data from the SMD-2B boiler plate fire simulation test (Reference 10-1) verified that the rupture of the C/M cabin accelerated the propagation of the fire by inducing forced convection.

3. INVESTIGATIVE ACTIVITIES

a. CABIN RUPTURE

(1) TIME OF RUPTURE

The time of cabin rupture was concluded to be between 6:31:19.3 pm EST (23:31:19.3 GMT) and 6:31:19.5 pm EST. This conclusion is supported by analysis of aft heat shield thermocouple data and Stabilization and Control System (SCS) spacecraft angular rate data. The thermocouple data indicated an open circuit at approximately 23:31:19.5 GMT. Inspection of the measurement wire leads near the origin of cabin rupture verified that the leads had been burned through. The indiced structural motions at rupture, indicated at 23:31:19.3 GMT by the SCS rate measurements, were analyzed and correlated with the origin of the fracture.

(2) CABIN PRESSURE HISTORY

Atmospheric pressure at the time of the accident was 14.68 pounds per square inch absolute (psia). Direct measurement of the cabin pressure was valid until approximately 6:31:16 pm EST at which time the cabin pressure measurement indicated full scale. However, the Guidance and Navigation System did respond to cabin pressure as discussed in Reference 10-2. AC Electronics Division analyzed the applicable data from OCP FO-K-0021-1 as well as data from a previous C/M 012 cabin pressure test. This and supporting test data obtained by simulation using Spacecraft 008 (Reference 10-3) verified the cabin pressure measurement and provided the additional data points shown in Enclosure 10-2.

An estimate of the minimum cabin pressure history for the time period 6:31:16 to 6:31:19.4 pm EST was calculated. The heat absorbed by the cabin gas was calculated up to the time of pressure transducer saturation. The rate of heat absorbed by the cabin gas was linearly extrapolated and the resulting pressures and average gas temperatures were calculated. Venting of the cabin pressure relief valve and the addition of oxygen to the cabin were included in the analysis (Reference 10-4 and 10-5). Operation of the cabin pressure relief valve was shown to have negligible effect upon the time until cabin rupture. The method of analysis used was judged to yield a minimum pressure history. The estimated minimum pressure at rupture was 29 psia.

Enclosure 10-2 presents the estimated cabin pressure from 6:31:06 to 6:31:22 pm EST. Pressure values plotted for the time of rupture are:

Design ultimate pressure 12.9 psi differential (27.6 psia)
Estimated minimum pressure at rupture 14.3 psi differential (29 psia)
Estimated maximum pressure at rupture (discussed in Section C3c(1))
23 psi differential (37.7 psia)

Average gas temperature at the time of rupture was estimated to be in excess of 700 degrees Fahrenheit (°F). The SMD-2B fire simulation test data (Reference 10-1) and analyses estimate a structural temperature at the time of rupture in the vicinity of the origin of fracture of less than 130° F.

b. C/M PRIMARY STRUCTURAL DAMAGE

(1) C/M EXTERIOR

Inspection of the C/M exterior indicated extensive primary structural damage to the +Y, -Z quadrant exterior structure. Evidence of degradation of the external thermal control coating was most severe in this region. Evidence of C/M crew compartment exterior structural damage was noted in the region between access panels 15 and 17, (Enclosure 10-3) and of the helium pressurization panel bracketry as illustrated in Enclosures 10-4 and 10-5. Inspection following heat shield removal indicated burned and melted secondary structure in this region.

(2) C/M CREW COMPARTMENT

Inspection of the interior of the C/M cabin determined that the primary structure was damaged in several locations. Burned penetrations of the bonded aluminum honeycomb sandwich cabin structure were observed in the aft bulkhead beneath the Environmental Control Unit (ECU) and Water Control Panel and in the aft sidewall behind the Water Control Panel. Rupture of the aft bulkhead was observed as illustrated in Enclosures 10-6 and 10-7. Melting and erosion of the fracture surfaces was evident and is illustrated in Enclosure 10-8.

Much of the fracture surface was not initially visible from the interior of the C/M due to equipment and secondary structure installations. The fracture surfaces are defined in detail in Enclosures 10-9 and 10-10. Exterior definition of the fracture is illustrated in Enclosure 10-11a, 10-11b, and 10-11c.

(3) C/M AFT HEAT SHIELD

The aft heat shield brazed stainless steel honeycomb sandwich structure was melted and eroded in the +Y, -Z quadrant as shown in Enclosures 10-12a, 10-12b, and 10-12c. Evidence of high temperatures and high velocity gas flow is further illustrated by the charred and missing insulation which is installed between the aft heat shield and cabin aft bulkhead. Evidence of impinging hot gas through penetrations in the cabin aft bulkhead in the +Z quadrant was observed. Little evidence of impinging gas was observed at the location of the burned-through area beneath the ECU and Water Control Panel.

c. ANALYSIS OF PRIMARY FAILURES

(1) BACKGROUND

Nondestructive pressure testing of the C/M crew compartment structure performed during the qualification tests of the Apollo Spacecraft structure predicted the observed mode of aft bulkhead rupture. The aluminum sheets forming the inner surface of the cabin are welded to form a pressure tight compartment. Thicker chemically milled sections at the circumferential joint of the aft bulkhead (Enclosure 10-7) are provided to facilitate the welding process and allow for the reduced unit strength of the weld. The junction of the aft sidewall aft bulkhead forms a discontinuity in the shell surface. The critical region of the cabin structure for internal pressure loading occurs in the aft bulkhead inner face sheet at the transition of the weld land to the thinner inner face sheet near this discontinuity.

The predicted failure mode is rupture due to meridional tensile stress of the inner face sheet. Calculation, using strain gage data from the qualification test, yields an estimated upper limit of burst pressure of 37.7 psia.

(2) ORIGIN

Detailed inspection of the bulkhead was correlated with the observed aft heat shield and cabin exterior structural damage. The motion of the structure due to cabin rupture, deduced from the Stabilization and Control System rate data, was consistent with the observed evidence. It was concluded that the cabin ruptured at point A shown in Enclosures 10-9 and 10-10 at the junction of the weld land to the inner face sheet. Enclosures 10-8, 10-9, 10-10, 10-11a, 10-11b, and 10-11c define the total fracture. Most of the fracture surfaces were burned and melted; little metallurgical analysis was attempted.

(3) FAILURE SEQUENCE

It was concluded that the tensile failure of the inner face sheet at point A (Enclosure 10-9) was followed immediately by tensile failure of the outer face sheet at point A (Enclosure

10-10). Rupture then propagated to points B and C. Failure of the inner face sheet to point H and failure of the outer face sheet along lines IJKL and CIJ were deduced from inspection and structural analysis to have occurred following the initial rupture and to have been of secondary significance. The bonded doubler at point K was added as a result of manufacturing process control testing performed during structural assembly. Failure of the inner face sheet along DEFG and delamination of the outer face sheet from the core with burn-through holes in the -Y, +Z quadrant occurred subsequent to the initial rupture at a pressure-structural-temperature combination less than that required to cause failure of the outer face sheet. Burn-through in the area beneath the ECU did not occur until the late stages of the fire at a time when cabin pressure was approximately ambient. Face sheet defects adjacent to this area are a result of the structural temperatures attained in this vicinity. The penetration in the aft sidewall, shown in Enclosure 10-13b, was concluded to be a result of locally impinging hot gas behind the Water Control Panel, occurring in the late stages of the fire.

(4) SECONDARY DAMAGE

Detailed inspection of the C/M inner secondary structure revealed buckled aluminum panels and burned and delaminated aluminum honeycomb sandwich panels. Typical damage is illustrated in Enclosure 10-14 and 10-15.

Aluminum melts at approximately 1200°F. With the exception of the aft bulkhead fracture, melting of aluminum was confined to the left hand (-Y) side of the inner cabin. Melted aluminum was observed in close proximity to plastic which was unmelted, indicating local flame impingement in specific areas.

Damage to the inner face sheet of the aft sidewall adjacent to the melted and deformed CO_2 Absorbers is shown in Enclosure 10-16. The structure shown is located in the -Y, +Z quadrant of the C/M. Significant structural damage was noted to plumbing beneath the ECU and in back of the Water Control Panel. The lines are identified and shown in Enclosures 10-13a, 10-13b, 10-13c, and 10-13d. Aluminum and stainless steel lines were melted in this area. It was also observed that soldered joints at couplings on the aluminum lines had parted.

Melted nickel-plated copper wire was observed in the vicinity of the ECU. Copper melts at approximately 1980°F whereas stainless steel and nickel melt at approximately 2600°F. These materials are distributed throughout the spacecraft and are unmelted at other locations.

d. SERVICE MODULE DAMAGE

The Service Module (S/M) structure was inspected for evidence of structural damage. No evidence of structural failure was observed. Nondestructive tests were defined to determine any degradation in design strength. It was recommended that these tests be accomplished within the normal Apollo program activity.

D. FINDINGS AND DETERMINATIONS

1. FINDING

The structural and mechanical subsystem was inactive at the time of the fire.

DETERMINATION

The structural and mechanical subsystem did not cause the fire.

2. FINDING

Visual inspection of the Service Module structure revealed no structural failures.

DETERMINATION

Verification of the structural adequacy for the design loads would require non-destructive testing.

3. FINDING

The crew compartment structure was a pressurized shell structure during the fire.

a. The resulting fire environment initiated the following sequence of major structural damage:

(1) Rupture of the C/M cabin aft bulkhead.

(2) Melting and erosion of C/M cabin and heat shield honeycomb sandwich face sheets adjacent to the origin.

(3) Penetration of the cabin structure beneath and adjacent to the ECU.

b. Minor structural damage resulting from the fire included:

(1) Honeycomb sandwich delamination

(2) Panel buckling

(3) Melting of metallic components

4. FINDING

Spacecraft data acquired during the OCP-FO-K-0021-1 test gave indications from which a spacecraft cabin pressure history could be estimated.

DETERMINATION

a. The C/M cabin structure ruptured at 6:31:19.4 (±0.1) pm EST at an estimated minimun cabin pressure of 29 psia.

b. The C/M cabin structure sustained cabin pressure in excess of its design ultimate pressure of 12.9 psi differential (27.6 psia). It is probable that the cabin pressure at rupture reached a range of 29 to 37.7 psia.

c. The estimated average gas temperature at rupture exceeded 700°F.

5. FINDING

The C/M cabin ruptured in the aft bulkhead adjacent to its juncture with the aft sidewall.

DETERMINATION

The failure occurred due to excessive meridional tensile stress in the inner face sheet at the weld land to thinner face sheet junction. The fracture was determined to have originated on the right-hand side of the C/M in the vicinity of coordinates Y=+45 inches Z=-30 inches.

6. FINDING

Penetrations of the C/M cabin structure occurred in the aft bulkhead beneath the ECU and in the aft sidewall.

DETERMINATION

a. The loss of structural integrity at these penetrations occurred after the primary rupture.

b. Failure of the water glycol and oxygen lines in the vicinity of the ECU resulted in local burning and melting of the adjacent structure.

7. FINDING

The aft heat shield stainless steel face sheets were melted and eroded.

DETERMINATION

The flame and gas temperature exiting from the fracture origin exceeded 2500°F.

8. FINDING

With the exception of the aft bulkhead fracture surfaces, melting of aluminum was confined to the left-hand side of the C/M. Melting of copper wire, stainless steel and aluminum occurred in the vicinity of the ECU and Water Control Panel on the left side and at the foot of the left-hand couch. These materials are distributed throughout the spacecraft and (excluding aluminum) are unmelted at other locations

DETERMINATION

a. The left-hand side of the inner cabin attained the maximum temperatures.

b. The hottest part of the C/M cabin occurred in the vicinity of the ECU and Water Control Panel.

9. FINDING

Melted aluminum was observed on the left-hand side of the C/M inner cabin in very close proximity to plastic which was unmelted, although the plastic had a much lower melting point than the aluminum.

DETERMINATION

A "blow torch" effect occurred where narrow "tongues of flame" impinged on certain areas at the same time as the general burning.

10. FINDING

Several aluminum tubes were parted at soldered joints at couplings.

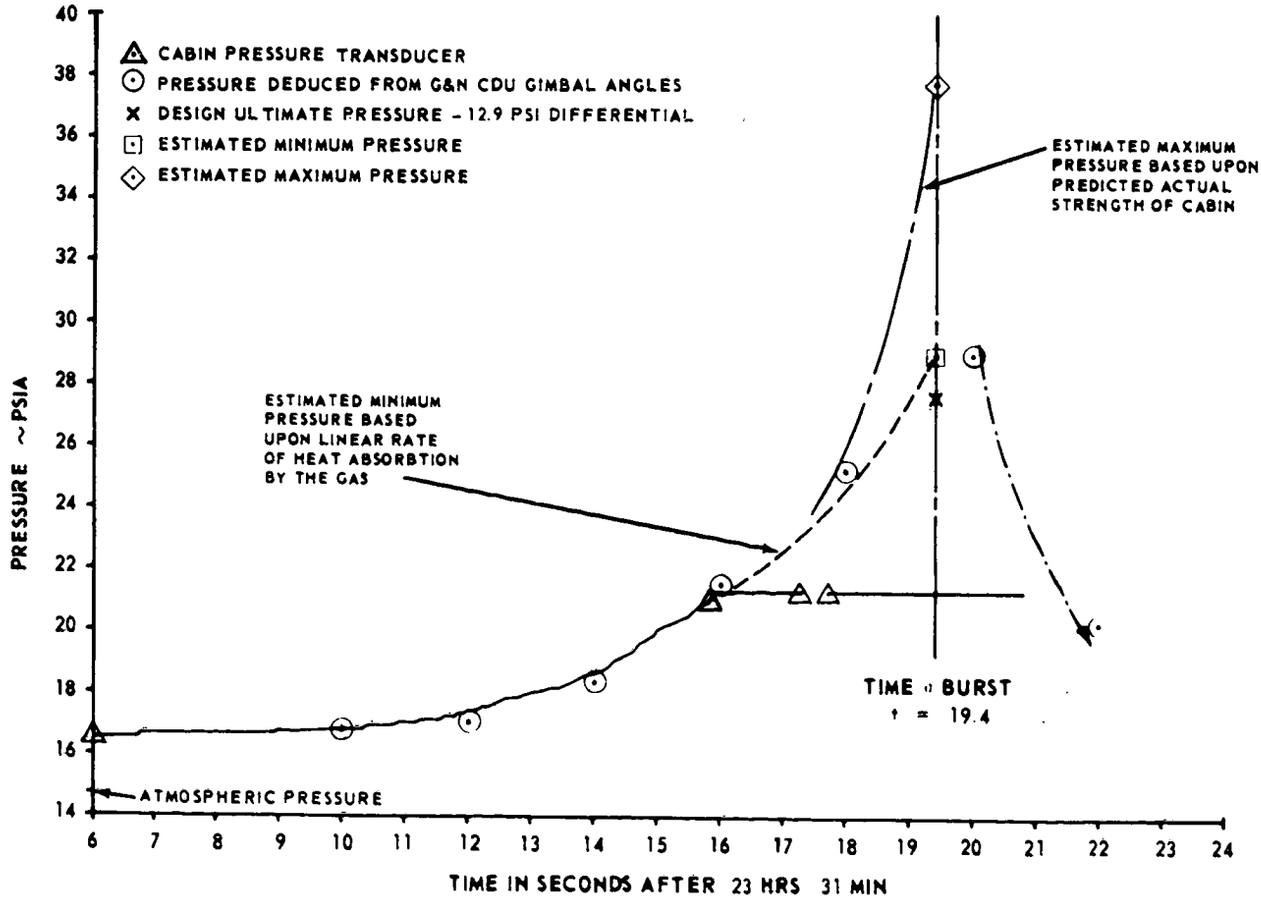
DETERMINATION

The soldered aluminum joints at unions will fail if the solder is raised to its melting point of approximately 360°F. The soldered aluminum joints at couplings were not adequate for the temperatures attained during the fire.

E. SUPPORTING DATA

LIST OF ENCLOSURES

10-1	Not Used.
10-2	Cabin Pressure
10-3	Heat Shield Access Panels
10-4	Helium Access Panel Number 15, +Y, Axis
10-5	Crew Compartment Structure, +Y Axis
10-6	Location of Cabin Fracture
10-7	Origin of Cabin Failure
10-8	Inner Fracture of Crew Compartment in Vicinity of Point B
10-9	Inner Face Sheet of Aft Bulkhead
10-10	Outer Face Sheet of Aft Bulkhead
10-11a	Aft Bulkhead of Crew Compartment, +Y View
10-11b	Aft Bulkhead of Crew Compartment, +Y Axis
10-11c	Aft Bulkhead of Crew Compartment, -Y Axis
10-12a	Aft Heatshield Damage, View I
10-12b	Aft Heatshield Damage, View II
10-12c	Aft Heatshield Damage, View III
10-13a	Tubing Codes for Use with Enclosures 10-13b, 10-13c, and 10-13d
10-13b	Inner Sidewall Penetration Behind Water Control Panel
10-13c	Tubing Beneath ECU
10-13d	Melted Tubing Beneath CO_2 Absorbers
10-14	Buckled Food Storage Compartment Doors
10-15	Damaged Food and Garment Storage Locker Doors
10-16	Damaged Inner Sidewall Below CO_2 Absorbers
10-17	List of References



CABIN PRESSURE

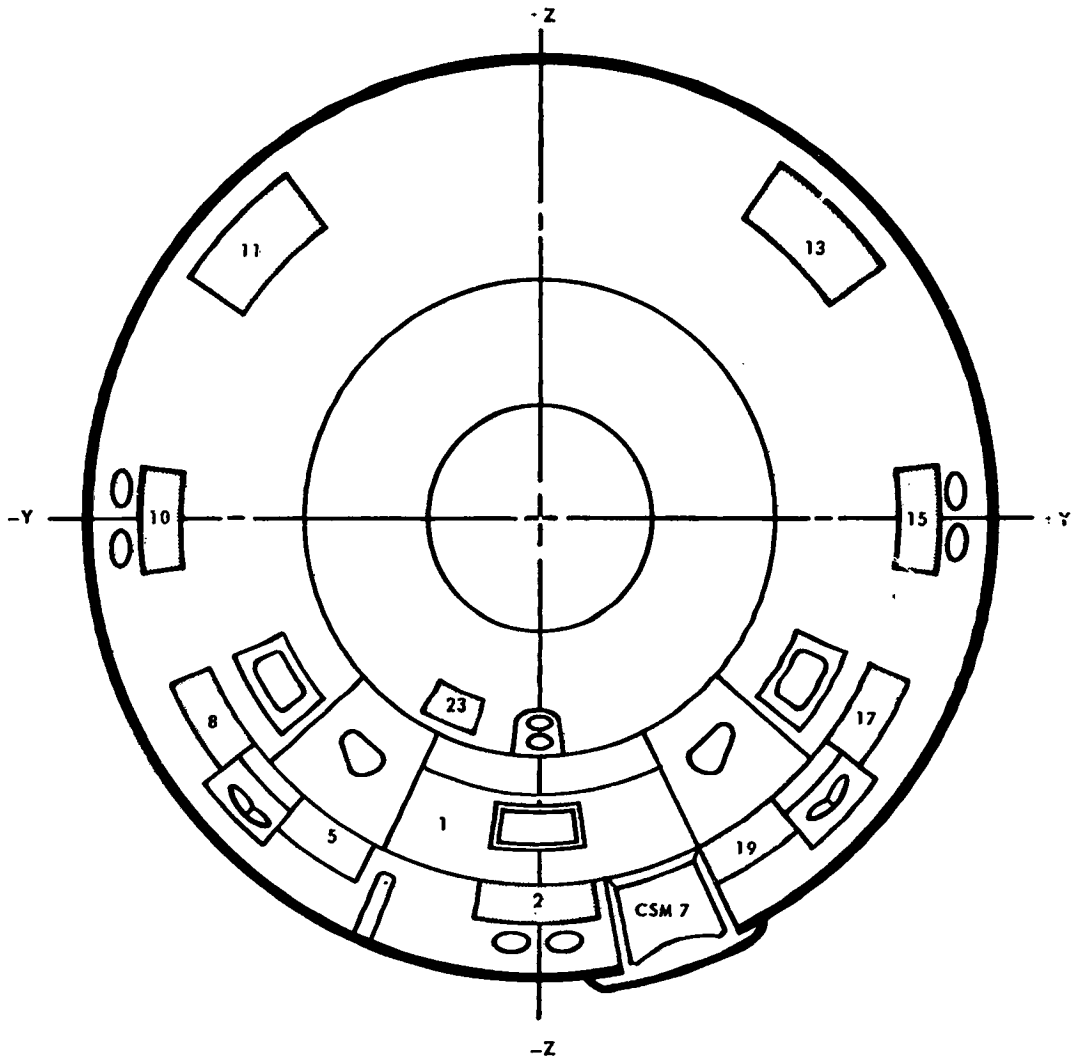
ENCLOSURE 10-2

ENCLOSURE 10-3

ACCESS PANEL NOMENCLATURE

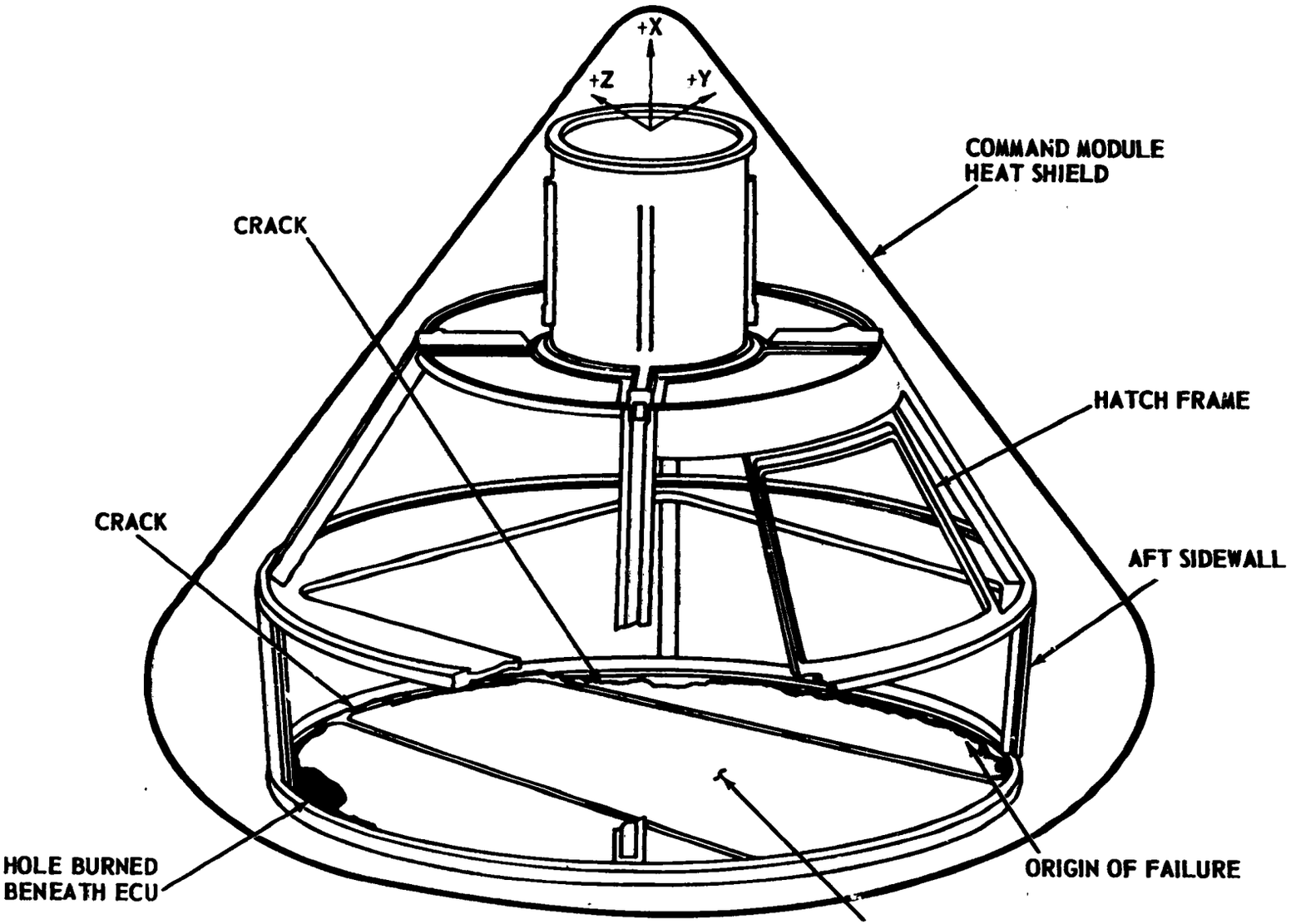
CM 1 CREW HATCHES
CM 2 PITCH ENGINE ACCESS
CM 5 ROLL ENGINE & URINE DUMP PANEL
CM 8 ROLL ENGINE ACCESS
CM 10 YAW ENGINE & He FILL ACCESS
CM 11 FUEL PANEL ACCESS
CM 13 OXYGEN PANEL ACCESS
CM 15 YAW ENGINE & He FILL ACCESS
CM 17 ROLL ENGINE ACCESS
CM 19 ROLL ENGINE ACCESS
CM 23 PITCH ENGINE ACCESS
CSM 7 CM TO SM UMBILICAL

NOTE: SHADED PANELS REPRESENT AREAS OPEN AT THE TIME OF THE ACCIDENT



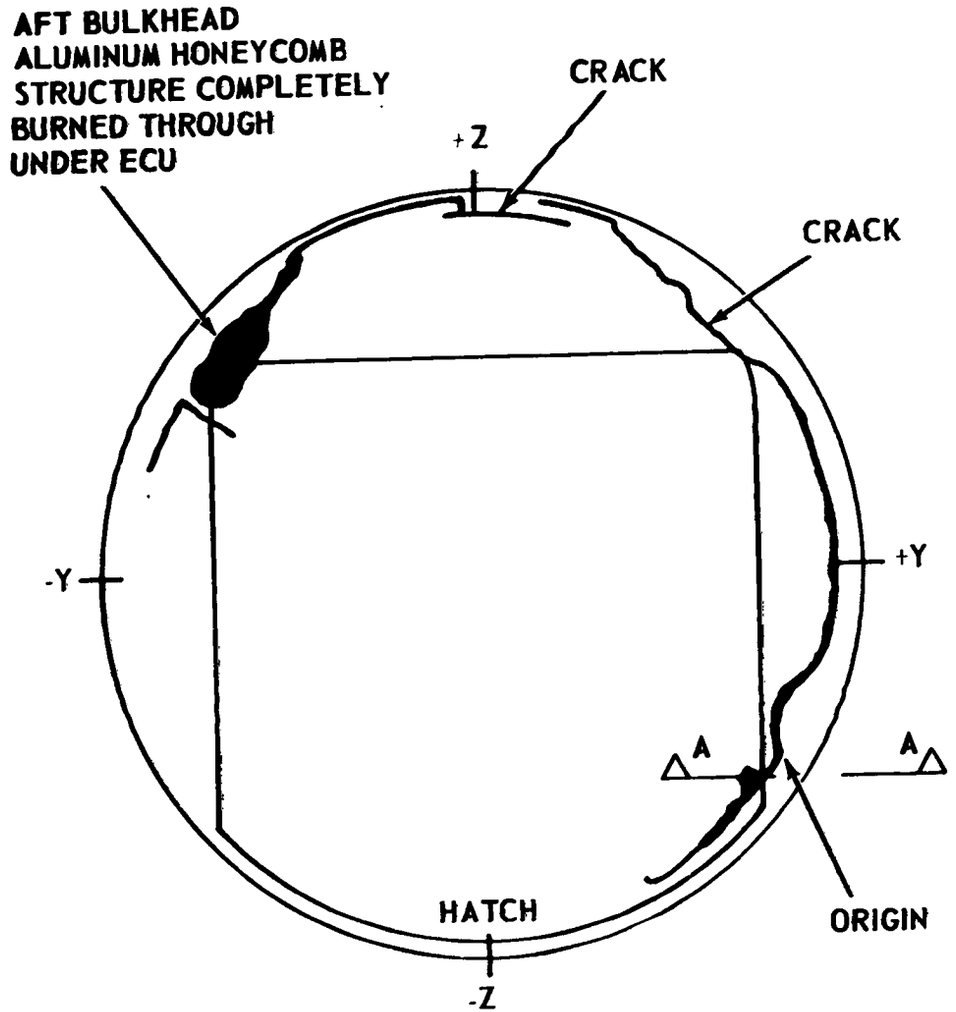
HEATSHIELD ACCESS PANELS

ENCLOSURE 10-6

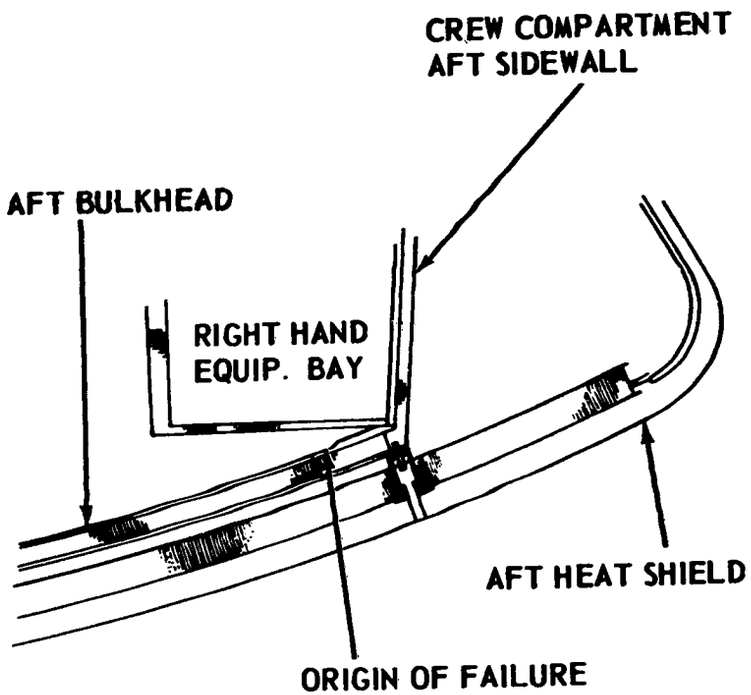


LOCATION OF CABIN FRACTURE
ENCLOSURE 10-6

LOCATION OF CABIN FRACTURE



AFT BULKHEAD

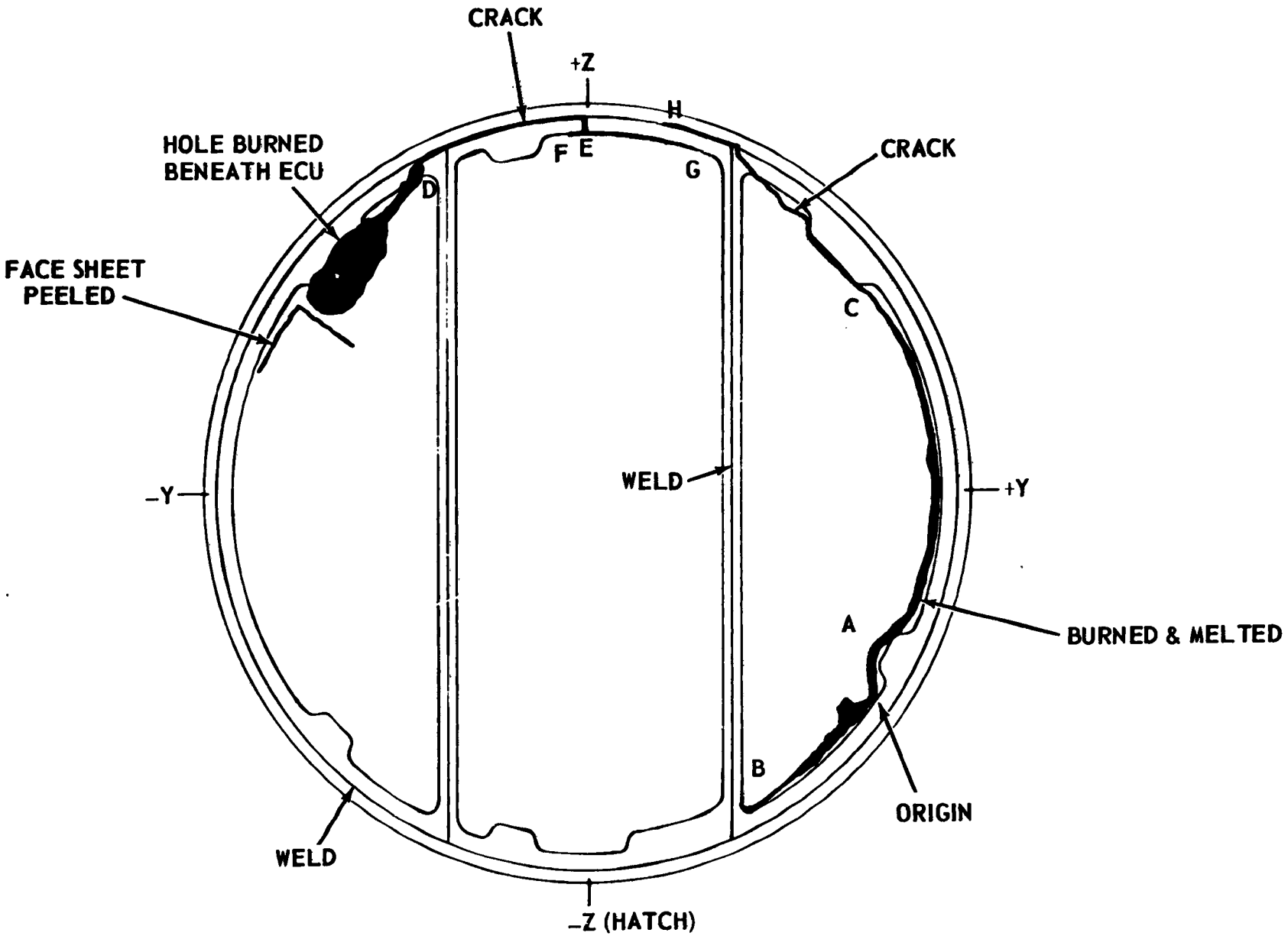


VIEW A

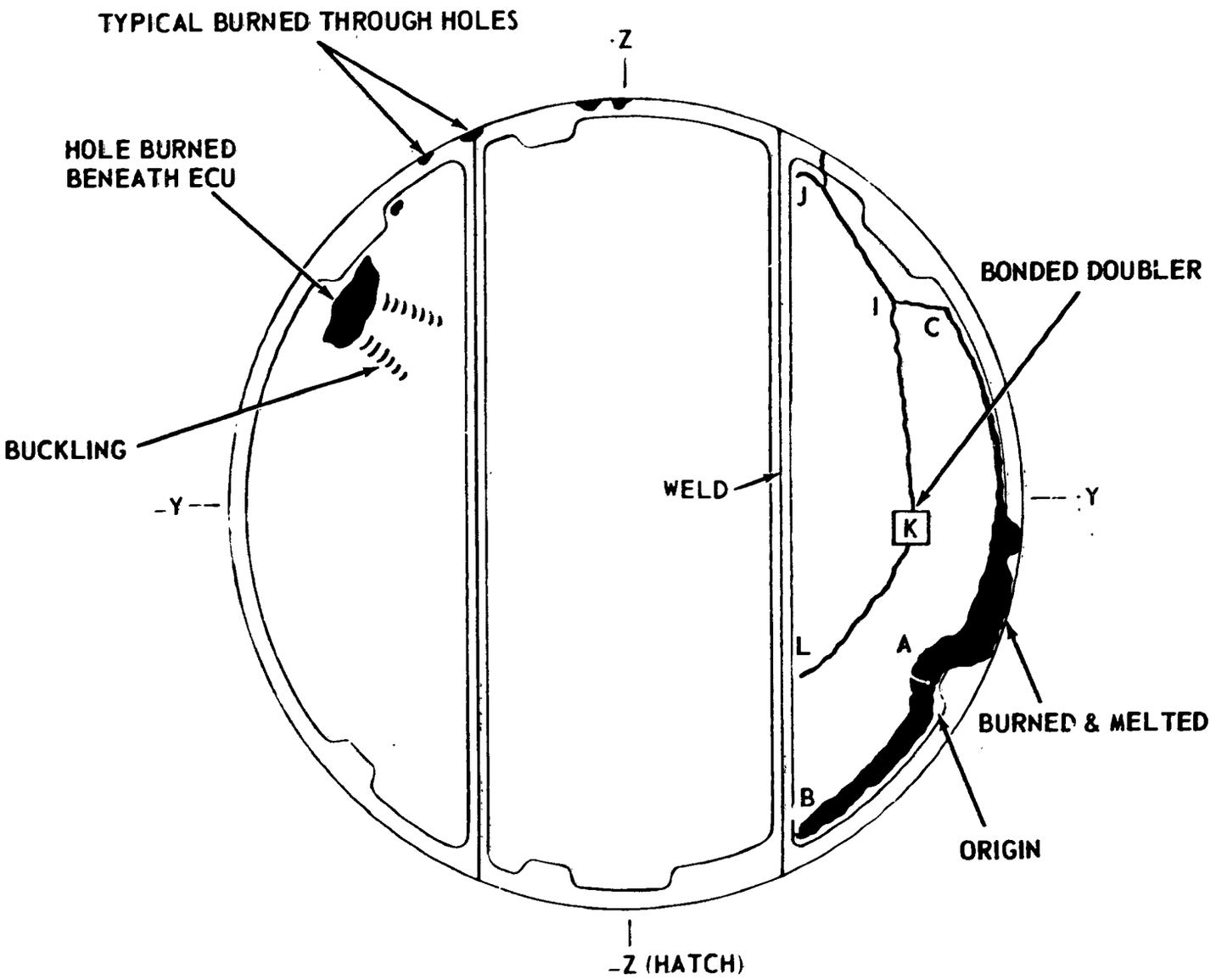
ENCLOSURE 10-7

ORIGIN OF CABIN PRESSURE

ENCLOSURE 10-9



INNER FACE OF AFT BULKHEAD



OUTER FACE SHEET OF AFT BULKHEAD

ENCLOSURE 10-10

CODE	GAS OR FLUID CONTAINED	PRESSURE
A	OXYGEN	SAME AS CABIN
B	OXYGEN	SAME AS CABIN
C	AIR	AMBIENT
D	AIR	AMBIENT
E	NITROGEN	AMBIENT
F	OXYGEN	700 PSI
G	OXYGEN	700 PSI
H	OXYGEN	100 PSI
I	NITROGEN	AMBIENT
J	WATER GLYCOL	50 PSIG
K	OXYGEN	20 PSIG

NOTE: RED ARROWS ON ENCLOSURES 10-13b, 10-13c, AND 10-13d INDICATE DIRECTION OF FLOW IN TUBE

TUBING CODES FOR USE WITH ENCLOSURES 10-13B, 10-13C, & 10-13D

LIST OF REFERENCES

10-1 "Apollo Mockup SMD-2B Plots, 0-60 Sec. .12 Window" Manned Spacecraft Center, NASA, March 6, 1967.

10-2 Panel Number 18, Integration Analysis (Appendix D-18) For Final Report to AS-204 Review Board

10-3 STN 43 - Delta P vs CDU Gimbal Angles

10-4 STN 42 - Cabin Pressure Relief Valve and Vent Line Flow Characteristics

10-5 STN 37 - Soot Comparative Analysis (Test results will be contained in Appendix G of the Apollo 204 Review Board Final Report)

END

DATE

FILMED

(NASA-TM-84100) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX D, PANEL 11 (NASA) 44 p

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REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANEL 11

(NASA-TM-X-72182) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX D, PANEL 11 (NASA) 44 p ~~LIMITED ACCESS~~

X75-70676

Unclas
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APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

REPORT OF PANEL 11
MEDICAL ANALYSIS PANEL
APPENDIX D-11
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

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MEDICAL ANALYSIS PANEL

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Medical Analysis Panel, 11. The task assigned for accomplishment by Panel 11 was prescribed as follows:

This panel is to provide a summary of medical facts together with appropriate medical analysis which would be of interest to the investigation. Examples would be cause of death, pathological evidence of overpressure, and any other areas that might be of technical value in determining the cause of accident or in establishing corrective action.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Medical Analysis Panel:

Dr. G. F. Kelly, Chairman, Manned Spacecraft Center (MSC), NASA
Dr. Alan C. Harter, Manned Spacecraft Center (MSC), NASA
Dr. Norman W. Pincock, Manned Spacecraft Center (MSC), NASA
Mr. Robert L. Spann, Manned Spacecraft Center (MSC), NASA
Mr. Richard L. Thompson, Pan American Airways (PAA)
Mr. Thomas H. Parish, David Clark Co.

2. COGNIZANT BOARD MEMBER:

Dr. Floyd L. Thompson, Langley Research Center (LaRC), NASA, was assigned to monitor the Medical Analysis Panel.

C. PROCEEDINGS

1. NARRATIVE:

In preparation for the Space Vehicle Plugs Out Integrated Test, the crew had been examined and fitted with sensors prior to departing the Manned Spacecraft Operations Building (MSOB) at approximately 12:30 pm EST (17:30 GMT). After ingress, voice, bioinstrumentation data and certain environmental parameters were monitored at the aeromedical console in the blockhouse. In the Apollo 204 spacecraft, only one crewman could be monitored at a time. During the course of the test, a switch in the cockpit was positioned at the request of the medical monitor so that data from each crewman could be monitored in turn. The Medical Data Acquisition System recorded data only from the Senior Pilot throughout the test.

At the time of the accident, two NASA physicians in the blockhouse were monitoring data from the Senior Pilot. Upon hearing the first voice transmission indicating fire, the senior NASA physician turned from the biomedical console to look at the bank of television monitors. He could see on one what appeared to be flames coming from around the spacecraft but could not pick out a monitor which was focused on the hatch. When his attention returned to the console, the bioinstrumentation data had stopped. The biomedical engineer in the Acceptance Checkout Equipment (ACE) Control Room called the senior medical officer for instructions; was told to make the necessary alarms and informed that the senior medical officer was leaving his console at that time. The two NASA physicians were transported from the blockhouse to the base of the umbilical tower shortly before ambulances and the Pan American physician arrived. The Pan American log fixes the time of ambulance arrival at 6:43 pm EST (23:43 GMT) (Reference 11-1).

At this time considerable smoke was still rising from the White Room area. An estimate of the number of individuals who were working in the White Room was obtained, and the Pan American physician was asked to make arrangements for the care of over 15 injured personnel. One of the injured who had proceeded to ground level was interviewed briefly as to the condition in the White Room and the Spacecraft.

The two NASA physicians and the Pan American physician then proceeded to the spacecraft. The time of arrival at the White Room on the 8th level is estimated at 6:45 pm EST (23:45 GMT). When the physicians first arrived, the hatches had been removed, the spacecraft was still smoldering, pyrotechnics had not been safetied and smoke was too thick to spend any time in the vicinity without a breathing apparatus.

After a quick evaluation, it was decided that nothing could be gained by attempting immediate egress and resuscitation. By this time, some 12 to 15 minutes had elapsed since the fire began. It was evident that the crew had not survived the heat, smoke, and thermal burns. Conditions within the spacecraft (later confirmed by toxicological determinations) were such as to produce high levels of carbon monoxide (CO), carbon dioxide (CO_2), and other toxic gases and irritants. Also, oxygen was markedly depleted after the rupture of the spacecraft. These conditions would have necessitated institution of resuscitative measures within a very few minutes, since under optimal conditions, resuscitation commenced more than four minutes after cardiac arrest is usually unrewarding. The three physicians then returned to ground level until adequate ventilation could be established.

Shortly thereafter, they returned to the spacecraft with equipment for an attempted removal. After trying to remove the Senior Pilot by cutting his suit umbilicals and electrical connections, it became apparent that extensive fusion of the suits to molten nylon from the spacecraft would make removal very difficult. For this reason, it was decided to discontinue efforts at removal in the interest of accident investigation and attempt to get photographs of the spacecraft and relative positions of the crewmen before evidence was disarranged. The two NASA physicians remained in the vicinity of the spacecraft while the Pan American physician returned to ground level. NASA Security arranged for photographic coverage.

After this was accomplished, one of the NASA physicians returned to the blockhouse for approval to resume egress operations. Approval was received from Major General Samuel C. Phillips, U.S. Air Force/Apollo Program Manager, shortly after midnight, local time, and egress was begun at approximately 12:30 am EST (05:30 GMT), January 28, 1967. The Pan American Dispensary log indicates that the ambulance with the Senior Pilot arrived at the Pan American Dispensary at 1:17 am EST (06:16 GMT). The ambulance with the Command Pilot arrived at 1:35 am EST (06:35 GMT) and the ambulance with the Pilot arrived at 2:08 am EST (07:08 GMT). Therefore, removal of the crew took approximately 90 minutes and was completed about seven and a half hours after the accident. The crewmen were removed to the Bioastronautics Operational Support Unit for post-mortem examinations at 4:17 am EST (09:17 GMT).

2. INVESTIGATION:

Conclusions of the Medical Analysis Panel are based on evaluation of information obtained by the following procedures:

a. Photographic Analysis:

Numerous color and black and white photographs were obtained of:

(1) The spacecraft and its interior prior to the removal of the crewmen.
(2) The suited bodies after removal from spacecraft.
(3) The suits, constant wear garments, and other crew equipment after removal.
(4) Special post-mortem photographs.

Photographs were studied in detail by the Panel and the Armed Forces Institute of Pathology investigators to correlate suit damage, position of bodies and pathological findings with fire propagation, sequence of events and cause of death. These photographs were made available to Members of the Board and other Panels as required.
(Reference 11-2)

b. Interrogation of Witnesses and Review of Records:

One Panel member was at the blockhouse aeromedical console at the time of the accident. Two members of the Panel participated in the removal of the crew from the spacecraft. Three Panel members were present during desuiting and post-mortem examination. Other witnesses were interrogated as required. These included some of the smoke inhalation victims, several Pan American Airways medical personnel and members of the egress crew.

Also reviewed in detail were:

(1) Witness statements

(2) Pan American Airways, Cape Kennedy Medical Facility treatment records of smoke inhalation victims (Enclosure 11-1)

(3) Complete Department of Defense (DOD) and NASA medical records of deceased crewmen (Reference 11-3)

(4) Pertinent findings of other Apollo 204 Review Board Panels.

c. Biomedical and Communications Data Analysis:

In order to coordinate voice and biomedical parameters with environmental measurements and establish sequence of events, the following procedures were performed in conjunction with Panel 3:

(1) Blockhouse biomedical tapes and on-board Medical Data Acquisition System tapes from the Senior Pilot were analyzed in detail. The electrocardiogram (EKG): PHONOCARDIOGRAM (PKG) and impedance pneumogram (ZPN) records were studied at speeds of 10, 25, 50 and 100 millimeters per second for indication of movement or change in physiological status. The EKG tracings were reproduced after passage through a 25, 35, and 100 cycles per second low-pass filters. Audio transcriptions and graphic records of the terminal five minutes of the Senior Pilot's phonocardiographic data were recorded after passage through 100, 200, 300, 400, 500, 750, and 1000 cycles per second low-pass filters. These were studied for evidence of voice communications and indications of movement. It is noted that physiological data were available only from the Senior Pilot.

(2) Pertinent sections of voice transmissions from the spacecraft were studied with Bell Telephone Laboratories personnel in both visual and auditory forms at various filter levels.

d. Pathological Studies:

At 11:00 am EST on January 28, 1967, gross examinations were commenced at the Bioastronautics Operational Support Unit located at Cape Kennedy Air Force Station. The autopsies were performed by the following personnel from the Armed Forces Institute of Pathology:

(1) Edward H. Johnston, Colonel, M.C., U.S. Army, Chief, Military Environmental Pathology Division

(2) Charles J. Stahl, Commander, M.C., U.S. Navy, Chief, Forensic Pathology Branch

(3) Latimer E. Dunn, Captain, U.S. Air Force M.C., Chief, Aerospace Pathology Branch

All Examinations included:

(1) Survey of medical history

(2) Examination of clothing

(3) External examination

(4) Appraisal of external evidence of injury

(5) Internal examination

(6) Microscopic examination

(7) Radiographic examination

(8) Toxicological examination for carbon monoxide saturation of lungs and venous blood, as well as blood from the kidney, liver, and muscle; cyanide in blood and lungs; lactic acid in brain; volatiles in liver and blood; acid, basic and neutral drugs in liver; and spectrographic analysis of lungs for seven other gases and nine metallic ions (Enclosure 11-2 and 11-3)

e. Toxicological Studies:

Toxicological studies progressed along the following lines:

(1) The quality of breathing oxygen supplied to the spacecraft before the fire was reviewed from data collected during the countdown. Additional samples collected, as a result of the crew report of odors prior to the accident, were evaluated.

(2) Attempts were made to determine cabin and suit environmental conditions from the time of onset of the fire until time of extinction.

(3) An evaluation of the products of combustion when the available consumable materials were burned in this atmosphere was considered. The variety of such materials and the decomposition variables of temperature, pressure and available oxygen condition preclude an accurate assessment of the conditions which existed at any one time during the fire.

(4) Environmental data recorded during the tests were reviewed to establish factors effecting environmental conditions. These parameters included suit flow, suit supply temperature, suit

differential pressure, compressor differential pressure, cabin pressure, surge tank pressure, compressor inlet temperature, cabin temperature, carbon dioxide (CO_2) absorber outlet temperature and CO_2 partial pressure.

(5) The Environmental Control Unit (ECU) was carefully inspected and residual samples were collected from the umbilical vent tubes and fittings. The samples were analyzed for inorganic constituents.

(6) Tests were performed to determine relative rates of carbon monoxide production from burning suit materials, polyurethane foam and activated charcoal in pure oxygen. (Reference 11-4)

(7) Information regarding possible products of combustion were transmitted to the Armed Forces Institute of Pathology for use in conjunction with the toxicological studies performed as a part of the post-mortem examination. (Enclosure 11-4)

(8) Other tests are in progress to determine the actual conditions for rapid heating of the CO_2 canisters. These tests should determine the potential of activated charcoal to provide a source of high carbon monoxide concentration into the suit loop.

f. Suit Evaluation:

A detailed visual and photographic examination of the suits was performed before desuiting in conjunction with gorss pathological studies. All items of crew equipment were removed to a secure area and a detailed analysis of damage to this equipment was performed by Flight Surgeons and suit specialists. This analysis included:

(1) Detailed mapping of items of crew equipment which became detached from the suits during the course of the accident.

(2) Photographic analysis.

(3) Detailed mapping of damage to suits.

(4) Examination of damaged metal fittings and suit material in conjunction with Panel 5.

(5) Chemical analysis of various deposits for identification of toxic products of combustion. (Enclosure 11-4)

g. Medical Analysis of Ground Emergency Procedures and Equipment:

In connection with Panel 13, Ground Emergency Procedures and Equipment were reviewed from a medical viewpoint to evaluate their adequacy in this type of emergency.

h. Medical Evaluation of In-Flight Emergency Procedures and Equipment:

In connection with Panel 20, In-Flight Procedures and Equipment were reviewed from a medical viewpoint to evaluate their adequacy in event of an in-flight fire.

i. Monitoring Capabilities

A review of capabilities for monitoring biomedical and environmental parameters in the spacecraft was performed. This review included an evaluation of spacecraft telemetry capabilities and consoles used for safety monitoring of such ground tests as well as during flight.

j. Environmental physiology:

A review of pertinent environmental physiology relative to spacecraft cabin atmosphere was performed. This review included a reexamination of physiological factors involved in the selection of a 5 pounds per square inch, 100% oxygen (O_2) environment in Apollo, and the requirement for a complete purge of cabin and suit circuit, prior to launch. This review was conducted in conjunction with the Director of Medical Research and Operations at Manned Spacecraft Center.

D. FINDINGS AND DETERMINATIONS

1. FINDING:

All three crewmen were interviewed by a Medical Officer several hours prior to ingress. Prophyllactic penicillin was administered because of exposure to Beta hermolytic streptococcus.

DETERMINATION:

There was no medical condition and no drug administration which might be expected to degrade their normal performance.

2. FINDING:

Breathing oxygen supplied to the spacecraft before the fire was of adequate quality and quantity.

DETERMINATION:
No anomalies in the suit atmosphere which could have adversely affected crew activities are evidenced from review of the data prior to the fire.

3. FINDING:
Biomedical data at the time of the accident were received from the Senior Pilot only and consisted of one lead of EKG, as well as PKG, and impedance pneumogram (respiration). These data were received by telemetry and from the on-board Medical Data Acquisition System (MDAS). (Reference 11-5)

DETERMINATION:
This configuration was normal for the test.

4. FINDING:
At 6:30:22 pm EST (23:30:22 GMT) on the biomedical tape there is some change in the respiration pattern and a moderate increase in the Senior Pilot's heart rate.

DETERMINATION:
This represents some increase in the Senior Pilot's activity, but does not indicate the degree of activity to be expected had he been aware of an emergency situation.

5. FINDING:
At 6:31:04 pm EST (23:31:04 GMT) on the biomedical tape there is a marked change in the Senior Pilot's respiratory and heart rates. There is also evidence of muscle activity in the EKG tracing and evidence of motion in the PKG. The heart rate continues to climb until loss of signal.

DETERMINATION:
This physiological response is compatible with the realization of an emergency situation. (Reference 11-5)

6. FINDING:
Voice contact from the crew was maintained until 6:31:22.7 pm EST (23:31:22.7 GMT).

DETERMINATION:
At least one member of the crew was conscious until this time.

7. FINDING:
Hatches were opened at approximately 6:36 pm EST (23:36 GMT) and no signs of life were detected. Three physicians viewed the suited bodies at approximately 6:45 pm EST(23:45 GMT) and decided that resuscitation efforts would be to no avail.

DETERMINATION:
Time of death cannot be determined from this finding.

8. FINDING:
The Command Pilot's couch was in the 170-degree position. The foot restraints and harness were released. The inlet and outlet hoses were connected. The helmet visor was closed and locked. The electrical adapter cable was disconnected from the cobra cable. The Command Pilot was found lying supine on the aft bulkhead of the spacecraft with his helmet under the Pilot's head rest and his feet resting upon his own couch. Parts of his suit and items of crew equipment were found in various locations in the spacecraft, described in the suit evaluation. A fragment of the suit material was found outside the pressure vessel five feet from the point of rupture. (Reference 11-6).

DETERMINATION:
The Command Pilot had moved from his normal position after the onset of fire. The suit failed prior to rupture of the pressure vessel (the time of spacecraft rupture has been estimated by Panel 5 to be 6:31:19 pm EST (23:31:19 GMT).

9. FINDING:
The Senior Pilot's couch was in the normal 96-degree position with the foot rest folded up against his lower couch. The head rest was up. The buckle releasing his shoulder straps and lap belts was not opened. (This strap configuration is normal for his emergency egress technique.) The straps were burned through. The suit outlet hose was connected but the inlet hose was disconnected. The helmet visor was closed and locked. All electrical connections were intact. The Senior Pilot was found lying on his left side, transversely across the spacecraft just below the level of the hatchway.

DETERMINATION:
The Senior Pilot did not leave his position until his restraining straps were burned through. He had moved from his normal position after the onset of fire.

10. FINDING:
The Pilot's couch was in the 264-degree position. All restraints were disconnected, all hoses and electrical connections were intact. The helmet visor was closed and locked. The Pilot was found supine in his couch.
DETERMINATION:
There is no evidence that the Pilot moved from his normal position after the start of the fire. This is consistent with the emergency egress procedure which calls for the Pilot to be the last to the leave the spacecraft.
11. FINDING:
The cause of death of the Apollo 204 Crew was asphyxia due to inhalation of toxic gases due to fire. Contributory cause of death was thermal burns. (Enclosures 11-3, 11-5, 11-6, and Reference 11-7)
DETERMINATION:
It may be concluded that death occurred rapidly and that unconsciousness preceded death by some increment of time. The fact that an equilibrium was not established throughout the circulatory system indicates that circulation of blood stopped rather abruptly before an equilibrium could be reached.
12. FINDING:
Panel 5 (Origin and Propagation of Fire) estimates that significant levels (over two percent) of carbon monoxide (CO) would be present in the spacecraft atmosphere by 6:31:30 pm EST (23:31:30 GMT). By this time at least one suit had failed, introducing cabin gases to all suit loops.
DETERMINATION:
The crew was exposed to a lethal atmosphere when the first suit was breeched.
13. FINDING:
The Environmental Control System contains activated charcoal which, if heated, will produce CO. (Reference 11-11)
DETERMINATION:
It is the opinion of Panel 5 that heating of the CO_2 canister occurred late in the progress of the fire after significant levels of CO were already present in the cabin atmosphere, and after at least one suit had failed.
14. FINDING:
The distribution of CO in various organs indicates that circulation stopped rather abruptly when high levels of carboxyhemoglobin reached the heart (Enclosure 11-3).
DETERMINATION:
Loss of consciousness was due to cerebral hypoxia due to cardiac arrest, due to myocardial hypoxia. Factors of temperature, pressure and environmental concentrations of carbon monoxide, carbon dioxide, oxygen and pulmonary irritants were changing at extremely rapid rates. It is impossible to integrate these variables, on the basis of available information with the dynamic physiological and metabolic conditions they produced in order to arrive at a precise statement of time when consciousness was lost and when death supervened. The combined effect of these environmental factors dramatically increased the lethal effect of any factor by itself. It is estimated that consciousness was lost between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within four minutes.
15. FINDING:
All three suits were breeched by fire to some degree.
DETERMINATION:
The suits were not capable of providing crew protection in a fire of this intensity. (Enclosure 11-7 and Reference 11-6)
16. FINDING:
Suit damage increased progressively from the Command Pilot's side of the spacecraft to the Pilot's side.
DETERMINATION:
The fire was most intense on the Command Pilot's side of the spacecraft.
17. FINDING:
The outer layer of all suits was considerably more damaged than the inner layer.

DETERMINATION:
This lends support to the conclusion that the fire originated in the cabin rather than in the suit circuit.

18. FINDING:
In the Pilot's and Senior Pilot's suits, there is evidence of a path of fire damage from the failed areas coursing toward the suit outlet. In these areas, the fire damage is greater in the comfort liner and less in the outer layers of the suit.

DETERMINATION:
This tends to indicate that the compressor was still active for a period of time after the suit integrity failed.

19. FINDING:
An examination of the Senior Pilot's helmet reveals scorched and charred areas of the anterior portion of both earcups, charred portions of the passive radiation dosimeter situated near the left earcup, and evidence of fire damage on the anterior side of both microphone wires.

DETERMINATION:
The Senior Pilot's faceplate may have been open during a portion of the fire.

20. FINDING:
During continuity checks of the Command Pilot's communication and biomedical harness, some damage to the communication harness was found. (Enclosure 11-8).

DETERMINATION:
This damage is not considered as significant as a possible cause of the fire.

21. FINDING:
It was not possible from biomedical and environmental data to accurately construct a time line of environmental conditions or crew activities during this emergency.

DETERMINATION:
Available environmental and biomedical instrumentaion cannot be considered optimum for a potentially hazardous test or for flight.

22. FINDING:
Medical examinations of the rescue personnel were made by the Pan American World Airways Dispensary. Breath analysis from the most severe victims of smoke inhalation were negative for gases other than low concentrations of carbon monoxide. Urinalyses for beryllium and chest x-rays were also negative in these men. (Enclosure 11-1)

DETERMINATION:
Medical records indicate that there were no permanent injuries to rescue personnel.

23. FINDING:
The purge with 100-percent O_2 at above sea-level pressure contributed to the propagation of fire in the Apollo 204 Spacecraft.

DETERMINATION:
This was the planned cabin environment for testing and launch, since prelaunch denitrogenation is necessary to forestall the possibility of bends at the mission ambient pressure of 5 pounds per square inch absolute. A comprehensive review of the operational and physiological trade-offs of the various methods of denitrogenation is in progress. (Reference 11-9)

24. FINDING:
Rescue personnel were equipped with gas masks designed for protection against hypergolic vapors. They had no heat-protective garments.

DETERMINATION:
Rescue personnel were inadequately equipped for a fire-type rescue.

E. SUPPORTING DATA

This section contains support data to which references have been made in previous sections. These data are organized in numerical sequence as they appear in the written text. A table of contents for this section is as follows:

ENCLOSURES

11-1 Industrial Injury Summary
11-2 Post-Mortem Examination, Introduction
11-3 Post-Mortem Examination, Toxicology

11-4 Thermal Degradation Products of Non-Metallic Materials
11-5 Post-Mortem Protocol
11-6 Post-Mortem Examination, Summary and Opinion
11-7 Analysis of Suit Damage
11-8 Continuity and Functional Tests of S/C-012 Crew Biomedical Equipment
11-9 List of References

INDUSTRIAL INJURY SUMMARY

During rescue attempts following the Apollo-204 accident on January 27, 1967, 27 persons were injured. Twenty-one of those injured were employed by North American Aviation Company, one by Pan American Aviation, and five were NASA employees.

A majority of the injuries were smoke inhalation, contusions, and abrasions. Two of the injured were admitted to the PAA Dispensary overnight for observation and released the following morning. Others were treated and sent home. There was no evidence of permanent injury and no sequelae are expected.

A record of these injuries are included in the Apollo-204 Review Board Medical Files at MSC.

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INTRODUCTION

During the late evening of 27 January 1967, The Director, Armed Forces Institute of Pathology, Washington, D. C. was alerted by National Aeronautics and Space Administration personnel that an accident had occurred aboard the Apollo spacecraft at Cape Kennedy, Florida resulting in the deaths of Lt. Colonel Virgil I. Grissom, USA F, Lt. Colonel Edward H. White, USAF, and Lt. Commander Roger B. Chaffee, USN. A request was later made the same evening for autopsy support and a team of three pathologists and a medical photographer (Colonel Edward H. Johnston, MC, USA, Commander Charles J. Stahl, MC, USN, Captain Latimer E. Dunn, USAF, MC, and TSgt Larry N. Hale, USAF) was sent to Cape Kennedy via special USAF plane. Facilities for the postmortem studies were made available by Colonel Frederick Frese, USAF, MC and his Deputy, Lt. Colonel Paul Hoffman, USAF, MC of the Bioastronautic Operational Support Unit. Following a general conference among Colonel Frese, Lt. Colonel Hoffman, Fred Kelly, M.D., NASA, Doctor Alan C. Harter, NASA, Doctor Freedland, NASA, and the AFIP team of pathologists, the detailed circumstances of the accident were discussed. The postmortem examinations were then started at 1100 hours, 28 January 1967, at the Bioastronautic Operational Support Unit. Following photographs and examination of the deceased still clothed in their space suits and helmets, the clothing was carefully removed under the general supervision of Doctor Fred Kelly and Doctor Alan Harter. All articles of clothing and personal effects were studied and then placed in separate duffle bags, labeled, locked and retained for examination by clothing experts designated by the Board of Inquiry. With the assistance of TSgt Freddie B. Moorehead, USAF X-ray Technician, Patrick AFB, total body x-rays were made of each body and the films examined prior to performing the internal examinations. Photographs of the front, back and specific areas of injury were made. A complete detailed description of the external body in each case was made by the pathologists. During the course of the autopsy, assistance was provided to the autopsy team by following USAF personnel who also served as witnesses to the examinations:

Lt. Colonel Paul Hoffman, USA F, MC
Major Pearl E. Tucker, USAF, NC
Captain Dorothy Novotny, USAF, NC
M/Sgt. Kenneth N. Springer, USAF
A/1C Virginia Roberts, USAF

The autopsies were completed at 0100 hours, 29 January 1967. A short conference was called by Doctor Fred Kelly in which the pathologists were asked to assist in the preparation of the death certificate.

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Chaffee, Roger B.
AFIP Accession 1232463

REPORT OF TOXICOLOGY

CARBON MONOXIDE	Lung - 69% saturation Blood - 45% " Kidney - 22% " Brain - 37% " Liver - 10% " Muscle - 7% " Spleen - 5% "
CYANIDE	Blood - 1 microgram/3ml Lung - 3 micrograms/5gm
LACTIC ACID	Brain - 151 mg%
VOLATILES	Liver - 0 Brain - 0 Blood - 0
DRUGS (Acid-Basic Neutral)	Liver - 0
*OTHER GASES	LUNG (Normal lung used as control was negative for these gases)

Acetylene	- 40 moles%
Hydrogen cyanide	- 32 "
Fluoro-methanes	- 14 "
Fluoro-ethanes	- 2 "
Hydrocarbon (unsaturated) as butane	- 7 "
Methane	- 5 "

**METALLIC IONS — LUNG (Normal lung used as control)

Lithium	- within level of concentration of control
Selenium	- "
Calcium	- "
Zinc	- "
Manganese	- "
Lead	- "
Chromium	- "
Nickel	- "
Beryllium	- "

* Examination by National Bureau of Standards (mass spectrograph)

** Examination by Biochemistry Division Walter Reed Army Institute of Research

All other examinations by Toxicology Branch Armed Forces Institute of Pathology

ENCLOSURE 11-3

White, Edward H.
AFIP Accession 1232464

REPORT OF TOXICOLOGY

CARBON MONOXIDE	Lung - 58% saturation Blood - 38% " Kidney - 44% " Brain - 18% " Liver - 27% " Muscle - 22% "
CYANIDE	Blood - 2 micrograms/3 ml Lung - 3 micrograms/5 gm
LACTIC ACID	Brain - 183 mg%
VOLATILES	Liver - 0 Brain - 0 Blood - 0
DRUGS (Acid - Basic - Neutral)	Liver - 0
*OTHER GASES	LUNG (Normal lung used as control was negative for these gases)
Acetylene	- 22 mole%
Hydrogen cyanide	- 16 "
Fluoro-methanes	- 5 "
Fluoro-ethanes	- 1 "
Hydrocarbon (unsaturated) as butane	- 2 "
Methane	- 54 "
**METALLIC IONS	LUNG (Normal lung used as control)
Lithium	- within range of normal control
Selenium	- slightly above control, but in range of normal
Calcium	- within range of normal control
Zinc	- "
Manganese	- "
Lead	- "
Chromium	- "
Nickel	- "
Beryllium	- "

*Examination by National Bureau of Standards (mass spectrograph)

**Examination by Biochemistry Division-Walter Reed Army Institute of Research

All other examinations by Toxicology-Branch-Armed Forces Institute of Pathology

Grissom, Virgil I.
AFIP Accession 1232462

REPORT OF TOXICOLOGY

CARBON MONOXIDE		Lung - 58% saturation Blood - 48% " Kidney - 37% " Brain - 20% " Liver - 20% " Muscle - 17% "
CYANIDE		Blood - 3 micrograms/3 ml Lung - 2 micrograms/5 gm
LACTIC ACID		Brain - 163 mg%
VOLATILES		Liver - 0 Brain - 0 Blood - 0
DRUGS (Acid - Basic - Neutral)		Liver - 0
*OTHER GASES		LUNG (Normal lung used as control was negative for these gases)
	Acetylene	- 39 moles%
	Hydrogen cyanide	- 28 "
	Fluoro-methanes	- 10 "
	Fluoro-ethanes	- 2 "
	Hydrocarbon (unsaturated) as butane	- 7 "
	Methane	- 13 "
**METALLIC IONS		LUNG (Normal lung used as control)
	Lithium	- within level of control
	Selenium	- slightly elevated above control, but in range of normal
	Calcium	- within level of control
	Zinc	- "
	Manganese	- "
	Lead	- "
	Chromium	- "
	Nickel	- "
	Beryllium	- "

*Examination by National Bureau of Standards (mass spectrograph)

**Examination by Biochemistry Division Walter Reed Army Institute of Research

All other examinations by Toxicology Branch Armed Forces Institute of Pathology

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OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : HU1/Dr. F. Kelly

DATE: FEB 23 1967

In reply refer to:
DB24/02/005

FROM : DB/Chief, Biomedical Research Office

SUBJECT: Thermal degradation products of nonmetallic materials

An analysis of nonmetallic materials in the suit loop and cabin results in a breakdown into several generic groups. Individual materials are too highly variable to obtain specific, reproducible degradation products. Ultimately, all hydrocarbons would be expected to produce CO_2 and H_2O in an excess of O_2 and high temperatures. However, the following compounds and classes can be expected to result from the uncontrolled thermal degradation of the nonmetallics:

a. Carbon monoxide.
b. Homologous aldehydes from formaldehyde and acetaldehyde upward.
c. Organic acids of all types.
d. Organotins as catalysts and preservatives in a variety of plastics.
e. Virtually every known solvent.
f. Methane.

ACRYLICS (various types)

Methyl alcohol
Acrylic acid
Methyl methacrylate
C_4-C_6 oxygenated compounds
Isobutylene
Methacrylic acid

DACRON (also Mylar)

Terephthalic acid and more complex chain fragments
Acetaldehyde
Methane
Ethane
Benzene
2-Methyl dioxolane

Enclosure 11-4

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

SILICONES

Too many and too complex to analyze - primarily methane, benzene, methyl silanols, and siloxanes

POLYETHYLENE, POLYPROPYLENE

Ethylene
Propylene

POLYVINYL CHLORIDE

Hydrochloric acid

TEFLON

Tetrafluoroethylene
Assorted fluorinated hydrocarbons
Fluorophosgene
Octa fluoroisobutylene
Hydrofluoric acid

POLYVINYL ACETATE

Acetic acid

NEOPRENE

Hydrochloric acid

RUBBER

Oxides of sulphur
Isoprene
Dipentene
p-Menthene

PHENOLICS

Formaldehyde
Formic Acid
Benzene
Phenol
Propanol
Methane
Acetylene
Ammonia
Toluene
Oxides of nitrogen

POLYCARBONATE

No information

NYLON (including Nomex, Velcro)

Hydrogen cyanide
Cyclopentanone
Ammonia
Aldehydes
Adipamide
Oxides of nitrogen

POLYURETHANE

Hydrogen cyanide
Halogenated hydrocarbons, HCl and HF from foaming freons
Oxides of nitrogen
Organic tins
Toluene 2, 4-diisocynates

EPOXYS

Ammonia
Methane
Benzene
Propylene
Acetone
Acetaldehyde
Dipropyl ether

Lawrence F. Dietlein, M.D.

DB24:ESHarris:jb 2/21/67

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Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-52 (Rev.)

* U.S. GOVERNMENT PRINTING OFFICE : 1961 O—661837

CLINICAL RECORD	AUTOPSY PROTOCOL			
DATE AND HOUR DIED: XXXX P.M. 27 January 1967	DATE AND HOUR AUTOPSY PERFORMED 1100 A.M. 28 January 1967 XXX	CHECK ONE: FULL AUTOPSY	HEAD ONLY	TRUNK ONLY
PROSECTOR: Charles J. Stahl, Commander, MC, USN	ASSISTANT: Colonel Edward H. Johnston, MC, USA	X		
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	Latimer E. Dunn, Captain, USAF, MC			

CAUSE OF DEATH: ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE

CONTRIBUTORY CAUSE OF DEATH: THERMAL BURNS

MANNER OF DEATH: ACCIDENTAL

PATHOLOGICAL DIAGNOSES

1. ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE, MANIFESTED BY:

   a. CARBON MONOXIDE POISONING.

   b. SOOT WITHIN NOSE, ORAL CAVITY, TRACHEA AND BRONCHI.

   c. HEMORRHAGIC PULMONARY EDEMA, DIFFUSE.

2. THERMAL BURNS, 1ST, 2ND AND 3RD DEGREE, ESTIMATED 60% TOTAL BODY SURFACE AREA, as follows:

   1st and 2nd Degree: Estimated 24% total body surface area.

   3rd Degree: Estimated 36% total body surface area.

   4th Degree: None.

(Continued)

APPROVED—SIGNATURE: [signature] Title: Director 8 March 1967
JOE M. BLUMBERG, MAJOR GENERAL, MC, USAF

MILITARY ORGANIZATION (When required)	AGE	SEX	RACE	IDENTIFICATION NO.	AUTOPSY NO.
Det. 1137 USAF Special Activities Sq.	40	Male	Caucasian	FR 22450	AFIP 1232462

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; date; hospital or medical facility)

REGISTER NO. --

WARD NO. --

GRISSOM, Virgil Ivan
Lieutenant Colonel, United States Air Force

AUTOPSY PROTOCOL
Standard Form 503
503-104

Armed Forces Institute of Pathology
Washington, D. C. 20305

Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-32 (Rev.)

* U.S. GOVERNMENT PRINTING OFFICE : 1961 O—582587

CLINICAL RECORD	AUTOPSY PROTOCOL		
DATE AND HOUR DIED: 27 January 1967 (A.M. / P.M.)	DATE AND HOUR AUTOPSY PERFORMED: 1100 A.M. 28 January 1967	CHECK ONE: FULL AUTOPSY X	HEAD ONLY	TRUNK ONLY
PROSECTOR: COL Edward H. Johnston, MC, USA	ASSISTANTS: Charles J. Stahl, CDR, MC, USN; Latimer E. Dunn, Captain, USAF, MC			

CAUSE OF DEATH: ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE

CONTRIBUTORY CAUSE OF DEATH: THERMAL BURNS

MANNER OF DEATH: ACCIDENTAL

PATHOLOGICAL DIAGNOSES

1. ASPHYXIA DUE TO INHALATION OF TOXIC GASES DUE TO FIRE, MANIFESTED BY:

   a. CARBON MONOXIDE POISONING.

   b. SOOT WITHIN NOSE, ORAL CAVITY, TRACHEA AND BRONCHI.

   c. HEMORRHAGIC PULMONARY EDEMA, DIFFUSE

2. THERMAL BURNS, 1ST, 2ND and 3RD DEGREE, ESTIMATED 48% TOTAL BODY SURFACE AREA, as follows:

   1ST and 2ND Degree: Estimated 8% total body surface area.

   3Rd Degree: Estimated 40% total body surface area.

   4TH Degree: None.

(Continued)

APPROVED—SIGNATURE: Joe M. Blumberg — The Records AFIP — 8 March 1967
JOE M. BLUMBERG, MAJOR GENERAL, MC, USA

MILITARY ORGANIZATION (When required)	AGE	SEX	RACE	IDENTIFICATION NO.	AUTOPSY NO.
Det. 1, 1137 USAF Special Activities Sq	36	Male	Caucasian	FR 23567	AFIP 1232464

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; date; hospital or medical facility)

REGISTER NO. --

WARD NO. --

WHITE, Edward Higgins II
Lieutenant Colonel, United States Air Force

Armed Forces Institute of Pathology
Washington, D. C. 20305

AUTOPSY PROTOCOL
Standard Form 503
503-104

Standard Form 503
Revised August 1954
Bureau of the Budget
Circular A-32 (Rev.)

* U.S. GOVERNMENT PRINTING OFFICE: 1961 O—582527

CLINICAL RECORD | AUTOPSY PROTOCOL

DATE AND HOUR DIED		DATE AND HOUR AUTOPSY PERFORMED		CHECK ONE		
27 JANUARY 1967	XXXX P. M.	27 JAN 1967 - 1100 HRS	A. M. P. M.	FULL AUTOPSY	HEAD ONLY	TRUNK ONLY
PROSECTOR		ASSISTANT				
L. E. DUNN, CAPT, USAF, MC		C. J. STAHL, CDR, MC, USN		X		
~~XXXX

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Grissom, Virgil I.
AFIP Accession 1232462

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Sautrn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological studies of Lieutenant Colonel Grissom indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There was evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion, or both.

Thermal burns, estimated as 60% total body surface area (36% third degree), are considered as a contributory cause of death. Burns involging this percentage of the total body surface are usually not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion, associated with a rapid increase in the pressure and temperature within the capsule, resulted in a state of severe hypoxia, or even complete anoxia, which explains a rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

White, Edward H.
AFIP Accession 1232464

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Saturn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo Project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White, USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological and studies of Lieutenant Colonel White indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion prior to death is confirmed by the presence of soot within the tracheobronchial tree. Products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There is evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion, or both.

Thermal burns, estimated as 48% total body surface area, (40% third degree) are considered as a contributory cause of death. Burns involving this percentage of the total body surface are not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion associated with a rapid increase in the pressure and temperature within the capsule resulted in a state of severe hypoxia or even complete anoxia which explains a very rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

Chaffee, Roger B.
AFIP Accession 1232463

SUMMARY AND OPINION

During the evening of 27 January 1967, a fire occurred within the Apollo-Saturn 204 Test Vehicle on Pad 34 at U.S. Air Force Station, Cape Kennedy, Florida. The primary team of astronauts for the Apollo Project, Lieutenant Colonel Virgil I. Grissom, USAF, Lieutenant Colonel Edward H. White, USAF, and Lieutenant Commander Roger B. Chaffee, USN, died as the result of the fire.

The post-mortem examination and toxicological studies of Lieutenant Commander Chaffee indicate that carbon monoxide poisoning is the most significant finding. Active inhalation of smoke and products of combustion prior to death is confirmed by the presence of soot within the tracheobronchial tree. Products of combustion in the form of acetylene, hydrogen cyanide, fluoro-methanes, fluoro-ethanes and other toxic gases were detected by mass spectrographic analysis of the lungs. There was evidence of early post-mortem change in the skin and internal organs, and the presence of methane in the lung may have resulted from either post-mortem decomposition or inhalation of products of combustion or both.

Thermal burns, estimated as 29% total body surface area (23% third degree), are considered as a contributory cause of death. Burns involving this percentage of the total body surface are usually not immediately fatal. It is not possible to state that all of the thermal burns are antemortem.

The distribution of carbon monoxide in the various tissues provides an evaluation of the saturation of blood in these organs by carbon monoxide. The sample of blood obtained for analysis is a mixture of venous and arterial blood from the inferior vena cava and both sides of the heart. The distribution studies of the tissues for carbon monoxide indicate that an equilibrium between the carbon monoxide and blood had not occurred in all areas of the body. These studies alone are consistent with a rapid death.

Rapid depletion of oxygen by fire within the closed environment, the formation and absorption of carbon monoxide gas, and the liberation and inhalation of other toxic products of combustion, associated with a rapid increase in the pressure and temperature within the capsule, resulted in a state of severe hypoxia, or even complete anoxia, which explains a rapid death. With the information obtained from the autopsy and the toxicological findings it is not possible to determine the exact time of death. Results of analysis of air samples from within the capsule at the time of the fire are not available for correlation with the post-mortem findings.

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APOLLO - 204 SUITS, ANALYSIS OF DAMAGE

ENCLOSURE 11-7

1. PURPOSE

The purpose of this report is to record the damage to the Space Suit Assemblies and associated personal equipment worn on board Apollo-204 at the time of the accident on January 27, 1967. A secondary purpose is to set forth observations recorded during the survey which may add useful information concerning origin and path of the fire and lead to recommendations and conclusions for future design.

2. INTRODUCTION

The survey was conducted during the period February 14 through February 28, 1967 at Kennedy Space Center, Florida, Pyrotechnics Installation Building (PIB), Room 106. The equipment had been brought to the location from the Bioastronautics Building, Cape Kennedy, after removal of the crewmen. The equipment had been impounded in Room 106 of the PIB and placed under direct control of Panel 11 Medical Analysis.

Also included, but laid out separately, was the constant wear garments with attached bioinstrumentation, short lengths of the Environmental Control System (ECS) umbilicals with nozzles for the Command Pilot and Senior Pilot, and still attached space suit cobra electrical adapters.

3. SCOPE

The survey was conducted during the period February 14, 1967 through February 28, 1967 at Kennedy Space Center, Florida, Pyrotechnics Installation Building (PIB), Room 106. The equipment had been brought to the location from the Bioastronautics Building, Cape Kennedy, after removal of the crewmen. The equipment had been impounded in Room 106 of the PIB and placed under direct control of Panel 11 Medical Analysis.

A thorough inspection was also made of the spacecraft removed components (couches, struts, back pans, electrical cables, ECS umbilicals, etc) and the spacecraft interior to identify and account for missing items. All items found on the couches and back pans were photographed in place, removed, and transferred by Test Preparation Sheet (TPS) to the space suit inspection area in Room 106, PIB. A total of eighteen (18) samples of deposits and materials of interesting condition and location were removed from the space suits (e.g. inlet and outlet connectors and nozzles, ECS umbilical interiors, helmet areas, and certain soft goods areas) and transferred to the Kennedy Space Center Materials Analysis Branch for analysis.

Electrical equipment was inspected on location by the Fire Panel and then removed to the Materials Analysis Branch for closer inspection and documentary photographs. Since there was evidence of possible pin burning at the pin interface between the cobra cable adapter and the cobra cable 37 pin connector on the Command Pilot suit (which was found disconnected at this joint), the connection between this adapter and the space suit 61 pin connector was not broken but was removed intact from the space suit (flange included) for electrical continuity and functional checks. Arrangements were made to have continuity and functional checks of all electrical components (e.g. helmet communications, biocommunication harness, bioinstrumentation belt components, and space suit cobra cable adapters). Prior to removal of samples, a complete photographic survey was made of the space suit components including close-ups of pertinent areas in stereo as well as regular color film.

4. BACKGROUND

a. Space Suit Configuration Description

The Apollo Block I Space Suit Assembly, Part Number S-987-000, NASA designation type A-1C, is basically identical to the Gemini G-4C space suit used in the Gemini-Titan 4,5,6,8,9,10,11, and 12 flights. The complete space suit assembly is described in detail in DCM-999A-019-00 CEI Detailed Specifications for the Apollo Block I Space Suit Assembly.

Specific part numbers of all components used in the assemblies aboard Apollo 204, together with inspection and utilization data packages, are set forth in the individual log books for these space suit assemblies (located in Room 3343, MSOB).

The serial number designations of the space suits (and respective log books)used were:
(1) Command Pilot: A-1C-16
(2) Senior Pilot: A-1C-17
(3) Pilot: A-1C-17

For parts descriptions and drawing numbers of the Apollo-204 suit configuration, see Reference 11-6

An additional more detailed description including sketches and photographic documentation, is available in the National Aeronautics and Space Administration, Manned Spacecraft Center Medical Files in Houston.

b. Pilot Accessories

The space suits provide accommodations for much of the pilot's personal equipment, primarily in any array of pockets attached to the outer coverlayer. The equipment carried on board Apollo 204 is listed below:

ITEM	PART NUMBER	PART NAME	LOCATION/NO. PER CREWMAN
(1)	SEB 4010000095-201	Life Vest Ass'y	One set of 2 for each crewman attached by harness at each armpit.
(2)	A-1193-000	Neck Seals (Water Egress)	One each, upper right arm pocket
(3)	A-1193-000	Neck Seal (Ventilation)	One each, any leg pocket
(4)	ACS 1505	Wrist Dams	Two each, upper left arm pocket
(5)	SEB 12100029-201 SEB 12100030-201	Chronograph Wrist Watches with Velcro band	One each, left wrist below suit pressure indicator
(6)	SEB 12100033-201	Sunglasses (In Nylon Pouch)	One each, left lower leg pocket
(7)	EC 30045	Combination Knife (with lanyard)	One each, Command Pilot and Pilot, Outboard lower right leg
(8)	EC 20541	Shroud Cutter (with lanyard)	One, Senior Pilot only
(9)	RFB-OP-4-3-003	Pocket Dosimeter	One, Senior Pilot only, Inboard Left leg
(10)	SEB 12100031-001	Marking Pens	Two each, one in left leg inboard pencil pocket, one in upper left arm pocket
(11)	SEB 12100032-202	Mechanical Pencils	Two each, upper left arm pocket

(12)	EC 30190	Apollo Scissors (with lanyard)	One each, Senior Pilot and Pilot, inboard lower right leg
(13)	CSD 20542	Gemini Scissors (with lanyard)	One-Command Pilot Only, inboard, lower right leg
(14)	EC 30115	Penlight	One each, inboard lower right leg penlight pocket
(15)	N/A	Nylon Glove Liners	Two each, worn on hands inside pressure gloves
(16)	RFB-OP-4-3-002	Passive Radiation Dosimeters	One set of four each: (a) In helmet at left of eye (b) In Constant Wear Garment at right chest (c) In CWG at inside left thigh (d) In CWG at inside right calf
(17)	14-0105	Urine Collection Device	Worn on crewman @ pelvic area
(18)		Biocommunication Harness (with 61 Pin Connect-Bioinstrumentation Package (a) Signal VConditioners	One each worn inside suit at chest with 61 Pin connector secured to Bio Flange
	103120 Phonocardiogram 104119 sig. cond. 103020	(a) Signal Conditioners (b) Wire Harness (c) Sensors	(a) Four each worn in pockets of CWG bio belt at abdomen (b) Connected at lower end of Signal Conditioners (c) Four, Senior Pilot only
(19)	A 1912-003	Constant Wear Garment	One each, color coded: (a) Command Pilot-Red (b) Senior Pilot-White (c) Pilot-Blue

c. VENTILATION SYSTEM

For purposes of clarification and to aid in the visualization of the damage description of the space suit ventilation system, the following description of the ventiliation system is offered as a reference guide.

The ventilation system consists of a network of individual tubes which extend from a common manifold at the inlet ventilation connector (blue) to the arms, legs, helmet, and waist which carry a fresh supply of ventilation or pressurization oxygen from the Spacecraft ECS hoses to provide metabolic requirements for body cooling, breathing oxygen, and CO2 removal. The flow exits at the bottom of the feet, the wrists, the scalp, across the face, and at the back waist. The flow is approximately divided as follows:

(1) Helmet: 35%
(2) Each leg: 15% (30% total)
(3) Each Arm: 15% (30% total)
(4) Waist: 5%

After exhausting from the ventilation channel ends, the flow returns across the body, exiting at the exhaust ventilation connector (red), and into the outlet ECS umbilical. The routing of the ventilation tube is as follows (all starting at the inlet manifold at the left abdomen area):

(1) To helmet; three double tubes up center of chest to connections at the neck ring sides and front center.

(2) To arms; one double tube each, up and across chest to armpits, across front of arm, to lateral surfaces of arm splitting into two single tubes above and behind the elbow and then running down each side of the forearm to the wrist connector.

(3) To legs; two quadruple tubes each running across abdomen to outside of legs splitting into two double tubes above the knee which continue down the side of the legs to the boot ventilation pads.

(4) To torso; one double tube around left side of waist to center back.

d. TORSO

The majority of the suit described in this damage assessment is the basic four layer soft goods anthropomorphous body covering encompassing the arms, legs, feet, and trunk, and including all major subassemblies such as glove connectors, helmet connectors, and ventilation system and fittings. Also considered are the Constant Wear Garment, Helmet, Gloves and Electrical Systems.

The torso layer is as follows:

(1) Outer Cover Layer: White, 6 oz. Oxford Weave HT-1 (Nomex) Nylon;
(2) Restraint Layer: Link net, HT-1 Nylon Cord
(3) Gas Container: Neoprene Coated Nylon Cloth
(4) Inner Liner: Blue, 3 oz. Oxford Weave Nylon Cloth

The cotton Constant Wear Garment is worn immediately under the inner liner.

5. INITIAL CONFIGURATION (before crew removal from Spacecraft)

a. Command Pilot: Suit Assembly Designation, A-1C-16

The ventilation hose nozzles were engaged with the suit connectors and the connectors in locked position. The Pressure Garment Assembly (PGA) electrical adapter was connected to the 61 pin space suit electrical connector but was disconnected at the cobra cable end (37 pin male); The helmet was installed and properly locked with the visor down and bailer bar fully locked. The gloves were installed and locked and entry closure assembly (pressure sealing zipper) was fully closed.

The ventilation umbilicals were cut 37 1/2 inches above the nozzle and removed still engaged with the suit.

b. Senior Pilot: Assembly Designation, A-1C-17

Outlet ventilation hose nozzle connected and connector in locked position. The inlet ventilation hose nozzle was disconnected and connector in the unlocked position. The PGA electrical adapter was connected to the space suit electrical connector and to the cobra cable connector (through the two stages of electronic adapters). This adapter cable had been cut through 6 in. above suit connector to allow crewman removal. The helmet was installed and properly locked with the visor down and the bailer bar fully locked. The gloves were properly installed and locked and the entry closure assembly (pressure sealing zipper) was fully closed.

The ventilation umbilicals were cut 18 in. above the nozzle and removed with the suit (outlet nozzle still connected).

c. Pilot: Assembly Designation, A-1C-18

The configuration was identical to the Command Pilot's described above except that the PGA electrical adapter was connected to the cobra cable. This was subsequently disconnected at the cobra cable to allow crewman removal from the Spacecraft. The ventilation hose nozzles were disengaged from the suit to allow crewman removal from the Spacecraft.

6. DAMAGE DESCRIPTION/OBSERVATION

a. Torso

The most severe damage was incurred at the Command Pilot's suit (70 percent destroyed), while the Senior Pilot's suit was moderately damaged (25 percent destroyed) and the Pilot's suit was the least damaged (15 percent destroyed).

The heaviest damage to the Command Pilot's suit was over the legs, right arm, and over the anterior trunk from chest to the upper abdomen.

The heaviest damage to the Senior Pilot's suit occurred over the left arm, left leg, left side of trunk extending across mid abdomen, and right knee.

The Pilot's suit shows damage along the lateral aspects of both arms, discrete areas on the posterior aspects of both shoulders, the anterior portions of the lower right leg, and at the back of the neck. The survival of areas with heavy seams was more apparent here, indicating less direct flame impingement to this suit than the other two. The greater percentage of coverlayer remaining indicated far less exposure to intense heat than the other two crewmen.

The damage patterns to the space suit assemblies indicated an external heat source. The external layer was the most severely damaged and the inner layer was the least damaged. Thus as the suits were qualitatively examined, a greater percentage of each individual layer remained as the examination progressed inward.

An observation which recurred often during the examination was that materials which were shielded from the flame path by the suits relative position, or by external material layers, generally survived relatively intact. This is especially true in areas of heavy seam construction, some areas and accessories covered by pockets, and webbing. It was also noticed that materials adjacent to hardware and layer build-ups of relatively high mass (e.g. neck ring, wrist ring, and ventilation connector flanges; and areas at the leg cuffs, wrist cuffs, and around the entry closure) escaped with moderate damage while surrounding areas were consumed.

In nearly all cases the burn damage for any sublayer followed an almost identical pattern to the damage of the next outermost layer, except that the damage was less, and more material remained, indicating partial protection from the preceding outer layer.

The Constant Wear Garment, on a percentage basis, showed less overall damage than any other suit layer. The damage area generally matched corresponding damage areas in the immediately preceding suit layer but the damage was not as severe.

b. Ventilation System-This system is indicated in detail in Section 4 c.

In general the major portion of the ventilation tubing systems remained intact. About 75 percent of the Command Pilot's system, and 90 percent each of the Senior Pilot's and Pilot's systems were undamaged. The ventilation tubes were penetrated at various places, apparently by external heat sources or direct flame impingement from adjacent materials or Spacecraft ambient circulation. This is indicated because most tube penetrations correspond in location to external penetrations of space suit layers between the tube surface and the cabin ambient. In many cases only the side of the tube exposed to the highest indicated heat source is burned away leaving the side away from the heat source intact. There is no evidence of an internal source of combustion causing rupture from the inside.

Examination of the interior of the Pilot's and Senior Pilot's ventilation tubes found them clean with little evidence of soot. The inlet manifolds of these two suits were perfectly intact showing no damage and little exposure to elevated temperatures, demonstrating that no appreciable heat or smoke was being introduced into the suit from the ECS system. The damage source and path determination of the Command Pilot's ventilation system is more difficult because of the destruction of the suit at the torso front. The inlet manifold section was entirely consumed except for an aluminized asbestos pad which backs the manifold. There is light sooting in the lines leading to the helmet, especially at the left side. This indicates that some smoke and heat were being forced into the helmet ventilation system. The sooted ventilation tubes leading to this area were badly burned upstream, while tubes leading to unsooted areas were relatively intact. Indications are, again, that penetration was from the outside of the ventilation tubes with smoke and heat initially being forced into the helmet ventilation by the incoming flow as it passed the ruptured area until the rupture became extensive enough to cause short circuiting of the helmet ventilation system.

All suit exhaust areas indicated that hot gasses were being drawn into a penetrated suit and out the exhaust port. This is evidenced by the blackened condition of the interior of the outlet nozzle, the localized damaged to the outlet port spacer spring material (adjacent areas were relatively undamaged except where flame paths led to the outlet), and melting of the trilock spacer pad (attached to the inner liner) and covering the exhaust port area on the surface between the bladder and comfort liner rather than the surface facing the man.

c. Hardware

(1) Helmet and Glove Connectors. The glove disconnects and helmet disconnects of all suits, except the Senior Pilot's, were in normal operating order and entirely functional with no signs of interior damage. The Senior Pilot's helmet disconnect could not be opened because of debris.

(2) Ventilation Connectors. All inlet (blue) and exhaust (red) ventilation fittings, except the Command Pilot's exhaust fitting, were functional, though somewhat stiff, with no evidence of damage to the locking mechanism or bore "O" ring. The areas of these fittings exposed to the interior of the suit are heavily blackened and show exposure to high heat.

The Command Pilot's outlet connector (red) showed exposure to extremely high internal heat as evidenced by the partially melted aluminum poppet valve and missing steel poppet return springs. This assembly, which had burned free of the suit, was disassembled and transferred to the KSC Materials Analysis Branch for metallographic analysis. (Report to be inclu

erials Analysis Branch for metallographic analysi. (Report to be included in Appendix G)

(3) Electrical Components. The electrical components, installed in the suits (including communications headset and harness, bioinstrumentation harness and signal conditioners) appeared to be relatively free of heat damage. These components were transferred to the appropriate technical personnel at KSC for continuity checks and functional testing. (Report to be included in Appendix G)

d. Helmet: The helmets were structurally undamaged and appeared to be in a pressurizable condition.

The bailer bar, pivot mechanism, and bi-lock assembly were functional. The visors were not penetrated but had been blackened on the exterior surface and had reached forming temperatures. This was evidenced because all visors were dished inward (concave outward) slightly with small bubbles appearing at the outer surface. The visor protector had melted into a shapeless mass. No external helmet material was observed to have burned.

The helmet interior showed little evidence of heat being conducted through the shell as evidence by undamaged leather covered polyurethane foam head liners and Velcro attachment pads. There is some evidence of polyurethane liner melting at forward exposed edges and of charring and blackening of the edges of the chamois covered earcups but this heat source is thought to have been secondary after penetrations of the upper portion of the suit.

e. Suit Mounted Accessories:

The accessories carried aboard on the day of the accident are listed above in Section 4b. All accessories have been accounted for and examined, although some of these accessories exhibit various states of melting, charring, and other damage. There is no evidence that any of these components could have been the source of the fire. In most cases, these components were relatively well protected by the space suit pockets or their individual packing covers. More complete individual descriptions of these items are contained in Reference 11-6.

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OPTIONAL FORM NO. 10 5010-107
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

TO : Chairman, Panel 11, Medical Analysis DATE: March 16,1967

FROM : J.A. Thomas, NASA/KSC

SUBJECT: Continuity and Functional Tests of S/C-012 Crew Biomedical Equipment

Report of results of TPS S/C-012 - CM-CA-034 to perform continuity and functional tests on S/C-012 suit biomedical and communications equipment and wiring.

NOTE: Procedures used and results of this TPS are referenced to the following attachments.

(1) Normal layout diagram of suit-torso (biomed-comm) wiring.
(2) PGA wiring print V16-960241
(3) Torso harness print 103120-D
(4) Configuration of PLT suit wiring at start of TPS
(5) " " SRP " " " " " "
(6) " " CMD " " " " " "

1. The PLT suit wiring was received in the Biomed Lab, Room 2440, in the configuration shown in Attachment 4.

2. A continuity check of the PLT suit wiring was performed by ringing from P2 of the PGA to connector MDI-21PL1 (comm) and MDI-9PL2 (biomed) of the torso harness.

3. Pin 21 of P2 to Pin 3 of MDI-21PL1 of the torso harness (audio warning signal shield, Reference Attachments 2 and 3) was found to be open. All other wiring was per prints.

4. The PLT PGA was disconnected from the torso harness and the PGA was continuity checked per print V16-960241 (Reference Attachment 2).

5. Pin 21 of P2 to Pin 57 of P1 of the PLT PGA was found to be open. This determined the open wire (audio warning signal shield) of step (4) above to be in the PLT PGA.

6. The PLT axillary electrode harness was checked for continuity per print with no wiring discrepancies.

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7. The PLT biomedical signal conditioners (ECG1, ECG2, ZPN, and DC-DC converter) and torso harness were functionally tested using a test subject and were all operational.

8. A PIA (preinstallation acceptance test) was performed on the PLT DC-DC converter per OCP-K-5110 and there were no discrepancies. This test was made to verify complete operation of this signal conditioner which converts S/C power (16.8VDC) to biomed power (+10VDC and -10VDC).

9. Communications - No testing of the PLT helmet communications hardware was performed due to lack of current wiring prints and specifications. Work to obtain needed data and technical support is in progress. Testing will be done on a subsequent TPS.

SRP

1. The SRP suit wiring was received in the configuration shown in Attachment 5.

2. The cut in the SRP PGA necessitated that the PGA be disconnected from the torso harness for continuity checks.

3. The SRP torso harness was continuity checked from the suit connector MD53-00E15-61PN to the biomed connector MDI-9PL2 per print 103120-D (Attachment 3) with no shorts or open wires.

4. The cut in the communications wiring of the SRP torso harness necessitated that the ribbon cable be stripped approximately ½" on each side of the cut to allow continuity checks.

5. Continuity checks from the suit-torso connector MD53-00E15-61PN to the communications connector MDI-21PL1 resulted in no shorts or open wiring.

6. The SRP biomedical signal conditioners (ECG1, ECG2, ZPN, and DC-DC converter) and torso harness were functionally tested using a test subject and were all operational.

7. The wires at the cut in the SRP PGA were separated to prevent any shorting and all pins of P2 of the SRP PGA were continuity checked for shorts to all other pins of P2.

8. There were no shorts in the SRP PGA as checked.

9. A PIA was performed on the SRP DC-DC converter per OCP-K-5110 and there were no discrepancies.

10. Communications - No testing of the SRP comm. hardware was done due to lack of data.

CMD

1. The CMD suit wiring was received in the configuration shown in Attachment 6.

2. A continuity check of the CMD suit wiring was performed by ringing from P2 of the PGA to connector MDI-9PL2 (biomed) of the torso harness.

3. Pin 29 of P2 of the PGA to Pin 1 of the MDI-9PL2 (torso harness) was found to be intermittent (16.8VDC biomed power).

4. The CMD PGA was disconnected from the suit-torso harness and the PGA was continuity checked per print V16-960241. All wiring was per print.

5. Results of the previous step determined the intermittent wire of step (3) above to be in the CMD torso harness between the suit connector and the MDI-9PL2 biomed connector. Wiring in this area of the torso harness was badly scorched.

6. The cut in the communications wiring of the CMD torso harness necessitated that the wiring be stripped approximately $\frac{1}{2}$" on each side of the cut to allow continuity checks.

7. Upon stripping the wires at the cut, damaged wiring inside the ribbon cable was discovered. The wires were discolored and the insulation appeared to be brittle. The wiring in the rest of the ribbon cable was normal. The wires were identified as microphone signal, microphone signal return, earphone signal, and earphone signal return.

8. Continuity checks from the CMD suit-torso connector MD53-00E15-61PN to the communications connector MDI-21PL1 resulted in the following:

   (a) Pins 45,46, and 47 of MD53-00E15-61PN were shorted (mike signal, mike signal return, mike signal shield).

   (b) Pins 10,11, and 12 of MDI-21PL1 were shorted (mike signal, mike signal return, mike signal shield).

   (c) Pins 3,4, and 10 of MD53-00E15-61PN were shorted (earphone signal, earphone signal return, earphone signal shield).

   (d) Pins 13,14, and 15 of MDI-21PL1 were shorted (earphone signal, earphone signal return, earphone signal shield).

These were the damaged wires referenced in step (7). All other wiring was per print.

9. Samples of the damaged wires were obtained per TPS S/C-012 - CM-CA-093 and delivered to the Malfunction Analysis Branch (MAB). The MAB is to perform metalagraphic analysis of these wires to determine temperature to which they were subjected.

10. The CMD biomedical wiring from the MDI-9SL2 connector to the biomedical signal conditioners and the DC-DC converter was continuity checked per print and pins 1,2, and 9 of MDI-9SL2 (biomed 16.8V power) were shorted. The ribbon cable in this area was completely burned away.

11. The CMD biomedical signal conditioners (ECG1, ECG2, ZPN and DC-DC converter) were functionally tested using a test subject and were all operational.

12. A PIA was performed on the CMD DC-DC converter per OCP-K-5110 and there were no discrepancies.

J. A. Thomas

J.A. Thomas

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANELS 12 thru 17

REPORT OF PANEL 12
WITNESS STATEMENTS
APPENDIX D-12
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

RECEIVED
NASA STI FACILITY
ACCESS DEPT.

WITNESS STATEMENTS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Witness Statements Panel, 12. The task assigned for accomplishment of Panel 12 was prescribed as follows:

An orderly process to collect all data from witnesses (includes eye witnesses as well as console monitors). This includes a determination of who to interview, arranging for competent people to conduct the interviews, recording data, and collecting it into a form suitable for publication as an appendix to the formal report. Included also in this taks is an analysis of the pertinent sequence of events as reported by the bulk of the witnesses together with a summary of that testimony which is contradictory to the main data.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Witness Statements Panel:

Mr. Norbert B. Vaughn, Manned Spacecraft Center, (MSC), NASA, Chairman
Mr. J. J. O'Donnell, Kennedy Space Center, (KSC), NASA
Mr. C. B. Netherton, Kennedy Space Center, (KSC), NASA
Mr. H. F. Blackwood, Headquarters, NASA
Lt. Col. J. W. Rawers, U. S. Air Force
Mr. C. J. McNanara, North American Aviation, (NAA), Kennedy Space Center (KSC)

2. COGNIZANT BOARD MEMBER

Colonel Charles F. Strang, U. S. Air Force, Board Member, was assigned to monitor the Witness Statements Panel.

C. PROCEEDINGS

1. OBJECTIVES

a. To collect all data through written statements and taped interviews from:
(1) Eye Witnesses
(2) All other personnel who had access to Launch Complex (LC) 34 during the test
(3) All monitoring personnel at:
(a) The Launch Complex 34 Blockhouse
(b) The Acceptance Checkout Equipment (ACE) Control Rooms in the Manned Spacecraft Operations Building (MSOB)
(c) All the other observation or recording stations where audio or television (TV) monitoring was available.
(4) Other personnel as required by the Board
(5) Volunteers of pertinent information that were not contacted in (1), (2), (3), or (4) above.
b. To construct a sequence of events from the bulk of witness reports and to update this information on a timely basis for use by the Review Board and other Panels.
c. To identify the pertinent inconsistent or contradictory statements to the main data as presented in 5. Ojbective (b).
d. To summarize the pertinent information for use by the Review Board and other Panels.
e. To prepare the statements in proper form for publication as Appendix B to the Final Report.

2. INTRODUCTION

For use as general information and orientation are Enclosures 12-1 through 12-5, which are drawn approximately to scale. Enclosure 12-1 is a simulated aerial view of Launch Complex (LC) 34. Enclosure 12-2 shows the Service Structure elevators and the Umbilical Tower elevator on LC 34. At the time of the incident, the Umbilical Tower elevator (450 feet per minute capability) was held at

the top of the tower in anticipation of the schedule "egress" exercise. The Service Structure elevators were programmed as follows for this test:

No. 1 (Northeast) - 200 feet per minute, capable of being stopped at every level
No. 2 (Northwest) - 100 feet per minute, capable of being stopped at every level
No. 3 (Southwest) - 200 feet per minute, capable of being stopped at every level
No. 4 (Southeast) - 450 feet per minute, capable of being stopped at every level

The Pedestal elevator (65 fpm capability) is a hydraulic lift type platform that rises to the 27 foot level. Enclosure 12-3 is a plan view of adjustable level 8 (A-8) at LC 34. Enclosure 12-4 is a plan view of adjustable level 7 (A-7) at LC 34. The overlays in Enclosures 12-3 and 12-4 show the position of the eye witnesses at the time of the incident. On the Enclosures 12-2, 12-3, and 12-4 are arrows indicating the direction North and an assumed North. The assumed North is a Kennedy Space Center common practice used for ease of locating items relative to the Service Structure axes. Witness statements make use of this in describing their existing the Structure on elevators after the incident. Enclosure 12-5 is a sketch of the Command Module, White Room, Egress Access Arm, and Umbilical Tower elevator, showing the egress route of astronauts on LC 34.

3. INVESTIGATION

Investigation by the Witness Statement Panel was initiated January 31, 1967 when the Panel received nine (9) miscellaneous written statements and twenty-six (26) "eye-witness" statements from the NASA-KSC Security Office. These were written or taped statements obtained the evening of the Apollo 204 incident. At the same time, twenty-one (21) Pan American World Airwasy (PAA) employee witness statements were received from the Air Force Eastern Test Range (AFETR) Representative to the Board.

4. OBJECTIVE A

Panel objective a (Collection of Data) was accomplished by contacting the contractors and agencies involved in the test operations. Those contacted were either "eye-witnesses", or television (TV) or audio monitors of the incident. A total of eighteen (18) agencies or contractors were contacted (See General File for list). There were responses for 590 people with 572 written statements and forth (40) recorded statements. Since some witnesses submitted more than one written statement or were interviewed twice, a total of 612 statements was obtained.

5. OBJECTIVE B

Panel 12 objective b (Sequence of Events) was accomplished as shown below, and by the Review Board Counsel as shown in Enclosure 12-6. Enclosure 12-6 is a detailed narrative description of the events. The sequence of events briefly listed herein was established from the bulk of the witness statements.

SEQUENCE OF EVENTS FROM WITNESS STATEMENTS

Between time 6:31:00 p.m. EST to 6:31.15 p.m. EST		Events:
The:	Witnesses in Launch Vehicle Aft Interstage, Level A-2:	Felt two definite rocking or shaking movements of vehicle seconds prior to "Fire" report. Unlike vibrations experienced in past from wind, engine gimballing or equipment input.
	Witnesses on Levels A 7 & A 8.	Heard "Fire" and/or "Fire in Cockpit" transmissions Heard muffled explosion, then two loud whooshes of escaping gas (or explosive releases). Observed flames jet from around edge of Command Module and under White Room.

TV Monitors:	Heard "Fire" and/or "Fire in Cockpit" transmissions. Observed astronaut helmet, arm, and back movements; increase of light in Spacecraft window, and tongue-like flame pattern within Spacecraft. Observed flame progressing from lower left corner of window to upper right, then spreading flame filled window, burning around hatch openings, lower portion of Command Module, and cables.
Between time 6:31:15 p.m. EST to 6:33 p.m. EST	
Witnesses on Levels A-7 & A-8:	Repeated attempts to penetrate White Room for egress action. Fought fires on Command Module, Service Module, and in White Room area.
TV Monitors:	Observed smoke and fire on Level A-8. Progressive reduction of visibility of Spacecraft hatch on TV monitor due to increase of smoke.
Between time 6:33 p.m. EST to 6:37 p.m. EST	Repeated attempts to remove hatch and reach crew. Continued fire-fighting on Levels A-7 and A-8 in White Room. Spacecraft Boost Protective Cover (BPC) removed by NAA personnel J. D. Gleaves and D. O. Babbitt. Spacecraft outer (Ablative) hatch removed by NAA personnel J. W. Hawkins, L. D. Reece, and S. B. Clemmons. Spacecraft Inner hatch opened and pushed down inside by NAA personnel J. W. Hawkins, L. D. Reece, and S. B. Clemmons at approximately 6:36:30 p.m. EST. No visual inspection of Spacecraft interior possible due to heat and smoke. No signs of life.
Between time 6:37 p.m. EST to 6:45 p.m. EST	Extinguish remains of fires. Fire and Medical support arrive. Fireman J. A. Burch, Jr. and NAA Technician W. M. Medcalf removed the Spacecraft Inner hatch from the Spacecraft. Examination of crew and verification of condition.
Between time 6:45 p.m. EST, January 27, 1967 to 2:00 a.m. EST, January 28, 1967	Service Structure cleared. Photographs taken. Crew removed. Complex and area under secure conditions. Personnel from Washington and Houston arrive and assume control of situation.

6. OBJECTIVE C

Panel objective c (Contradictory Statements) was accomplished. The only significant deviation, which had no other substantiation, was the statement of Mr. Gary W. Propst, RCA Technician. The Witness was monitoring Operational Intercommunication System (OIS) channel Black 3 and observing the TV view of the S/C 012 hatch. The call of "Fire" over the OIS and observation of a bright glow in the spacecraft occurred simultaneously. He stated there was a two to two and one-half minute time elapse from the call until flames increased and covered the hatch opening. At about three (3) minutes, Mr.

Propst stated, the flames from the outside bottom of the spacecraft began to eat through the area where the bottom lip of the White Room meets the Spacecraft, and the White Room began to fill with smoke. He also stated there was movement inside the Spacecraft lasting about two (2) minutes before the flames began to block the view, and no one entered the White Room until it had become smoke-filled some minutes later. Mr. Propst stated that he changed the electronic control knobs on the hatch TV monitor while the incident was happening. This caused all the other TV monitor screens as mentioned by some witnesses, to have a monetary (1 to 2 seconds) loss of picture, with either gray, black, or white-out, but most probably white appearance. As the camera built-in electronics and internal mechanisms were adjusting themselves, the hatch area could have appeared washed-out due to the Spacecraft interior brightness for approximately 2 seconds.

7. OBJECTIVE D

Panel objective d (Summary of Pertinent Information) was accomplished as shown herein. Section (a.) is a summary prepared from the statements of witnesses located primarily on adjustable levels 7 and 8 of the Launch Complex 34 Service Structure. Section (b.) is a summary prepared from statements of witnesses who had access to TV monitors located at either the Launch Complex 34 Blockhouse or at the ACE Control Rooms. These summaries indicate only the initial observations of the witnesses. Subsequent observations and actions taken are contained in the witnesses entire statements found in Appendix B.

SUMMARY OF WITNESS OBSERVATIONS REGARDING FIRE

a. Levels A-7, A-8 and other Areas of Service Structure

Name, Duty, Location	Time Reference	Initial Observation
Donald O. Babbitt NAA, Project Engineer Pad Leader; A-8 Pad Leader Desk	Immediately after OIS report	Flame from under BPC near steam duct - followed by concussion.
James D. Gleaves NAA, Mechanical Lead Technician; A-8 Flyaway Umbilical	Shortly after hearing OIS report - believed to be Astronaut Chaffee.	Heard loud shoooooc - entered White Room, saw flash - followed by fire and debris covered right side of Spacecraft.
L. D. Reece NAA, Systems Technician; A-8, Flyaway Umbilical	Immediately after OIS report.	Sheet of flame from Command Module 12 access.
Richard A. Hagar NAA, Electrical Systems Technician; A-8, -Y Area	Immediately after OIS report.	Two loud pops - fire blew out of -Y and +Y access panels.
Richard L. Bachand NAA, Systems Technician; A-8, +Z +Y area	Immediately after OIS report.	Low burp, large whoosh, wall of flame - floor to ceiling.
Stephen B. Clemmons NAA, Systems Technician; A-8, Pad Leader Desk	Immediately after OIS report.	White glow around BPC, access paned between umbilical and White Room. Loud venting of gases, then ignition like gas jet being ignited. No loud explosion.
James E. Cromer PAA, Elevator Technician; Umbilical tower elevator looking at White Room	Did not hear report - saw flash first.	Flash of fire from White Room door-side doors blew open.
Joseph H. Pleasant NAA, Systems Technician; A-8, near stairs to White Room	Someone called "There's a fire in spacecraft".	Heard someone call fire in Spacecraft - heard muffled explosion - fire around bottom of Command Module - several places - smoke.
Bruce, W. David NAA, Systems Technician; A-8, Flyaway umbilical	Immediately after OIS report.	Flames within open access panels near umbilical - followed by whoosh and flames shooting out of the panels.
Friend D. Hickenbottom NAA, Systems Technician; A-8, South of Tower	Immediately after OIS report.	Spurt of flame under White Room - explosion - flames at all Command Module openings.

Jerry W. Hawkins NAA, Systems Technician; A-8, Swing Arm	After hearing someone yell "Fire".	Flame from Spacecraft to Pad Leader desk.
W. Donald Brown NAA, Mechanical Inspector; A-8, -Y Quality Control Desk	No time reference	Command Module 012 access seemed to ignite - minor explosion - 2 loud whooshes - escaping gas
Jessie L. Owens NAA, Systems Engineer; A-8, Pad Leader Desk, +Y area	Immediately after OIS report.	Heard relief valve open - hi-velocity gas escaping, burst into flame.
Robert C. Hedlund NAA, Systems Technician; A-8, +Z +Y Area	Immediately after OIS report.	Hears whoosh - saw small flames from access hatches.
John E. Markovich NASA/KSC, Q. C. Inspector; A-8, +Z (NW)	Heard explosion - first notice	Heard muffled explosion - saw huge flash fire - service port +Z axis.
Joseph L. Stoeckl NASA/KSC, Q. C. Inspector; A-8, SW corner	Hears explosion - first notice	Muffled explosion - Command Mod engulfed in flame.
Henry H. Rogers, Jr. NASA/KSC, Q. C. Inspector; A-8, on S.W. Elevator	Very shortly after hearing report on PA	Entered White Room - fire appeared burning from inside Spacecraft out.
Creed A. Journey NAA, Electrical Leadman; A-8, +Z -Y axis Area	Heard shout as entering level A-8 from A-7. Threw self to floor as fire burst out.	Fire broke out of Command Module in high velocity streams, 6 to 7 feet long out of servicing ports in southeast corner (-Y area).
William J. Schneider NAA, GSE Technician; A-7, with back to Service Module at +Y Area	Heard "Fire" either over squawk box or down from level A-8.	Felt heat on back at call "Fire". Went out to get on NE passenger elevator. Didn't get on. Saw fire inside Service Module. Got fire extinguisher and extinguished fire in Service Module.
Dave E. Howard NAA, Systems Technician; A-7, near access to Service Module	After initial fire - no reference to OIS report. Heard Astronaut say, "Fire in cockpit".	Saw fire dimish from first flame - loud swoosh ball of flame from bottom of Command Module.
J. C. Scott NAA, Q. C. Inspector; A-7, under umbilical	Heard someone say, "Fire in cockpit"	Heard noise - then second noise - ball of fire fell from Command Mod to Service Module.

Robert I. Bass NAA, Systems Technician; ACE Room	Hears explosion - saw smoke - heard shouts of "Fire".	Muffled explosion - smoke pouring out and around swing arm into White Room.
John C. McConnell NAA, GSE Technician; Umbilical Tower level 190 Ft.	Heard someone on A-8 or else over OIS say "Fire in the Spacecraft".	At indication of "Fire" sound - level A-8 all lit up when it exploded. Got fire extinguisher - and crossed over to A-6, grabbed 2 gas masks and went up to level A-8.
Burt B. Belt NAA, GSE Leadman; On Service Structure express elevator, level 2	Heard people yelling "Fire in the Spacecraft" as elevator was going to level A-6.	Wanted elevator to go to A-8 but stopped at A-6. Grabbed gas masks and took up to A-8. Started fighting fires coming from parts of Command Module with extinguishers.
George W. Rackleff NAA-Tulsa, Systems Technician; A-7, under White Room	Heard report from spacecraft crew member	Large puff of smoke and explosion - swing arm entry hatch.
Samuel Williams NAA, GSE Technician; A-7, A14-019 Fly-Away umbilical connection	Astronaut: "Fire in cockpit" over headset.	Heard explosion immediately follow-by another, then fire down through A-7 at Swing Arm.
Forrest R. Rooker NAA, GSE Technician; A-7, A14-019 Fly-Away umbilical connection	Astronaut: "We have fire in cockpit" over headset.	Heard small explosion then larger one - Flash of flame through opening A-8 and A-7 at umbilical swing arm.
William H. Wingfield NAA, GSE Electrical Technician; Level A-5	Heard Chaffee say "Fire" over OIS.	Smoke came down to area, saw paper on fire flying from A-8 level. Went up to A-8 for few moments only and went down to 188 ft. level to open power supply breakers.
Marvin L. Nelson NASA/KSC QC Inspector; A-7, N.E. side of Service Module	Immediately after report from P/A	Smoke began to fill the area.
Patrick E. Mitchell NASA/KSC QC Inspector; A-7, A14-019 umbilical disconnect	Immediately after report	Level filled with smoke
William C. Deaver NAA, Electronic Technician; A-7, A14-019 Fly-Away umbilical connection	Heard someone say, "Fire in Cockpit"	Heard 2 explosions - then fire between Command Module and Service Module.
Willis M. Medcalf NAA, Mechanical Technician; Service Structure elevator between levels 3 and 4	Heard cry of "Fire" as elevator passed levels 3 and 4	Elevator stopped at level A-8 Ran down a level or two and took gas masks to A-8.

Robert C. Foster NAA, QC Inspector; Complex 34 Fuel Area	Saw smoke	Looked upward and saw smoke. Carried gas masks and fire extinguishers to SE elevator and took to level A-8.

b. TV and Audio Monitors

Name, Duty, Location	**Initial Notice**	**Observation**
Clarence A. Chauvin NASA/KSC Test Conductor; Test Conductors Console ACE Control Room 1, MSO Building	"Fire" over Operational Intercommunications System (OIS).	Noticed flames in vicinity of apex cover at top of Command Module. Not aware fire was in Spacecraft until heard over headset shortly after.
William H. Schick NASA/KSC Assistant Test Supervisor; Test Supervisor's Console - Blockhouse Launch Complex 34	"Fire in Cockpit" over OIS	Saw flames climbing about halfway up the side of the Spacecraft coming from the interface between the Command Module and the Service Module.
Gary W. Propst RCA Technician; Operational TV Control Racks - Blockhouse Launch Complex 34	"Fire in the cockpit" over OIS	Observed hatch in TV monitor. Saw bright glow in Spacecraft. Observed Astronaut arm and leg movements lasting about 2 minutes until flames obscured vision. A split second later flames go past window. Fire increased steadily. Flames from outside bottom of Spacecraft where it meets lip of White Room and from under hatch.
Alan R. Caswell RCA-Communications Controller; Communication Control Racks - Blockhouse Launch Complex 34	Technician Propst called attention to monitor - stating Fire in Spacecraft.	Observed hatch on TV monitor. Flames flickered inside Spacecraft on left side of window and in 15-20 seconds almost covered window. Saw center astronaut's helmet move during first few seconds.
Donald K. Slayton NASA-MSC, Director of Flight Crew Operations; Astronaut Console Blockhouse Launch Complex 34	Call of "Fire" on OIS	Observed Spacecraft hatch on TV monitor. Flame around hatch. Smoke increased. Detected people trying to get to hatch door. Smoke obscured view from TV Camera.
Daryl O. Cain NAA, Spacecraft 017 Test Conductor; ACE Control Room No. 2, MSO Building	Hatch Camera seemed to blank out like someone had shined a very bright light into lens of camera.	Picture was regained. Saw "Guttery" type flames about 6 inches high mostly on right hand side at base hatch. Impression one of the quads had fired and fire was outside Spacecraft underneath the Command Module. Observed the fire fighting attempts and

		assumed Astronauts were safe and staying inside craft until fire exinguished and smoke cleared from area. Camera eventually turned off. Not aware of tragedy for couple of hours because principally engaged in monitoring own test on spacecraft 017.
Donald R. Jones NASA/KSC - Chief, Electrical Systems, Saturn IV-B; VIP Room - Blockhouse Launch Complex 34	Illumination within Spacecraft and call of "Fire" over OIS	Noted tongue of flame between center Astronaut's helmet and hatch window on hatch camera. Saw Astronaut's arms move toward hatch. At this time interior of Spacecraft was illuminated to such brilliance picture blacked out.
Albert E. Jorolan NASA/KSC - Launch Vehicle Measuring Instrumentation Engineer; Measuring Station-Blockhouse Launch Complex 34	"Hey, there's a fire in here", over Spacecraft communication channel. Identifies voice as Chaffee's.	Observed 2 distinct tongues of fire positioned at 11 and 7 o'clock on TV monitor. Screen was dark, location of fire not identifiable. Camera and/or target was not identified in statement.

8. APPENDIX B - WITNESS STATEMENTS

The witness statements and releases for the statements contained in Appendix B are from:

(1) Personnel on adjustable levels 7, 8, and other areas of Launch Complex 34 Service Structure (34 total)

(2) Representative TV monitors (7)

(3) Representative audio monitors (2)

(4) Other Witnesses (3)

The index of Appendix B contains witnesses names, organization, position or duty, location at the time of the incident, and date(s) of statement(s). A page of common abbreviations and definitions is included in Appendix B. Only the witness statements containing testimony relevant to the investigation are included in this Appendix.

9. OTHER STATEMENTS

The statements of witnesses (names listed in Appendix B), which do not provide relevant testimony, are retained in the Apollo 204 Review Board General File as a matter of record. These statements, not part of Appendix B, are arranged by order of primary importance within the categories:

(1) TV monitors

(2) Audio monitors

(3) Related areas

(4) Miscellaneous

The relevancy of testimony has been reviewed by Counsel to the Board. The Board Administrative Procedure No. 16, titled "Coordination Policy for Interviewing Witnesses", was used when obtaining recorded witness statements. The General File also includes all original statements and/or tape recordings of all witnesses.

10. OTHER RESPONSIBILITIES

A total of thirty (30) requirements for information were placed on the Panel. These requests varied from lists of witnesses to information in definite disciplines (Enclosure 12-7). The requirements came from the Board, the Board Panel Coordination Committee, other Panels, and NASA Headquarters.

11. WITNESS CATEGORIES

Several categories of witnesses were established on the basis of information contained in their statements. These were: gas or vapor odors during pre-ingress, astronaut ingress, eye-witnesses of the incident, TV monitors, audio monitors, and rescue, security and medical personnel. A tape recorded conference among members of Panel 7 (Test Procedures), Panel 8 (Materials Review), and witnesses who had mentioned an unusual odor during ingress or cabin purge, was conducted February 9, 1967. The purpose of this conference was to ascertain the exact articles passed in and out of the Spacecraft hatch, the placement of articles in the Spacecraft, and a more detailed description of any odors noticed. The findings obtained in this conference were forwarded to Panels 7 and 8. The minutes of the conference are contained in the Review Board General File.

D. FINDING AND DETERMINATION

FINDING

A total of 612 witness statements were obtained by Panel 12.

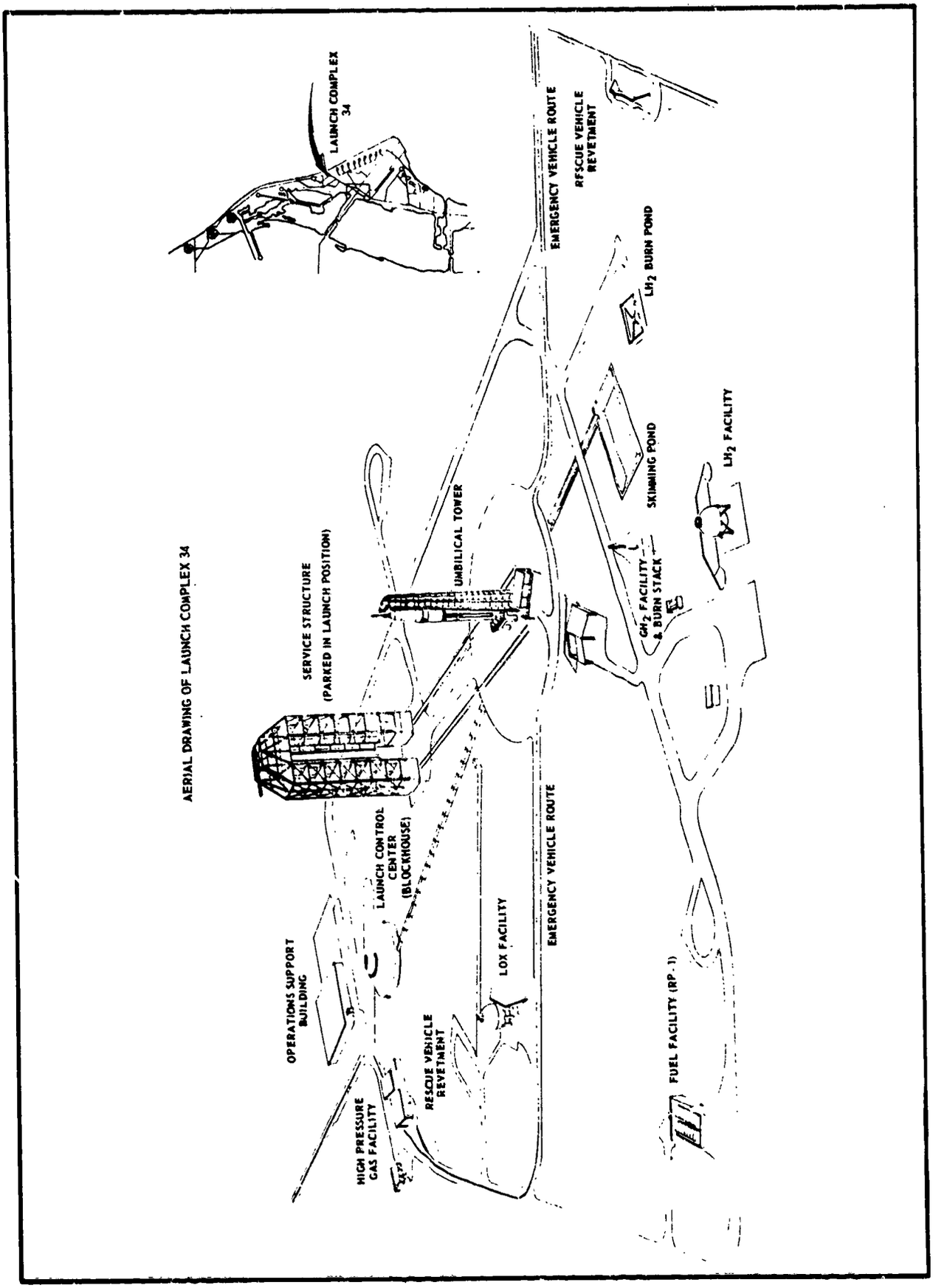
DETERMINATION

The Witness Statements Panel 12 believes that all people with pertinent information regarding the Apollo 204 incident of January 27, 1967 have been contacted.

E. SUPPORTING DATA

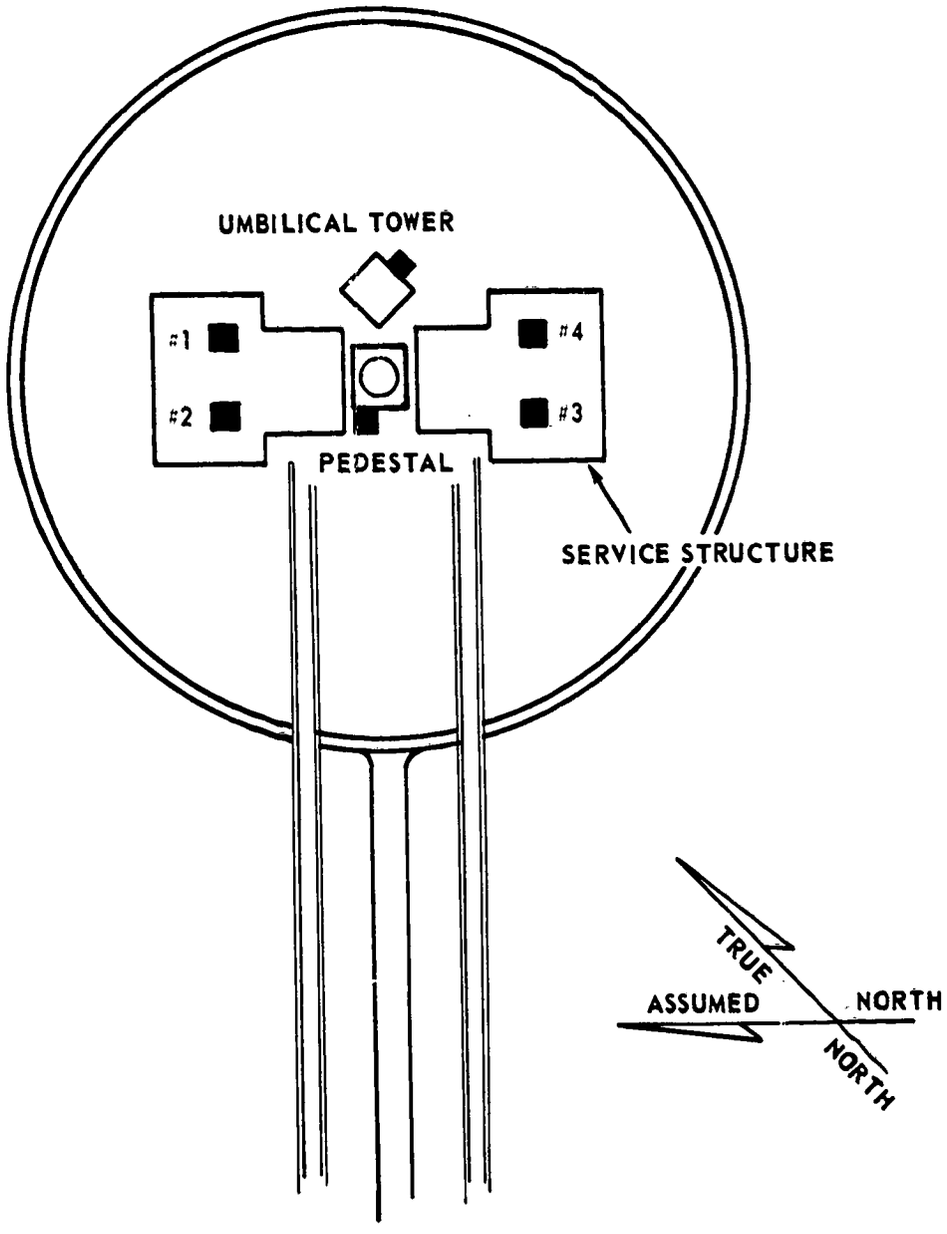
Enclosure

12-1	Aerial Drawing of Launch Complex 34
12-2	Launch Complex 34 Elevators
12-3	LC 34 Service Structure Adjustable Level 8 Platform
12-4	LC 34 Service Structure Adjustable Level 7 Platform
12-5	LC 34 Egress Route for Astronauts
12-6	Detailed Narrative Description of the Sequence of Events
12-7	Requirements placed on Panel 12.



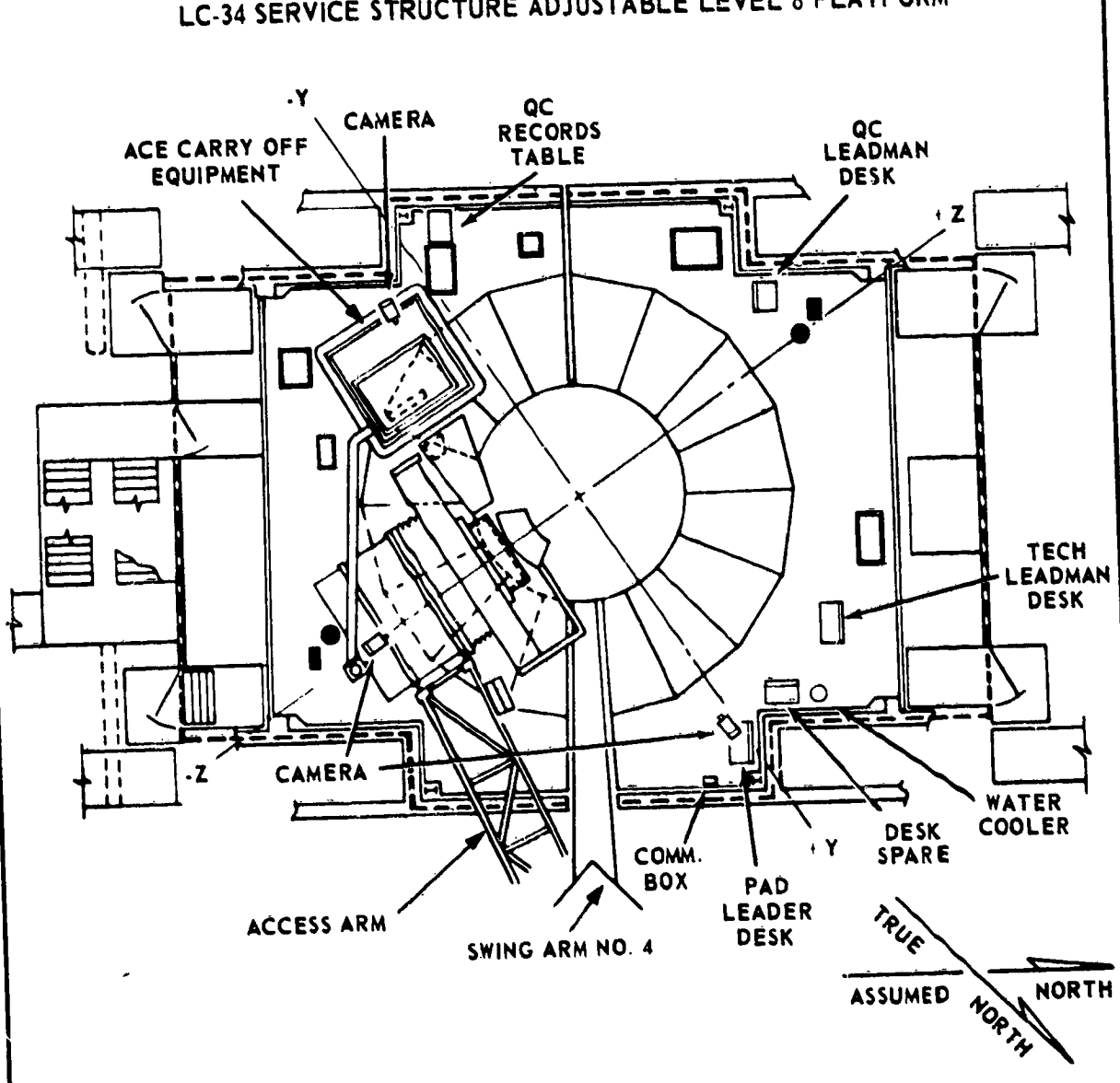
ENCLOSURE 12-1

LAUNCH COMPLEX 34 ELEVATORS



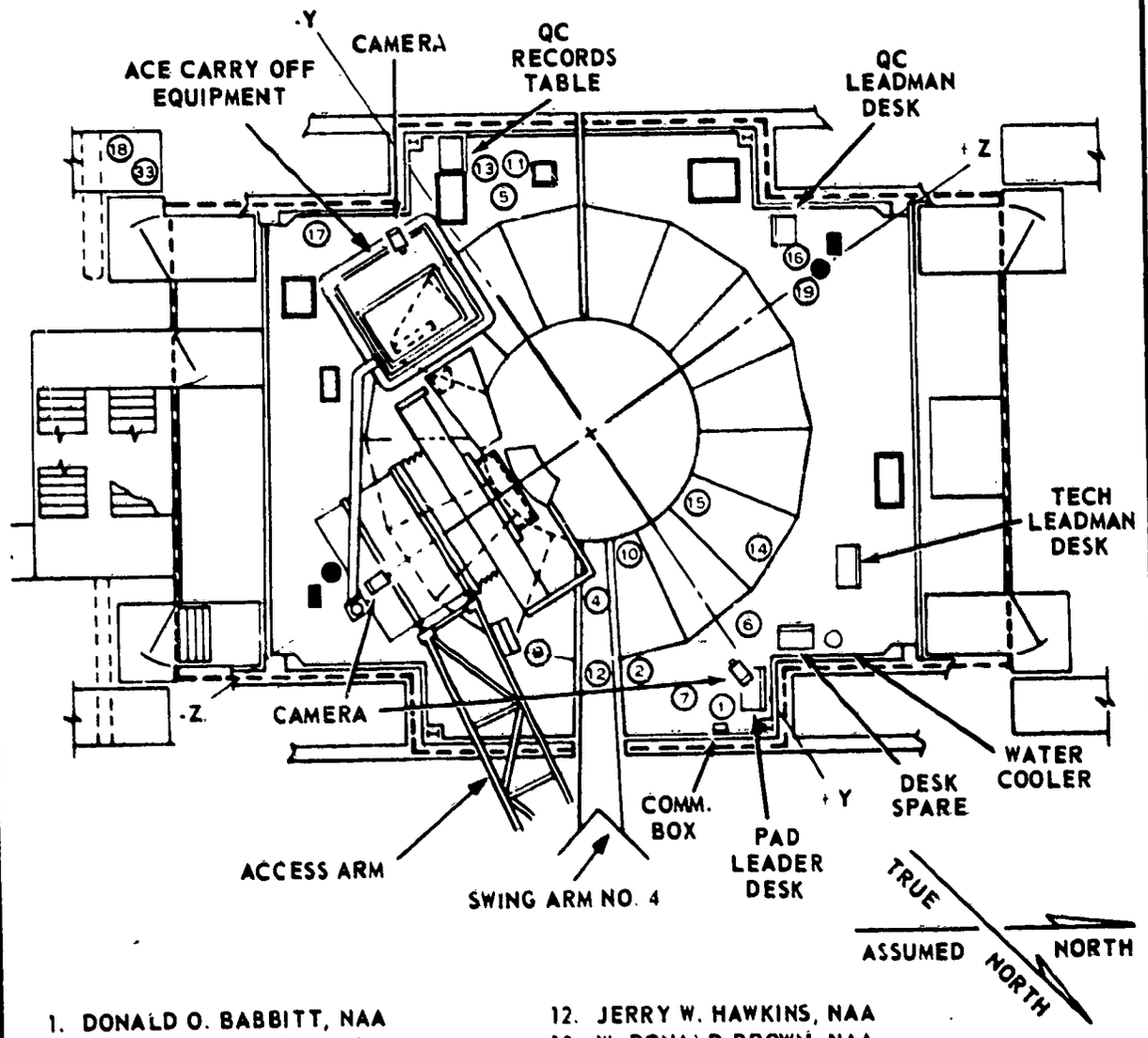
ENCLOSURE 12-2

LC-34 SERVICE STRUCTURE ADJUSTABLE LEVEL 8 PLATFORM



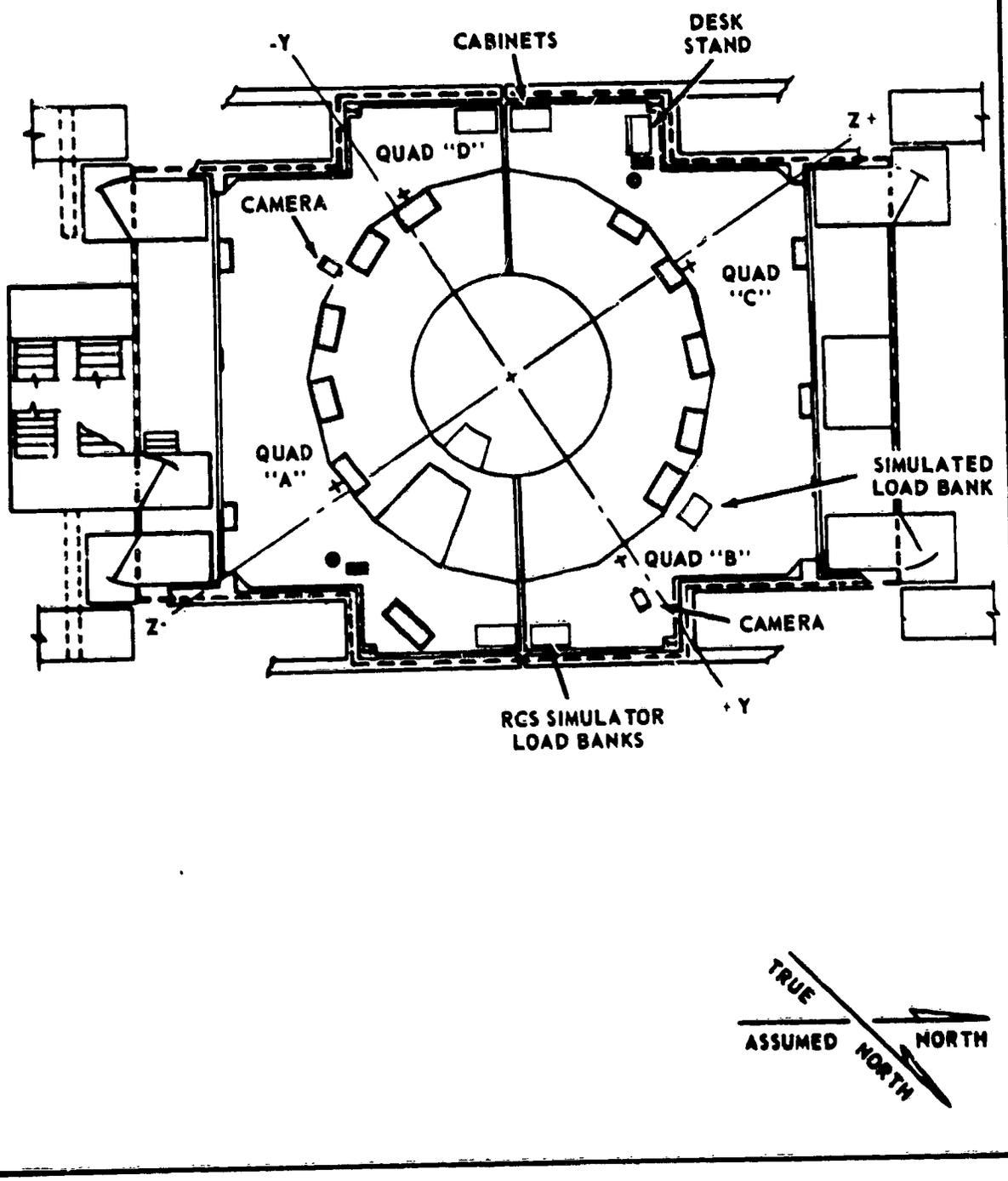
ENCLOSURE 12-3A

LC-34 SERVICE STRUCTURE ADJUSTABLE LEVEL 8 PLATFORM



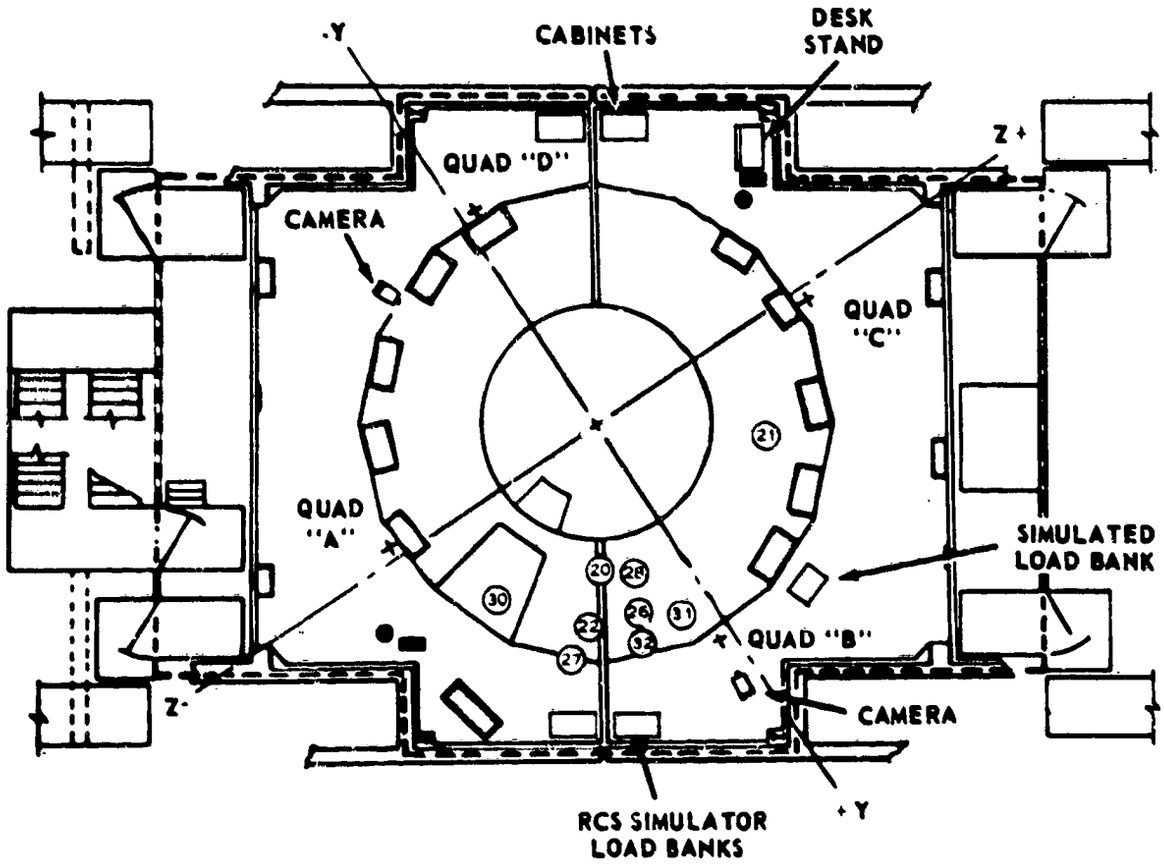
1. DONALD O. BABBITT, NAA
2. JAMES D. GLEAVES, NAA
4. L. D. REECE, NAA
5. RICHARD A. HAGAR, NAA
6. RICHARD L. BACHAND, NAA
7. STEPHEN B. CLEMMONS, NAA
9. JOSEPH H. PLEASANT, NAA
10. BRUCE W. DAVIS, NAA
11. FRIEND DALE HICKENBOTTOM, NAA
12. JERRY W. HAWKINS, NAA
13. W. DONALD BROWN, NAA
14. JESSIE L. OWENS, NAA
15. ROBERT C. HEDLUND, NAA
16. JOHN E. MARKOVICH, NASA
17. JOSEPH L. STOECKL, NASA
18. HENRY H. ROGERS, JR., NASA
19. CREED A. JOURNEY, NAA
33. WILLIS M. MEDCALF, NAA

LC-34 SERVICE STRUCTURE ADJUSTABLE LEVEL 7 PLATFORM

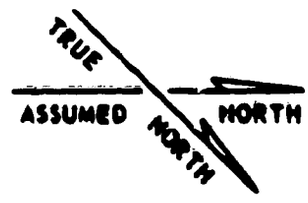


ENCLOSURE 12-4A

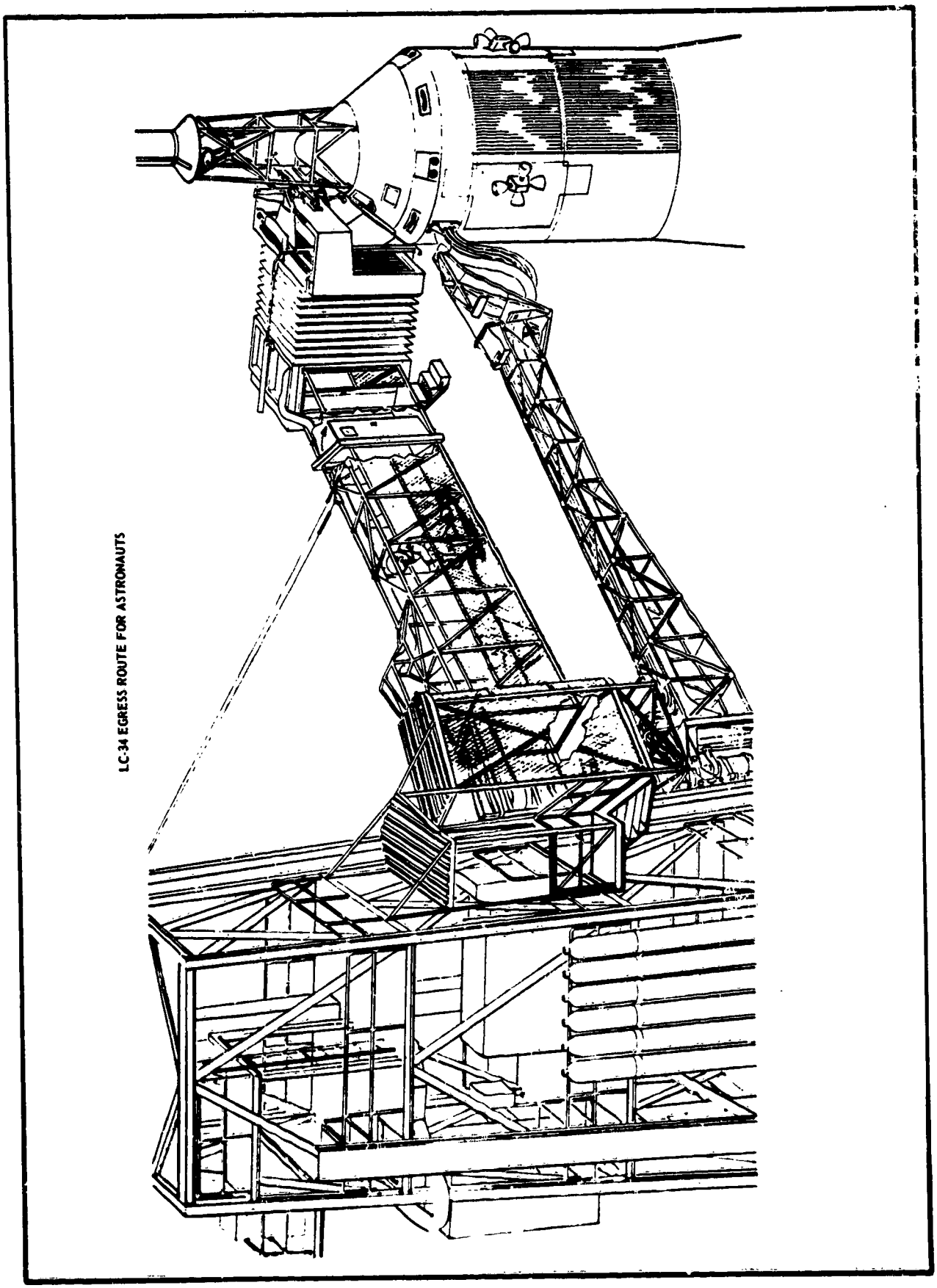
LC-34 SERVICE STRUCTURE ADJUSTABLE LEVEL 7 PLATFORM



20. WILLIAM J. SCHNEIDER, NAA
21. DAVE E. HOWARD, NAA
22. J. C. SCOTT, NAA
26. GEORGE W. RACKLEFF, NAA - TULSA
27. SAMUEL WILLIAMS, NAA
28. FORREST R. ROOKER, NAA
30. MARVIN L. NELSON, NASA
31. PATRICK E. MITCHELL, NASA
32. WILLIAM C. DEAVER, NAA



ENCLOSURE 12-4B



LC-34 EGRESS ROUTE FOR ASTRONAUTS

ENCLOSURE 12-5

DETAILED NARRATIVE DESCRIPTION OF THE SEQUENCE OF EVENTS

The following is a description of the events surrounding the Apollo 204 incident, as determined by the Apollo 204 Review Board Counsel. This narrative is based upon witness statements (Appendix B), a recording of the communications on the OIS channel Black 3, and re-interviews (non-recorded) of the principal participating witnesses. The re-interviews (March 28, 29, and 30, 1967) were done by the Review Board Counsel with the Witness Statements Panel 12 chairman and one Panel 12 member present. The following was reviewed by the chairman of Panel 12 and in his opinion is a true representation of the facts.

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It should be recognized that during the attempt to remove the various hatches, visibility within the working areas was virtually non-existent. At the same time, some individuals were wearing gas masks making identification extremely difficult. It is possible that individuals have been improperly placed during the description of a particular sequence. Care has been taken to reconstruct the scene as accurately as human memory will allow. In an effort to identify the individuals involved during the various hatch removals, participants ran through an experiment on a mock-up spacecraft. The experiment tended to clarify the sequence of events and is relied upon in this narrative as being a reliable indication of the actions involved in the crew rescue attempt.

Complex 34 consists of the Service Structure containing adjustable levels which completely surround the vehicle and the Command Module and an umbilical tower. Work on the vehicle during erection and preparation for launch, is carried out on the various enclosed adjustable levels. Prior to launch, the entire service tower is moved away from the erected vehicle.

The umbilical tower is a fixed installation containing an elevator, umbilicals to the Launch Vehicle, and an environmental control assembly (called a "white room"), at the end of a swinging access arm. The "white room", which is relatively small, swings against, and surrounds the hatchway of the Command Module. It is separate from adjustable Level 8 which completely surrounds the Command Module, until the service tower is pulled away. When the service tower moves away, the "white room" stays in position, pressed against the Command Module hatch, until 30 minutes prior to launch. It is through the white room, the access arm and the elevator, that crewmen can escape from the Command Module in the event hazardous conditions are discovered. After the access arm and the white room swing away from the vehicle, escape from hazardous conditions on the pad would be via the Launch Escape System (LES). It contains a solid fueld rocket motor, capable of pulling the Command Module clear of the complex. Prior to the Plugs Out Test, the Launch Escape System, with its rocket motor, was erected on top of the Command Module. While the wires activating the LES were shorted, there nevertheless remained the possibility that if sufficient heat were generated, the solid fuel could explode or the motor ignite. This would cause wide spread destruction to the adjustable levels of the service tower and to the Launch Complex itself.

The "white room" is completely separate from the service structure since it is an integral part of the umbilical tower. However, the "white room" and the access arm, swing into Level A-8 where the Command Module is situated. In this configuration, the "white room", the access arm and the umbilical tower appear to be part of the service structure.

The "white room" is attached to the Command Module by an hydraulically operated adapter boot. The boot fits against the Command Module, it's flexible material forming a seal around the Command Module hatch. From inside the rectangularly shaped "white room", the adapter boot presents a ramp-like appearance to the Command Module hatch; the floor of the white room being elevated above the hatchway. A door opens from the access arm into the "white room". Another white room door directly opposite the access arm doorway leads into Level A-8. This second door was sealed shut at time of the accident. The door is sealed as a safety precaution to prevent use once the service structure is pulled away from the Command Module. Until that time, access into Level A-8 is possible from the access arm itself.

Four corner elevators on the service structure serve the various levels.

The count on OCP-FO-K-0021, the Plugs Out Test, was at T-10 minutes and holding. Efforts were being made to correct communications difficulties which had existed throughout the test. However, the communications difficulties, while still existing, were not deemed important enough to halt the test. The count was due to resume within minutes when the first report of fire was heard.

The report from inside the Command Module is believed by the witnesses on Level A-8 to have been made by the Pilot. Some heard the report over their headsets, others heard it over speakers installed on Level A-8.

After the initial shock of the report of fire, followed within seconds by the rupturing of the Command Module with flames pouring out of the failed area of the Command Module, efforts were begun to remove thr three hatches of the Command Module.

At the instant of the report of fire, J. D. Gleaves, standing on the access arm, immediately began moving toward the "white room". He heard pressure escaping from the cabin relief valve and recalls thinking at the time, that the Command Pilot had dumped the pressure of the Command Module in accordance with the fire emergency procedures. It was his feeling that since the cabin was being depressurized he would have no difficulty in removing the inner hatch. As Gleaves started to step into the white room, he saw a very bright flash of light emanating through the porthole of the Command Module. He turned around. With him at this time was J. W. Hawkins. As they neared the door on the access arm, Gleaves recalls feeling a pressure and seeing tongues of flame escaping from the failed portion of the Command Module. The force of the pressure pushed him against Hawkins. With some difficulty they opened the door, which opened toward them. Their first thoughts after seeing the Command Module rupture and the flames spread across Level A-8, was that Pad Leader D. O. Babbitt and the others must have been killed. It was only after Babbitt and others joined them on the swing arm, that they realized that no one on Level A-8 had been seriously injured as a result of the rupture of the Command Module. Hawkins secured a fire extinguisher, entered the "white room" and put out two localized fires. Babbitt and Gleaves immediately returned to the white room area and began the job of removing the boost protective cover (BPC) hatch, which is the Command Module's outermost hatch. Though the BPC hatch had not been fully installed, that is, dogs which attach it to other portions of the boost protective cover surrounding the Command Module had not been engaged, it was necessary to insert a tool into te hatch in order to secure a hand hold. Babbitt and Gleaves report that the BPC hatch itself had been distorted, probably by the fire and rupturing of the Command Module. The hatch, which normally would have been easily removed, had to be forced. During this period of time, the "white room" continued to fill with smoke.

While some individuals had working gas masks, others did not. Even when the gas masks, primarily designed for use in toxic atmospheres, became operative, they were unable to work efficiently except for very short periods of time in the dense smoke-filled atmosphere of the white room.

Visibility was virtually zero. The various crews working in relays had to proceed primarily by the sense of touch.

After removal of the boost protective cover by Babbitt and Gleaves, they left the "white room". Gleaves had no gas mask and was obviously feeling the effects of the dense smoke. He was beginning to gag and choke, and yet, in spite of his physical condition, was able to complete, with Babbitt's assistance, the complete removal of the boost protective cover hatch. The tool used to remove this hatch is the same tool used to remove the ablative hatch and the inner hatch of the Command Module. As Babbitt and Gleaves left the "white room", Gleaves recalls handing the tool to Hawkins. Hawkins does not recall who handed him the tool. He knows someone did.

With Hawkins were S. B. Clemmons and L. D. Reece. During the ablative hatch removal, Babbitt

was also in the "white room". Within one minute and 30 seconds of the first report of fire, Babbitt had entered the "white room" at least once and perhaps twice. He had recovered his headset and was able to contact the blockhouse and describe the conditions as they were developing.

The removal of the ablative hatch was relatively simple. After the tool was inserted, the hatch was lifted off and carried out of the white room by Reece who threw it on the floor of adjustable Level 8 once he was clear of the "white room".

Hawkins remained in the "white room" after the ablative hatch was removed. Continuing to use the removal tool, he began work on the inner hatch. With him were Clemmons and Reece, though the witnesses at this point, because of the dense smoke, do not recall seeing all others in the "white room" at the time. Hawkins and Clemmons were apparently nearest the hatch, Hawkins using the tool to unlock the hatch while Clemmons was attempting to secure a hand hold on it.

There are two handles on the exterior of the inner hatch which, when installed, are wired down with safety wire. Whether or not Clemmons broke the safety wires holding the handles flush to the hatch, he does not recall. Once the hatch was unlocked, both men pushed it upward to relieve it from the dogs. Once the inner hatch was free, they attempted to drop it down onto the Command Module door. The hatch went only part way down.

The pad crew realized that it was not necessary to completely remove the inner hatch in order to provide access to the interior of the Command Module. During the scheduled egress exercise the inner hatch would have been unlocked by the crew and placed on the floor of the Command Module. While a small portion of the hatch cover extends above the lower rim of the hatch, access to and from the Command Module is possible.

When the inner hatch was unlocked, intense heat ans smoke came out of the open hatchway. No flames were visible on the inside. Two floodlights installed on the couches were barely visible through the smoke.

Hawkins attempted to examine the interior of the Command Module. He called out to the crewmen. He remembers there was an unusual silence from the Command Module interior.

Babbitt too had examined the Command Module's interior. Concerned about reporting over the wide communications net that he was then using that the astronauts were dead, he simply advised the ground that he would not describe what he had seen.

Babbitt and H. H. Rogers, Jr., returned to the "white room" after the inner hatch had been unlocked and partially lowered into the Command Module. During the efforts to lower the hatch, it dropped further down into the Command Module. Babbitt and Rogers then returned for fresh air to the swing arm.

Shortly, thereafter, Babbitt, suffering from smoke inhalation in the efforts of the attempted rescue, was relieved as Pad Leader by L. Curatolo.

Gleaves who had at various times been forced to the swing arm by the smoke, returned, saw that the hatch was part way down and gave it a kick. As a result of the kick, the hatch fell even further into the Command Module. Gleaves had secured a flashlight from his tool box during one of his entries into the white room and peered into the dark smoke and soot-covered interior of the Command Module. He could see nothing except the faint glow of the floodlights mounted near the couches. The lights were within inches of his position, but they appeared to be small candles very far away.

W. M. Medcalf entered the "white room" and began his attempt to remove the inner hatch completely from the Command Module.

Members of the regular fire department began arriving at Level A-8. The pad egress team, which had been standing by at the fire station, also responded to the call, but in much slower M113 Armored Personnel Carriers. The team was scheduled to participate in the egress exercise, scheduled at the end of the plugs out test.

Fireman B. Dawes arrived at Level A-8 through a service elevator and went to the "white room". He recalls seeing the hatch laying inside the Command Module. Fireman J. A. Burch, Jr., upon his arrival at the "white room" saw people working around the hatch. He joined them and began to pull at the inner hatch in an effort to remove it completely from the Command Module. He began to feel the effects of the smoke and had to run out of the "white room" to the access arm. On the access arm he found a gas maks, donned it, and returned to the "white room" to continue in his attempt to remove the hatch from the Command Module. Once again he was not successful. He was forced out of the "white room" by the smoke. He replaced his gas maks, and returned for a third attempt at the inner hatch removal. This time with the aid of Medcalf, he was successful. With the exception of Assistant Chief J. C. Mooney, who was a member of the pad egress team, none of the firemen were familiar with the configuration of the Command Module. They had received no training in the removal of the various hatches, since it was felt that the pad egress team would be available to perform this function during hazardous tests or launches. The pad egress team did have knowledge of the Command Module configuration and had appropriate tools to remove the three hatches. Chief Mooney arrived at "white room" after the inner hatch cover had been completely removed from the Command Module.

After the hatch was removed, Burch leaned into the Command Module. Everything was black. He could not see any bodies. He secured a flashlight but even with its assistance he was unable to see anything. As he was crawling out of the open hatchway, he did notice one body. He attempted to pick it up, but he was unable to move it. He then left the Command Module. In the meantime, Fireman B. H. Batts with others was removing the panel that sealed the second door of the "white room", which led directly onto Level A-8. This was necessary in order to vent the "white room" and the Command Module. The use of fans to blow the smoke out of the Command Module was considered unwise, since the fans could possibly re-ignite substances within the Command Module. Chief Mooney, a member of the pad egress team which had planned to participate in the egress exercise scheduled for the end of the Plugs Out Test, also made an effort to remove crewmen from the Command Module. This activity was stopped, confirmed by physicians who had arrived at the Command Module, that all three astronauts were dead, and that an investigation of the Command Module as it was found after the hatches were open would be important in attempting to determine the cause of the fire.

Photographs were then taken of the Command Module, of Level A-8, and other portions of the service structure.

Witnesses reported seeing firemen on the complex without firefighting equipment. Since each level contains fire extinguishers as well as hose lines, it was not necessary for them to being equipment from the ground in order to fight fires. The hose lines were working and lines were charged, though not used. Fire extinguishers from Level A-8 and other levels of the service structure were used to control blazes outside the Command Module and at other locations on the service structure.

Because of the proximity of fires, workers removed their nylon work smocks. Examination of the smocks after the incident showed that some of them had been burned, apparently from fire brands erupting onto Level A-8 when the Command Module ruptured.

The access arm was the closest position to the "white room" in the Command Module where fresh air was available for the workers. While a few witnesses reported that their gas masks were operative, a majority indicated they were of little assistance during the rescue attempt, because of the density of the smoke.

J. E. Cromer, on duty at the Umbilical Tower elevator, reported that the elevator was at Level 200, which corresponds with Level A-8, at the time the fire began. While the elevator could be remotely controlled from the blockhouse, Cromer could also control it from his position on the umbilical tower. The elevator remained at Level 200 until Gleaves, choking and gagging from the smoke inhaled in his repeated entries into the "white room", had to be sent to the ground. Cromer reports that the first indication that he received of the fire was the sensation that there was an explosion on Level A-8. He also reports seeing a tongue of flame emanating from the "white room '. Immediately after the explosion, personnel from the inside of Level A-8 came out on the access arm. After reporting there was a fire to his control point within the blockhouse, Cromer broke out a box containing gas masks. Cromer reports that personnel on the access arm immediately began re-entering the "white room" in their efforts to remove the hatches and effect crew rescue.

Gary Propst, an RCA technician, stationed in the blockhouse and responsible for controlling remote television cameras installed on Level A-8 and in the "white room", first became aware of the fire through the report heard on his headset. He immediately looked at the "white room" monitor. He saw light in the Command Module emanating from a point on it's left side. At the same time he saw hands reach above the hatch, and movement of the crew inside of the Command Module. With the light increasing in intensity inside of the Command Module, Propst immediately adjusted the camera to the light levels within the Command Module. This action may have caused television monitors to show what appeared to be an explosion of white light, but was in reality an adjustment of the camera's sensitivity to the light.

Propst is convinced that the time of the accident, from the moment he first learned of the fire, until the "white room" filled with smoke, was much longer than data indicates. He recalled engaging in a conversation with others in the blockhouse as to when the crew would blow the hatches. Propst was not aware that the hatches on the Command Module could not be exploded off. He recalls, by viewing other monitors at Level A-8, that the "white room" did not fill with smoke until visibility was almost impossible on Level A-8 itself. As the fire progressed, smoke did fill the "white room" making detailed viewing through the TV camera impossible. However, Propst could tell that there was activity going on in the "white room" as individuals would stand in front of lights installed for the TV cameras, thus varying the light intensity. While he could discern that something was going on, he could not see in detail, what was happening.

While arrangements can be made to video tape the television monitors, facilities for doing this are not located within the blockhouse, and a video tape does not exist of what the monitors showed during the fire period.

Propst viewed a motion picture of a test fire in a boilerplate Command Module taken in Houston, Texas, after the incident. He states that the film showing fire through the boilerplate hatches, at 16.4 pounds per square inch pure oxygen, were very close to what he viewed through the monitor. At one point in the film, bright white flames sweep across the hatch. Propst does not believe that this happened the night of the fire, though the quality of flickering light was similar to what he observed. It should be noted that in the boilerplate fire test, the vessel was vented at a different point than where rupture occurred on Spacecraft 012 during the night of the fire.

The report of fire was radioed to the fire station by G. C. Meyer, Pad Safety Officer. As the fire trucks approached the complex in response to Meyer's call, firemen looked at the top of the launch complex and saw very little smoke. Thinking that the area would be relatively clear, they did not take air packs with them, which were available on the truck. Later, after the smoke conditions were discovered by the firemen, the air packs were taken to the fire scene.

The total elapsed time from the report of fire to the opening of the inner hatch into the Command Module could not have exceeded five minutes, 27 seconds. This is based upon a timing of the tapes

made of voice transmissions during the incident. The timing is verified by a log matintained by W. H. Schick from within the Blockhouse. Schick's log is based upon reports he heard over the communications network. While the GMT timer he was using did not show "seconds" he was able to discern minutes and record them in his log. He shows the first report of fire as having been received at 6:31 p.m. and the first report that the hatches were off at 6:36 p.m. Since he did not have a "seconds" display he was unable to record the exact second the fire report was heard, nor the exact time of the report that the hatches were off.

None of the men working on the hatch removal believed the crew could have survived the fire. The heat was described as intense, the destruction considerable. Despite their belief that the crew was lost, and their knowledge of the hazard which existed because of the rocket motor above them on the Launch Escape System, they proceeded under almost impossible conditions to open the Command Module in a desperate effort the save the crew. That the hazard was real in their minds, is shown by the statement of one witness, that he considered jumping from the tower immediately after the Command Module erupted. He felt that death was imminent in any event. He, nevertheless, stayed at Level A-8 and worked in the "white room" to remove the hatches.

Curatolo, who had relieved Babbitt, was relieved by J. Murphy at 8:00 p.m. By then, all of the fires had been exinguished for some time.

Removal of the crew was to begin only after complete photographic coverage of the Command Module had been completed. The exact configuration of the Command Module, the position of its switches, and the evidence of what lights were burning, were considered to be important for further investigation.

By 2:00 a.m. Saturday morning, the crew had been removed from the Command Module.

REQUIREMENTS PLACED ON PANEL 12

From	Subject
1. Dr. Floyd Thompson, Board Chairman	Required memorandum regarding Baron and Parker reports.
2. Col. Charles F. Strang, Board Member	Requested information from witnesses on Levels A-7 and A-8 on whether they touched or caused movement of the Command Module or Service Module in the five-minute interval immediately preceeding the incident.
3. Mr. George C. White, Jr., Board Member	Requested a statement from LeRoy G. West (NAA) regarding placement of gas chromatograph plug.
4. Board Panel Coordination Committee	Requested copies of extracts of witness statement information be sent to the Committee members.
5. Board Panel Coordination Committee	Required Panel 12 to submit a status report to the Committee at the daily 5:00 p.m. meeting.
6. Board Panel Coordination Committee	Requested Interim Report on Panel activities.
7. Board and Panels 6, 8, 11, 14, 17, 18, and 19	Required copies of all published witness statements and extracts.
8. Dr. George E. Mueller, NASA Headquarters	Requested number of people located on Levels A-7 and A-8 of the Service Structure and on the Umbilical Tower at LC 34 at the time of the incident.
9. Panel 1	Requested statements from personnel involved in pre-crew ingress, crew ingress, cabin close-out, and cabin purge.
10. Panel 2	Requested a set of witness statements for temporary perusal.
11. Panel 3	Requested copies of Bendix Gas Analyses.
12. Panel 5	Required further statement from James F. Terry (NASA-KSC) regarding times in relation to indications of fire versus TV monitor image.
13. Panel 7	Requested information on documents that went into and out of Spacecraft 012 prior to hatch closure.
14. Panel 8	Required: (a) Information concerning astronaut placement of loose articles. (b) Interview of ingress and hatch close-out crew. (c) Interview of witnesses regarding knowledge of solvents used and or strange odors detected.

	(d) A list of personnel who visited Levels A-7 or A-8 on LC 34 for the 24-hour period prior to the incident. (e) Certain witnesses to participate in s niff test.
15. Panel 10	Requested statements regarding cabin relief valve operation, or times of explosive or popping noises during the first 15 to 20 seconds of the fire.
16. Panel 11	Requested: (a) A PAA Dispensary list including medication given to personnel involved in the incident. (b) All information regarding astronaut body positions.
17. Panel 13	Requested witness comments regarding emergency equipment.
18. Panel 14	Required: (a) List of all personnel who were on LC 34 from 5:30 p.m. EST to 7:30 p.m. EST on January 27, 1967. (b) Copies of statements made by Thomas R. Baron (self-employed), Donald O. Babbitt (NAA), James D. Gleaves (NAA), and Rocco A. Petrone (NASA-KSC). (c) Copies of any statement that comments on security or lack of security. (d) Copy of Arthur E. Vreeland (Federal Electric Corporation) statement.
19. Panel 16	Requested certain witnesses observe the TV simulation film to obtain witnesses reaction regarding clarity and detail of the simulation.
20. Panel 17	Requested Panels 3, 11, and 12 prepare a final "Time Line" from onset of T-10 minutes hold through medical determination of deaths.
21. Panel 18	Requested: (a) Certain primary witnesses view the Panel 16 TV simulation film and note any changes in, or verify, the witness observations and time correlations. (b) Interviews of Richard A. Hagar (NAA) and Richard L. Bachand (NAA) regarding movement of any article in the Spacecraft during crew removal.

REPORT OF PANEL 13
GROUND EMERGENCY PROVISIONS
APPENDIX D-13
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

GROUND EMERGENCY PROVISIONS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Ground Emergency Provisions Panel, 13. The task assigned for accomplishment by Panel 13 was prescribed as follows:

> This task involves an orderly review of planned ground emergency procedures relative to their adequacy, as well as a review to determine that emergency procedures, in fact, exist for all appropriate activities. This review should concentrate on activity at the launch site, and should include recommendations to the Board for changes in existing procedures and for the creation of new emergency procedures if deemed necessary.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Ground Emergency Provisio Panel:

Mr. G. F. Page, Chairman, Kennedy Space Center (KSC), NASA
Mr. L. A. Barnett, Kennedy Space Center (KSC), NASA
Mr. N. M. Carlson, Kennedy Space Center (KSC), NASA
Mr. J. H. Chappee, Manned Spacecraft Center (MSC), NASA
Mr. R. W. Cunningham, Manned Spacecraft Center (MSC), NASA
Mr. R. S. Sayers, Manned Spacecraft Center (MSC), NASA
Col. H. G. Russell, U. S. Air Force, Office of Manned Space Flight (OMSF), NASA
Mr. R. Rochester, North American Aviation (NAA), Downey, California
Mr. G. F. Smith, North American Aviation (NAA), Downey, California
Mr. K. C. Wishon, North American Aviation (NAA), Downey, California
Mr. H. H. Luetjen, Consultant, McDonnell Company, Kennedy Space Center (KSC)

2. COGNIZANT BOARD MEMBER

Colonel Frank Borman, U. S. Air Force, Board Member, Manned Spacecraft Center (MSC), NASA, was assigned to monitor the Ground Emergency Provisions Panel.

C. PROCEEDINGS

1. The Panel approached the assigned task in two phases. First, a review and evaluation of the emergency provisions at the time of the accident. This review included investigations of:

a. The emergency procedures in the published documents;
b. The emergency equipment internal and external to the spacecraft;
c. The emergency training of the flight crew and checkout test team personnel.

The second phase was a review of the existing methods used to identify hazards and insure adequate documentation of appropriate safety procedures and applicable emergency instructions in the operational test procedures.

2. PUBLISHED EMERGENCY PROCEDURES

a. The Apollo Crew Abbreviated Checklist (Reference 13-1) was prepared by the contractor under the direction of the Manned Spacecraft Center (MSC) Flight Crew Support Division. The document includes flight crew emergency procedures for:

(1) Fire or smoke in the cockpit in flight; and,
(2) Pad egress from T-30 minutes to lift-off.

The in-flight fire or smoke procedures considered in (1) above are not appropriate for the situation involving internal fire during ground operations. (Reference report by Panel 20.) The unaided Command Module (C M) egress instructions provided in (2) above were applicable for

actions required by the crew to effect egress from the C/M for any reason. A minor change to the unaided crew procedure was documented during the course of a briefing given to the AS-204 Flight Crew by members of the Apollo Emergency Egress Working Group (Enclosure 13-1) on January 23, 1967. This change reflected an agreement to maintain suit oxygen flow and crew communications until the hatches were removed.

b. The Apollo Operations Handbook (AOH) (Reference 13-2) is prepared by the contractor under the direction of MSC and contains flight crew emergency procedures similar to those described above in paragraph a. In practice, the emergency procedures developed and documented in the abbreviated crew checklist are subsequently included in the AOH so that ground control personnel are made aware of the crew actions to be followed in the event of an emergency.

c. The Apollo Flight Crew Hazardous Egress Procedures Manual (Reference 13-3) is prepared by the Emergency Egress Working Group of the Apollo Launch Operations Committee (Enclosure 13-2). This manual is the definitive document concerning spacecraft and pad egress procedures and represents the combined efforts of Kennedy Space Center (KSC), MSC, and the Air Force Eastern Test Range (AFETR). The scope of this document is limited to cover only the terminal 30 minutes of a launch countdown or countdown demonstration. The procedures defined concern only the actions involved in unaided, aided, or incapacitated crew egress during that time period. Actions required to cope with the contingencies which could require crew egress are specifically excluded.

The procedures in this manual which define flight crew actions involved in unaided egress agree with those documented in the Crew Checklist and the AOH. The time line on Page 25 (Enclosure 13-3) of the egress manual indicates 60 seconds are required for the flight crew to open the spacecraft hatches and egress once the cabin pressure is vented. Practice runs under ideal conditions involving non-flight spacecraft configurations indicate that estimate to be correct. (A practice run involving a fully suited flight crew, venting cabin pressure, removing the three flight configuration hatches and egressing the spacecraft has never been performed.) Although there are no documented data available, the portion of the unaided egress time (60 seconds) involved in hatch removal by the flight crew is considered to be 40 to 50 seconds.

Incapacitated flight crew egress procedures defined in the egress manual are intended for use by the trained members of the Pad Egress Team. The time lines on Pages 26 and 27 of the manual (Enclosure 13-4) indicate 10 minutes is required from initiation of the operation to completion of crew removal. However, the portion of that time required to remove all three hatches from the outside is 70 seconds, assuming cabin pressure is already vented. Numerous practice runs by Pad egress personnel have verified that time to be correct under ideal conditions.

At the time of the AS-204 accident, the trained Pad Egress Team was not on station at Launch Complex 34. Their presence during the Space Vehicle Plugs Out Integrated Test had not been required since the operation was not previously identified as hazardous. However, the entire egress team was due on station following completion of the test in support of an unaided egress practice operation.

d. The spacecraft checkout procedure for the AS-204 Space Vehicle Plugs Out Integrated Test was OCP FO-K-0021-1 (Reference 13-4). This document, like all spacecraft test documents at KSC, was prepared by the contractor and approved by NASA-KSC-Spacecraft Operations (SCO). The document did not contain emergency procedures other than two pages of instructions for emergency shutdown of spacecraft direct current (DC) and alternating current (AC) power. The safety requirements included in the Operational Checkout Procedure (OCP) do not designate any portion of the test procedure as hazardous. (Enclosure 13-5).

The test objectives listed for the procedure include:

(1) To verify overall Spacecraft Launch Vehicle (SC/LV) compatibility and demonstrate proper function of Spacecraft (S/C) systems with all umbilicals and Ground Support Equipment (GSE) disconnected.

(2) To verify no electrical interference at time of umbilical disconnect.

(3) To verify astronaut emergency egress procedures (unaided egress).

Objective (3) required suited crew operations in a closed cabin with a pressurized 100 percent oxygen atmosphere. This was the first time this third objective was combined with a Space Vehicle Plugs Out Integrated Test.

e. The Launch Vehicle Checkout Procedure being used for the AS-204 Space Vehicle Plugs Out Integrated Test was I-20015-SA204 (Reference 13-5) prepared by Chrysler (CCSD) and approved by NASA-KSC-Launch Vehicle Operations (LVO). This document contains emergency procedures (Section AW) which provide instructions for recycling the Launch Vehicle following a cutoff or a hold at any point in the final 30 minutes of the count. No reference is made to any hazardous operations being involved in the LV portion of the test other than standard safety procedures for handling LV ordnance items.

f. The only other published procedure involved in the AS-204 Space Vehicle Plugs Out Integrated Test was the Integrated Space Vehicle Procedure I-41001-204 (Reference 13-6) prepared and approved by NASA-KSC-Launch Operations Directorate (DLO). This document was used by the NASA-KSC Test Supervisor to coordinate LV-to-S/C interface activities and all off-site real-time support functions. The procedure does not contain any emergency procedures.

g. Published emergency procedures are of limited value to a flight crew in the presence of an extremely time critical emergency. In such instances, they must resort to those procedures committed to memory or instinctive action. Such procedures are developed by the crews as a result of intimate knowledge of the written procedures coupled with a real-time awareness of spacecraft configuration.

For time critical egress from the C/M, the flight crew would have eliminated all unnecessary steps from the documented procedures. Reaction would have been by reflex to the following minimum escape procedures:

(1) Initiate cabin pressure dump
(2) Unfasten restraint harnesses
(3) Release inner hatch dogs
(4) Wait for pressure decay
(5) Remove inner hatch
(6) Release and push out ablative hatch and boost protective cover
(7) Disconnect umbilicals and cobra cables
(8) Exit spacecraft

Post-accident investigation (Reference Panel 11 report) indicates that the AS-204 flight crew accomplished very little, if any, of the above minimum procedures before being incapacitated by the fire.

3. EMERGENCY EQUIPMENT INSIDE THE COMMAND MODULE

a. Spacecraft Cabin Depressurization Equipment:

As established in paragraph 2.g., the initial requirement for S/C egress is cabin depressurization. The Apollo Block I spacecraft incorporates no provisions for emergency cabin depressurization. Three depressurization methods are possible from within the cabin:

(1) The normal and documented method of cabin depressurization requires activation of one of the cabin relief valves. It has an effective venting area of 1.5 square inches and would accomplish venting from 16.4 pounds per square inch absolute (psia) to 14.8 psia in approximately 18 seconds (Enclosure 13-6, Figure 4).

(2) Activation of the post-landing cabin vent fans would also initiate cabin depressurization. This method, designed for use after water impact, opens two sliding valves in the tunnel area, each of which has an effective opening of 19.5 square inches. The specification limit for operation of these valves is 0.75 pounds per square inch differential (psid), although they have been demonstrated to 5 psid. There are no available data to indicate time of venting through these valves into the closed forward deck area (prelaunch configuration). Venting by this method was not included in the documented emergency egress procedures

(3) As a last resort, emergency depressurization could be accomplished by breaking one of the cabin windows. This method has never been demonstrated and there are no data indicating the

venting time involved.

There is no indication that the AS-204 flight crew was able to initiate cabin depressurization following the outbreak of the fire. In the presence of the rapidly increasing cabin pressure which resulted from the fire, activation of the normal vent would have had no noticable effect.

b. Quick Release Crew Restraint Harness:

Each crewman is provided with an individual restraint harness. The harness assembly consists of two shoulder straps and one lap belt. The shoulder straps and lap belt are connected together by means of a three-point locking/release mechanism attached to one side of the lap belt. Release of both the shoulder straps and the lap belt is accomplished by pulling a release lever located on the top of the lap belt buckle.

c. Internal Spacecraft Hatch Release Equipment:

The main hatch assembly provides the only means of crew egress on the pad. The hatch assembly consists of three separate covers or hatches (Enclosure 13-7). The inner hatch serves as a spacecraft structural load carrying member and crew compartment pressure seal. It has an effective area of 1200 square inches. The ablative (middle) hatch provides thermal protection for entry. Over this fits the boost protective cover (outer) hatch. Removal of all three hatches was essential for crew egress. Removal of the inner hatch requires rotation of a wrench counter-clockwise through approximately 220 degrees to release six latch assemblies located on the bottom edge (outer side) of the hatch (Enclosure 13-8). A prerequisite to inner hatch removal is the lowering of cabin pressure to approximately ambient. A crewman may then lift the inner hatch (approximately 55 pounds) up and in for stowage in the spacecraft.

The Boost Protective Cover (BPC) is released by the crewman striking a push-type plunger which extends through the middle hatch and is attached to the BPC. The middle hatch is then released by pulling on a cable arrangement. Both middle and outer hatches may then be pushed out of the egress path permitting crew egress.

d. Flight Crew Protective Clothing:

The protective clothing worn by the AS-204 crew at the time of the fire were Pressure Garment Assemblies (PGA) (P/N A 1936). They were essentially the same as the non-Extravehicular Activity (EVA) suits used on Gemini missions. The suit is fabricated of an outer layer of HT-1 nylon, a nylon webbing layer, a neoprene inner-pressure vessel, and a nylon comfort liner. Each crewman also wore a cotton constant wear garment (P/N A 1912-003) under the spacesuit.

Tests conducted at MSC in late 1965 (Enclosure 13-9) using six-inch-square swatches of similar suit material indicate its fire protective qualities. The swatches were tested in a 100% oxygen, 14 psia environment for high temperature flame impingement effect.

Samples were exposed to the pure oxygen environment following two evacuation periods at a pressure of 5 millimeters of mercury (mmHg) to allow out-gassing. A 30-minute soak at 14 psia, 100% oxygen was then made. At the end of this soak, a propane flame was then brought into contact with the swatches. The results were:

(1) No scorching occurred in three seconds.

(2) Burning occurred after five seconds flame exposure.

e. On-Board Communications:

Reliable and clear communications are a significant requirement in support of any emergency operation. The status of the communications system therefore requires consideration. In addition to an on-board intercom system there are two Radio Frequency (RF) systems for voice transmission from crew-to-ground personnel during pad testing. These two systems are the Very High Frequency (VHF) and S-band. A single hardline communication line using the on-board intercom system is also available. Voice transmission by the crew-to-ground support and test personnel is controlled by the switch configuration on the three individual crew communications center panels, panel 20 on the main display console, and the individual cobra cable switches. Voice distribution between the ground personnel and crew is controlled through the capsule communicator's console located in the Launch Complex 34 Blockhouse.

On the afternoon of the accident, the test had been plagued with communication difficulties. Communications had been sometimes good, generally poor, and occasionally intermittent. At the time of the accident, the spacecraft test personnel thought that the communications problems had been "worked around". Voice quality was still poor, however, and it was subsequently discovered that the Command Pilot's communications were continuously keyed. Post-accident inspection disclosed discrepancies between all three communications panels with respect to positions of the VHF and intercom switches.

f. On-Board Fire Fighting Equipment:

There were no provisions for extinguishing a fire within the spacecraft at the time of the accident. This statement is based on the on-board crew stowage list in effect for the AS-204 Space Vehicle Plugs Out Integrated Test. No procedures existed at the time of the fire for on-board fire fighting by the crew.

g. On-Board Fire Detection Equipment:

The primary means of fire detection available to the crew were the physiological cues of smell, sight and touch. With helmet visors closed (as was the case) they were limited to sight and touch only. No instrumentation other than normal spacecraft systems instruments were available for fire warning. Depending upon the source of ignition, the normal spacecraft systems instrumentation could indicate a hazardous condition such as excessive electrical current flow. However, the normal instruments apparently did not provide any warning to the crew in the case of this accident.

4. EMERGENCY EQUIPMENT EXTERNAL TO THE SPACECRAFT:

a. Fixed Facility Fire Extinguishing Equipment:

Launch Complex 34 is supplied by two separate water systems, Potable Water and Industrial Water. The potable water supplies the safety showers, eye baths, and two 1¼ inch diameter 50-foot reel hose lines on each of the spacecraft work levels. This system was operable during the emergency.

The Firex Water System (deluge) supplies industrial water to four spray nozzles on each spacecraft level. Local push-button controls are at all exits to the elevators. However, these controls were not operable during the time of the accident because the system was being modified and had not been functionally tested as a complete system. Had water deluge been necessary on the Command Module level, two valves on the Service Module level (A-7) would have had to be manually operated. There is no remote (from the blockhouse) activation capability for this system.

On the Service Module (S/M), a Gaseous Nitrogen (GN_2) Deluge System is used to inert the S/M in the event of Hydrogen leakage during or after Liquid Hydrogen (LH_2) servicing. The GN_2 system was not active for the Space Vehicle Plugs Out Integrated Test since LH_2 servicing activities were not involved.

b. Portable Fire Fighting Equipment at the S/C Work Levels:

The Pan American Aviation (PAA) Fire Department inventory calls for two 50-pound wheel Carbon Dioxide (CO_2) units and two 15-pound hand-held CO_2 units on each S/C work level. The latest Fire Department inspection of these units was not within the 30-day inspection schedule. (Enclosure 13-10). Under full flow conditions (outlet valve wide open), all of the above units have a specification flow time of 10 to 35 seconds.

An inventory following the accident shows that two 50-pound wheeled CO_2 units, sixteen 15-pound CO_2 units and one 30-pound dry powder unit were expended on the C/M fire. Two 15-pound CO_2 units were used on the Service Module. The additional units were carried to the S/C levels to aid in extinguishing the fire.

c. Auxiliary Breathing Apparatus:

There were 80 masks available at the S/C work levels at the time of the accident. The masks were packed in sealed boxes (20 masks to a box) located as follows: One box on the lower S/M work level (A-6); two boxes on the C/M work level (A-8); and one box on the S/M work level (A-7). Of the available masks, 76 were Mine Safety Appliance (MSA) Rocket Propellant Fuel

Handler's Gas Masks incorporating M-15A1 type canisters. These canisters are designed for use in the presence of toxic vapors and are not suitable for use in high smoke density situations. The remaining four masks were Wilson masks containing LG-6-RTGD canisters which include smoke filters as well as toxic vapor protection.

Witness statements (Reference report by Panel 12) indicate that the dense smoke concentration in the White Room was a major deterrent to the rescue effort. Investigation indicates that 15 of the MSA masks and 3 of the Wilson masks had been used in the rescue attempt.

d. Protective Clothing:

The test in progress was not classified as hazardous; therefore, no special protective clothing was required to be available. S/C technicians on station were clothed in the normal white coveralls or smocks over street clothes.

e. External Hatch Removal Equipment:

No special emergency provisions were available for rapid cabin depressurization and hatch removal from the outside. Tools normally used for installing and removing the hatches were in the hatch close-out kit along with 34 other associated items. This kit was located in the White Room to the left of the access arm entry door A special heavy duty hatch removal tool had been developed by the Emergency Egress Working Group for use by the Pad Egress Team. It is more rugged and easier to use than the standard tool and is normally available in the White Room only during launch countdown or countdown demonstration when the Pad Egress Team is on station; therefore, it was not there at the time of the AS-204 accident.

Cabin depressurization, if required from outside the S/C, can be accomplished by removing the plug from the inner hatch purge fitting. Venting is then accomplished through an effective opening of 0.378 square inches. Figure 3 of Enclosure 13-6 indicates that 80 seconds would be required to vent by this method from 16.4 psia to a pressure that would allow inner-hatch removal. An alternate venting method of breaking the inner-hatch window had been approved for use in Pad Egress Team operations, if required.

f. Ventilation Equipment for Smoke Removal:

There is no ventilation equipment in the White Room that would remove smoke. Filtered conditioned air is supplied to the White Room from the facility conditioning air plant. There are two exhaust ventilating fans on the C/M work level. These were operating during the time of the accident. Two exhaust fans were being installed on the lower S/M level, (A-6) but at the time of the accident, they were not operable. There are no exhaust fans on the upper S/M level (A-7) for the removal of smoke.

g. Test Team Personnel Evacuation Equipment:

There are two means of access or escape; elevators and stairs. There are five elevators and two stairways from ground level to Level 9 (one level above S/C level). The stairways are located on the outer structure, one on the North side and one on the South side. There is also one inner-structure stairway from Level 9 to Level A-6 where it is possible to reach the South outer-structure stairway. On other S/C levels, there is not direct access to the outer-structure stairways.

There are five doorways to the inner-structure on the C/M and S/M levels. All doors are equipped with inside panic bars and open out. For security reasons, all doors except one were locked from outside (could be opened from the inside but not from outside). However, the only means of escape from any of the elevator bridges, if the elevator is not available, is to re-enter the inner-structures. A personnel hazard resulted during the subject accident when one member of the test team was locked out and reached a stairway by climbing out across structural members. The access arm door which must be used for ingress or egress to the umbilical tower is an inward (toward the White Room) swing door. It has a pull latch on the inside and a push button latch on the outside.

h. Communication Equipment:

Communications to the S/C levels are provided by four standard black phones, operational intercom (OIS), hard lines and the public address (PA) system. The OIS hard lines provide for

communications to the blockhouse, support building, necessary NAA and NASA trailers, control center, and crew members on board the spacecraft.

The PA system is controlled from the blockhouse and any OIS station can be patched in for transmitting PA announcements. For this test, the Test Supervisor's console was the only transmitting station patched in.

i. Emergency Lighting:

There are no fixed or portable emergency battery lights on the S/C work levels or in the White Room. The only auxiliary lighting available during the emergency was a limited number of personal flashlights.

j. Stand-by Emergency Equipment at Launch Complex 34:

Due to the non-hazardous classification of the S/C test operation, there were no medical or fire equipment or personnel on standby at the Launch Complex in support of the operation. AFETR disaster team and fire fighting equipment arrived at the Launch Complex within five minutes of the first indication of the emergency. The first firemen to arrive at the spacecraft were not equipped with self-contained breathing apparatus. One fireman had to return to the bottom of the gantry to obtain suitable equipment.

k. Complex 34 Egress Facilities:

The facilities for flight crew egress at Complex 34 include the Apollo Access Arm and Enviromental Enclosure (White Room) as depicted on Enclosure 13-11. During post-accident investigation, the following undesirable features of these facilities were noted:

(1) The fiberglass ledge at opening between the White Room (W/R) and S/C makes egress difficult.

(2) A low step in the W/R leading to the S/C entry hatch is a tripping hazard.

(3) The combination hinged and sliding door normal exit from the W/R is very difficult to operate.

(4) Two steps along the access arm (one at the pivot point and one at the W/R entrance door) could cause a fully suited crewman to trip.

(5) The access arm entry door at the juncture of the work level is hinged inward and incorporates no means for emergency escape.

5. FLIGHT CREW EMERGENCY TRAINING:

a. AS-204 primary crew spacecraft egress training was conducted in the mockup building at NAA-Downey, utilizing Block 2 mockup on July 13, 1966. The mockup was equipped with flight type couches, restraint system, and pressure and ablative hatches. A White Room adapter mockup similar to the one on Launch Complex 34 was used. The training included a 30-minute lecture on procedures and equipment and an examination of the hatches and latching mechanisms. Following crew ingress, the hatches were installed and a total of four practice egress runs were performed in street clothes. Several improvements to the egress procedures were made as a result of this session.

b. Further crew training specifically for purposes of effecting spacecraft egress was conducted at the Manned Spacecraft Center and in the Gulf of Mexico as a part of water egress training. A total of four egress exercises were conducted as a part of this training. Pressure Garment Assemblies were worn by the crew in all of the egress runs. The boilerplate vehicle used was in a near-flight configuration with all significant geometry, couches, and pressure and ablative hatches installed. The boost protective cover was not used. Its use would be inappropriate for water egress.

c. On January 24, 1967, the Emergency Egress Working Group of the Apollo Launch Operations Committee briefed the AS-204 flight crew for approximately two hours. As a result of this briefing, several minor changes were made to the procedures in order to make them more compatible with pad egress requirements (Reference Paragraph C.2.a.).

The egress exercise to be conducted at the end of the Space Vehicle Plugs Out Integrated Test on January 27, 1967, was to be the most valid run-through of the procedure up to that time. It was to be the first egress demonstration with the actual spacecraft in prelaunch configuration and with full flight equipment utilized by the crew.

6. CHECKOUT TEST TEAM EMERGENCY TRAINING:

a. The spacecraft test team personnel most closely associated with emergency operations involved in the AS-204 accident were the technicians at the spacecraft. They were responsible for external removal of the spacecraft hatches under normal circumstances. The NAA personnel primarily assigned this function were the Pad Leader (who has the responsibility for all technicians working on or around the spacecraft), the mechanical engineer, and his two assigned mechanical technicians. None of the NAA personnel on duty at the time of the accident had ever been given training in hatch removal operations under emergency conditions. Hatch technicians on station at the time of the accident had all performed hatch installation and removal operations under normal conditions on numerous occasions and were familiar with the procedures involved.

b. The NASA-KSC Test Supervisor stationed in the firing room of the blockhouse has overall test team responsibility during test operations on Launch Complex 34. Detailed spacecraft test functions are delegated by the Test Supervisor to the S/C Test Conductor also stationed in the firing room. The Test supervisor and S/C Test Conductor on duty at the time of the AS-204 accident were both experienced in hazardous egress practice operations. They had both participated in similar egress operations on numerous manned Gemini and Mercury operations. The Test Supervisor had conducted the only previous Launch Complex 34 hazardous egress exercise on Apollo which was performed during the AS-202 Countdown Demonstration Test in August 1966.

c. There is no record of any type of emergency training exercises pertinent to general launch pad hazardous operations having been conducted on Launch Complex 34. Personnel assigned to pyrotechnic, hypergolic, and cryogenic handling operations do receive specific training in the hazards involved in those activities. However, there are no regular emergency drills to insure that all pad personnel are familiar with the location and use of the available emergency equipment.

7. INVESTIGATION OF THE METHODS PRESENTLY USED TO IDENTIFY HAZARDS AND DOCUMENT EMERGENCY PROCEDURES:

a. Spacecraft ground test operations at KSC are primarily documented in Operational Checkout Procedures (OCP) prepared by the contractor and approved by NASA-KSC-SCO personnel. Special non-repetitive type test operations are documented on Test Preparation Sheets (TPS) which are originated by contractor system engineers and also approved by KSC-SCO. The process by which test requirements from MSC are transferred into specific OCP's is defined in detail in the Panel 7 report. The following discussions are confined to the hazard identification and emergency procedure provisions of that process.

b. Primarily, the documented instructions for determining hazardous and emergency procedures for S/C test documents are contained in the Apollo Pre-Flight Operations Procedure (APOP). As defined in APOP G-100 (Enclosure 13-12), this document is the instrument by which joint contractor / NASA management directives are documented, approved and levied upon the S/C operations conducted at KSC. APOP 0-202 (Enclosure 13-13) is the pertinent directive concerning the generation of test procedures and the associated safety considerations. The KSC document defining the overall safety program at KSC is Kennedy Management Instruction (KMI) 1710.1 (Reference 13-7) which includes general guidelines concerning the generation and approval of hazardous test documents. A third documented source of instructions concerning this subject is a NAA internal directive (Enclosure 13-14).

c. Review of these three sources reveals a certain amount of specific instructions, but very little in the form of an overall plan for insuring adequate safety considerations and emergency procedures in the test documents. In actual practice, those features of the S/C OCP's are developed as defined in the following paragraphs.

d. The Test Outline (Reference Panel 7 Report) for each spacecraft defines, in outline form, all of the tests planned for that vehicle at KSC. The Contractor Safety Office reviews the outline and establishes a list of the operations considered hazardous. The criteria for determination of the hazardous tests is based upon guidelines established in Reference 13-7. The list of hazardous OCP's and all of the test outlines are reviewed by the KSC and AFETR Safety Offices. They, in turn, release a letter establishing the official KSC and AFETR Safety Review Requirements List designating the OCP's for that S/C which must be reviewed and approved by those offices.

e. OCP's are prepared by contractor operations support personnel in conjunction with contractor system engineers. The OCP writer, or originator, is responsible for including all references to safety, hazardous situations and emergency instructions. The instructions defining the scope of this responsibility are completely general and in many instances vague. As a result, the specific test procedures reflect a lack of definitive instructions in these areas.

f. Copies of the draft release of procedures identified as hazardous are reviewed by the Contractor Safety Office and the systems engineers. Significant comments or inputs from the Contractor Safety Office are incorporated in the master-draft copy which is then approved by KSC-SCO, and published as the released document.

g. Copies of released test procedures are forwarded to the KSC Safety Office. Those procedures specified on the list created in paragraph 7.d require review and approval by KSC Safety. Procedures involving hazardous operations at AFETR are forwarded by KSC Safety to AFETR Safety for comments and approval. Approval by KSC Safety is made in writing to the contractor after AFETR Safety has signified their formal approval. Receipt of formal KSC Safety Office approval (after the procedure is released) is a constraint upon initiating the test operation involved.

h. Revisions to procedures originally reviewed by the KSC Safety Office require the same review and approval as the basic document. The AFETR Safety Office must also approve revisions to procedures which will be conducted under their jurisdiction. Real-time deviations required during the performance of a test procedure are orally approved by the responsible on-site Safety Supervisor to the NASA Test Conductor.

i. There is no formal review requirement in the area of S/C safety or emergency procedures between KSC and MSC. As described in Panel 7's report, the existing procedure review system between the two Centers is loosely defined. There is no approval requirement from the MSC Flight Crew Operations Directorate on those procedures involving flight crew participation.

j. TPS's as defined in paragraph 7.a do not presently require review or approval by either Contractor or KSC Safety Offices. The TPS originator is responsible for determining safety or emergency considerations and for soliciting Safety Office review.

D. FINDINGS AND DETERMINATIONS

1. FINDING

The applicable test documents and flight crew procedures for the AS-204 Space Vehicle Plugs Out Integrated Test did not include safety considerations, emergency procedures or emergency equipment requirements relative to the possibility of an internal spacecraft fire during the operation.

DETERMINATION

The absence of any significant emergency preplanning indicates that the test configuration (pressurized 100 percent oxygen cabin atmosphere) was not classified as a potentially hazardous operation.

2. FINDING

There are no documented safety instructions or emergency procedures in existence which are applicable to the possibility of a serious internal spacecraft fire.

DETERMINATION

The occurrence of an internal spacecraft fire of the magnitude and intensity experienced in this accident was not considered to be a significant possibility under any operational circumstances.

3. FINDING

The propagation rate of the fire involved in the AS-204 accident was extremely rapid (Reference report by Panel 5). Removal of the three spacecraft hatches to effect emergency egress from either the inside or outside involved a minimum of 40 and 70 seconds respectively under ideal conditions.

DETERMINATION

Considering the rapidity of propagation of the fire and the time constraints imposed by the existing

spacecraft hatch configuration, it is doubtful that any amount of emergency preparation would have precluded injury to the crew prior to crew egress.

4. FINDING

Procedures for unaided egress from the spacecraft were documented and available. The AS-204 flight crew had participated in a total of eight egress exercises employing those procedures.

DETERMINATION

The AS-204 flight crew was familiar with and well trained in the documented emergency crew procedures for effecting unaided egress from the spacecraft.

5. FINDING

The Apollo Flight Crew Hazardous Egress Procedures Manual contains procedures relative to unaided, aided and incapacitated flight crew egress. By scope and definition, this document is concerned only with evacuation of the flight crew from the spacecraft and the pad under hazardous conditions occurring primarily external to the spacecraft during a launch operation.

DETERMINATION

The Apollo Flight Crew Hazardous Egress Procedures Manual does not contain adequate emergency provisions for significant emergency conditions internal to the spacecraft any time the crew is on board.

6. FINDING

The spacecraft pad work team on duty at the time of the accident had not been given emergency training drills for combating fires in or around the spacecraft or for emergency crew egress. They were trained and equipped only for a normal hatch removal operation.

DETERMINATION

The spacecraft pad work team was not properly trained or equipped to effect an efficient rescue operation under the conditions resulting from the fire.

7. FINDING

There was no equipment on board the spacecraft designed to detect or extinguish a cabin fire.

DETERMINATION

The flight crew had to rely upon physiological cues to detect the presence of a fire. When all face masks were closed, the cues were limited to sight and touch. Once detected, there were no means by which the fire could have been contained or extinguished.

8. FINDING

Frequent interruptions and failures had been experienced in the overall communications system during the operations preceding the accident. At the time the accident occurred, the status of the system was still under assessment.

DETERMINATION

The status of the overall communication system was marginal for the support of a normal operation. It cannot be assessed as adequate in the presence of an emergency condition.

9. FINDING

Emergency equipment provided at the spacecraft work levels consisted of portable CO_2 fire extinguishers, Rocket Propellant Fuel Handler's Gas Masks and 1-1/4-inch diameter fire hoses.

DETERMINATION

The existing emergency equipment was not adequate to cope with the conditions of the fire. Suitable breathing apparatus, additional portable CO_2 fire extinguishers, direct personnel evacuation routes

and smoke removal ventilation are significant items which would have improved the reaction capability of the personnel involved.

10. FINDING

There are steps and doorways on the Launch Complex 34 Apollo Access Arm and in the environmental enclosure (White Room) which consitute safety hazards, particularly under emergency conditions.

DETERMINATION

The present configuration of the access arm and White Room is not compatible with emergency personnel evacuation requirements or with fast, safe flight crew egress.

11. FINDING

During the preparation of S/C test procedures at KSC, safety considerations for hazardous operations and documentation of applicable emergency procedures are limited in most cases to routine safety reference notations and emergency power-down instructions.

DETERMINATION

Insufficient emphasis is applied by the test procedure originator upon documenting emergency procedures and identifying specific hazards and applicable safety requirements.

12. FINDING

Under the existing method of test procedure processing at KSC, the cognizant Safety Offices review only those procedures which are noted in the OCP outline as involving hazards. Official approval by KSC and AFETR Safety is accomplished after the procedure is published and released.

DETERMINATION

The scope of contractor and KSC Safety Office participation in test procedure development is loosely defined and poorly documented. Post-procedure-release approval by the KSC Safety Office does not insure positive and timely coordination of all safety considerations.

13. FINDING

Criteria for defining hazardous test operations are not complete.

DETERMINATION

A positive method does not exist for insuring identification and documentation of all possible hazards involved in test operations.

14. FINDING

Requirements for the review and concurrence of KSC S/C test procedures by MSC are not well defined.

DETERMINATION

The present review system does not insure that MSC concurs with released KSC test procedures.

E. SUPPORTING DATA

Enclosure

13-1 Memo dated Nov. 19, 1965, containing minutes of the First Apollo Emergency Egress Working Group Meeting and a copy of the Charter of that group.

13-2 KSC KMI 1150.8 dated Oct. 11, 1966, defining the Charter of the Apollo Launch Operations Committee.

13-3 Time line for unaided flight crew egress. Page 25 of the Apollo Flight Crew Hazardous Egress Procedures Manual.

13-4 Time line for aided and incapacitated flight crew egress. Pages 26 and 27 of the Apollo Flight Crew Hazardous Egress Procedures Manual.

13-5 Page 0-8 of OCP FO-K-0021-1 showing documented safety instructions for the AS-204 Space Vehicle Plugs Out Integrated Test.

13-6 BELLCOM, INC. report concerning C/M depressurization during terminal countdown. Case 330, dated Jan. 20, 1967.

13-7 Figure 1-4 of Apollo Operations Handbook (AOH) showing spacecraft hatch arrangement viewed from the outside.

13-8 Drawing of spacecraft inner hatch showing emergency handle, viewed from inside.

13-9 MSC memo dated Jan. 26, 1965, concerning the results of Gemini suit flammability test.

13-10 Memo dated Mar. 8, 1967, concerning inspection of the fire extinguishers used at the time of the AS-204 incident.

13-11 Drawing of Apollo Access Arm and environmental chamber. Page B-10 of the Apollo Flight Crew Hazardous Egress Procedures Manual.

13-12 Definition of the Apollo Preflight Operations Procedures APOP G-100, dated Nov. 4,1966.

13-13 Instructions for processing test procedures APOP 0-202, dated May 13, 1966.

13-14 NAA Florida Facility Implementing Instruction, II 12-5, dated Jan. 27, 1966, titled, Safety Criteria for Apollo C/M and S/M and S II Operations.

13-15 List of reference documents

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27

5010-107

UNITED STATES GOVERNMENT

Memorandum

TO : Distribution

DATE: November 19, 1965
Memo No. SC033-65-214

FROM : Chairman, Apollo Emergency Egress Working Group

SUBJECT: Minutes of the First Apollo Emergency Egress Working Group Meeting

1. The first meeting of the Apollo Emergency Egress Working Group was held at Kennedy Space Center (KSC) on 18 November 1965. The charter was read and approved and a copy has been enclosed. Per Section 3 of the charter, each member organization is requested to furnish the chairman the names of a primary member and an alternate.

2. The following action items were given to the Working Group and were discussed:

a. A discussion was centered on the access arm and environment room mock-up procurement, and the design of a mock-up with flight weight equipment. It was decided that a suited-astronaut-run with flight type equipment would be mandatory to obtain adequate time motion studies to develop the operational procedures. An action item was placed on the Apollo Launch Operations Panel (ALOP) Emergency Egress Sub-panel through Frank W. Horn to have a suitable mock-up review as soon as possible for both the Block I and Block II versions.

b. It was also decided that air packs are needed in the environment controlled room on the access arm for each crew member and should be in place for launch. Safety showers are needed at level A on the LUT (Complex 39); a survey will be made by Norris Gray of SOP-22 to determine the need for additional showers.

c. ALOP asked this Working Group to decide on placement of the pyro bus arm switch, elevator control, and access arm controls. To properly place the switches and controls it will be necessary to define the relationship between the Launch Director, Test Supervisor, and Test Conductor. The KSC Test Conductor Office has been assigned this as an action item to report on by December 15, 1965.

d. The manning of the emergency armored vehicles was discussed with the three (3) M113's each being manned by a Pan American Airways Pad Safety Supervisor, two (2) PAA firemen, and two (2) DOD medical technicians. The M59 armored fire fighting vehicle manning will be determined by Norris Gray and the rescue personnel.

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ENCLOSURE 13-1

3. Cleanliness requirement was discussed by L. Miller of Bellcom and an air lock or other cleanliness requirement changes to the access arm may be made. Any changes to the access arm will be reviewed by this group to determine the emergency egress impact.

4. There is a need to define what criteria is to be used for determining hazardous and emergency conditions. This will be discussed at the next meeting.

5. The next meeting will be held after the mock-up review discussed above..

S. T. Beddingfield
Chairman

Distribution:

MSC

CF-24/R. S. Sayers
CB-7/C. C. Williams
FL/R. R. Kirby
FL/Walt Jadeland

NAA

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KSC

SOP-22/N. C. Gray
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SCO-5/G. F. Page
LVO/E. Fannin
EDV-15/R. T. Moore, Jr.
EDV-2/J. H. Deese
SCO-8/G. T. Sasseen
SCO/J. J. Williams
LDO/G. M. Preston
LDO/P. C. Donnelly

PAA

Pad Safety, Mail Unit 5260, Elmer Brooks

AFETR

ETORS-1/Capt. C. D. Parker

OMSF

MSS/MAS (Bellcom)/L. G. Miller
MO-1/C. H. Bolender

List of Attendees:

Lewis G. Miller, MAS (Bellcom)
Ryborn R. Kirby, FL/MSC Houston
Capt. C. D. Parker, ETORS-1, PAFB
F. J. Powell, NAA/Cape
Ralph Wilson, SOP-21
F. W. Horn, PPR-71
N. C. Gray, SOP-22
W. F. Williams, PAA Pad Safety
C. C. Williams, MSC/CB
S. T. Beddingfield, SCO-33

CHARTER

APOLLO EMERGENCY EGRESS WORKING GROUP

1. Purpose.

The Apollo Emergency Egress working group is established by the Apollo Launch Operations Committee to develop and integrate spacecraft crewman egress procedures for the pad areas of the Saturn Apollo Operations.

2. Function.

The Working Group will be the direct link between the Apollo Launch Operations Panel and the various organizations performing special activities in the egress-rescue area.

The Working Group will recognize existing organizations, provide guidelines, make recommendations, and formulate procedures as necessary to coordinate and integrate all elements of the egress operation.

3. The formal membership of the Working Group consists of the following:

NASA KSC-SCO Chairman
NASA MSC - APO
NASA - MSC - FCSD
NASA - MSC Landing Recovery Division
NAA - NAA-21
NASA - KSC LVO
AFETR - ETORS-1 - PAFB
PAA - Pad Safety
NASA - MSF/MAS (BELLCOMM)
NASA - LSEED
NASA - LVO

One permanent member and one alternate member will be designated by each member organization and will represent their organization in all Working Group functions.

4. Meetings will be held as necessary to accomplish the function of the Working Group. Authority for calling meetings rest with the chairman.

Reports: Minutes of all Working Group Meetings will be provided by chairman for distribution to members and the chairman of the Apollo Launch Operations Committee.

P. C. Donnelly

S. T. Beddingfield

TRANSMITTAL SHEET

TO	
"H"	October 11, 19[illegible]

MATERIAL TRANSMITTED

KMI 1150.8, "Apollo Launch Operations Committee"

This is a new Instruction.

FILING INSTRUCTIONS

File in a standard 3-ring binder in numerical sequence, in accordance with the alphabetic prefix which identifies the type of issuance.

KMI 1150.8

October 11, 1965
Effective Date

JOHN F. KENNEDY SPACE CENTER, NASA
MANAGEMENT INSTRUCTION

SUBJECT : APOLLO LAUNCH OPERATIONS COMMITTEE

1. PURPOSE

This Instruction incorporates into the KSC Issuance System as Attachment A the charter establishing the Apollo Launch Operations Committee.

Simon J. Burttschell
Chief, Administrative Services Office

Attachment:
A. Charter--Apollo Launch Operations Committee

Distribution "H"

ATTACHMENT A to
KMI 1150.8

CHARTER

APOLLO LAUNCH OPERATIONS COMMITTEE

1. PURPOSE

This charter establishes an Apollo Launch Operations Committee at KSC and assigns certain responsibilities and authorities to it. The ALOC is a NASA-Contractor Management Team responsible to the Director, Launch Operations.

2. OBJECTIVES & RESPONSIBILITIES

The objective of the Apollo Launch Operations Committee (ALOC) is to provide the KSC, Launch Operations Directorate, a management tool for assuring coordination of Apollo prelaunch/launch interorganizational operational activities at the Kennedy Space Center. The primary responsibilities of the ALOC are to:

a. Serve as a point of input into the Launch Operations Directorate for Apollo prelaunch/launch operational problems which affect the working interfaces between the various elements in the total launch team.

b. Develop problem definitions, propose solutions, and forward to the cognizant KSC organizations for decision and/or action.

c. Receive reports, status information, and recommended solutions on problem areas from supporting working groups and operational organizations.

d. Serve as a policy reviewing group; providing guidance and policy advice for assuring coordination and effective solution to problem areas.

e. Serve as a mechanism for the Director of Launch Operations to implement management policy that has been established by the Center Director of a prelaunch/launch operational nature, and

f. Provide input to the Space Vehicle Planning & Supervision Office such that Launch Operation Plans, Space Vehicle Test Sequences, and Space Vehicle Test Catalogues may be developed in compliance with the test requirements.

ATTACHMENT A to
KMI 1150.8

3. CHAIRMAN

The Chairman of the Apollo Launch Operations Committee will be the Director, Launch Operations or his designated representative.

4. ORGANIZATION

The Apollo Launch Operations Committee will be supported by two management subcommittees, Saturn IB and Saturn V.

5. MEMBERSHIP

Membership on the Apollo Launch Operations Committee will consist of representatives from appropriate management elements of KSC, other NASA elements and interfacing organizations. A list of members of the Apollo Launch Operations Committee and the industry representatives of the Saturn IB and Saturn V subcommittee is as follows:

APOLLO LAUNCH OPERATIONS COMMITTEE MEMBERSHIP

Chairman Director, Launch Operations
Space Vehicle Test Supervisor
Saturn IB Operations Manager
Saturn V Operations Manager
Technical Planning & Scheduling Office
Apollo Spacecraft Operations Manager
LEM Spacecraft Operations Manager
Chief Spacecraft Test Conductor
Representative, Assistant Director for Information Systems, KSC
Representative, Assistant Director for Support Operations, KSC
Representative, Director, Plans, Programs, & Resources, KSC
Representative, Apollo Spacecraft Program Office, MSC
Representative, Saturn Industrial Operations, MSFC
Representative, Assistant Director for Flight Operations, MSC
Representative, Assistant Director for Flight Crew Operations, MSC
Representative, NASA Hdqts. Apollo Flight Operations
Representative, Apollo Support Planning Office, DOD
Representative, Assistant Director for Administration
Recorder

SATURN IB SUBCOMMITTEE INDUSTRY REPRESENTATIVES

Representative - Chrysler
Representative - Douglas

Representative - North American (Spacecraft)
Representative - Grumman
Representative - IBM (IU)

SATURN V SUBCOMMITTEE INDUSTRY REPRESENTATIVES

Representative - Douglas
Representative - North American (Spacecraft)
Representative - Grumman
Representative - Boeing
Representative - North American (Launch Vehicle)
Representative - IBM (IU)
Representative - Bendix

Attendance at the subcommittee meetings will be based on the agenda of each meeting and could possibly include, in addition to the attendance of appropriate members of the ALOC, and the above assigned industry representatives, additional representatives from industry and the government at the discretion and invitation of the subcommittee chairman.

6. MEETINGS

The Apollo Launch Operations Committee will have periodic meetings which will be called by the Chairman as necessary. Normally, meetings will be held on a bi-weekly basis.

a. Agenda

Agendas will be provided to all members of Apollo Launch Operations Committee by the Chairman prior to each meeting.

b. Minutes

Minutes of Apollo Launch Operations Committee meetings will be taken by an Apollo Launch Operations Committee recorder provided by the Chairman. Minutes of Apollo Launch Operations Committee meetings will be made available to all members.

7. RELATIONSHIP TO KSC ORGANIZATIONAL ELEMENTS

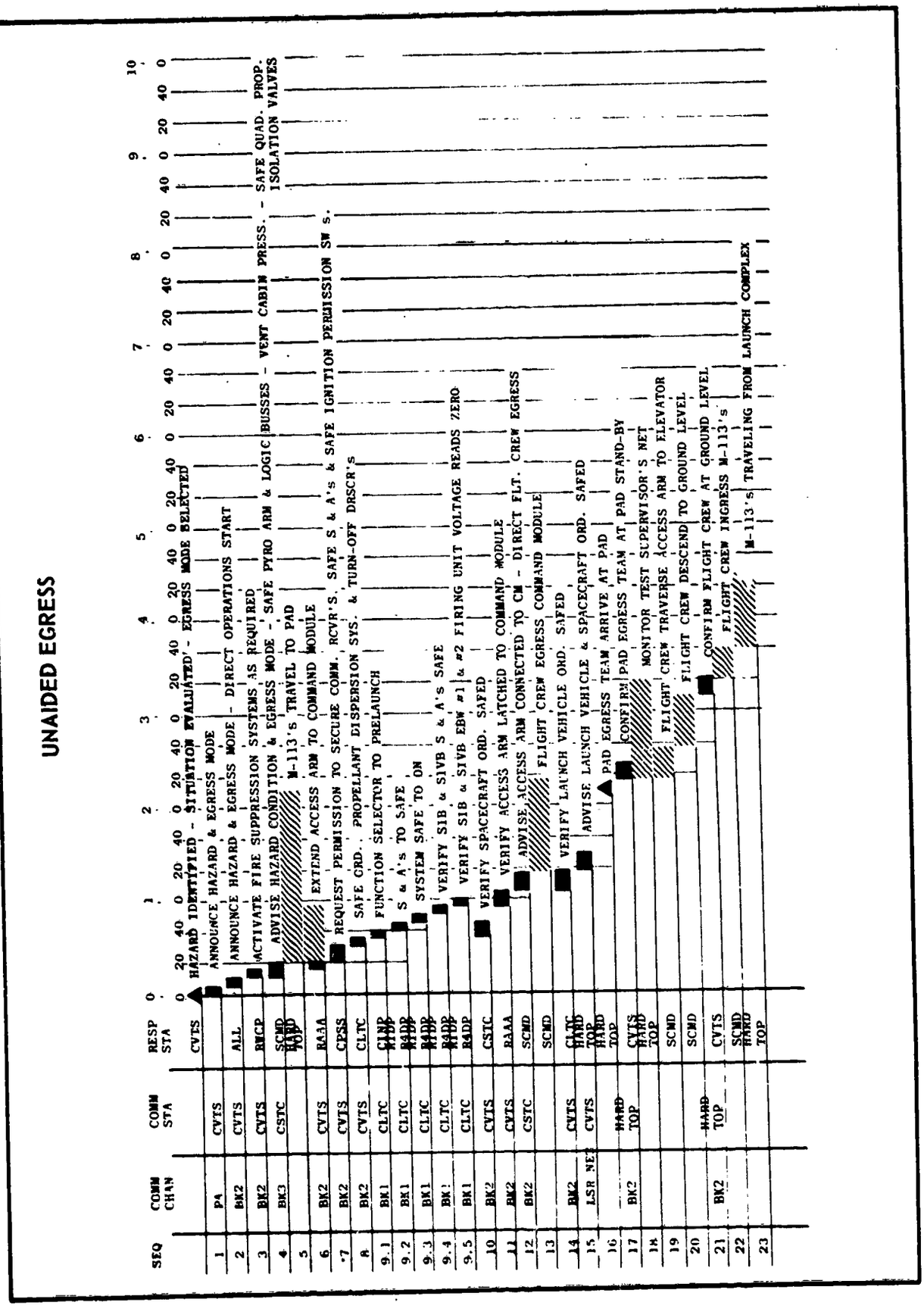
The creation of the Apollo Launch Operations Committee does not change in any respect the responsibilities of KSC organizational

elements as currently assigned. The Committee Chairman, therefore, shall assure that the Committee conducts its activities with full regard for the assigned functions of other elements of the Kennedy Space Center.

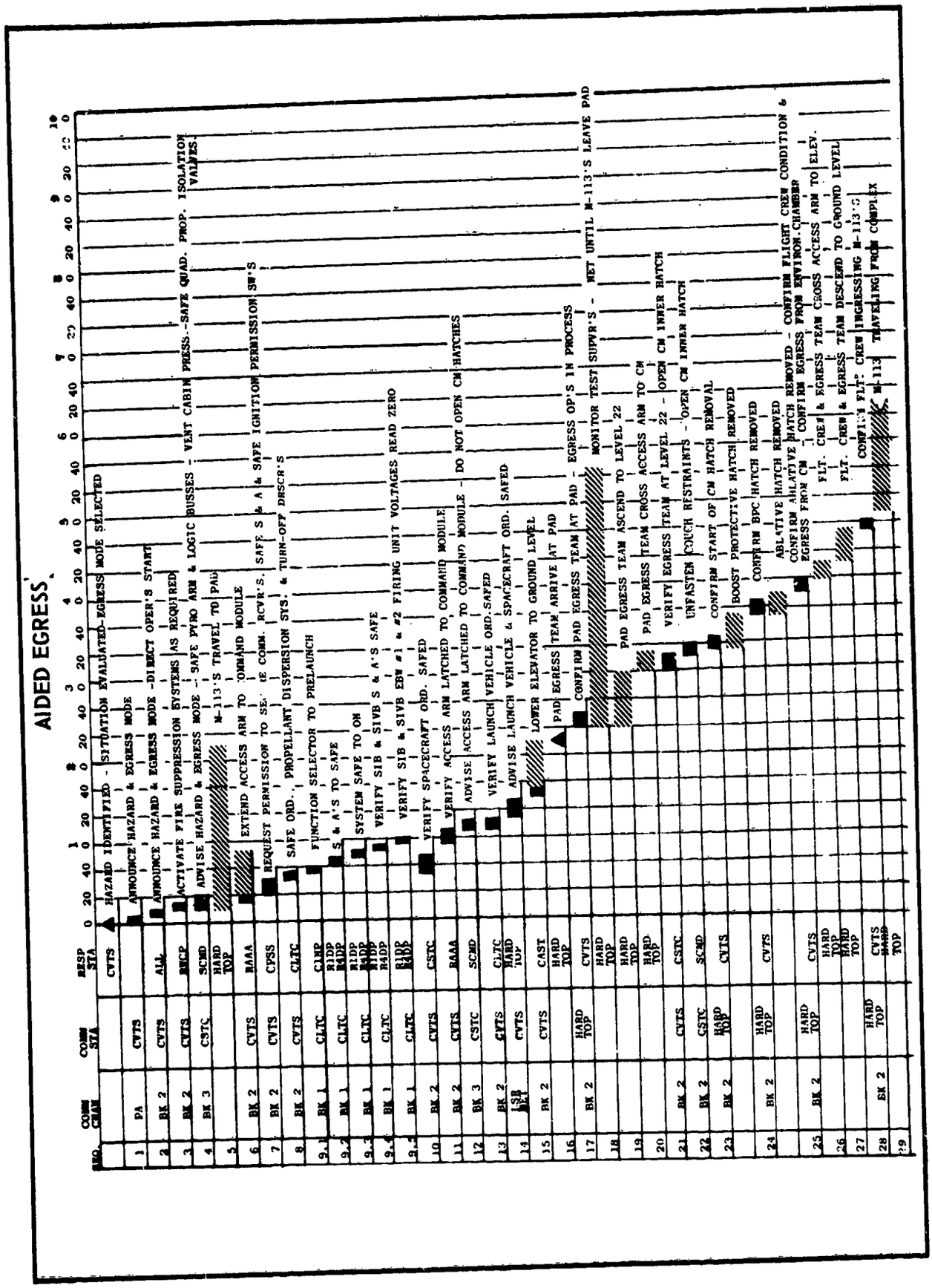
The Apollo Launch Operations Committee will consider items assigned by the Director of Launch Operations and report its findings to him.

APPROVED:

Kurt H. Debus
Director, Launch Operations



ENCLOSURE 13-3



ENCLOSURE 13-4

INCAPACITATED FLT. CREW EGRESS

1 THRU 24 SAME AS AIDED FLIGHT CREW EGRESS

SEQ	COMM CHAN	COMM STA	RESP STA	
25	BK2	CVTS	CSTC	VERIFY CABIN PRESS. OK TO REMOVE INNER HATCH
26	BK2	HARD TOP	CVTS	CONFIRM ABLATIVE HATCH REMOVED - VERIFY CABIN PRESSURE OK
				INNER PRESSURE HATCH REMOVED
27	BK2	HARD TOP	CVTS	CONFIRM INNER HATCH REMOVED/CONFIRM PYRO ARM & LOGIC BUSS & QUAD. PROP. ISOL. VALVES SAFED. CONFIRM FLIGHT CREW CONDITION & REMOVAL STARTED
				CENTER ASTRO. REMOVED FROM CM
28	BK2	HARD TOP	CVTS	CONFIRM 1ST ASTRO REMOVED FROM CM
				1ST ASTRO CARRIED TO ELEV.
29	BK2	HARD TOP	CVTS	CONFIRM 1ST ASTRO DESCENDING TO GND. LEVEL
				1ST ASTRO DESCENDING TO GND. LEVEL
30	BK2	HARD TOP		CONFIRM 1ST ASTRO AT GND. LEVEL
31			HARDTOP	SEND ELEVATOR TO LEVEL 22
32	BK2	HARD TOP	CVTS	CONFIRM 1ST M-113 LEAVING PAD AREA WITH 1ST ASTRO
				2ND ASTRO REMOVED FROM CM
33	BK2	HARD TOP	CVTS	CONFIRM 2ND ASTRO REMOVED FROM CM
				2ND ASTRO CARRIED TO ELEVATOR
34	BK2	HARD TOP	CVTS	CONFIRM 2ND ASTRO CARRIED TO ELEVATOR
				2ND ASTRO DESCENDING TO GND
35	BK2	HARD TOP	CVTS	CONFIRM 2ND ASTRO AT GND
36			HARD TOP	SEND ELEVATOR TO LEVEL 22
37	BK2	HARD TOP	CVTS	CONFIRM 2ND M-113 LEAVING PAD AREA WITH 2ND ASTRO
				3RD ASTRO REMOVED FROM CM
38	BK2	HARD TOP	CVTS	CONFIRM 3RD ASTRO REMOVED FROM CM
				PAD EGRESS TEAM & 3RD ASTRO CROSS ACCESS ARM
39			HARD TOP	PAD EGRESS TEAM & 3RD ASTRO DESCEND
40	BK2	HARD TOP	CVTS	CONFIRM PAD EGRESS TEAM AND 3RD ASTRO LEAVING PAD
41			HARD TOP	LAST M-113's LEAVES PAD AREA

5.0 SAFETY REQUIREMENTS

5.1 SUPERVISION IS RESPONSIBLE FOR PROVIDING COMPLIANCE WITH ALL NASA/NAA APPLICABLE SAFETY RULES AND REGULATIONS.

5.2 THE TEST CONDUCTOR SHALL COORDINATE DEVIATIONS FROM ACCEPTED SAFETY STANDARDS, WITH NAA AND NASA SAFETY REPRESENTATIVES.

5.3 ALL PERSONNEL WILL BECOME FAMILIAR WITH THE FOLLOWING DOCUMENTS:

A. AFETRM 127-1 RANGE SAFETY MANUAL

B. APPLICABLE SAFETY STANDARD AND SAFETY SUPPORT PLAN.

C. AFETR PAD SAFETY PLAN FOR LC34

D. SOP FOR LC34

E. KSC GENERAL SAFETY PLAN KMI-1710.1 ATTACHMENT-A

5.4 ALL PERSONNEL WILL BECOME FAMILIAR WITH THE EMERGENCY SHUTDOWN PROCEDURE.

5.5 THE EMERGENCY PROCEDURE SHALL BE UNFOLDED AND REMAIN VISIBLE THROUGHOUT THE TEST.

5.6 PERSONNEL INVOLVED IN TESTING WILL BE INFORMED OF THE SPECIFIC HAZARDS OF EACH TEST.

5.7 INSTALLED PYROS SHORTED PER OCP'S K-2016 AND 4617.

BELLCOMM, INC.

SUBJECT: Final Report: Command Module Depressurization During Terminal Countdown – Case 330

DATE: January 20, 1967

FROM: L. G. Miller

ABSTRACT

For some time, there has been concern about the time required to effect on-pad depressurization of the CM sufficient to permit hatch opening. Because of their specific interest in astronaut pad egress under hazardous conditions, the Emergency Egress Working Group of ALOC had instituted an action item to define the scope of the problem. In connection with this effort, a previous memorandum recommended that the times associated with cabin venting under various conditions be determined experimentally. Such a test was recently performed and is reported herein.

To verify experimental findings, an analytical solution was attempted. A computer program was developed which simulates CM depressurization both in flight and on the ground. The program is described and compared with one being prepared by NAA. Results are presented in a form which should aid preplanning for on-pad contingencies, and future application of the program is briefly described.

The combination of experimental and analytical findings was sufficient to close the action item.

MEMORANDUM FOR FILE

INTRODUCTION

In a previous memorandum[1] it was concluded that the times associated with cabin venting under various conditions should be verified experimentally in order to facilitate planning for on-pad contingencies during final countdown. If the experiments had shown that excessive time was required to vent the cabin using the cabin pressure relief valve, it was proposed that specific methods of improving performance be explored. These consisted of (1) using the post landing ventilation system, (2) using the purge fitting on the side pressure hatch, and (3) determining the time required to open the side pressure hatch under a number of overpressure conditions.

A cabin venting test was subsequently performed at MSC and is described herein. Although little data was obtained, it was sufficient to establish the order of magnitude of the time required to vent the CM cabin. To extend this knowledge, attention was focused on the mathematical basis for predicting depressurization times. In order to make use of this theory, it was necessary to employ a digital computer. Therefore, a FORTRAN IV computer program which theoretically calculates CM depressurization times under various conditions was developed by the writer and Miss P. A. Cavedo of Department 2013. The program, named DEPRES, is described and compared with a similar program prepared at North American Aviation.

---

[1] "Command Module Pressurization During Terminal Countdown - Current Status," Case 330, by L. G. Miller, Bellcomm Memorandum for File, dated October 14, 1966.

DEPRESSURIZATION TEST ON S/C 008

A test, in which the CM cabin was partially depressurized via the cabin pressure relief valve, was performed in conjunction with the S/C 008 Thermal Vacuum (T/V) Test #3 at MSC. At an initial cabin pressure of 5 psig (vacuum chamber pressure = Opsig), a valve which simulates a ½ inch diameter micrometeoroid puncture was opened. Cabin pressure decreased to 3 psig in 80 seconds at which time the micrometeoroid valve was closed. The cabin pressure relief valve was then placed in its "manual dump" position, and the cabin pressure fell from 3 psig to 0 psig in 20 seconds. Pressure was reported to have been measured with a large diameter (approximately 25-30 inches) pressure gage having a scale of from zero to 15 psig.

SIGNIFICANCE OF TEST RESULTS

Flight crew hazardous egress procedures require that the CM cabin be vented as soon as the egress decision has been announced. Since (1) NAA has indicated that it is quite unlikely that the CM cabin pressure will be in excess of 2 psig after CM closeout and (2) it takes approximately 40 seconds for the CM Access Arm to extend and attach to the LES tower, the time reported in the T/V test is considered to be compatible with egress requirements for aided and unaided egress during the period following spacecraft closeout. This leaves two cases unresolved.

The first case is for "Incapacitated Flight Crew." In order for difficulties to arise, all three crewmen would have to be incapacitated[2]. In this unlikely case, any cabin overpressure would have to be vented through a purge fitting on the inner side crew hatch (i.e. the side pressure hatch).

The second case, which could occur prior to spacecraft closeout, is the possibility of a hazardous condition during the CM cabin leak check. Cabin pressure could be as high as 6.2 psig, and depressurization times using either the cabin pressure relief valve or the purge fitting would be of interest.

The lack of data for the two cases cited above prompted an investigation of the theoretical basis for predicting depressurization times. If the available data could be duplicated, the formula would then be used to predict depressurization times for the remaining cases. The iterative nature of the calculation called for the use of a digital computer in performing the work. Hence, DEPRES came into being. The mathematical theory behind this FORTRAN IV program and the program itself are described in Appendix A.

USE OF THE DEPRES PROGRAM

An early version of DEPRES[3] was used to simulate CM depressurization on the launch pad from overpressures of 3.00 and 6.20 psig. The results, plotted in terms of absolute pressure, are shown in Figures 1 and 2 for three different values of orifice coefficient. Since

[2]Ordinarily, the crewman in the left hand couch would open the cabin pressure relief valve. It is possible, though, that the other crewmen could reach over or crawl over and perform the task.

[3]See Appendix B.

the area is a constant in the iteration formula, varying K corresponds with varying the effective are of the orifice used for depressurization (cf. Appendix A where effective area is defined as the product KA). Figure 1 shows the data point obtained during the #3 T/V test. Both figures show the value predicted by a conservative method of calculation contained in a Bellcomm Memorandum for File[4] by T. A. Bottomley.

Information obtained from NAA specifies an effective area for the cabin pressure relief valve of 1.5 sq. in. in the manual dump mode. Hence, for the cases shown in Figure 1, the data point should fall between the curves for K = .7 and K = .8. Considering the asymptotic nature of the curves, agreement is quite good. If we extend this level of confidence to the curves of Figure 2, it can be seen that depressurization from an overpressure of 6.2 psia should take about 28 seconds, a time which is quite reasonable with respect to egress requirements.

A round of discussions followed which probed the need for a computer program with broader capabilities. Interest was expressed in acquiring the in-house (i.e. Bellcomm) capability for calculating depressurization times in flight; this called for a program which could duplicate the response of the Environmental Control System (ECS) to both intentional and unintentional cabin depressurizations. A number of other refinements were also considered. The subsequent changes are described in Appendix A, and the program itself will be found in Appendix C.

This refined version of DEPRES, without the ECS option, was used to compute on-pad depressurization times with an area corresponding to that of the purge fitting on the inner side crew hatch. Overpressures ranging from 6.2 to 0.3 psi were used, the results being shown in Figure 3. The curve represents time required to depressurize to 0.1 psig from various values of cabin overpressure. The data is most useful for planning purposes when presented in this form. A companion curve, representing depressurization through the cabin pressure relief valve, is shown in Figure 4.

COMPARISON WITH NAA PROGRAM

Having developed what appeared to be a useful tool for studying depressurization problems, a number of telephone contacts were made at both MSC and NAA in order to determine if the DEPRES program could be profitably applied by those organizations. Some encouragement was offered by ECS personnel from both groups, and a conference was arranged. Thus, the writer had the opportunity to examine and discuss an NAA computer program which, it was learned, has been developed during the past year or so. It differs from DEPRES in two major respects. First, it simulates repressurization of the CM and pressurization of the LM as well as CM depressurization. Secondly, the effects of upstream pressures and temperatures are considered in determining ECS flow rates. This latter difference gives a slightly conservative flavor to DEPRES results when the ECS is used to maintain cabin pressures.

Although a direct comparison of results was not possible, one set of data was examined which seemed to be quite close to the conditions used for a DEPRES run. For a final pres-

[4] "CSM Depressurization Considerations for Astronaut Pad Abort," Case 330, by T. A. Bottomley, Jr., Bellcomm Memorandum for File, dated March 29, 1966.

sure of 0.1 psia, DEPRES predicted a depressurization time of 1864 seconds with the ECS on whereas the NAA program predicted 1780 seconds. Results for an intentional cabin depressurization, with no attempt to maintain cabin pressure through the use of the ECS, showed very close agreement. The times required to reach 0.1 psia differed by no more than a few seconds.

The two advantages that DEPRES possesses are its clarity and the ease with which changes can be accomplished. The NAA program has been developed and modified by several different engineers and is not yet officially documented. This, when added to the multiple-purpose nature of the NAA program, makes it somewhat more difficult to see what is going on. The fault could be remedied, just as DEPRES could be changed to give it a repressurization capability.

It seems unlikely, though, that NAA will make use of the DEPRES format since it lacks the degree of sophistication which their program contains. Given a continuing need for the calculations, it seems more probable that they will devote some effort toward improving their own program.

It is of interest to note that NAA also has a boost and reentry program for CM pressure. A brief look indicated that it has the same advantages and disadvantages as the pressurization-depressurization program. That is, it is available, fairly sophisticated, but hard to follow.

CONCLUSIONS

Study of on-pad depressurization times for the CM came about as an adjunct to the writer's activities with the Emergency Egress Working Group of the Apollo Launch Operations Committee. As a result of the MSC data and subsequent work with the DEPRES program, it was recommended that an EEWG action item on the subject be closed. This memorandum will serve, in part, as a final report to the Chairman of the EEWG in support of the closure. In addition, Figures 3 and 4 should serve as an adequate planning tool for determining depressurization times under various, non-standard conditions. For a given cabin pressure, they will yield a good estimate of the time required to open the side pressure hatch using either the cabin pressure relief valve or the purge fitting on the hatch.

Further work with DEPRES is planned in support of an investigation of ECS capabilities. Depressurization times will be developed as a function of micrometeoroid puncture size, and impacts on emergency in-flight procedures will be sought.

2032-LGM-gmp

S L. G. Miller

Attachments
Appendixes A-D

Copy to Messrs. F. B. Benjamin – NASA MM
C. H. Bolender – NASA MO-1
L. E. Day – NASA MAT
J. K. Holcomb – NASA MAO
C. Bidgood
D. R. Hagner
J. J. Hibbert
W. C. Hittinger

T. A. Keegan – NASA/MA-2

S. T. Beddingfield – KSC/KB-4
F. W. Horn – KSC/DK
C. A. Turner – KSC/HC/GE
J. C. Wootton – KSC/DB

R. J. Gillen – MSC/EC9
C. M. Jones – MSC/FL
R. D. Langley – MSC/ES
J. P. Loftus – MSC/PM5
F. H. Samonski, Jr. – MSC/EC9
R. S. Sayers – MSC/CF-24
C. C. Williams – MSC/CB-7

B. T. Howard
P. R. Knaff
J. Z. Menard
I. D. Nehama
T. L. Powers
I. M. Ross
T. H. Thompson
G. B. Troussoff
R. L. Wagner
Department 1023
Department 2032
Central Files
Library

APPENDIX A

THEORY OF DEPRESSURIZATION CALCULATIONS

The mass flow of a compressible fluid through an outlet from a reservoir is given by

$$Q = KA \sqrt{2g \left[\frac{\gamma}{\gamma+1}\right] P_1 \rho_1 \left[\left[\frac{P_2}{P_1}\right]^{\exp\left[\frac{2}{\gamma}\right]} - \left[\frac{P_2}{P_1}\right]^{\exp\left[\frac{\gamma+1}{\gamma}\right]}\right]}$$

where

K	=	orifice coefficient
A	=	area of the outlet
g	=	acceleration of gravity
P_1	=	pressure of the fluid in the reservoir
ρ_1	=	density of the fluid in the reservoir
P_2	=	pressure of fluid outside the reservoir
γ		ratio of specific heats of fluid

Putting

$$C \sqrt{2g \left[\frac{\gamma}{\gamma+1}\right]}$$

$$\frac{P_2}{P_1}$$

and

$$m = \epsilon \exp\left[\frac{2}{\gamma}\right] - \epsilon \exp\left[\frac{\gamma+1}{\gamma}\right]$$

we have

$$Q = KAC\sqrt{P_1 \rho_1 m} \quad --$$

and the ratio, ϵ determines the character of the flow. If

$$\epsilon \leq \epsilon^* = \left[\frac{2}{\gamma+1}\right] \exp\left[\frac{\gamma}{\gamma-1}\right]$$

the velocity of the fluid through the orifice is equal to the velocity of sound, and m is constant and equal to

$$m^* = \epsilon^* \exp\left[\frac{2}{\gamma}\right] - \epsilon^* \exp\left[\frac{\gamma+1}{\gamma}\right]$$

Then, the mass flow depends only upon the parameters of the fluid and of the reservoir. (Dimensional units for this Appendix will be found in Appendix D.)

THE DEPRES PROGRAM

An early version of the DEPRES program is contained in Appendix B. Basically, the program assumes that an outlet of area A is opened at time equal to zero. The CM cabin has a volume of V and is initially at pressure P and temperature T. A 100% oxygen atmosphere is assumed, whence the values for R and GAM (i.e. γ). PO is the pressure of the fluid outside the cabin, and G is the acceleration of gravity. A final value for density of the fluid in the cabin (RHOF), corresponding to a cabin pressure of 14.8 psia for the present case, is used to determine when the calculation should end.

When the computer is instructed to execute the program, an initial value of fluid density in the cabin (RHO) is calculated. If RHO is less than or equal to RHOF, the value of N (i.e. elapsed time in tenths of a second), RHO and P are printed. If not, a mass flow rate (QN) through the outlet is computed, and a new value of RHO is obtained, assuming that the flow rate holds constant for a time interval (DLT) of .1 second[5]. RHO is then tested again and iterations continue until the termination criteria is met. N, RHO and P are printed every second.

---

[5]Use of a .01 second time interval did not affect results significantly.

Appendix C contains a more recent version of DEPRES. While the basic iterative process is the same, a number of refinements have been added. These are listed as follows:

1. The constant orifice coefficient was replaced by K = .85 – .22 EPSLON (i.e. .22ϵ), this being a linear approximation of Shapiro's curve* for the variation of orifice coefficient with pressure ratio.

2. A program path was created which approximates the behavior of the Environmental Control System. It includes a cabin pressure regulator with a flow rate (CPREG) which increases, linearly, from zero to full flow between pressures P_1 and P_2 and is turned off at P_5. An emergency inflow regulator, with flow rate EIREG, opens in a similar fashion between P_3 and P_4 and stays on until pressure P_6 is reached. The Environmental Control System can be shut off at any pressure by setting a variable named PSTOP. TOTAL is the maximum flow rate from the Service Module Regulator. It is used to replenish the amount of oxygen (OTANK) in the surge tank when EIREG is on. If the quantity OTANK falls below a certain amount (EMPTY), then the total flow from the Environmental Control System (QP) equals TOTAL, assuming that the system has not previously been shut off. Losses due to normal cabin leakage (QLEAK) and metabolic usage (QMETA) are also considered.

3. A test was included to see if the value of EPSLON is such that sonic flow exists in the orifice. If sonic flow exists, m (i.e. M in the program) assumes a constant value, corresponding to m^6, in the calculation of QN.

4. A variable (IECS) was included to specify whether the Environmental Control System is turned on (=1) or off (=0). When IECS = 1, values for QP, OTANK and QN are printed at time intervals of one second.

The net result of these refinements is to give DEPRES the capability of simulating conditions not only on the launch pad but in outer space as well. There is a large amount of flexibility built into the program. The values of both constants and variables can be changed quickly and easily.

---

[6] Ascher H. Shapiro, "The Dynamics and Thermodynamics of Compressible Fluid Flow," Volume I. The Ronald Press Company, New York, 1953, page 100.

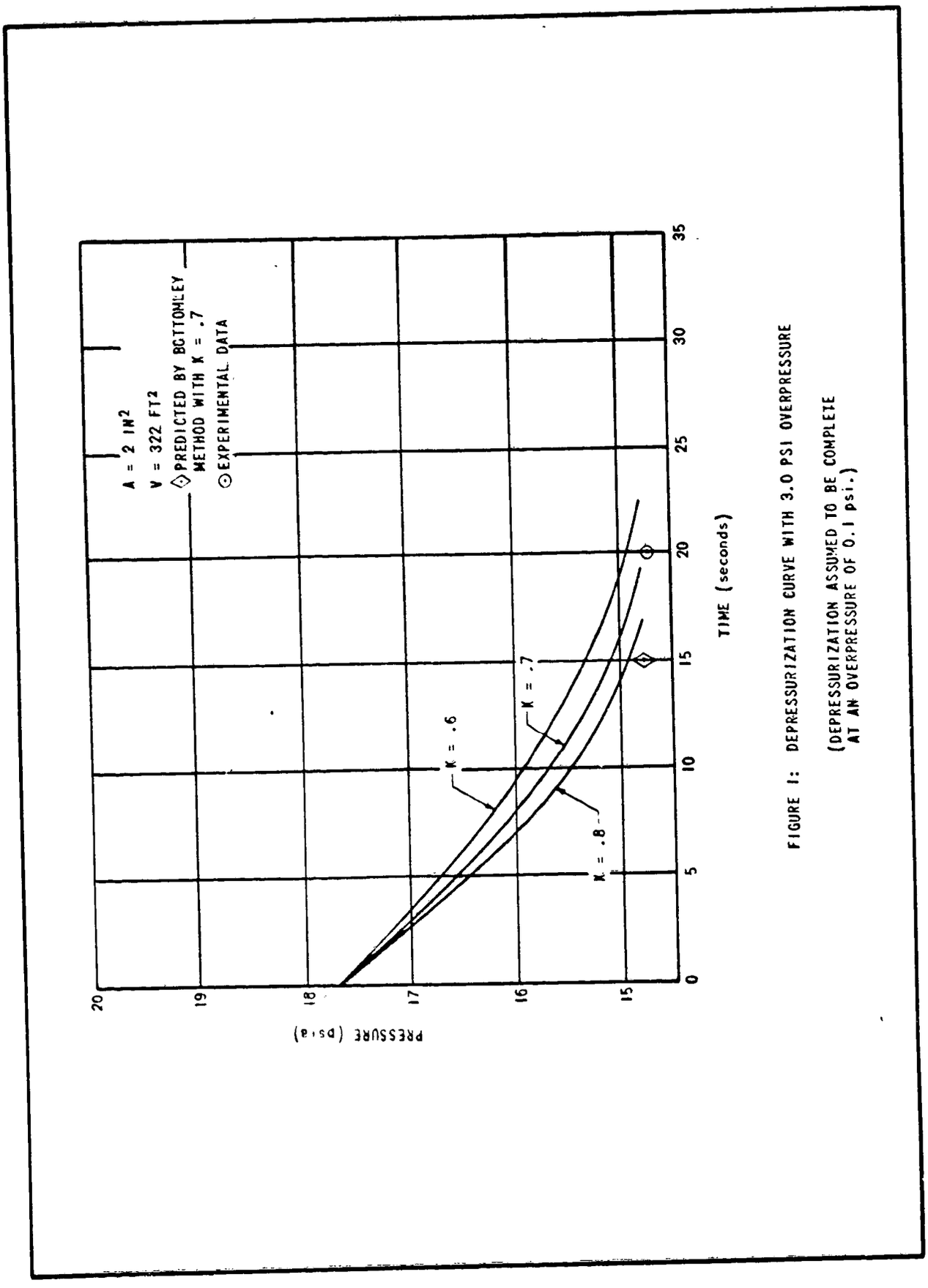


FIGURE 1: DEPRESSURIZATION CURVE WITH 3.0 PSI OVERPRESSURE

(DEPRESSURIZATION ASSUMED TO BE COMPLETE AT AN OVERPRESSURE OF 0.1 psi.)

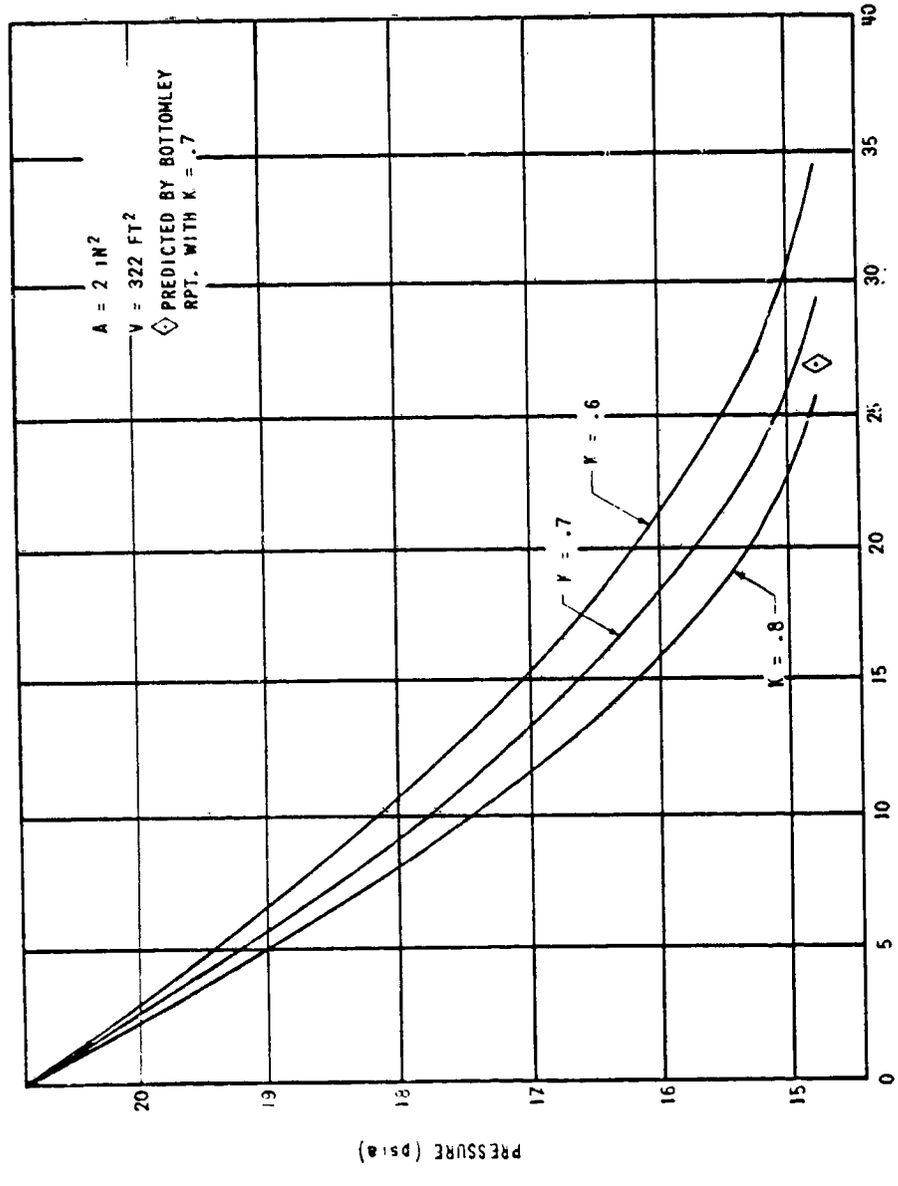


FIGURE 2: DEPRESSURIZATION CURVE WITH 6.2 PSI OVERPRESSURE

(DEPRESSURIZATION ASSUMED TO BE COMPLETE AT AN OVERPRESSURE OF 0.1 psi.)

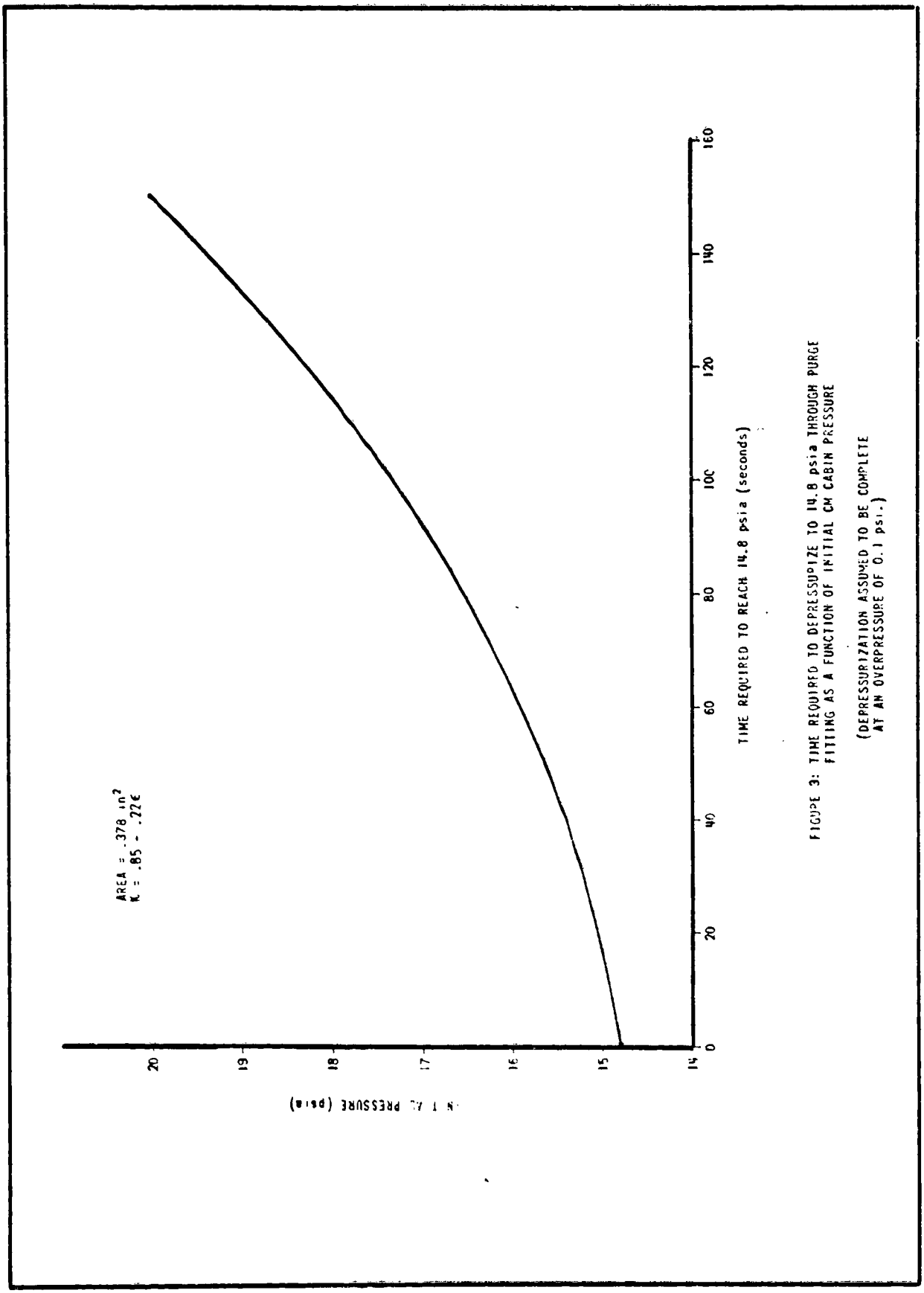


FIGURE 3: TIME REQUIRED TO DEPRESSURIZE TO 14.8 psia THROUGH PURGE FITTING AS A FUNCTION OF INITIAL CM CABIN PRESSURE

(DEPRESSURIZATION ASSUMED TO BE COMPLETE AT AN OVERPRESSURE OF 0.1 psi.)

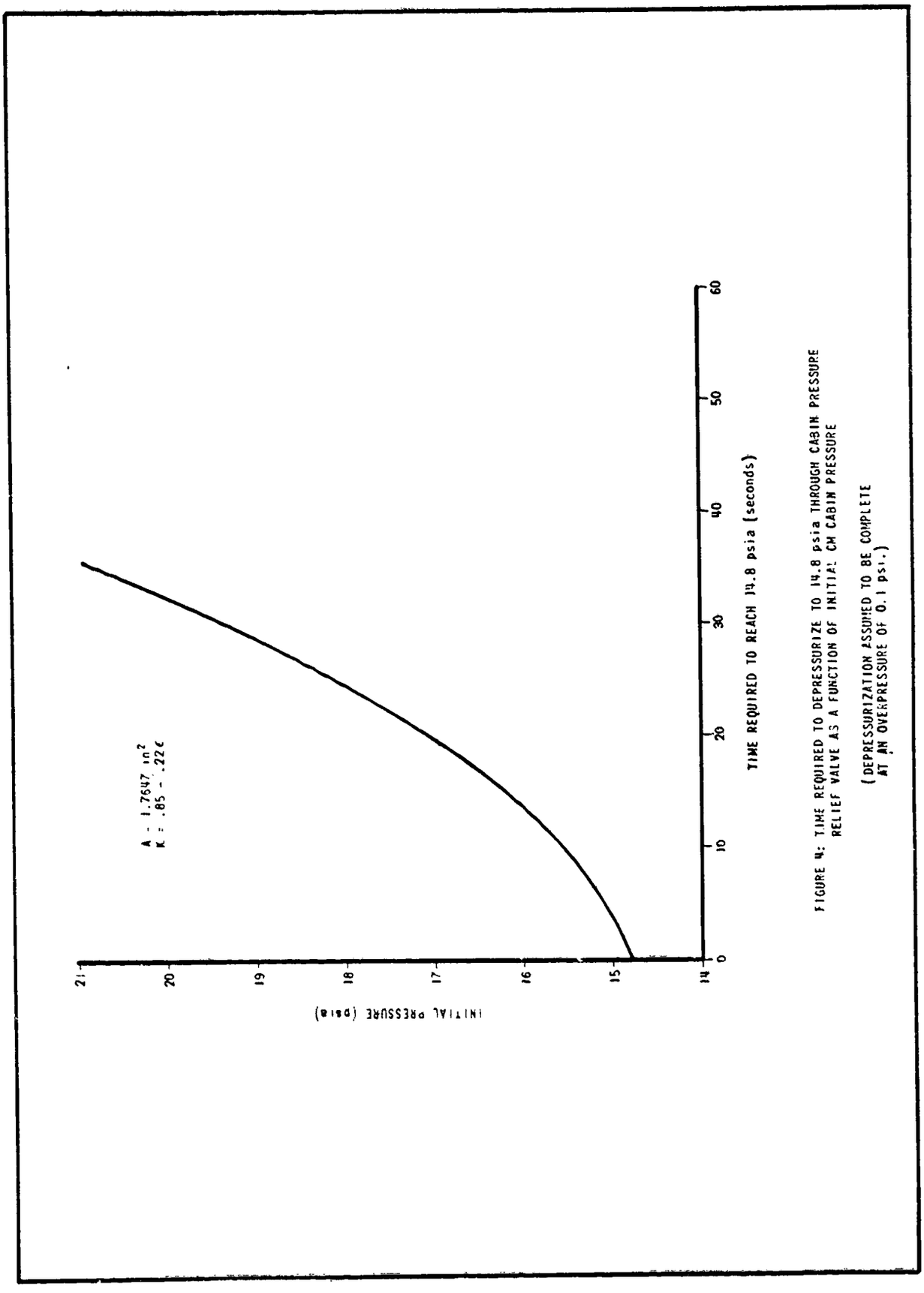
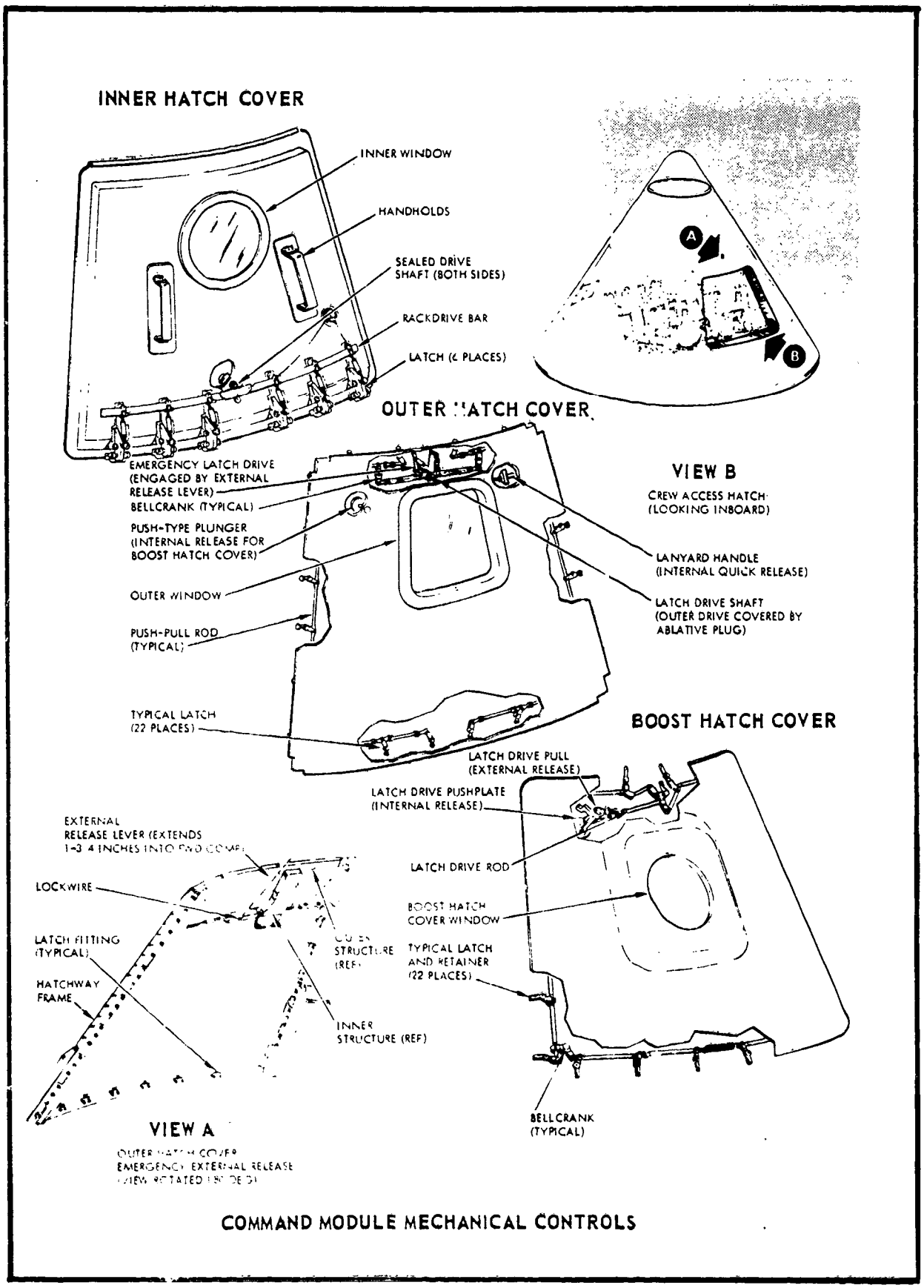
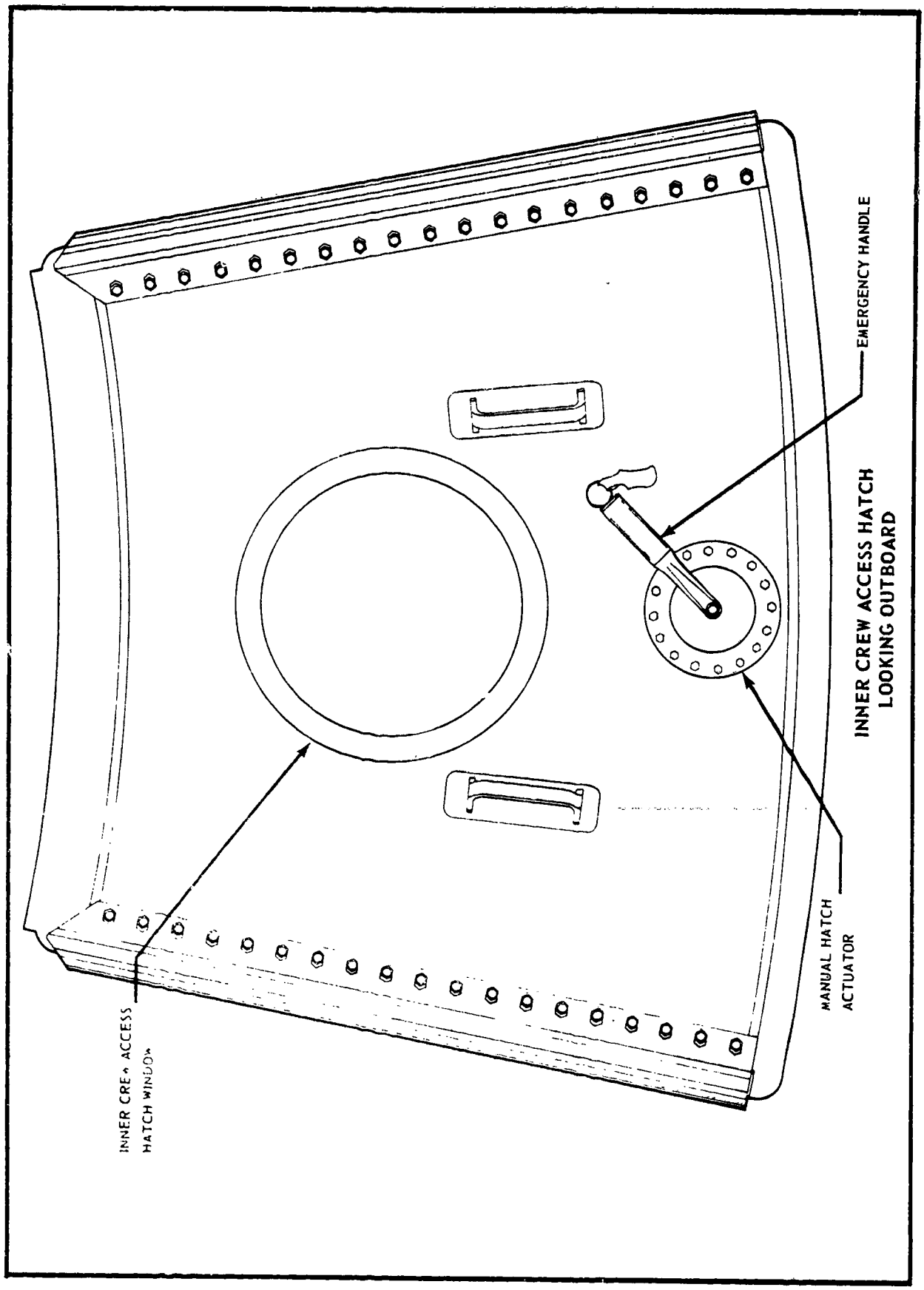


FIGURE 4: TIME REQUIRED TO DEPRESSURIZE TO 14.8 psia THROUGH CABIN PRESSURE RELIEF VALVE AS A FUNCTION OF INITIAL CM CABIN PRESSURE

(DEPRESSURIZATION ASSUMED TO BE COMPLETE AT AN OVERPRESSURE OF 0.1 psi.)



COMMAND MODULE MECHANICAL CONTROLS



ENCLOSURE 13-8

CF23/C. D. Wheelwright

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : GA/Gemini Program Office

DATE: Jan. 26, 1965

FROM : CA/Assistant Director for Flight Crew

In reply refer to:
CF23-5M-5

SUBJECT: Ejection seat catapult rocket fire flash effects on Gemini suit material

Before a full scale 100 percent O_2, 14 psi "off-pad" abort test is conducted on the tower at China Lake, it was decided to conduct a series of pilot tests in one of the small chambers at MSC. Five 6-inch by 6-inch swatches were made using the materials in the Gemini thermo integrated space suit (outer layer HT-1 nylon, 7 layers of mylar and interpressure vessel). One 6-inch by 6-inch swatch of the outer parachute pack and a miniature parachute pack were tested in the same manner.

The 7 swatches of materials, 5 similar to the Gemini space suit, 1 similar to the parachute pack, and 1 the outer parachute pack covering, were tested in a 100 percent O_2, 14 psi environment for high temperature flame effect. Each swatch was tested separately in a small chamber. The swatches were placed in the chamber and the chamber was evacuated to 5 mm Hg and left for 5 minutes to insure complete out-gassing of the swatches. The chamber was brought to ambient with 100 percent O_2 and the swatches were soaked for 5 minutes. At the end of the 5-minute soak, the chamber was again evacuated to 5 mm Hg for 5 minutes. The chamber was brought to 14 psi with 100 percent O_2 and the swatches soaked for 30 minutes. At the end of 30 minutes, a propane flame with a flame temperature above 1,800°F was brought into contact with the swatches. Each of the 5 suit swatches were brought into contact with the flame for 0.5 second, 1 second, 2 seconds, 3 seconds, and 5 seconds respectively. The parachute pack outer material was in the flame for 7 seconds and the simulated parachute package for 2 seconds.

The results were:

a. No scorching occurred before 3 seconds in the flame.

b. Burning occurred after 5 seconds for the suit material.

c. Smoldering occurred after 7 seconds for the parachute outer pack material.

d. No effect was noted to either the parachute canopy or the pack during a 2-second flame contact duration.

5016-100

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

The attached photographs show the results of the above test. All the materials were in contact with the flame considerably longer than the suit or parachute would be during an "off-pad" ejection. The maximum duration that the man is partially engulfed in the flame in an "off-pad" abort will be 0.01 second (10 milliseconds).

The results of these tests indicate that during an ejection, the fire flash of the ejection seat catapult is not of sufficient duration to cause the space suit to burn. Therefore, the test recommended in paragraph 1 is no longer considered mandatory and a decision to run the test must be based on program considerations.

/s/ D. K. Slayton

Donald K. Slayton

Enclosures 2

cc:
AM/D. O. Coons
AM2/G. F. Kelly
CB/A. B. Shepard
A. L. Bean
CF23/J. C. Joerns
EC/R. S. Johnston
EC4/F. S. Dawn
EC8/E. M. Tucker

CF23:CDWheelwright:bsf 1/22/65

OPTIONAL FORM NO. 10 5010-107
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

TO : Mr. S. Beddingfield, KB-4 DATE: March 8, 1967

FROM : KSC Fire Protection Officer, RF-1

SUBJECT: Fire Extinguishers used on 204 incident.

1. Attached is a copy listing the conditions found on each extinguisher used on the 204 incident.

2. All extinguishers were out of date in accordance with the last date of inspection according to AFM 92-1 dated 15 January 1964, Section D, Paragraph 6-16 (1), Page 6-6, which states all extinguishers should be inspected monthly.

3. We are holding these extinguishers under bond until notified in writing by proper authority to release them.

4. Some of the discrepancies noted might have occurred during or after their use, (i.e., pins bent or missing, defective plunger, etc.).

N. C. Gray

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

ENCLOSURE 13-10

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 202 . Tag No. 93 15 lb.. CO_2 Used

1.	Factory stamp number	15-2060378
2.	Hydrostatic	10/65
3.	Stencil Inspection date	9/13/66
4.	Last Inspection date	12/1/66
5.	Empty weight	27-1/4 lbs.
6.	Full weight	44-5/8 lbs.
7.	Weighed at KSC	31 lbs.
8.	Discrepancies	Out of date.
9.	Useable remaining CO_2	Empty (18 seconds gas only)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 203	Tag. No. 93	15 lb. CO_2	Used
1.	Factory Stamp number	15-224028	
2.	Hydrostatic	1/65	
3.	Stencil Inspection date	8/1/66	
4.	Last Inspection date	No tag	
5.	Empty weight	27-1/2 lbs.	
6.	Full weight	44-7/8 lbs.	
7.	Weighed at KSC	30 lbs.	
8.	Discrepancies	Out of date	
9.	Useable remaining CO_2	Totally empty	
10.	Recharged discharge time	28 seconds, good CO_2	

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 204 . Tag No. 93 . 15 lb. CO_2 . Used

1.	Factory stamp number	15-252929
2.	Hydrostatic	8/65
3.	Stencil Inspection date	12/3/66
4.	Last Inspection date	12/1/66
5.	Empty weight	26-1/2 lbs.
6.	Full weight	43-5/8 lbs.
7.	Weighed at KSC	32-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty (14 seconds, gas only)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 205 Tag No. 93 15 lb. CO_2 Used

1.	Factory stamp number	15-220110
2.	Hydrostatic	12/64
3.	Stencil Inspection date	12/22/66
4.	Last Inspection date	12/1/66
5.	Empty weight	27-1/4 lbs.
6.	Full weight	44-5/8 lbs.
7.	Weighed at KSC	31 lbs.
8.	Discrepancies	Out of date, horn split badly
9.	Useable remaining CO_2	Empty (12 seconds, gas only)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 206	Tag No.	15 lb. CO_2.	Used
1.	Factory stamp number	HH 26940	
2.	Hydrostatic	11/62	
3.	Stencil Inspection date	8/22/66	
4.	Last Inspection date	12/1/66	
5.	Empty weight	Not legible	
6.	Full weight	Not legible	
7.	Weighed at KSC	32 lbs.	
8.	Discrepancies	Out of date, defective trigger plunger	
9.	Useable remaining CO_2	Empty (20 seconds, gas only)	

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 207 , Tag No. 93 , 15 lb. CO_2. Used.

1.	Factory stamp number	USA-16535BN
2.	Hydrostatic	1/64
3.	Stencil Inspection date	9/66
4.	Last Inspection date	12/1/66
5.	Empty weight	25 lbs.
6.	Full weight	40 lbs.
7.	Weighed at KSC	39-1/2 lbs.
8.	Discrepancies	Out of date, defective trigger plunger
9.	Useable remaining CO_2	21 seconds, good CO_2

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 208 Tag No. 94 15 lb. CO_2 Used

1.	Factory stamp number	15-224214
2.	Hydrostatic	1/66
3.	Stencil Inspection date	8/1/66
4.	Last Inspection date	12/1/66
5.	Empty weight	27 lbs.
6.	Full weight	44-3/4 lbs.
7.	Weighed at KSC	29-1/2 lbs.
8.	Discrepancies	Out of date, band broken
9.	Useable remaining CO_2	Empty

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 209 Log No. 94 15 lb. CO_2 Used

1.	Factory stamp number	15-39-926
2.	Hydrostatic	8/63
3.	Stencil Inspection date	8/9/66
4.	Last Inspection date	9/30/66 - on tag
5.	Empty weight	23-3/4 lbs.
6.	Full weight	38-3/4 lbs.
7.	Weighed at KSC	35-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	19 seconds, good CO_2

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 210 Log No. 94 50 lb. CO_2 Used

1.	Factory stamp number	TC-2807
2.	Hydrostatic	10/59
3.	Stencil Inspection date	12/1/66
4.	Last Inspection date	12/1/66 - Wood
5.	Empty weight	137 lbs. (cyl.) - with cart 160 lbs.
6.	Full weight	187 lbs. (cyl.)
7.	Weighed at KSC	205 lbs (cyl. and cart)
8.	Discrepancies	Out of date, discharge lock pin missing
9.	Useable remaining CO_2	Empty (1 min. 42 sec. gas only)
1.	Actual empty weight at KSC	104-1/2 lbs. (cyl.)
2.	Actual empty weight at KSC	45.5 lbs. (cart)
3.	Actual empty weight at KSC	150 lbs. (cyl., cart and hose)
10.	Recharged discharge time	1 min. 46 sec., good CO_2

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 211	Log No. 94	30 lb. Dry Chem. Used Ansul, Met-X
1.	Factory stamp number	None
2.	Hydrostatic	5/64
3.	Stencil Inspection date	8/10/66
4.	Last Inspection date	12/1/66
5.	Empty weight	Not marked
6.	Full weight	Not marked
7.	Weighed at KSC	42 lbs.
8.	Discrepancies	Cartridge punctured, Cylinder marked by stencil "ABC Dry Chemical"
9.	Useable remaining Dry Chem.	Visual inspection - approximately 2/3rds full of agent

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 212 — 1.5 lb. CO_2 — Used

1.	Factory stamp number	15-223723
2..	Hydrostatic	10/60
3.	Stencil Inspection date	8/1/66
4.	Last Inspection date	12/1/66
5.	Empty weight	27-3/4 lbs.
6.	Full weight	45-1/8 lbs.
7.	Weighed at KSC	31 lbs.
8.	Discrepancies	Out of date, no band or horn clamp
9.	Useable remaining CO_2	Empty (6 seconds gas only)
10..	Recharged discharge time	29 seconds, good CO_2

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 213. Log No. 94 15 lb. CO_2 Used

1.	Factory stamp number	15-223653
2.	Hydrostatic	1/65
3.	Stencil Inspection date	8/1/66
4.	Last Inspection date	No tag
5.	Empty weight	27-5/8 lbs.
6.	Full weight	45 lbs.
7.	Weighted at KSC	31-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty (21 seconds gas only)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 214 . Log No. 95 . 15 lb. CO_2 . Used

1.	Factory stamp number	HSC-27898F
2.	Hydrostatic	6/63
3.	Stencil Inspection date	11/3/66
4.	Last Inspection date	No tag
5.	Empty weight	Not legible
6.	Full weight	46 lbs.
7.	Weighed at KSC	31-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 215 . . . Log No. 95 50 lb. CO_2 Used

1.	Factory stamp number	TT 7128.
2.	Hydrostatic	1/57
3.	Stencil Inspection date	8/1/66
4.	Last Inspection date	12/1/66
5.	Empty weight	Cyl. - not legible, with cart 148-1/2 lb.
6.	Full weight	183 lbs. (Cyl.)
7.	Weighed at KSC	194-1/2 lbs. (Cyl. and cart)
8.	Discrepancies	Out of date, Hose pitted near connection to bottle, defective trigger pin
9.	Useable remaining CO_2	Empty (1 min. 56 seconds, gas only)
1.	Actual empty weight at KSC	98 lbs. (Cyl.)
2.	Actual empty weight at KSC	143-1/2 lbs (Cyl., cart and hose)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr Tag No. 95 15 lb. CO_2 Used

1.	Factory stamp number	USA-61538BL
2.	Hydrostatic	11/64
3.	Stencil Inspection date	12/1/66
4.	Last Inspection date	12/1/66
5.	Empty weight	26 lbs.
6.	Full weight	41 lbs.
7.	Weighed at KSC	27-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty. (10 seconds gas only)

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 218 Tag No. 96 15 lb. CO_2 Used

1.	Factory stamp number	223584
2.	Hydrostatic	1/65
3.	Stencil Inspection date	12/1/66
4.	Last Inspection date	12/1/66
5.	Empty weight	28 lbs.
6.	Full weight	45-3/4 lbs.
7.	Weighed at KSC	32-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty (16 seconds gas only)
10.	Recharged discharge time	35 seconds, good CO_2

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr 219	Tag No. 96	15 lb. CO_2	Used

1.	Factory stamp number	F-458277
2.	Hydrostatic	8/60
3.	Stencil Inspection date	7/26/66
4.	Last Inspection date —	12/1/66
5.	Empty weight	Not legible
6.	Full weight	52 lbs.
7.	Weighed at KSC	38 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	Empty

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

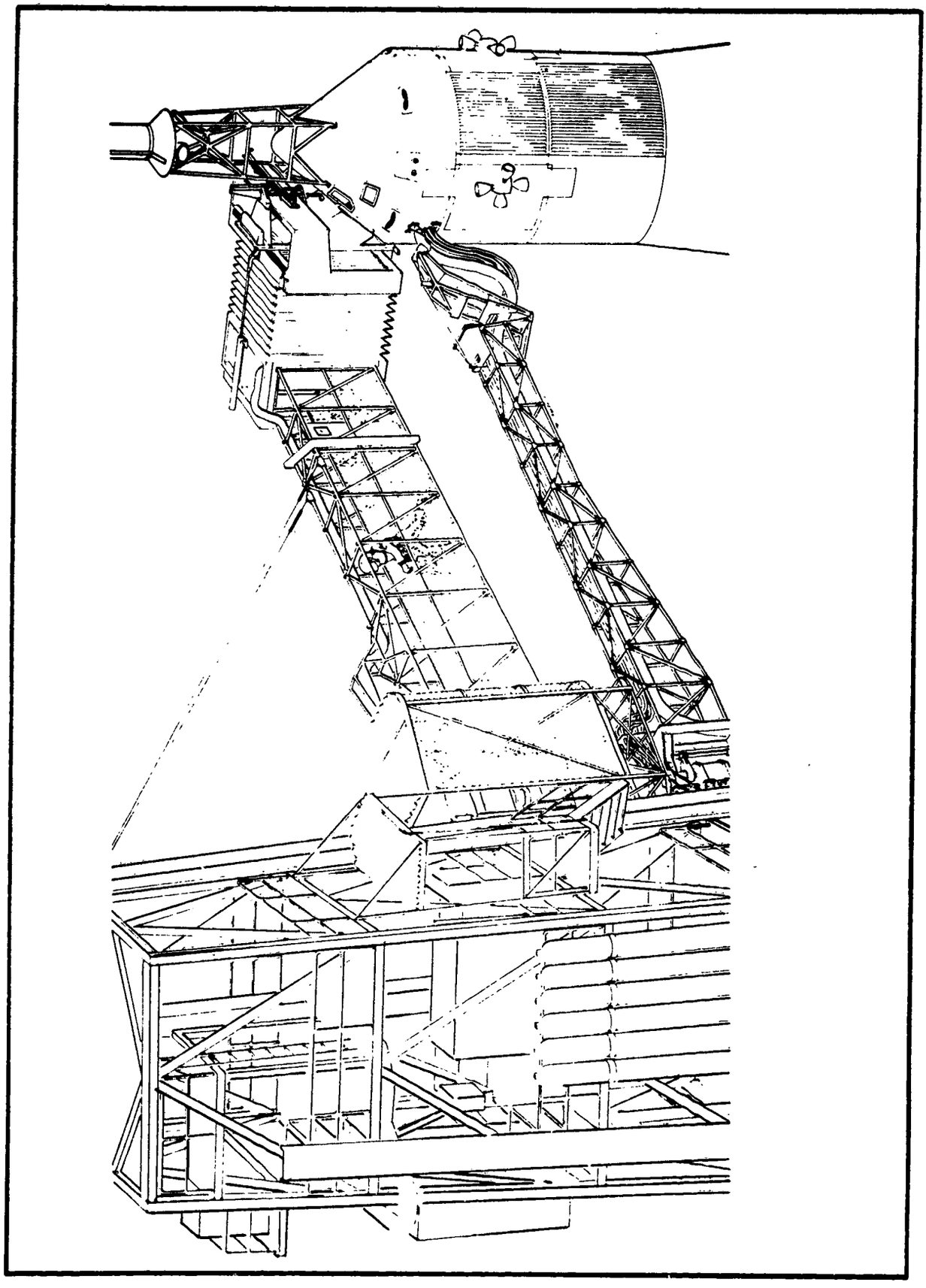
Pirr	Tag No. 227	15 lb. CO_2	Used
1.	Factory stamp number	15-176031	
2.	Hydrostatic	2/65	
3.	Stencil Inspection date	7/1/66	
4.	Last Inspection date	2/1/66	
5.	Empty weight	30-3/4 lbs.	
6.	Full weight	45-5/8 lbs.	
7.	Weighed at KSC	33-1/2 lbs.	
8.	Discrepancies	Out of date, pin bent in head	
9.	Useable remaining CO_2	Empty	

LC-34 - - 204
Bonded Extinguishers
Examined by KSC Fire Service
2/28/67 by Inspectors Weber and Olsson

Conditions Found

Pirr . Tag No. 228 _ 15 lb.. CO_2 Used

1.	Factory stamp number	15-210863.
2.	Hydrostatic	12/64
3.	Stencil Inspection date	8/1/66
4.	Last Inspection date.	12/1/66
5.	Empty weight .	27-5/8 lbs.
6.	Full weight	45 lbs.
7.	Weighed at KSC	44-1/2 lbs.
8.	Discrepancies	Out of date
9.	Useable remaining CO_2	25 seconds good CO_2
10.	Recharged discharge time	31 seconds good CO_2



ENCLOSURE 13-11

KSC

SO

S&ID

FLORIDA

APOLLO

PRE-FLIGHT OPERATIONS PROCEDURE

NO. G-100

DATE: November 4, 1966

TITLE: Originating and Changing Apollo Pre-Flight Operations Procedures

1. PURPOSE

This procedure establishes the method of initiating, coordinating, publishing, and distributing new and revised Apollo Pre-Flight Operations Procedures (APOP's).

2. FORMS

Apollo Manual Change Request (AMCR, KSC Form 4-33NS - 7/66)

3. DEFINITIONS

Apollo Pre-Flight Operations Procedure: A basic procedure necessary to manage the technical operations performed at the Kennedy Space Center which requires joint and/or concurrent action by NASA and NAA/S&ID. "Joint and concurrent action" as delineated herein refers to: direct participation by NASA and NAA in signature approval or acceptance stamping of a disposition, operation, or document. Examples that do not constitute joint and concurrent action are: (a) independent review and evaluation of prior actions, (b) receipt of documents, and (c) need-to-know without direct participation.

4. RESPONSIBILITY AND HANDLING

Ø 4.1 Cognizant NASA/NAA employees may propose a new procedure or a revision to an existing one. Proposals will be transmitted by preparing an AMCR in triplicate. NASA initiated AMCR's will be signed by the originator and approved by his supervisor. NAA initiated AMCR's will be signed by the originator and approved by his manager. One copy will be retained on file and two copies will accompany the procedure and be forwarded to NASA Spacecraft Operations Procedures Control Office or the NAA Procedures Representative as applicable. A clearly stated reason for the proposal will be included on the AMCR.

Ø 4.1.1 Proposed new procedures or revisions will be reviewed by NASA Spacecraft Operations Procedures Control, or the NAA Procedures Representative, to determine if they (1) contain joint or concurrent action as outlined in paragraph 3 above, (2) duplicate or conflict with existing procedures, (3) conform to established format. Proposals that are not valid will be returned to the originator with reasons for the rejection stated on the AMCR.

Revision: Remove and destroy APOP G-100, dated December 13, 1965, and replace with this issue. Ø indicates revisions. Retain Appendix "A" dated December 13, 1965. Revised to update signature requirements, organizational titles and provide for the use of Addendums.

4.1.2 NASA Spacecraft Operations Procedures Control will forward coordination copies of NASA originated procedures to the NAA Procedures Unit and applicable NASA coordination points requesting comments be returned on the due date specified. NAA Procedures Unit will forward copies to applicable NAA coordination points.

4.1.3 The NAA Procedures Unit will forward coordination copies of NAA originated procedures to the NASA Operations Procedures Control Office, and applicable NAA coordination points requesting comments be returned on the due date specified.

4.1.4 Comments submitted will be clearly stated, referencing specific paragraphs, giving reasons, and offering alternate instructions where possible.

4.1.5 Comments to the draft must be returned by the due date. If comments are not returned, concurrence with proposals will be assumed.

4.1.6 When the coordination period has expired, the comments received will be reviewed and coordinated with the affected groups. Those deemed applicable will be incorporated into the procedure. An attempt will be made to resolve conflicting comments by means of telephone calls, meetings, etc. If conflicting comments cannot be resolved, they will be brought to the attention of NASA/NAA management for decision.

4.1.7 When coordination is complete and conflicts resolved or management decision made, the procedure will be typed by NAA for publication, signed by the NASA Spacecraft Operations Procedure Control and the NAA Procedures Representative, and forwarded to the NASA Manager, Test and Operations Management Office and the NAA Director of Apollo CSM Operations for approval signatures.

4.2 Minor Revisions

Minor revisions (i.e., grammatical corrections, format corrections, and word changes that have only a minor effect on the intent of the procedure), may be issued as pen and ink changes upon approval of the NASA Spacecraft Procedures Control and the NAA Procedures Representative.

4.3 Interim Procedures

4.3.1 APOP's may be published on an interim basis upon approval by NASA/NAA Management. Requests will be forwarded on an AMCR to the NASA Spacecraft Procedures Control or NAA Procedures Representative as applicable; however, action may be initiated by a verbal request and confirmed in writing on an AMCR prior to publication. NAA originated AMCR's for interim publication must be signed by a NAA/FF manager or above.

4.3.2 NASA Spacecraft Procedures Control and NAA Procedures Representative will obtain preliminary approvals of interim procedures by the most rapid means available.

4.3.3 When preliminary approvals are obtained, the procedure will be distributed as an interim procedure with a life span of 30 to 60 days. The expiration date will be noted on the first page under the publication date. Approval signatures will be the same as for a regular procedure or revision.

4.3.4 The life span will serve as the coordination period. At the end of this interim period, the procedure will be issued as a regular procedure incorporating changes or published as is, if no comments are received. If an interim procedure is unresolved, conflicting points will be referred to NASA/NAA management for decision.

4.4 Addendums

4.4.1 Certain key procedures require frequent revisions to accurately reflect the latest change in the NASA/NAA operations. These revisions include both minor and major changes in procedure, and, depending upon the circumstances, may need to be issued on an emergency basis. To expedite this kind of procedural updating and to avoid the frequent and time consuming retype and reissue of lengthy procedures, such revisions may be published as addendums. However, addendums will be used only as a last resort and under emergency conditions when time will not permit a normal revision or interim publication.

4.4.2 The addendum will normally be a one or two page statement of the changes being adopted. The paragraphs affected will be clearly referenced and the new or revised information will be clearly stated.

4.4.3 Requests for publication of revisions as addendums will be processed in the same manner as other proposed revisions (see paragraph 4.1). However, action may be initiated by a verbal request and confirmed later in writing on an AMCR.

ORIGINAL PAGE IS
OF POOR QUALITY

4.4.4 NASA Spacecraft Procedures Control and the NAA Procedures Representative will coordinate the proposed addendum and obtain necessary approvals. Normally addendum changes will receive regular coordination. However, when operational requirements dictate immediate publication, coordination similar to that for interim procedures will be used. (Reference paragraph 4.4.2).

4.4.5 When approvals are obtained, the addendum will be typed on multilith mats and signed by NASA Manager, Test and Operations Management Office and the NAA Director of Apollo CSM Operations.

4.4.6 Following the publication of an addendum, the procedure affected will be revised as soon as practical, incorporating the revisions outlined in the addendum.

4.5 Distribution and Control

4.5.1 Request to be placed on distribution for the APOP's will be made by memorandum and submitted to the NASA Spacecraft Procedures Control or the NAA Procedures Representative, as applicable.

4.5.2 The NAA Procedures Unit will maintain complete history files of all APOP's and will be responsible for the publication and distribution.

4.6 Format

4.6.1 When preparing a draft for a proposed procedure, the originator should organize the material into a format as shown in Appendix "A". Paragraphs should be numbered using the decimal system, and when possible, four decimal places should not be exceeded. Information such as lengthy Forms Guide Instructions, Flow Charts, List of Names, Categories, etc., should be omitted from the basic instructions and included as an Appendix.

Coordinated by: Sam Bridges Jr
Procedures Unit
NAA/S&ID Florida Facility

Coordinated by: Tom Barga
NASA Spacecraft Operations
Procedures Control

Approved by: J. L. Pearce
J. L. Pearce, Director
Apollo CSM Operations
NAA/S&ID Florida Facility

Approved by: for J. Jamboti
NASA Manager, Test and
Operations Management
Office

KSC

80

S&ID

FLORIDA

APOLLO

PRE-FLIGHT OPERATIONS PROCEDURE

NO. O-202

DATE: May 13, 1966

TITLE: Operational Checkout Procedure

1. PURPOSE

This procedure establishes the methods for the preparation, processing, release, and use of Operational Checkout Procedures.

2. REFERENCE DOCUMENTS

2.1 Apollo Pre-Flight Operations Procedure T-501, "Work Authorization - TPS"
2.2 Apollo Documentation Procedure No. 2
2.3 Apollo GSE Plan S&ID 62-14[illegible]C
2.4 APOP O-201, "Access Control of Test and Work Areas"

3. FORMS

3.1 Operational Checkout Procedure (OCP, Form KSC 11-16A)
3.2 Parts Installation and Removal Record (NAA Form FLA-62)
Ø 3.3 Apollo Launch Operations Test Summary Sheet (KSC Form OT-109)

4. DEFINITIONS

4.1 OPERATIONAL CHECKOUT PROCEDURE (OCP) - An engineering document which provides detailed instructions to personnel for operational checkout and verification of equipment during site activation, pre-launch, launch, or post-launch operations.

4.2 OPERATIONAL CHECKOUT PROCEDURE CHECKLISTS - A checklist especially designed to supply the necessary information to accomplish routine tasks in a particular order, prepared on an 11 x 17 sheet and providing for inspection buy-off.

4.3 INTEGRATED OPERATIONAL CHECKOUT PROCEDURES - An OCP which unites two or more Apollo Command and Service Module (CSM) systems or unites CSM systems with the booster.

4.4 DEVIATIONS - A change to a published OCP, such as changes in equipment lists, test parameters, sequences added or deleted or modified by order of occurrence or content to permit accomplishment of the test. Obvious errors, such as typographical errors, wrong page numbers, etc., are not considered deviations.

Revision: Remove and destroy APOP O-202, dated February 4, 1966, and replace with this issue. Ø denotes revisions. Retain Appendix A and B, dated February 4, 1966.

4.5 REVISION - Technical changes including permanent deviations published in page form for insertion into a published OCP.

4.6 RE-ISSUE - A complete re-write of an OCP published to supersede a previously released OCP.

4.7 APOLLO OCP CONTROL GROUP - A joint NASA/NAA Management Committee responsible to assure timely and technically adequate OCP's and to establish policy concerning NAA Florida Facility (FF)/Kennedy Space Center (KSC) OCP's.

5. GENERAL REQUIREMENTS

5.1 OCP's are based on NAA Process Specifications. Those applicable should be referenced in the OCP by document number.

5.2 A series of OCP's for each vehicle will be prepared and released at the Florida Facility in accordance with OCP requirements as specified in this and referenced documents.

5.3 OCP's will (1) provide detailed step-by-step delineation of required personnel activity for the operation, assembly, handling, or test of the equipment and for system(s) involved, (2) provide for insertion of program requirement record data, (3) provide NASA/NAA Engineering and Inspection acceptance, (4) provide for safety of personnel and equipment.

5.4 Ground Support Equipment (GSE) nomenclature will be standardized in accordance with Reference 2.3. The GSE model number and title will be listed in the special equipment section. In the procedure section, the model number and abbreviated title will be used.

5.5 All OCP's will include the following statement: "NAA supervision and the responsible NAA test engineer are directly responsible for the safety of all NAA personnel, safe working conditions, and implementing all safety requirements".

5.6 All safety requirements will be considered in the preparation of OCP's, and the OCP originator will coordinate the procedure with the NAA/KSC Safety Offices and affix his signature to the FF "Safety Office Sign-off Statement" (file card) prior to publication.

5.7 Any OCP which involves any of the critical operations described in Reference 2.4 will be designated on the front page as follows: "This Test Procedure Is a Critical Operation"

5.8 Emergency shutdown procedures (sequentially if necessary) will be included for all equipment.

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5.9 Applicable KSC/NAA Safety Directives will be referenced and complied with or waivers will be obtained, prior to commencing the test to ensure safe operations.

5.10 Notes, Cautions and Warnings will not be numbered within the OCP, but will be set apart from the text by placing them in the center of the page above the procedural step as shown below:

NOTE

An operation or special requirements, etc., in which no danger exists but which, if not accomplished, may cause inconvenience, delay, or invalidation of test.

CAUTION

Operational step practice, etc., which, if not strictly adhered to or observed, could result in damage of equipment.

WARNING

Operational step practice, etc., which, if not strictly adhered to or observed, could result in personal injury.

5.11 Illustrations will be used only to aid in the overall clarity of the text when necessary and will be referenced in the text, but in no case will they be used as directives for accomplishing work.

6. RESPONSIBILITIES AND HANDLING

6.1 Preparation, Processing and Release

6.1.1 OCP's to accomplish work tasks are developed to support a specific Florida Operations Flow Plan. Titles and numbers are provided for the OCP Control Group for review and approval.

6.1.2 OCP outlines are prepared by the NAA Systems Engineer, reviewed by the NASA Engineers, and submitted to the OCP Control Group for review and approval.

6.1.3 Rough drafts for each individual OCP are prepared with text and illustrations as outlined in Reference 2.2.

6.1.4 Rough drafts are forwarded through the NASA to Electronic Data Processing (EDP) for processing in flimsy print-out form.

6.1.5 Flimsies are forwarded to the NAA Documentation Support Group, who send copies to Systems Engineering, NAA Quality Engineering, NAA Safety, Downey, Engineering, and NASA Technical Library for distribution to GSC Engineering, NASA QC, Safety, and Manned Spacecraft Center (MSC) Houston.

6.1.6 Review comments from those agencies listed in 6.1.5 are returned to the responsible NAA Systems Engineer. The responsible Systems Engineer then develops a master review copy which is reviewed and signed by the input agencies. On integrated procedures, a formal review is held for final comments and sign-off.

6.1.7 NAA Documentation Support Group attaches a cover sheet and releasing Field Engineering Order (FEO) - see Appendix A - to the signed master flimsy, and obtains appropriate NAA signatures. Following NAA sign-off, the signed FEO is released by NAA Configuration Control, and a copy of the released FEO is provided for Documentation Support at the time of release. The master flimsy and cover sheet are then given to the NASA for procurement of appropriate signatures as directed by the NASA/NAA OCP Control Group. The released FEO is maintained by Documentation Support until the OCP is submitted to Technical Services (TS) for publication.

6.1.8 When all signatures are affixed to the cover sheet, and the package is returned to NAA Documentation Support, the master flimsy is forwarded through the NASA to EDP for processing of final offset masters for printing.

6.1.9 The finalized offset masters, the signed-off cover sheet, and the released FEO are provided to TS for publication and distribution 30 days prior to test.

6.1.10 TS is responsible for OCP distribution directed by the NASA/NAA OCP Control Group; in addition, three (3) published copies will be forwarded to each Test Site OCP Coordinator.

6.2 Deviations to OCP's

6.2.1 All deviations will be recorded on pre-printed deviation sheets and will become an official part of the record copy OCP. Pretest deviations will be written by the Systems Engineers; the deviation [illegible] with [illegible] deviation number (one numeral per item); and a copy will be given to Inspection prior to starting the test.

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6.2.2 Deviations that occur during the test will be recorded by the Systems Engineers or NAA OCP writer if one is assigned to the test (integrated tests only). When the requirements for a deviation become known, the Systems Engineer will be notified. The Systems Engineer or writer will assign a deviation number and inspection will record the number in the record copy OCP. If no writer is assigned, the Systems Engineer will read the OCP, issue deviation numbers, and notify Inspection who will record the numbers as stated above. At no time will a test be held up to record deviations on an official deviation sheet. This can be done upon completion of the test.

6.2.3 Upon completion of the test all deviation sheets will be completed and signed as [illegible] in paragraph 6.2.5 and turned over to Inspection to [illegible] in the record copy OCP. Deviation sheets are self-relieving and do not require an FEO.

6.2.4 It is the responsibility of the Systems Engineer to assure that properly approved deviation sheets are supplied to Inspection and to NAA Documentation Support following completion of the test. No OCP will be bought by Inspection until official deviations are provided by engineering for ALL deviations noted during performance of the OCP.

6.2.5 Approval signatures for deviation sheets will be as follows: for Systems test of specific systems sections of integrated OCP's - NAA and NASA System Engineers; for control sections of integrated OCP - NAA Test Project Engineer (TPE) and NASA Spacecraft Test Conductor (STC); for electrical and mechanical check lists - NAA and NASA system engineers.

Ø 6.2.6 Deviations that should be incorporated in like OCP's for future CSM should be marked PERMANENT and later incorporated by NAA Documentation Support into the applicable OCP and released in accordance with Paragraphs 6.1.6 through 6.1.9. Deviations that are "one time only" items are recorded on the deviation sheet as Temporary Deviations. No further action is required on Temporary Deviations.

6.3 Open Item Review

Ø 6.3.1 NAA service engineering will maintain current TAIR book status and will publish a daily status report ("pink sheet"). Only TPS's, DR's and DRSS's will be statused.

Ø 6.3.2 Completed OCP's that are still open will be reviewed for constraints. Special attention will be given to the open, non-transferred IP's.

Ø 6.3.3 Review of open PIRR's and TIR's and shortage sheets will be accomplished by the NAA Systems Engineer prior to the Open Item Review. Any constraining shortages, PIRR's, or TIR's will be listed by the Systems Engineer and submitted to the Test Project Engineer (TPE)/Spacecraft Test Conductor (STC) at the Open Item Review.

Ø 6.3.4 The open items review will be conducted from the status report, and constraining items will be listed on a separate sheet, or the status report may be marked up accordingly. The determined constraints will be listed, signed by the TPE and STC, and published to insure that concentrated effort is applied to those items.

Ø 6.3.5 NAA and NASA engineering will sign the cover of the reviewed status report along with the TPE and STC. The signed copy of the status report will be filed with the record copy of the OCP upon completion of the test.

Ø 6.3.6 NAA Project Engineering and NASA Engineering must approve the Open Item Review Sheet by signature, prior to beginning the test. The original signed copy of the review sheet will be filed with the record copy of the OCP upon completion of the test.

Ø 6.3.7 NAA Technicians will work required constraints for NASA/NAA Inspection Acceptance.

6.4 All tests will be conducted by the NAA TPE and NASA STC. The TPE and STC may delegate their duties as necessary.

6.5 Quality Control Responsibilities during Test

6.5.1 Quality Control responsibilities after satisfactory completion of an OCP step or operation are as follows:

6.5.1.1 NAA Inspection will enter acceptance stamp impression and date after each operation requiring verification on each horizontal line designated for NAA inspector and at the bottom of each completed page of the OCP.

6.5.1.2 NASA Inspection will conformance stamp each line item requiring NASA inspection verification during all CSM testing and on GSE testing designated as NASA Mandatory Inspection Points (MIP).

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6.5.1.3 When NASA MIP's have not been entered in the NASA block for a GSE OCP, NAA Quality Control will double stamp, date and enter N/R in each NASA Quality Control Block after stamping the NAA Inspector block.

Ø 6.5.1.4 When an inspection stamp entry is required for verification or witnessing of an operation occurring at a remote area, which is removed from the location of the Quality Control buy-off copy of the OCP, the inspector will verify over the Operation Intercom System (OIS) the satisfactory completion of an operation, and will affix a functional test inspection stamp impression to the verified step in the OCP. The NAA final acceptance stamp will not be used for verification over the OIS.

6.5.1.5 Recycles, shutdowns at the end of shift or subsequent restarting of test at the beginning of the next test shift do not require deviations since these situations do not exceed nor change the scope of the test as specified by OCP, e.g., CSM power may be removed at the end of a shift to secure from the test until the next shift starts. At that time CSM power may be reapplied and the test resumed where it was terminated. No deviation is required for either the power down or power up. However, the point and time of events will be recorded in the record copy and will be noted in the OCP Test Summary Sheets.

Ø 6.5.1.6 The following time entries will be required on certain OCP s as specified. During the test, the NAA Inspector will record the time, using the 24-hour clock system, in the OCP as follows: (a) in the time column adjacent to the first sub-sequence entry on each page, (b) at stop and restarts due to test "holds." (In addition, a reference to the problem causing the hold will be noted: IDR Number, Deviation Number, etc.), (c) at the start and completion of sequences, (d) at intervals of 5 minutes as an objective, but not more than 15 minutes between sub-sequences. (If the duration of a sub-sequence does not exceed 5 minutes, the time need only be recorded once for that particular sub-sequence. The date is not required for this item).

NOTE: (1) Additional time recording may be necessary for critical points in the OCP. The above time requirements are to be considered as minimum.

Revision: Remove and destroy pages 7 and 8 ONLY of APOP 0-202, dated May 13, 1966 and replace with this page. Revised to incorporate the Functional Inspection Stamp. Ø denotes changes.

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(2) The date will be included with the first and last time entry during each 24-hour period and at the end of the OCP.

6.5.2 All deviation entries on the Quality Control buy-off copy of the OCP will be verified by the responsible NAA inspector affixing the double stamp and date adjacent to the entry.

6.5.3 If an OCP is to be rerun, a new copy of the OCP will be used. "Inspection Copy" will be entered on the front cover of the OCP along with the notation "Run Number 2" and authority.

6.5.3.1 Sequence reruns will be indicated by the notation Run #2 or Run #3, etc. as applicable, entered on the upper right portion of the page.

6.5.3.2 As deemed practicable, use one of the following methods for documentation of sequence reruns and for the run time involved: (a) File duplicate OCP pages in the OCP, indicate rerun as in paragraph 6.5.3.1, and proceed in the normal manner: (b) File a rerun time record adjacent to the OCP page being rerun, indicate rerun as in Paragraph 6.5.3.1, and log time as indicated on the rerun time record. (Indicate acceptance of each rerun sequence on the OCP page).

6.5.4 When an OCP is discontinued before completion the NAA Inspector will

6.5.4.1 Enter "Discontinued" and reason for discontinuance after the last entry, and double stamp and date beneath the entry.

6.5.4.2 When a discontinued test is resumed, the NAA TPE and NASA STE will be responsible for determining the step at which testing should resume; however, all Interim Discrepancy Records and/or Discrepancy Records which will remain open against the previous run are valid until dispositioned and satisfied.

6.6 OCP Test Summary Sheet

After each OCP Test, the NAA TPE or his designated alternate will prepare a Test Summary Sheet (signed by the NASA counterpart engineer) providing the information listed below.

NOTE: Test Summaries for the [illegible] systems will be required for individual systems by Systems Engineering and will be approved by the TPE and STC.

6.6.1 Summary of major problem indicating:

6.6.1.1 Corrective action
6.6.1.2 Time of occurrence
6.6.1.3 Sequence
6.6.1.4 Applicable TPS's and IDR's

6.6.2 Summary of re-runs necessary to accomplish a given sequence of test successfully.

6.6.3 A listing of all IDR's that are transferred but not closed.

6.6.4 Bar Chart to indicate the actual order in which testing was accomplished, including actual test time.

6.7 OCP Acceptance Criteria

Following the completion of each OCP, NASA/NAA Inspection will close out the record copy OCP after all of the following steps have been completed by stamping each Summary Sheet and by signature on the last Summary Sheet.

6.7.1 The checklist PIRR forms have been recapped for subsequent tests or operations.

6.7.2 Sequences in the OCP have been verified as complete.

6.7.3 Deviations have been recorded and approved per Paragraph 6.2.

6.7.4 OCP Test Date Summary Sheets have been completed and signed by NASA/NAA.

6.7.5 Test Summary Sheets have been completed and approved.

6.7.6 The Bar Chart has been completed in accordance with Paragraph 6.6.4 above.

6.7.7 IDR's that have been assigned to CSM or GSE categories are either closed out or specifically dispositioned to:

6.7.7.1 Eliminate restraint on the next scheduled test.

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6.7.7.2 Reflect the subsequent test which will be restrained.

6.7.7.3 Retest requirements following any planned rework to insure system readiness.

6.7.8 "Other" category IDR's have been closed out (sold).

6.7.9 A copy of the IDR log, each IDR, all deviations and open item recall have been filed with the closed out OCP.

Coordinated by: K. Alfred Ahs
Procedure Unit
MAA/S&ID Florida Facility

Coordinated by: Karl A Kennamer
NASA APOB Coordinator

Approved by: J. C. Hazard
J. C. Hazard, General Manager
MAA/S&ID Florida Facility

Approved by: George A Sneeer
NASA Manager of Apollo
Spacecraft Operations

NORTH AMERICAN AVIATION, INC.
S&ID and INFORMATION SYSTEMS DIVISION

S&ID

IMPLEMENTING INSTRUCTION

FOR

THE FLORIDA FACILITY

NO. 12-5

DATE 27 Jan 1966

REFERENCE: (a) Florida Facility Implementing Instruction 12-1, "Florida Facility Safety Program"
(b) Operations Systems Safety Notice 1-65, dated 21 July 1965
(c) Apollo Documentation #2 (NASA/MSC)
(d) Operations System Safety Handbook
(e) S&ID Policy E-4.1, "Crew Qualification and Environmental Readiness for Critical Tests"
(f) S&ID Policy E-4 , "Employee Qualification/Certification for Critical Job Assignments"

SUBJECT: Safety Criteria for Apollo Command & Service Module and Saturn S-II Operations.

1. PURPOSE

This procedure identifies certain operational areas that shall be considered hazardous or critical. It establishes requirements to insure that all such administrative procedures, test procedures, work processes, methods, work authorizations and corrective action documents are reviewed to insure the inclusion of the necessary safety criteria.

2. SCOPE

The requirements established in this procedure are applicable to all programs at the S&ID Florida Facility and will be implemented as appropriate by all operational activities.

3. GENERAL

3.1 The following categories of Apollo Command & Service Module and Saturn S-II operations are designated critical. These operations will require specific safety reviews and must include certain specific requirements in preparation of procedures and related documents.

3.1.1 Ordnance System - any operation involving the handling, transporting, installation and checkout of live ordnance devices. Also any operation or checkout of an ordnance system after live ordnance items have been installed.

3.1.2 Propellants - any operation involving the loading, downloading, or system activation with operating propellants.

3.1.3 Cyrogenics - any operation involving the loading and/or downloading of the test vehicle and system activation with cyrogenics.

3.1.4 Environmental Tests - any environmental tests conducted in an environmental chamber where combustible gases or fumes are to be utilized in the test articles, or when an altitude chamber is at altitude with personnel in the chamber or vehicle.

New Procedure

Form 965-8-1 New 7-63

3.1.5 Hi-Energy Potential Systems - operations designated by the Systems Safety Engineer involving the operations of pressure systems or operation of gaseous systems utilizing tanks or reservoirs.

3.1.6 Handling Operations - any operation involving the lifting, hoisting, loading or transporting of an end item flight vehicle and such other itmes as may be specificially designated by the Systems Safety Engineer.

3.2 All safety requirements will be considered in the preparation of all test procedures and work authorization documents: Operational Checkout Procedures (OCP), Detailed Operating Procedures (DOP), Detailed Installation Procedures (DIP), General Operating Procedures (GOP), General Work Orders (GWO), Test Information Sheets (TPS), and Discrepancy Records (DR). Safety requirements will also be considered in revisions to OCP's, DOP's, DIP's, and GOP's. The originator will coordinate test procedures (OCP's, DIP's, DOP's and GOP's) with the Florida Facility Safety Office and affix his signature to the Florida Facility "Safety Office Sign-off Statement" (file copy) prior to publication.

3.3 The responsible systems engineer will coordinate with the Florida Facility Safety Office for all test procedures (OCP's, DOP's, DIP's, and GOP's) for operations that have been designated as critical.

3.4 Safety checklists will be used in the preparation of test procedures (OCP's, DIP's, DOP's, GOP's) and work authorization documents (TPS's, DR's and GWO's). Safety checklists will also be used in conducting the pre-operation review described in paragraph 4.7. These checklists will be developed by the Florida Facility Safety Office in coordination with representatives from Operations, Quality Assurance, Project Engineering and KSC Safety.

3.5 The Florida Facility Safety Office will submit safety reports in accordance with Reference (a).

3.6 It is the responsibility of supervision to ensure that all personnel are certified or qualified to perform assigned tasks in accordance with References (e) and (f).

4. INSTRUCTIONS

4.1 Any test procedure which involves any of the critical conditions described in paragraphs 3.1.1 through 3.1.[illegible] will be designated on the front page as follows: "This test procedure is a critical operation".

4.2 When a test procedure has been designated as "critical", cautions and warnings shall be used as necessary and precede critical steps. This will ensure that the instruction is received prior to actual need. The words CAUTION and WARNING shall be centered on the page.

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4.2.1 CAUTION: Used prior to any operation that could result in damage to equipment if not followed.

Example: CAUTION

If C14-075 gage PG12 exceeds 170 PSIG report condition to test conductor.

4.2.2 WARNING: Used prior to any operation that could result in injury or death to personnel if not followed.

Example: WARNING

High pressure gas will now be in lines G14017793 and G14-17798.

4.3 The Operations Department will be responsible for informing the Safety Office of any simultaneous operation to be performed in the same area as a critical operation.

4.4 Emergency shutdown procedures for all equipment will be included in all test procedures.

4.5 Applicable KSC and NAA safety directives will be referenced and complied with or waivers obtained prior to commencing the test to ensure safe operations.

4.6 It is the responsibility of the Test Project Engineer to brief all personnel involved in the test, prior to participation, on all cautions and warnings contained within the procedure.

4.7 Before each test designated as critical, the responsible systems or test engineer will conduct a safety review of the operation with all test team members. Those present to include not only personnel actually engaged in the operation but also any others that may be required, depending upon the nature of the operation (Project Engineer, Safety, Quality Assurance, NASA Representatives, etc.). The review shall consist of a "talk through" of the operation, a "walk through" inspection of the area, and a dry run of the operation by the personnel involved.

For the General Manager

W. S. Ford
Assistant General Manager
Florida Facility

LIST OF REFERENCES

The following documents, referenced in the Ground Emergency Provisions Panel Report, are contained in the AS – 204 Review Board permanent file:

REFERENCE

13-1 The Apollo Crew Abbreviated Checklist SM 2A-03-SC012/CL, dated 23 January 1967.

13-2 The Apollo Operations Handbook, SM 2A-03-SC012, dated 12 November 1966, revised 30 November 1966.

13-3 The Apollo Flight Crew Hazardous Egress Procedures Manual, dated 1 November 1966, revised 7 November 1966.

13-4 Operational Checkout Procedure, OCP FO-K-021-S/C012/14, dated 13 December 1966, revised 24 January 1967.

13-5 Launch Vehicle Test Procedure I-20015-SA 204, dated 18 January 1967, revised 23 January 1967.

13-6 Space Vehicle Test Procedure I-41001-204, dated 12 January 1967, revised 23 January 1967.

13-7 KSC Management Instruction, KMI 1710.1, dated October 4, 1966, defining KSC Safety Program.

REPORT OF PANEL 14
SECURITY OF OPERATIONS
APPENDIX D-14
TO FINAL REPORT OF
APOLLO 204 REVIEW BOARD

SECURITY OF OPERATIONS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Security of Operations Panel, 14. The task assignment by Panel 14 was prescribed as follows:

> This group shall review existing security practices for adequacy. This includes such things as access control, personnel sign-in requirements, buddy systems, background investigation requirements, etc. They shall also make responsible recommendations to the Board on changes to existing practices.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Security of Operations Panel:

Mr. Charles L. Buckley, Jr., Chairman, Kennedy Space Center (KSC), NASA
Mr. William J. Horner, Jr., Kennedy Space Center (KSC), NASA
Mr. Charles A. Buckel, Manned Spacecraft Center (MSC), NASA
Mr. Howard G. Maines, Headquarters, NASA
Mr. S. Drake Ellis, Marshall Space Flight Center (MSFC), NASA
Mr. Robert W. Gaines, Lewis Research Center (LeRC), NASA
Lt. Col. William Dugan, U. S. Air Force

2. COGNIZANT BOARD MEMBER:

Colonel Charles F. Strang, U. S. Air Force, Board Member, was assigned to monitor the Security of Operations Panel.

C. PROCEEDINGS

1. In response to the Board directive of February 1, 1967, the Panels' task was outlined in detail, as follows:

a. Conduct review of physical security practices at Kennedy Space Center and other appropriate locations supporting the mission. This review would include, but would not be limited to, the following:

(1) Launch Complex, including blockhouse, pad, and white room, access control system before and during the accident.

(2) Sign-in procedures which were in effect for persons having access to various critical locations during the pre-accident time period.

(3) Escort requirements that were in effect at the Launch Complex.

b. Examine the efforts of participating NASA management and security organizations aimed toward assuring the integrity and reliability of persons having critical access to key locations prior to and during the mission period.

2. The Panel prepared a tentative detailed schedule agenda and established milestones for the Security Panel's deliberations and activities.

3. The Panel accumulated pertinent background data, such as guard orders, access lists, samples of

badges, back-ground documentation, etc., for use by the Panel upon its initial convening.

4. Attended to necessary security administrative duties in support of the Board and other Panels. These reviews were conducted during the course of the Panel deliberations, reviews, analyses and interviews aimed toward determining whether a security-related factor caused or contributed to the accident.

5. A concurrent and detailed analysis of the general security posture prior to and at the time of the accident was accomplished. The plans for subsequent operations and tests were also reviewed.

6. The entire Panel visited Launch Complex 34 (LC 34) area for direct observation of security posts, including observation of the eighth adjustable level of the service structure, white room, and spacecraft.

7. Interviews and discussions were conducted with representatives of supervisory and operational elements of the KSC Security Office and uniformed security (guard) forces to establish:

a. The responsibility for (1) establishing security principles and guidelines and (2) monitoring implementation.

b. The responsibility for implementation of principles and guidelines.

c. The effectiveness of the management, structural, and communications relationships between the KSC Security Office and the implementing organizations.

8. An analysis was conducted of the various principles and guidelines designed to provide physical security and personnel access control involved in Apollo missions and their implementation by the uniformed security forces.

9. Reviewed and discussed the KSC and Air Force Eastern Test Range (AFETR) regulations concerning the "controlled area" personnel access concept at Cape Kennedy Air Force Station. Analyzed and discussed the North American Aviation, Inc. (NAA) instruction concerning the "controlled area" concept.

10. Interviewed the KSC Security Office representative concerning the concept and function of the access controls provided through use of the Apollo Saturn Operations Area Permit and the mechanics of implementing the "controlled area" concept at LC 34.

11. Reviewed security post requirements, post orders, badge and access control systems for the arrival and movement of flight hardware at Cape Kennedy and KSC; the KSC Industrial Area locations, the Astronaut Quarters and Suiting Room at KSC, the Astronaut Van; and LC locations such as the main gate, the blockhouse, and various work levels of the Space Vehicle at the pad.

12. The NASA representative in charge of the Astronaut Support Office at KSC (Astronaut Quarters, Suiting Room, etc.) was interviewed concerning access controls, control of the Astronaut Van; purchase, handling and preparation of astronauts' food (non flight); occupational health examinations of Support Office personnel (e.g. maids, cooks, stewards, etc.); kitchen and dining facilities; and the investigative program concerning the Support Office personnel and the information resulting therefrom.

13. The Panel:

a. Analyzed the NASA NAA Apollo Prelaunch Operations Procedures concerning access control of test and work areas.

b. Interviewed the NASA Apollo 204 Test Supervisor concerning physical security and personnel access controls at LC 34.

c. Interviewed the NAA pad leaders concerning the NAA system of administrative access control of personnel to the service structure spacecraft work areas, including the white room and Command Module.

d. Reviewed the Command Module Ingress Egress Log maintained by NAA personnel.

e. Interviews, analyses, and reviews conducted by the Panel (it should be noted that Panel 6 is also conducting an inquiry in this area) reflected that

(1) In some cases, individuals over whom the contractor had not exercised access control gained

entry to the spacecraft areas on the fifth, sixth, and seventh adjustable levels;
(2) No "off shift" log exists;
(3) The Command Module Ingress/Egress Log in some cases failed to reflect:
(a) the names of all individuals who entered the Command Module;
(b) whether or not equipment or tools were taken into the Command Module;
(c) that all equipment or tools were taken out or otherwise disposed of;
(d) the time individuals ingressed and, or egressed the Command Module;
(e) the authorization basis for individuals entering the Command Module;
(f) sufficiently legible writing to determine the identity of individuals entering the spacecraft.

14. An analysis was conducted of the investigative program which formed the basis for access to LC 34. A similar analysis was conducted of the system in effect at the Mission Control Center/Houston. An inquiry was conducted to verify the clearance and investigative status of a representative sampling of all persons who were at selected locations on the Launch Complex, in the Command Module, on the eighth adjustable work level of the service structure, etc., prior to the accident. The Panel analyzed the benefits which can reasonably be expected to result from measures suggested in a letter of December 30, 1966, from NASA Office of Manned Space Flight (OMSF) to selected Apollo contractors, emphasizing the need to be exceedingly selective in the placement of reliable and trustworthy persons at the launch facility during the critical period immediately prior to launch. The analyses reflected the degree to which a prior standard National Agency Check (NAC) investigation was a reasonable precaution in controlling unescorted access to the Launch Complex. In most cases, the standard NAC relied upon was the one which had been conducted in the processing of the individual's industrial security clearance for access to classified information. In these cases, the results of the NAC were not furnished to NASA. The last Government-conducted NAC Investigation relied upon for access varied from being current to in excess of ten years old. A sampling of such NAC's on individuals at LC 34 on the day of the accident established that a standard NAC is apparently not designed to include a check of pertinent files of all appropriate Federal agencies. These agency files contain information, some of which would be relevant in evaluating individual trustworthiness and reliability.

15. Reviewed and analyzed the uniformed security force's General guard orders.

16. Interviewed PAA Security policemen who performed security post duties at LC 34 to establish the individual officer's comprehension and understanding of his responsibilities, and the extent to which actual performance matched assigned duties. Interviewed supervisory and patrolmen personnel concerning their actions on the day of the accident.

17. Reviewed disciplinary action cases concerning uniformed security personnel resulting from minor instances of noncompliance with their security post responsibilities at LC 34 in order to establish the degree of discipline at the Launch Complex.

18. Representatives of the Federal Bureau of Investigation were interviewed concerning their prior investigations of various types of incidents (thefts, fraud, malicious damage to Government property) at Cape Kennedy and KSC with emphasis on LC 34. They were also interviewed regarding their participation in the activities at LC 34 immediately following the accident.

19. The Panel reviewed all statements taken by the Witness Panel for any items having a security implication.

20. An analysis was conducted of pertinent incident reports and daily log sheets (prior to and at the time of the accident) maintained by the KSC Patrol and the PAA Security Police.

21. Reviewed and discussed the NASA Headquarters Apollo Mission Failure Contingency Plan, and the KSC Apollo/Saturn 1B Failure Investigation Plan.

22. Discussed approaches to personnel security investigative program to be used in future Apollo missions.

D. FINDING AND DETERMINATIONS

1. FINDING

a. The KSC Security Office:

(1) Developed security principles and guidelines, concept for badge, access control systems, and security post requirements, and furnished them to the uniformed security forces.

(2) Provided technical direction to the uniformed security forces and published physical and personnel security regulations, instructions, and notices.

(3) Developed security procedures for each Apollo mission and issued a security plan setting forth prelaunch, test, and launch security requirements.

(4) Periodically inspected the uniformed security forces.

(5) Frequently surveyed the field and security post operations of the uniformed security forces.

b. By contract, the uniformed security forces (PAA Security Police at Cape Kennedy, and the KSC Patrol at Kennedy Space Center) were responsible for the implementation of established security principles and guidelines.

DETERMINATION

The KSC Security Office adequately established security principles and guidelines and effectively monitored implementation of same. Uniformed security forces properly implemented these principles and guidelines. The KSC Security Office, in a timely fashion, effectively emphasized with the uniformed security forces, the importance of the forthcoming Apollo manned missions.

2. FINDING

Current written orders were in existence for all established security posts related to the AS-204 mission. The orders were furnished to uniformed security forces in a timely manner. The interviews and analysis of pertinent records revealed no significant instances reflecting a failure by uniformed security personnel to comply with their post orders.

DETERMINATION

Uniformed supervisory security personnel were knowledgeable concerning their responsibilities. Uniformed security policemen understood their duties and performed satisfactorily. Operational security requirements placed on PAA were timely and adequate. Security post orders were realistic and adequate.

3. FINDING

KSC Security personnel and or uniformed security personnel were assigned to all locations requiring safeguarding measures, including Launch Vehicle stages and spacecraft from the time of arrival at KSC to time of the accident.

DETERMINATION

The number of KSC Security personnel and uniformed security personnel utilized was adequate.

4. FINDING

Apollo Preflight Operations Procedures (APOP) 0-201, dated October 17, 1966, and January 24, 1967, concerning access control of test and work areas, required that: (1) access controls to spacecraft work areas be exercised by the contractor; (2) the contractor maintain a log of all personnel permitted access during "off-shift" non-work periods, (3) the contractor control Command Module ingress-egress, and maintain a log concerning same.

DETERMINATION

The procedures established in the APOP were not followed in that: (1) the contractor failed to exercise adequate access controls on the fifth, sixth, and seventh spacecraft levels, (2) the contractor failed to maintain an "off shift" log; (3) the Command Module ingress egress log was inadequately

maintained.

5. FINDING

The investigative program, which was used as the basis for authorizing access to LC 34, consisted of a determination that a National Agency Check (NAC) investigation had been conducted on each Government or contractor employee. In the absence of a NAC, an escort was required. (Similar provisions existed at the Mission Control Center/Houston.)

DETERMINATION

This practice provides inadequate support for the objective of NASA management that great care be taken to assign reliable and trustworthy persons to perform critical work during mission periods.

6. FINDING

a. Access to the Astronaut Quarters and the Suiting Room was limited by an access list attached to the Security Post Orders, to those few people having an official reason to be there, i.e., astronauts, biomedical people, suit technicians, etc. Compliance with this procedure was enforced by KSC uniformed security patrolmen. The Van used to transport the astronauts from their Quarters to the Launch Complex was inspected, driven, and remained under the control of KSC Security personnel when astronaut activity was involved. Uniformed security personnel escorted the Van when astronauts were being transported.

b. The purchase, handling, and delivery of the astronauts' food (non-flight) served in their Quarters is processed through the contractor's routine channels.

c. Only the results of an NAC are available to NASA management in their evaluation of the reliability and trustworthiness of support personnel in the Astronaut Quarters.

DETERMINATION

The personnel access controls for the Astronaut Quarters, the Suiting Room, and the Van were adequate.

Inadequate safeguards are provided concerning the purchase, handling, and delivery of astronauts' food (non-flight), notwithstanding the fact that it is known by persons coming in contact with it that it is to be consumed by the astronauts.

NASA management has insufficient knowledge to fully evaluate the reliability and trustworthiness of support personnel in the Astronaut Quarters.

E. SUPPORTING DATA

REFERENCES

The following is an enumeration of referenced materials (which are not included as part of this report), copies of which have been submitted to the Board.

14-1	Panel Preliminary Report Number 1, February 1, 1967
14-2	Panel Preliminary Report Number 2, February 4, 1967
14-3	Summary Panel Report, February 9, 1967
14-4	Preliminary Panel Analysis Summary Report, February 16, 1967
14-5	Summary of Panel Interview - Buckley
14-6	Signed Statement - Buckley
14-7	Summary of Panel Interview - Morford
14-8	Statement of Chief Merrill
14-9	Gemini 12 Security Plan, October 14, 1966
14-10	AS-201 Security Plan, December 14, 1965

14-11 Apollo Launch Operations Committee Meeting Minutes, September 20, 1966
14-12 Proposed AS-204 Complex 34 Security Controls
14-13 Apollo Launch Operations Committee Meeting Minutes, November 1, 1966
14-14 Proposed Security Controls for Complex 34 for AS-204
14-15 Summary of Interview - Evans
14-16 Summary of Interview - Matthews
14-17 Summary of Interview - Tatham
14-18 Written Statement - Tatham
14-19 Air Force Eastern Test Range Regulation 125-10
14-20 Air Force Eastern Test Range Regulation 125-15
14-21 Summary of Interview - Morford (No. 2)
14-22 Summary of Interview - Horner
14-23 KSC Patrol Synopsis of Events
14-24 APOP Number 0-201, October 17, 1966
14-25 APOP Number 0-201, January 24, 1967
14-26 Summary of Interview - Buckel
14-27 Office of Manned Space Flight letter to Apollo Contractors
14-28 Summary of Interview - Page
14-29 Summary of Interview - Babbitt
14-30 Summary of Interview - Curatolo
14-31 Sample Pages from Command Module Ingress/Egress Log
14-32 Summary of Interview - Furgason
14-33 Summary of Interview - Smith
14-34 Summary of Interview - Tully
14-35 Summary of Interview - Graham
14-36 Summary of Interview - Friedlander
14-37 Security Post Orders - Altitude Chamber
14-38 Security Post Orders - Astronaut Quarters
14-39 Security Post Orders - Astronaut Suit Room
14-40 Security Post Orders - Complex 34 Main Gate
14-41 Security Post Orders - Complex 34 Rear Gate
14-42 Security Post Orders - Complex 34, 1st Floor Blockhouse
14-43 Security Post Orders - Complex 34, Blockhouse Stairwell
14-44 Security Post Orders - Complex 34, 4th Level/"1U"
14-45 Security Post Orders - Complex 34, Roving Guard, 4th- 11th Adjustable
14-46 Security Post Orders - Complex 34, Roving Guard 27 foot level/Adjustable 3
14-47 Security Post Orders - Complex 34, Hypergolic Area
14-48 Statement PAA Policeman - Allen
14-49 Statement PAA Policeman - Bilbrey
14-50 Statement PAA Policeman - Brewer
14-51 Statement PAA Policeman - Darnell
14-52 Statement PAA Policeman - Dasse/Lane
14-53 Statement PAA Policeman - Hayes, O. B.
14-54 Statement PAA Policeman - Hayes, R. E.
14-55 Statement PAA Policeman - Hayes, R. E. (No. 2)
14-56 Statement PAA Policeman - Hennigan
14-57 Statement PAA Policeman - Nicholson
14-58 Statement PAA Policeman - Riddle
14-59 Statement PAA Policeman - Smith
14-60 Statement PAA Policeman - Thomas
14-61 PAA Security Police Blotter, January 25, 1967
14-62 PAA Security Police Blotter Log, January 27, 1967
14-63 Security Section Summary
14-64 Security Police General Post Instructions

14-65 Memorandum for Record - Disciplinary Actions, February 14, 1967
14-66 APOP G-100, November 4, 1966
14-67 NAA Implementing Instruction 4-4, July 13, 1966
14-68 NAA FRT letter (Moore), December 22, 1966
14-69 NAA FRT letter (Haight), December 22, 1966
14-70 NASA Headquarters Apollo Mission Failure Contingency Plan
14-71 KSC Management Instruction 1610.3 "Personnel Circulation Control and Identification", November 10, 1966
14-72 Summary of Interview - Turner
14-73 Statement - Turner

REPORT OF PANEL 15
BOARD ADMINISTRATIVE PROCEDURES
APPENDIX D-15
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

BOARD ADMINISTRATIVE PROCEDURES

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Board Administrative Procedures Panel, Panel 15. The task assigned for accomplishment by Panel 15 was prescribed as follows:

> This group shall establish and document administrative procedures for the Board to use. This includes activity such as procedures for the control of spacecraft work, logging and filing of exhibits, maintenance of log of Board activities, scheduling of meetings, preparation of agenda for Board meetings, arrangements for secretarial services, reproduction of material, etc.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Board Administrative Procedures Panel:

Mr. A. G. Griffin, Jr., Chairman, Kennedy Space Center (KSC), NASA
Mr. G. A. Huffines, Manned Spacecraft Center (MSC), NASA
Mr. W. D. Moody, Kennedy Space Center (KSC), NASA
Mr. P. C. Reed, North American Aviation, Inc. (NAA), Florida Office

2. COGNIZANT BOARD MEMBER:

Mr. E. Barton Geer, Langley Research Center (LaRC), Board Member, was assigned to monitor the Board Administrative Procedures Panel.

C. PROCEEDINGS

1. APPROACH

To accomplish the basic task of providing Board Administrative Procedures the following approach was developed:

a. IDENTIFICATION: Specific areas requiring rigid controls, definitive methods, or policy guidelines to be controlled by the Review Board were identified.

b. ASSIGNMENT: The responsibility for each procedure was assigned to a member of the Panel who assembled the pertinent information, prepared a draft procedure, coordinated with affected elements, and provided a finished procedure ready for implementation.

c. SUBMISSION: The finished procedure was submitted through the cognizant Board Member to the Board Chairman for his signature.

d. COORDINATION: Publication and distribution were accomplished through the Administrative and Secretarial Support Office.

e. REVISION: Existing procedures were revised as required through the same steps as outlined above.

2. SUMMARY OF ACTIVITY

Panel 15 performed the task of providing Board administrative procedures and subsequent revisions as required. In addition, several other tasks were assigned which were performed by the Panel over and above the work statement. Periodic reports of progress were made to the Review Board through the Panel Coordination Committee and the cognizant Board member. Panel activities are discussed in the following paragraphs.

a. Twenty-five (25) Board administrative procedures were issued to cover all phases of the Review Board's activities. They were developed and processed in accordance with the planned approach discussed in paragraph 1 above. Periodic lists of the procedure titles and the current revision status were issued and distributed. Board administrative procedures are contained in Enclosure 15-1.

b. The Administrative and Secretarial Support Office was established by Panel 15 in accordance

with Administrative Procedure 4. This support was provided on a two-shift, 7-day per week basis, unless otherwise required, with some third shift support. The support included secretarial services, arrangements for office space, furniture, office supplies, reproduction and graphics, mail service, and messenger service.

c. The Photographic Data Control Center was established by Panel 15. Included were the development of a grid system to correlate photographs with spacecraft area, the handling and distribution of photographs, and the maintenance of a film library. The latter two areas were covered by Administrative Procedure 8. The negative and a print of all photographs are included in the Board's General File. The total grid plan uses the North American Aviation top assembly drawing V14-000003 as a spacecraft base for developing the grid system. A set of photograph books are provided for each major grid area of the spacecraft Command Module and the Service Module. The appropriate individual spacecraft area grid plan is provided in the front section of each photograph book. Following is a breakdown of the major spacecraft areas which have been gridded and book sets provided.

(1) For the Command Module interior:
- (a) Left Hand Equipment Bay
- (b) Lower Equipment Bay
- (c) Right Hand Equipment Bay
- (d) Couches
- (e) Aft Bulkhead (Floor)
- (f) Upper Bulkhead (At head of couches)
- (g) Main Display Console

(2) For the Command Module exterior:
- (a) Aft Girth Ring Area (Frames 1 through 24)
- (b) Top Deck

(3) For the Service Module interior:
- Sectors 1 through 4

(4) For the Service Module exterior:
- (a) Top Deck
- (b) Reaction Control System Quad Panels
- (c) Aft Area (Service Propulsion System Engine)

(5) It was the policy that when any particular functional unit was removed from the spacecraft for further study a separate photograph book was established on that particular unit if warranted by the number of additional photographs. Following is a list of removed units for which separate photograph books have been established.
- (a) Batteries
- (b) Cobra Cables and Octopus Cable
- (c) CO2 Absorbers
- (d) Inverters
- (e) Environmental Control Unit
- (f) Engines (Command Module) (Pitch, Roll, Yaw)
- (g) Control Panels (Oxygen, Water)
- (h) Controllers (Rotational and Translational)
- (i) Floodlights
- (j) Hatches

(6) Additional books on special subjects are as follows:
- (a) Lab Tests (Non-metallic Materials and Flammability)
- (b) Special Tests (Suits-Static Discharge)
- (c) Crew Mobility Test in Mockup 2
- (d) Heat Shields Removals
- (e) Spacecraft 012 Movement to Pyrotechnic Installation Building

(7) Other books available for reference include:
- (a) Spacecraft 012 before fire
- (b) Spacecraft 014 interior

(c) Mockups (No. 2 and Non-metallic Materials)

(d) Set of documentary photograph books

(8) A major part of the functional arrangement of the library reference and control system is based on the proper identification of each photograph. Each photograph is captioned on the reverse side and includes the negative number, date and time picture was made, any applicable Spacecraft Test Preparation Sheet Number, and a brief subject description. All photographs are identified as Apollo 204 Review Board Material.

(9) The two key parts of the captions are the negative number and subject description.

(a) The negative number allows all negatives and one set of prints to be filed numerically by the roll and frame number included as the last two parts of the three part negative number. All negative frame numbers are accounted for, including blank frames.

(b) The subject description allows one set of photographs to be inserted in the appropriate photograph books through use of the spacecraft area grid plan. Within any particular subject area of a photograph book the photos are arranged in order of date and time. This allows review of subject configuration at any time since January 27, 1967.

(10) Some photograph captions include the word "Stereo." This indicated that a stereo slide is available for review. All stereo slides are arranged numerically by negative roll number and frame number in identified storage trays.

(11) The original reel and any prints of required motion pictures are arranged in file by subject description. Most of the motion pictures were for documentary purposes.

(12) For control purposes a log book for the Review Board and each Panel was maintained to provide records of all photographs distributed from the library. Each log book includes the photograph negative number, the number of prints, the data and name of the person receiving the photographs for the Review Board or Panel.

d. Panel 15 processed letters, telegrams, and telephone messages offering assistance, recommendations, and comments relative to the Apollo 204 accident. All such correspondence was logged in a master log, and the author's name was placed in an alphabetical file. Material received was reviewed, and, where appropriate, copies were forwarded to other Panels and Board Members for such consideration as they might require. Replies were prepared for the signature of the Board Chairman to all correspondence which had not been previously acknowledged or which required an additional acknowledgement. The log and file of all correspondence processed are included in the Board's General File.

e. Support was provided to the Review Board by periodically issuing approved schedules of work being performed as a part of the Review Board investigation. Information was collected, coordinated, displayed, and, after approval, published for distribution.

f. The Audio Magnetic Tape Library was established by Panel 15 in accordance with Administrative Procedure 22. It provided control of ¼-inch voice transmission tape recordings relative to Spacecraft 012 during the Space Vehicle Plugs-Out Integrated Test January 27, 1967. A storage and playback capability in a centralized area was also established. At the conclusion of Board use, these tapes were filed with other reference data relative to the Apollo 204 investigation.

g. Numerous memoranda and telephone calls were provided by Panel 15 to clarify or interpret Review Board administrative matters where required.

D. FINDINGS AND DETERMINATIONS

Not applicable.

E. SUPPORTING DATA

Enclosure

15-1 Board Administrative Procedures

APOLLO 204 REVIEW BOARD
ADMINISTRATIVE PROCEDURES

No. 1A	Access to the Review Board Meeting Room
No. 2A	Access to Complex 34
No. 3B	Access Control to Pyrotechnic Installation Building
No. 4A	Apollo 204 Review Board Secretariat & Administrative Support
No. 5C	Material testing in support of Apollo 204 Review
No. 6	Establishment of the Advisory/Group to the Apollo 204 Review Board
No. 7A	Handling of Sensitive Material under the jurisdiction of the Apollo 204 Review Board
No. 8	Photo Support Service for the Apollo 204 Review Board
No. 9	Transcribing Apollo 204 Review Board Proceedings
No. 10A	Control of Data and Documents
No. 11	Categorization and Control of AS 204 Material Required to Support the AS 204 Review Board
No. 12	Access to Apollo 204 Review Board Office
No. 13A	Preparation of Apollo 204 Review Board Meeting Agenda
No. 14	Access to Spacecraft 012
No. 15	Official File for Apollo 204 Review Board
No. 16	Coordination Policy for Interviewing Witnesses
No. 17	Response to Offers of Assistance or Recommendation
No. 18C	Use and Control of Task Preparation Sheets (TPS)
No. 19A	Establishment of the Panel Coordination Committee
No. 20A	Establishment of Apollo 204 Review Board Panels
No. 21	Access Control to Service Module Disassembly Area

No. 22	Control of Audio Magnetic Tapes
No. 23	Disposition and Storage of Physical Evidence
No. 24	Environmental Control System (ECS) Investigation
No. 25	Continuation of Testing in Support of Apollo 204 Review after recess of Board

/S/ A. G. Griffin, Jr.
Chairman, Task Panel No. 15

APOLLO 204 REVIEW BOARD
FEBRUARY 4, 1967

Administrative Procedure Number 1, Revision A

TITLE: Access to the Review Board Meeting Room

SCOPE: This procedure covers access to the Mission Briefing Room, MSO Building, KSC, which is herein designated the Apollo 204 Review Board Meeting Room for the period of time that the Board shall require its use.

POLICY: 1. Access to the Review Board Meeting Room shall be limited to the following personnel:

a. Board members (see attached list).

b. Advisory Group members (per access list).

c. Designated key personnel (per access list).

d. Security, communications, and administrative personnel.

e. Other personnel summoned or approved by designated individuals (designating officials noted by asterisk on access list).

2. Access will be controlled on a full time basis (24 hours per day) by a security monitor.

3. A log of all personnel not on the access list that are permitted entry will be maintained by the security monitor.

PROCEDURES: 1. Personnel will enter and leave the Meeting Room via the main door on the north-south hallway just east of the cafeteria.

2. Personnel will clear through the security monitor prior to entering the inner Meeting Room door.

a. Personnel on the access list will be issued an Apollo 204 Review Board badge with green stripes and may enter and leave the Meeting Room as required. Acquired visitors will be issued a temporary badge with yellow stripes and will be logged in and out at the security desk.

b. Personnel providing security, communications, and administrative support will be issued a temporary Apollo 204 Review Board badge with yellow stripes and will be logged in and out at the security desk.

3. The access list will be changed only by Mr. E. B. Geer or his designated representatives.

S Dr. Floyd Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 2, 1967

Administrative Procedure Number 2, Revision A

TITLE: Access to Complex 34

SCOPE: This procedure covers access to certain Complex 34 areas for the period of time required by the Apollo 204 Review Board.

POLICY: Access to the Service Structure, Umbilical Tower, AGCS Room, and pad areas adjacent to the structure will be controlled by special security procedures.

PROCEDURES AND RESPONSIBILITIES:

1. The service structure, umbilical tower, AGCS room and pad areas adjacent to the structure will be subject to a special security control as delineated in the paragraphs below. Access to these areas will be subject to the approval of the test supervisor who, through NASA Security, will provide instructions to the security guards concerning logging procedures and escort requirements. Entry into areas other than the spacecraft levels of the service structure will be provided to those NASA and contractor personnel who have a need justified through channels to the test supervisor.

Access to service structure levels A-5, A-6, A-7, and A-8 will be authorized only by a Board Member, a Panel Chairman, R. A. Petrone, P. C. Donnelly, or G. F. Page. Any work on or photographs of the spacecraft must be authorized by a Board Member or a Panel Chairman.

1. Responsibilities of Board Members and Panel Chairmen: Authorize, in writing, access to the spacecraft areas of the service structure for purpose of photographing the spacecraft, or performing any work on the spacecraft.

a. Authorize access to the spacecraft areas of the service structure for the purpose of photography or work only after reviewing written authorization signed by a Board Member.

b. Authorize access to the spacecraft areas of the service structure for normal maintenance or safety functions except for work of this nature on the spacecraft or its GSE.

c. Authorize access to the other portions of the complex under special security controls for work of an essential nature.

d. Provide the necessary instructions to the security guards so that all personnel admitted are properly logged.

e. Maintains a detailed log of all complex activities and personnel movements within the areas under special security control.

f. Briefs personnel who have a need and authorization to enter the restricted areas as to hazards, restrictions and personal conduct.

4. Responsibilities of NAA Pad Leader:

Maintains a control position on platform A-8 of the service structure for the purpose of coordination of all activities on platforms A-5, A-6, A-7, and A-8 of the service structure. Also, he will maintain a log of these activities. He is advised by the Test Supervisor as to the mission of all visitors to these platforms.

5. Responsibilities of NASA Security and PAA Security:

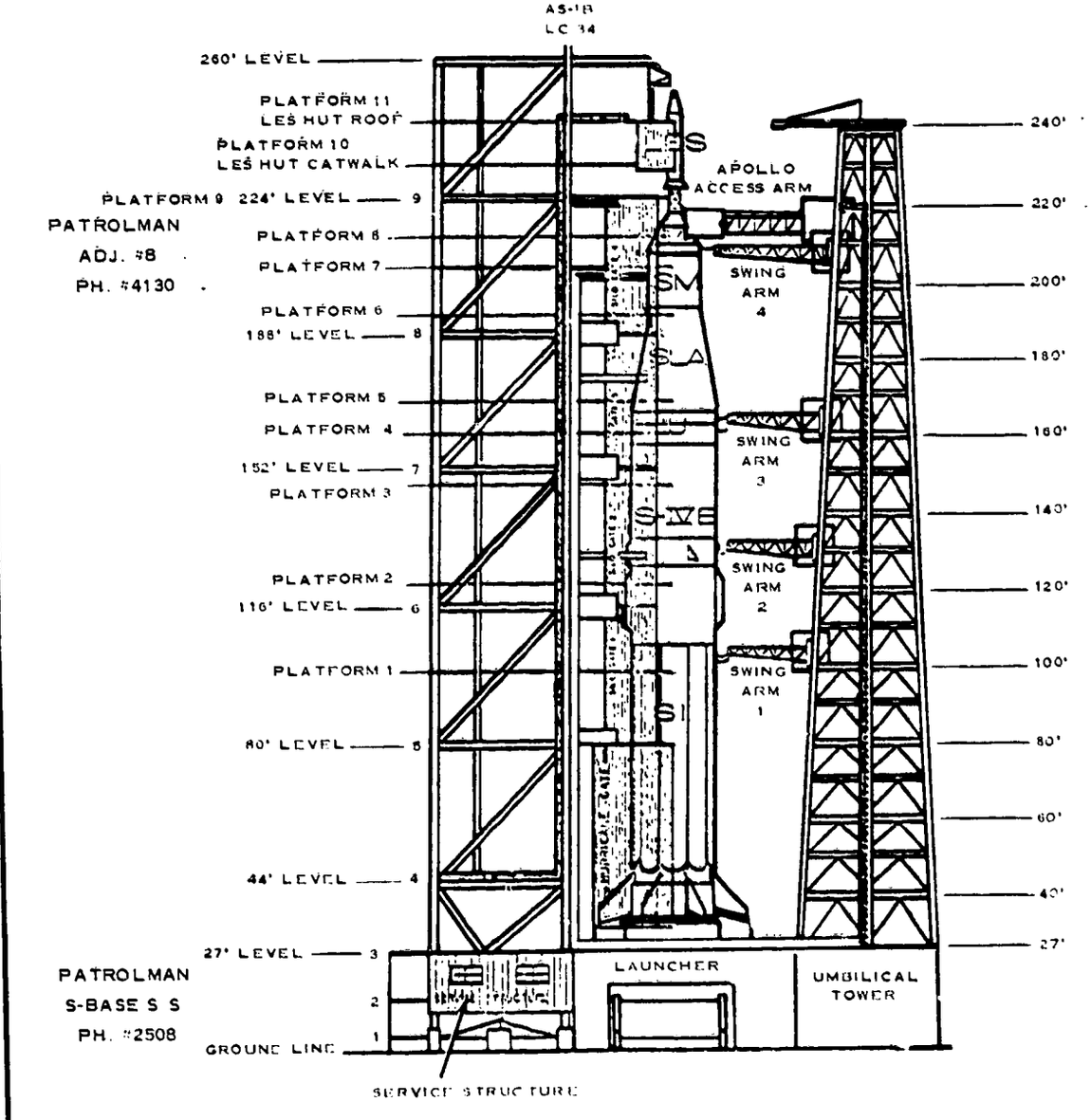
a. NASA Security is provide a Security Specialist to serve as an escort for photographers and other visitors to serve as required. Another security specialist is provided to coordinate overall security matters.

b. PAA will furnish seven (7) patrolemen to be stationed as follows:

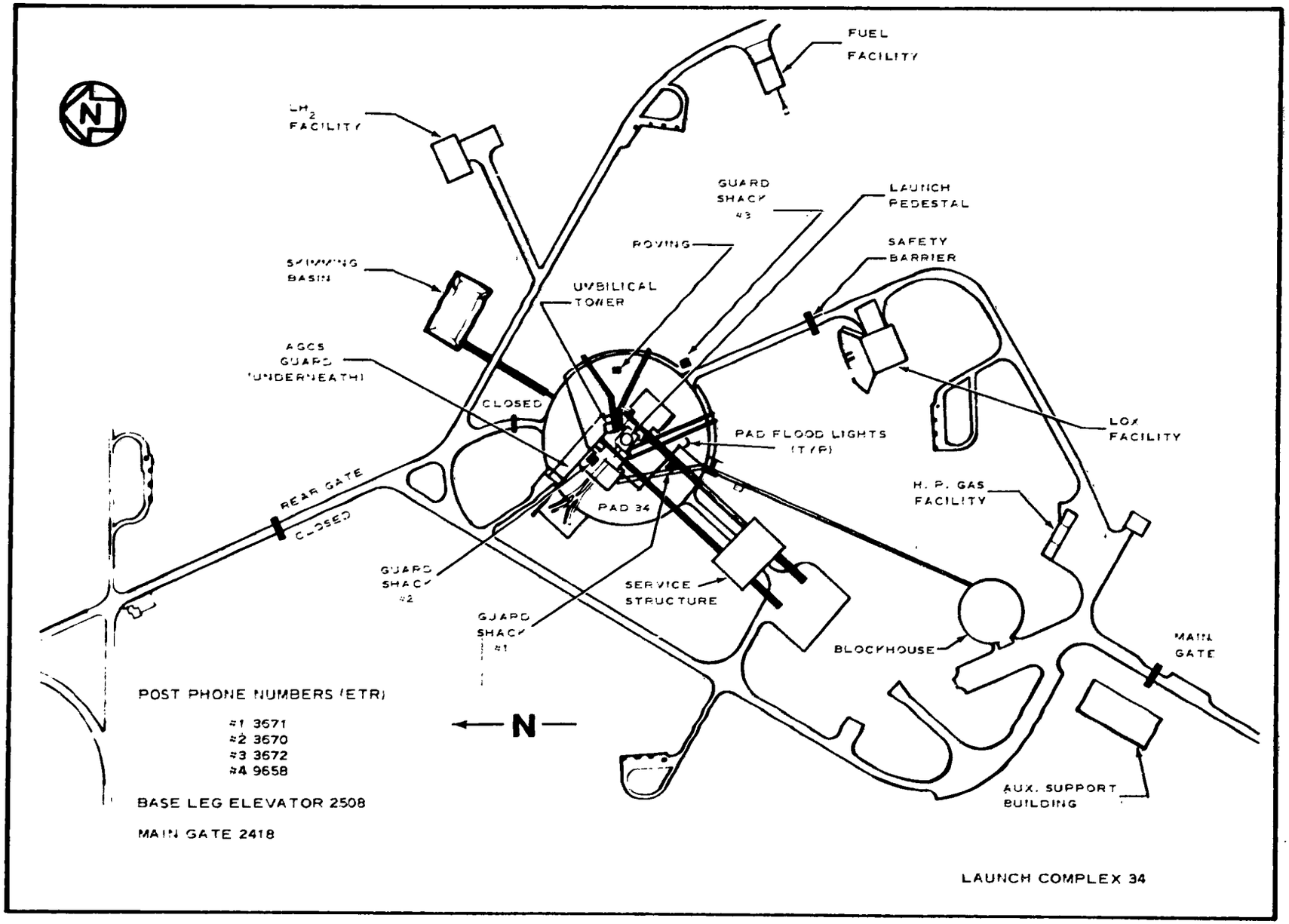
Post 1	S. E. Barricade
Post 2	West Barricade
Post 3	East Barricade
Post 4	AGCS Room
Pad Roving Patrol	
S. E. Base Leg	
Platform A-8	

PAA will also furnish one patrol supervisor to inspect all posts and coordinate required changes to procedures.

S Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board



ELEVATORS LOCKED OUT EXCEPT 3 4 LOCATED S-LEG S S


FUEL FACILITY
LH_2 FACILITY
GUARD SHACK #3
LAUNCH PEDESTAL
ROVING
SAFETY BARRIER
SWIMMING BASIN
UMBILICAL TOWER
AGCS GUARD (UNDERNEATH)
CLOSED
PAD FLOOD LIGHTS (TYP)
LOX FACILITY
REAR GATE CLOSED
PAD 34
H. P. GAS FACILITY
GUARD SHACK #2
SERVICE STRUCTURE
GUARD SHACK #1
BLOCKHOUSE
MAIN GATE
AUX. SUPPORT BUILDING
N
POST PHONE NUMBERS (ETR)
#1 3671
#2 3670
#3 3672
#4 9658
BASE LEG ELEVATOR 2508
MAIN GATE 2418
LAUNCH COMPLEX 34

APOLLO 204 REVIEW BOARD
FEBRUARY 6, 1967

Administrative Procedure No. 3, Revision A

TITLE: Access Control to Pyrotechnic Installation Building

SCOPE: This procedure covers access control to the bonded area and Room 106 of the Pyrotechnic Installation Building, herein after abbreviated PIB, for spacecraft work during the period of time required by the Apollo 204 Review Board.

POLICY:

1. Access to the PIB bonded area shall be limited to the following personnel:

   a. Members of Task Panel No. 4, Disassembly Panel (per access list).

   b. Board Members and designated key personnel (per access list).

   c. Other personnel requested and approved by designated individuals (designating officials noted by asterisk on access list).

2. Access to the PIB bonded area will be controlled on a full time basis (24 hours per day) by a security monitor.

3. A log of all personnel not on the access list that are permitted entry into the PIB bonded area will be maintained by the security monitor.

4. Access to PIB Room No. 106 shall be limited to the following personnel:

   a. Dr. G. Kelly

   b. Other personnel requested and approved by Dr. G. Kelly.

5. Access to PIB Room No. 106 will be controlled at all times by Dr. G. Kelly who is sole custodian of the key. Full time security monitor is provided.

PROCEDURES:

1. Personnel will clear through the security monitor prior to entering the PIB bonded area.

   a. Personnel on the access list will be issued a serialized PIB badge with blue stripes and may enter and leave the PIB bonded area as required.

   b. Other personnel requested and approved by the asterisked individuals on the list will be issued a temporary serialized PIB badge with black stripes and will be logged in and out by the security monitor. Such personnel will be escorted except for Government and North American Aviation personnel.

2. Personnel will enter and leave the PIB bonded area via the outside door of room 103 (see attached sketch). All other doors to the bonded area will be maintained in a locked condition except as required for equipment handling covered in paragraph 3.

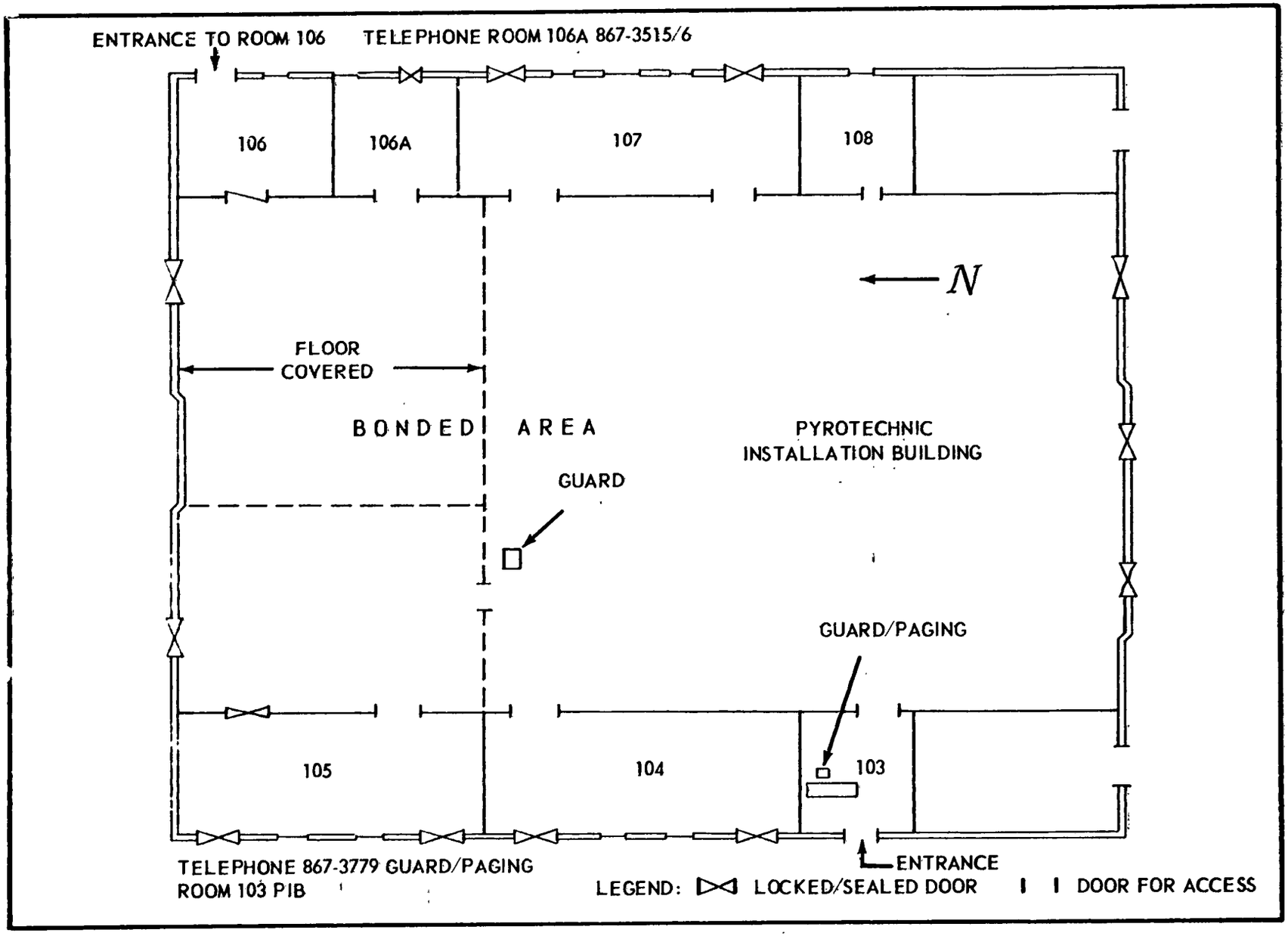
3. Equipment will be moved in and out of the PIB under the control of personnel on the list via the equipment door and located inside the PIB bonded area.

4. Personnel will not be permitted to enter PIB Room No. 106 except in the presence of and with the express permission of Dr. G. Kelly.

5. Changes to the attached access list can be made only by Mr. E. B. Geer or his designated representative.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

Attachments: Sketch of PIB


ENTRANCE TO ROOM 106
TELEPHONE ROOM 106A 867-3515/6
106
106A
107
108
N
FLOOR
COVERED
BONDED AREA
PYROTECHNIC
INSTALLATION BUILDING
GUARD
GUARD/PAGING
105
104
103
TELEPHONE 867-3779 GUARD/PAGING
ROOM 103 PIB
ENTRANCE
LEGEND: LOCKED/SEALED DOOR
DOOR FOR ACCESS

APOLLO 204 REVIEW BOARD
MARCH 8, 1967

Administrative Procedure No. 4, Revision A.

TITLE: Apollo 204 Review Board Secretarial and Administrative Support

SCOPE: This procedure covers the arrangements for providing secretarial and administrative support for the Apollo 204 Review Board and task panels.

POLICY: Secretarial support will be provided on a two-shift, sixteen hour per day basis (0800 to to midnight) near the Apollo 204 Review Board Meeting Room. (This support will be decreased to a one shift basis (0800 to 1630) when the workload is consistent with this period.)

PROCEDURES: 1. Apollo 204 Review Board Members and members of the Board Advisory Group will request secretarial and administrative support at Room No. 1805, MSO Building, telephone 867-5628/5611.

2. Requests will be made to Mr. Dave Allen, the Administrative Officer in control of administrative and secretarial support, and in his absence, his designated representative. The requests will consist of notes, drafts, special instructions, tapes, letters and reports. Stenographic and dictograph capability will also be provided.

3. The administrative officer will provide an estimate regarding completion time and will make whatever reasonable adjustments are necessary to meet deadlines.

4. The administrative officer will notify the requester upon completion of the work.

5. Other services that will be made available include arrangements for office space, furniture, office supplies, telephones, reproduction, graphic, mail and messenger services.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
MARCH 3, 1967

Administrative Procedure No. 5, Revision C

TITLE: Testing in Support of Apollo 204 Review

SCOPE: This procedure is applicable to all elements of the AS-204 Review Board which require testing and/or analysis of sub-systems, components, and sample materials removed from Spacecraft 012 in support of the AS-204 investigation. This procedure applies to Apollo 204 material and components leaving the KSC area and testing which is required on-site. This procedure applies to Category A and B material as defined in Administrative Procedure No. 11.

POLICY: 1. Task panel chairmen are responsible for initiating requests for testing required in their areas. The requests will be submitted in accordance with procedures as outlined in the procedure section below.

2. All proposed Spacecraft 012 hardware testing will be approved by the Apollo 204 Board Chairman. The Apollo 204 Review Board Chairman will decide on a case by case basis if a S/C 012 hardware test is to be performed at other sites such as a vendor plant, on-site at KSC, or both.

3. Wherever possible, two independent agencies will be required to perform analysis on sample materials. Whenever the quantity of material is insufficient to allow two tests, a single test may be conducted at KSC provided the test is witnessed by a representative of an independent agency. Examples of independent agencies available are:

a. U. S. Bureau of Mines

b. Air Force Materials Laboratory,
Wright-Patterson Air Force Base

c. NASA facilities other than Kennedy Space Center

4. Examples of sample materials which may require independent testing and/or analysis are protective equipment, fuel, lubricants, metals, non-metals, electrical components, fabrics, and gases.

PROCEDURE: Apollo 204 material procedure is shown in Attachment 1.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

TESTING IN SUPPORT OF APOLLO 204 REVIEW
ATTACHMENT 1
MARCH 2, 1967

PROCEDURE: 1. This procedure establishes the S/C 012 Equipment Screening Committee and delineates the Committee's authority. This procedure also establishes the system to be utilized in acquiring Board approval for the testing and analysis of all S/C 012 Category A&B equipment for both off-site and KSC testing.

2. The Screening Committee shall consist of the following personnel:

T. Sasseen	Chairman (KSC)
D. Mayhew	(MSC)
D. Levine	(NAA)

3. The committee is responsible for reviewing equipment removed from S/C 012 in the sub-system areas as listed in Appendix A and classifying such equipment as category A or B as defined in AS 204 Administrative Procedure No. 11. For the purpose of this procedure, equipment which has evidence of external damage and could be the cause of the fire is specified as category A. Equipment which has evidence of minor fire damage and obviously does not appear to be the fire origin is specified as category B.

4. The result of this screening activity will be the preparation of an equipment screening authorization form (appendix B) and a Material Release Record (MRR) by the appropriate subsystems engineer (as listed in appendix A) for committee approval. The MRR's will be submitted to the Review Board for ratification on a periodic basis.

5. That equipment classified as Category B shall be sent to bonded storage after external photographs have been taken.

6. That equipment classified as Category A shall be subjected to the following actions:

a. colored photos of burned or damaged area

b. X-ray penetration of damaged area

c. removal of external appendage if it will permit better visual examination

d. recommend return of equipment to manufacturer by submittal of an Apollo Spacecraft Hardware Utilization Request (ASHUR)

7. It should be emphasized that all hardware that has identified data glitches from the OCP 0021 shall be fully investigated. In addition, items of equipment that had pertinent open discrepant items shall also require full investigation.

8. All hardware will remain in the bonded storage at the Pytotechnic Installation Bldg. (PIB) unless specific instructions have been provided by an approved Apollo Spacecraft Hardware Utilization Request (ASHUR) authorizing off site testing for hardware being returned to the prime contractor, subcontractor, vendor, or other test agency. Testing accomplished on site (KSC) will continue to utilize a TPS in accordance with Administrative Procedure Number 18.

9. An ASHUR may be initiated by an Apollo 204 Panel Member but must have concurrency by the cognizant NAA & NASA subsystems engineer and must be approved by the Chairman of Panel 18 or his designated representative. Final approval by the Apollo 204 Review Board is required.

10. The ASHUR shall specify test requirements necessary to thoroughly analyze the system or component under investigation. The preparation of the test procedure shall be the responsibility of the prime contractor, subcontractor, or vendor in conjunction with the NASA and NAA subsystem engineer. All test procedures shall require an acceptance test, as was originally performed, to be conducted. Government and NAA inspectors are required to witness all testing of category A equipment at the vendor facility with an agent of the Board who is designated to supervise and witness all off-site testing. If the acceptance testing results show no change from previously recorded data, all testing will be discontinued, the data package updated, the results documented on the ASHUR answer sheet and the hardware, with all paperwork, returned to bonded storage at KSC.

11. In the event an anomaly is discovered, a failure analysis shall be conducted to determine exact cause of anomaly and positively explain that it is a result of fire rather than cause. In accomplishing this:

a. Justify, if possible, continuation of the acceptance testing;

b. If the acceptance testing cannot be continued, satisfy requirement to (1) stop and test and (2) return, with the properly updated documentation, to bonded storage at KSC.

If, during the process of investigation, the test procedure requires modification, the NASA and NAA subsystems engineers jointly have the authority to change this procedure provided the test requirements, as specified on the ASHUR, are still maintained. Any test or procedural change which alters the ASHUR test requirements must be submitted, by a revision to the original ASHUR, to the Apollo 204 Board for approval.

12. After completion of requested tests, test reports, as follows, are to be prepared by the test agency and signed by that agency, the cognizant NAA subsystem engineer and the NASA monitor:

a. One report is to cover test and inspection findings associated with the origin and propagation of the fire, the physical and functional condition of the equipment, and any unusual condition which may relate to one of the anomalies, discovered on S/C 012. Twenty (20) copies plus the original of this report are to be transmitted to the Apollo 204 Review Board by the NASA monitor within ten (10) days after the item is received by the supplier, subcontractor or independent test agency.

b. The second report is to cover other findings such as design, quality and fire survivability information. Two copies of this report are to be sent to each cognizant NASA and NAA Subsystem Engineer and three copies are to be sent to the Panel 9 Chairman. The original will be sent to the Panel 17 Chairman.

13. Responsibilities:

a. Originator

(1) Based on an approved MRR, complete ASHUR form in accordance with Appendix C.

(2) Obtain signatures of the appropriate NASA and NAA subsystems engineers.

(3) Forward to Panel 18 for approval.

b. Panel 18

(1) Approve or disapprove each ASHUR

(2) Submit ASHUR to the Apollo 204 Review Board via the Panel Coordinating Committee for approval.

(3) Maintain the Master file, status, and assure implementation of the requirements as specified on the ASHUR.

(4) Forward Board approved ASHUR to the Action Control Center for transmittal to the prime contractor, subcontractor, or vendor.

(5) Receive appropriate test data, reports, and related documentation and make available to the Apollo 204 Review Board as required.

c. Action Control Center

(1) Assure that the business and contractual interfaces between the government, prime contractor, subcontractor, and vendor are compatible.

(2) Assume responsibility for shipment logistics.

(3) Supervise the packaging.

(4) Assure, in conjunction with the Apollo 204 Board and Panel 18, that the couriers accompany the shipment in accordance with Appendix G.

(5) Assure that an ASHUR accompanies the hardware.

(6) Assure that a DD 1149 is executed.

(7) Assure that test data, reports (Appendix D) and related documentation is submitted to Panel 18 in a timely manner.

(8) A log will be maintained for documenting each item shipped and for providing evidence that the shipped component was received by the supplier.

d. Couriers

(See Appendix G)

e. Subsystems Engineers

(1) Approve/disapprove all ASHUR's under his cognizance.

(2) Reviews his hardware and screen into Category A or B.

(3) Proposes and submits MRR to Screening Committee for approval.

(4) Maintain status of all activities concerning hardware authorized for testing.

14. Special attention to careful handling of all S/C 012 parts will be provided in the following manner:

a. Parts will not be moved from one area to another within KSC without being accompanied by a NAA or NASA courier.

b. A parts tag will be attached to each component and the reverse side of the tag will be stamped, "Apollo 204 Review Board Material." Each component will be "D" stamped.

c. NAA/NASA Quality personnel will witness all packaging operations to insure good packaging and handling practices. Where special attention to packaging is required, NAA Engineering will be requested to provide special instructions.

d. Prior to shipping, each package or container will be sealed and stamped by both NAA and NASA Inspection with words "NOT TO BE OPENED WITHOUT CONTRACTOR AND GOVERNMENT AGENCY INSPECTION WITNESS." All material shall also be accompanied by a representative (witness) appointed by the Board unless otherwise specified by the Board. A NAA or ACED or NASA Quality Control courier may be assigned to accompany each shipment to its destination.

e. The Local Government Inspection Agency shall provide continuous (24 hour) inspection coverage while the hardware is being tested and/or analyzed..

f. Prior to shipping, NAA and NASA will notify the appropriate contractor and government agency Qualify Assurance representative at the destination of anticipated arrival of the parts.

g. Each shipment will contain a copy of the updated acceptance Data Package, ASHUR, and DD-1149 (shipping document). The courier accompanying the parts will hand-carry a copy of the DD-1149 for signature by the delegated contractor's representative upon receipt of the component.

h. The properly negotiated DD-1149 master will be returned to the MSC Action center by the courier.

i. Whenever possible, NASA aircraft or commercial aircraft will be chartered or reserved for shipment of these items to assure expeditious and safe handling.

SUBSYSTEM ENGINEERS
APPENDIX A

	MSC	KSC	NAA
Steering	D. Mayhew	T. Sasseen	D. Levine
Communication	L. Luse	T. Broughton	G. Covington, III
Instrumentation	F. Rotrammel	W. Glusing	G. Covington, III
Guidance & Navigation	R. Gardner	J. Tadich	ACED
Stabilization & Control	R. Burt	J. Stilley	C. Conrad
Environmental Control	F. Samonski	R. Hunnings	M. Stelzreide
Electrical Power System	R. Munford	M. Guidry	L. Updegraff
Controls & Displays	C. Creech	NONE	C. Fischer
	D. Grimm		
Sequential	G. Johnson	M. Guidry	R. Hartley
Reaction Control System	R. Taueber	R. Butterworth	J. Montgomery
Structures & Mechanical (Incl. LES)	P. Glynn	H. Shoaf	P. Hanifin
Secondary Propulsion System	N. Townsend	R. Butterworth	D. Levine
Earth Landing	R. West	H. Shoaf	R. Hartley
Crew Equipment	F. McAllister	J. Thomas	J. Montgomery
Experiments	C. Vaughn	J. Thomas	G. Covington, III
Pyrotechnics	W. Simmons	E. Timmons	R. Hartley
SLA/Service Module (Panel 21)	W. Petynia	D. Carothers	B. Haight

APPENDIX B

EQUIPMENT SCREENING AUTHORIZATION

SUBSYSTEM SCS

ITEM HAND CONTROLLER

P/N XXXXXXXXX

S/N XXXX

JUSTIFICATION FOR CATEGORY C CLASSIFICATION

Reference TPS's XXX-XX-XX, XXX-XX-XX

NASA KSC SUBSYSTEM	NASA MSC SUBSYSTEM	NAA SUBSYSTEM
T. SASSEEN	D. MAYHEW	D. LEVINE
FIRE PANEL	MAB	

APPENDIX C

INSTRUCTIONS FOR PREPARATION OF ASHUR

A. ASHUR (MSC FORM 1148)

Numbers correspond to the numbers shown on each block.

1. Spacecraft Number. Insert the spacecraft number to which the request applies (i.e., CSM 012 or 014).

2. System(s) Affected. Indicate the spacecraft system(s) affected.

3. ASHUR Number. Identification number of the ASHUR will be filled in by Panel 18. The ASHUR shall be identified by a series of numbers which reflect spacecraft number. Those ASHUR's initiated on Spacecraft 012, Mission 204 shall be numbered consecutively from 012500 to 012999 or Spacecraft 014, i.e., 014500 to 014999.

4. Purpose. Specify the purpose of the ASHUR, i.e., one of the following:

a. To investigate a suspect anomaly or malfunction.

b. To insure that function or operation of the system or component was adequate for the mission.

c. To initiate a test and/or analysis of a system or component in support of Apollo 204 Review Board investigation.

d. Other - specify.

5. Justification. This space will be utilized for the concurrency, by signature, of the NASA Subsystem Engineer, the NAA Subsystem Engineer, and Panel #18.

6. Description. The initiator of the ASHUR shall describe the test requirements, inspection, analysis, and disposition in detail. Sufficient detail should be indicated to convey exactly what is required. The description shall include, but not be limited to, the following, where applicable:

a. Specify conditions.

b. Instrumentation requirements, including both spacecraft and GSE.

c. Environmental requirements.

d. Type or types of data required, i.e., magnetic tapes, strip charts, etc.

e. Input parameters to be varied and to what degree.

f. Parameters to be measured.

g. Specify time reference if applicable.

h. Events to be simulated.

i. Special test procedures or instructions (or supplemental instructions as required).

7. To Be Accomplished By. Indicate which contractor or special facility is to accomplish this test. Indicate where the test is to be accomplished or the disposition location. If a failure analysis is to be conducted, indicate where this is to be accomplished. If it is a location other than those listed specifically, check "Other" block and indicate by name on line provided to the right. It is recognized that some facilities are better equipped for disassembly and/or failure analysis than others. Each case must be assessed as it occurs as to where the analysis will be performed and the recommendations must be based on a thorough assessment of the best possible combination of disassembly and analysis capabilities. The spacecraft contractor and the vendor of the failed component should be consulted prior to determining the locations for the various phases of failure analysis. Regardless of where each phase of the failure analysis is performed, it is required that NASA, contractor, and the vendor be represented.

8. Name of the individual assigned as the point of contact at the facility where the work is conducted. J. C. Campbell, PIB, ext. 3515, 3779; will be MSC/KSC contact.

9. Disposition of hardware after requested action has been completed.

10. Requested By. Insert signature of individual preparing the ASHUR and panel number.

11. Not applicable for purposes of this procedure.

12. or 13. Signature of KSC/MSC action control authority is required.

14. Type of Action. Check the block which describes the type of action requested. There will be only one block checked for each ASHUR initiated. The testing block should have "Project X" typed by it.

15. Sheet ___ of ___. Indicate the sheet number and total number of sheets.

B. ASHUR Continuation Sheet (MSC Form 1148A)

Numbers correspond to numbers shown on sample continuation sheet.

1. Spacecraft Number - same as paragraph A.1.

2. System(s) Affected - same as paragraph A.2.

3. ASHUR Number - same as paragraph A.3.

4. NAA TPS Number - Appropriate NAA TPS number(s) assigned to hardware designated, if appropriate.

5. Not applicable.

6. Photograph Number - Applicable NASA photograph numbers, if known.

7. Description - Continuation of information detailed in the description of the ASHUR, MSC Form 1148, if required (see paragraph A.6.). In addition, the ASHUR continuation sheet shall be used to document the summary results of the tests, inspection, or analysis. These results shall be documented as soon as they are known and shall constitute a summary of the results. If the results are final, a statement shall be made to that effect, i.e., "This ASHUR is considered closed." Care should be taken to assure this has been done prior to being submitted to Action Control. For example, if the intent of the ASHUR is to disposition hardware, the continuation sheet should reflect the action taken with reference to applicable shipping documents. Action Control will be responsible for assuring that all ASHUR's are answered and closed out, interfacing with the Integration Panel 18 and the Disassembly Panel 4, and the Board, as necessary.

8. Signature of ASHUR Contact - Signature of person whose name appears in Block 8 on ASHUR, MSC Form 1140. This space will be used to document the contractor or test administrator signature. In that case, it will be signed and dated by the contact at the facility where the investigation was conducted. This signature is not a validation of the test results, but is an indication of the source of the information and is accurate documentation of the information obtained via the ASHUR system.

9. Sheet ___ of ___. Indicate the sheet number and the number of sheets.

APPENDIX D (4)

APOLLO SPACECRAFT HARDWARE UTILIZATION REQUEST

SPACECRAFT NUMBER	SYSTEM(S) AFFECTED	ASRUR NUMBER
(1)	(2)	(3)

PURPOSE

(4)

JUSTIFICATION

(5)

DESCRIPTION

(6)

TO BE ACCOMPLISHED BY: (7)

☐ NAA ☐ KSC MAB ☐ VENDOR

☐ GAEC ☐ MSC ☐ OTHER

LOCATION OF WORK ACTIVITY

CONTACT FOR STATUS

(8)

FINAL DISPOSITION OF HARDWARE

(9)

TYPE OF ACTION

☐ TEST REQUEST Project X

☐ REUSE REQUEST (14)

☐ DISPOSITION REQUEST

REQUESTED BY	ORGANIZATION	DATE
(10)		

CHIEF ANALYST	DATE
(11) N/A	

ASRUR APPROVED	DATE	ASRUR DISAPPROVED	DATE	SHEET (15) OF
(12)		(13)		

MSC FORM 1148 (REV JAN 67) (Previous editions are obsolete)

APPENDIX C (5)

APOLLO SPACECRAFT HARDWARE UTILIZATION REQUEST (Cont'd)

SPACECRAFT NUMBER	SYSTEM(S) AFFECTED	ARMD NUMBER
(1)	(2)	(3)

NAA IPS NUMBER	NAA AIR NUMBER	PHOTOGRAPH NUMBER
(4)	(5) N/A	(6)

(7)

SIGNATURE OF ARMD CONTACT	DATE	SHEET (9) OF
(8)		

MSC FORM 1140A (OCT 66)

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OF POOR QUALITY

APPENDIX J (6)

APOLLO SPACECRAFT HARDWARE UTILIZATION REQUEST

SPACECRAFT NUMBER	SYSTEM(S) AFFECTED	ASRUR NUMBER
012	SCS Pitch ECA	012502

PURPOSE

To investigate for possible anomaly

JUSTIFICATION

NASA Systems Engr. — Panel #13

NAA Systems Engr.

DESCRIPTION

1. Remove the SCS Pitch ECA - from the PIB and hand carry to Minneapolis Honeywell, for analysis.
2. Upon arrival, visually inspect, externally, and photograph all four sides, as well as top and bottom.
3. Conduct a low level continuity check.
4. Perform an electrical/mechanical functional check, utilizing the BMF, as per the PIA procedure.
5. Remove the covers and visually inspect internally, taking photographs as appropriate.
6. Any area of difficulty disclosed during functional check shall require a failure analysis to be performed. Controlled disassembly shall be executed and such x-rays as are deemed necessary shall be taken.
7. Upon completion of all tests and failure analysis, the hardware shall be reassembled and returned to bonded storage, PIB, KSC.

EXAMPLE

TO BE ACCOMPLISHED BY:

☐ NAA ☐ KSC MAB ☒ VENDOR
☐ GAEC ☐ MSC ☐ OTHER

LOCATION OF WORK ACTIVITY: MINNEAPOLIS HONEYWELL, MINNEAPOLIS, MINNESOTA

CONTACT FOR STATUS: J. CAMPBELL, PIB EXT. 3515

FINAL DISPOSITION OF HARDWARE: Return to bonded storage, PIB, KSC

TYPE OF ACTION

☒ TEST REQUEST PROJECT X
☐ REUSE REQUEST
☐ DISPOSITION REQUEST

REQUESTED BY	ORGANIZATION	DATE
R. PURT	PANEL 13	3/1/67

CHIEF ANALYST	DATE
N/A	

ASRUR APPROVED	DATE	ASRUR DISAPPROVED	DATE	SHEET ___ OF ___

MSC FORM 1148 (REV JAN 67) (Previous editions are obsolete)

ATTACHMENT 1

APPENDIX D

CONTRACTOR REPORT FORMAT RECOMMENDED FOR
S/C 012 REVIEW

SUBJECT: Type of work, location, systems and job No.

RELATED DOCUMENTATION: Include known failure reports, discrepancy reports, deviations, etc., drawing numbers, pertinent specs, and technical information.

WITNESSES:

1.0 Foreword

1.1 Identify requestor, requestor organization, state general problem and when submitted.

1.2 State analysis or evaluation requested. Detail in steps if required.

1.3 Briefly cite known failure history and/or previous tests performed.

1.4 Other pertinent items.

2.0 Configuration Verification (Part Numbers, Drawing Numbers, Specification Numbers).

Investigation Procedures (Dealing with device itself)

Evaluation Procedures (Dealing with related materials)

Analytical Procedures (Dealing with chemical analysis)

Describe field examinations, samples taken, equipment employed, consultations with outside personnel and other activities. Each distinct action shall be defined in a separate paragraph.

3.0 Analytical Test and Results

Describe results and relations between the various analytical tests. Correlation between chemical/physical findings and problem being considered should be clarified.

4.0 Conclusions

Concise statements in a natural order based on investigative and analytical procedures. If conclusions are assumptive in nature, so state and give reasoning for assumptions. In all cases provide a specific conclusion.

5.0 Recommendations

Should be applicable, constructive in nature and workable. Applicability to other Apollo hardware should be identified.

Signatures:

Investigator: (Not above first level of Supervision For Board Interrogation when necessary).

Concurrence: (Knowledgable of All Steps in Investigation).

Approval: _____

Witnesses: _____
(Government Agency)

_____
(Contractor)

NOTE: APPENDICES AND PHOTOS SHOULD BE REFERENCED IN TEXT AND RELATED TO NARRATIVE TEXT.

APPENDIX E

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

COURIER INSTRUCTIONS

The courier is appointed by the Apollo 204 Review Board to accompany the shipment of a specified piece of hardware to its predetermined destination as outlined in the Administrative Procedure 5 and revisions thereto.

The courier will report to the MSC Action Office at the PIB where he will be briefed by the MSC ASHUR Action Control. J. C. Campbell, PIB Room 106A, phone 867-3515 or 3779.

The courier will receive the package or container in the presence of the MSC Hardware Control Officer and the designated NASA Quality Control Representative.

The courier will sign for the package(s) and/or container(s) received on the DD 1149 and will receive an ASHUR, MSC Form 1148, approved by the MSC Hardware Control Officer.

The courier will maintain positive control of the package(s) and/or container(s) entrusted to him. Special precaution must be taken if unchartered commercial transportation is utilized.

The courier will notify MSC Action Center of his arrival by telephone AC 305, phone 867-7163, 3779, or 3515.

The courier will witness the opening of the package(s) and/or container(s) in the presence of the receiving agencies and the Government Agency Inspection (Quality Control) Representative.

The courier will insure that the DD 1149 master is properly negotiated and returned to the MSC Action Center, KSC, Room 2130.

The courier will deliver a copy of the updated Acceptance Data Package to the Government Agency Inspection (Quality Control) Representative.

The courier will notify the Government Agency Inspection (Quality Control) Representative at the destination to telephone the Action Center, KSC, MSOB, telephone 867-7163, to verify the final disposition stated on the ASHUR before compliance.

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure No. 6

TITLE: Establishment of the Advisory/Group to the Apollo 204 Review Board

SCOPE: This procedure is an implementation of the Deputy Administrator's memorandum of February 3, 1967.

POLICY: 1. The Apollo 204 Review Board was established by the Deputy Administrator, NASA, on January 28, 1967, pursuant to NASA Management Instruction 8621.1. By memorandum dated February 3, 1967, the Deputy Administrator amplified and documented verbal instructions given to the Chairman of the Review Board as follows:

a. The Chairman shall establish such procedures for the organization and operation of the Board as he finds most effective. Such procedures shall be part of the Board's records.

b. Board members shall be appointed or removed by the Deputy Administrator after consultation with the Chairman as necessary for the Board's effective action.

c. The Chairman may establish procedures to assure the execution of the Chairman's responsibility in his absence.

d. The Chairman shall appoint or designate such representatives, consultants, experts, liaison officers, observers or other officials as required to support the activities of the Board. The Chairman shall define their duties and responsibilities as part of the Board's records.

e. The Chairman shall keep the Deputy Administrator advised periodically concerning the organization and operations of the Board and its associated officials.

f. The Chairman shall assure that the Counsel to the Board develops and maintains memoranda records covering possible areas of litigation.

2. Pursuant to paragraph 1.d., the Chairman has established an Advisory Group, the membership of which is set forth in Attachment A. The duties and responsibilities of the members are:

Representative - An individual representing a major element of NASA or other Government agency having programs and activities associated with the Apollo program who participates in general meetings of the Board.

Consultant - An individual who serves as an advisor to the Apollo 204 Review Board. It is the responsibility of the consultant to give his views or opinions on problems or questions presented by the Board or Panels. Consultants will, as appropriate, recommend to the Board or cognizant Panels, courses of investigative action to be undertaken in the field of their competence.

Liaison - An individual representing an activity having a recognized interest in the Apollo 204 Review who attends general meetings of the Board for the purpose of familiarizing himself with the current status of the Apollo 204 Review. Liaison personnel are empowered to coordinate with Panel Chairmen or Board Members, as appropriate, in areas of interest to acquire data that is of interest to the activity represented by the liaison individual.

Panel Chairman - An individual designated by the Board to serve as a manager to direct and coordinate the activities of the Panel to which appointed in accordance with the statement of work prescribed for the Panel by the Board. The Panel Chairman reports directly to the appropriate Board monitor. Panel Chairmen will report to the Board, when required, on the progress of work and obtain Board approval of work plans.

Observer - An individual who attends general meetings of the Board for the purpose of familiarizing himself with the current status of the Apollo 204 review, particularly in the area of his expertise and responsibility. Observers are empowered to enter restricted areas, upon approval, in order to be able to assist the Board or Panels; they shall also be prepared to submit to the Board, either orally or in writing, such reports and recommendations as the Board may require.

Secretariat - Provides administrative, secretarial, clerical and other supporting services to the Board and Advisory Groups.

3. The Board and Advisory Group will conduct business, as a body, in the following manner:

a. A general meeting is a meeting of the Board, Advisory Group and other persons requested to attend for the purpose of conducting the business of the Board, establishing the record, presentations of panels and subcommittees, and such other business as is necessary.

The Mission Briefing Room (MSO Building) is the place where the general meetings of the Board are held.

b. An Executive session of the Board is a meeting limited to Board members, Counsel, and to individuals requested by the Board to attend. These sessions are held for the purpose of determining policy, formulating courses of action, deliberation on matters restricted to Board members, decisions as to the findings of fact, determinations, recommendations and other essential matters to be included in the Final Report to the Administrator.

Executive sessions will normally be held in Room 1814, MSOB, and at such other locations as the Board may designate.

S/ Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

Attachment A
Apollo 204 Review Board
Admin. Procedure No. 6
February 3, 1967

ADVISORY GROUP

Representatives	
Gen. C. H. Bolender	OMSF, represents Apollo Program Director
Mr. C. Mathews	OMSF, Director, Saturn/Apollo Applications
Mr. R. A. Petrone	Director, Launch Operations, KSC
Dr. J. Shea	MSC, Manager, Apollo Spacecraft Program Office
Lt. Col. W. Baxter	USAF, Chief, Range Safety Office, Air Force Eastern Test Range
Consultants	
Dr. Frank A. Long	Vice President for Research and Advanced Studies, Cornell University
Mr. J. Yardley	Gemini Program Technical Director, McDonnell Company
Mr. G. W. Jeffs	Chief Engineer, Apollo Program, North American Aviation, Inc.
Alternate: Mr. R. L. Benner	Assistant Chief Engineer, Apollo Program, North American Aviation, Inc
Mr. Irving Pinkel	Chief, Fluid Systems Components, Lewis Research Center
Mr. Thomas G. Horeff	Program Manager, Propulsion Engineering and Safety Division, Aircraft Development Service, Federal Aviation Agency
Dr. H. Carhart	Chief, Fuels Branch, Chemistry Division, Naval Research Laboratory
Mr. John S. Leak	Chief, Technical Services Section, Engineering Division, Bureau of Safety, Civil Aeronautics Board
Liaison	
Mr. Duncan Collins	Special Advisor, Secretary of the Air Force, SL Program

Attachment A
Apollo 204 Review Board
Admin. Procedure No. 6
February 3, 1967

Panel Chairmen

Panel No.	Panel Title	Chairman
1	S/C and GSE Configuration	J. Goree, MSC
2	Test Environments	W. Hoyler, MSC
3	Sequence of Events	D. Arabian, MSC
4	Disassembly Activities	S. Simpkinson, MSC
5	Origin and Propogation of Fire	F. Bailey, MSC
6	Historical Data	J. T. Adams, MSC
7	Test Procedures Review	D. Nichols, KSC
8	Materials Review	W. Bland, MSC
9	Design Reviews	R. Williams, MSC
10	Analysis of Fracture Areas	P. Glynn, MSC
11	Medical Analysis	G. Kelly, MSC
12	Witness Statements	N. Vaughn, MSC
13	Ground Emergency Provisions Review	G. Page, KSC
14	Security of Operations	C. Buckley, KSC
15	Board Administrative Procedures	E. Mathews, KSC
16	Special Tests	G. Stoops, MSC
17	Final Board Report	Lt. Col. K. H. Hinchman, USAF
18	Integration Analysis	A. Mardel, MSC
19	Safety of Investigation Operations	J. Atkins, KSC
20	In Flight Fire Emergency Provisions Review	Capt. J. Lovell, MSC
21	Service Module Disposition	C. A. Chauvin, KSC

Attachment A
Apollo 204 Review Board
Admin. Procedure No. 6
February 3, 1967

Observers

All Astronauts, MSC

Maj. P. A. Butler, USAF

Dr. Kurt H. Debus, KSC

Mr. P. C. Donnelly, KSC

Lt. Col. W. Dugan, USAF

Mr. J. King, KSC

Mr. H. E. McCoy, KSC

Mr. R. E. Moser, KSC

Dr. George Mueller, OMSF

Mr. W. P. Murphy, KSC

Gen. S. C. Phillips, OMSF

Mr. G. M. Preston, KSC

Gen. J. G. Shinkle, KSC

Mr. A. F. Siepert, KSC

Mr. W. Williams, KSC

Secretariat

Ernest Swieda — Executive Secretary

APOLLO 204 REVIEW BOARD
FEBRUARY 13, 1967

Administrative Procedure Number 7, Revision A

SUBJECT: Handling of Sensitive and Non-Sensitive Information and Material Under the Jurisdiction of the Apollo 204 Review Board.

PURPOSE: Information and Material Sensitivity Controls for Apollo 204 Review Board.

POLICY: 1. All information, data, hardware, etc., related to the Review is considered sensitive until one of the following has made an analysis of the information or material and made a determination that it is not sensitive: Chairman of the Board, Board Members (within the areas for which the member is acting as monitor) and Panel Chairmen (in the areas in which they are cognizant).

2. Until analysis and contrary determination, unclassified sensitive material related the Apollo 204 Review Board will be treated as if it were classified CONFIDENTIAL.

3. Apollo 204 Review Board material classified as SECRET or CONFIDENTIAL by the Apollo or Saturn Security Classification Guide must be first handled according to NASA Security Directives and then according to Board policies.

4. All Apollo 204 Review Board information, material, etc., whether classified or unclassified, sensitive or non-sensitive, will be released (a) only to persons authorized access for official Board purposes, or (b) following the Board's decision that the material is no longer needed for Board purposes, at which time the material will revert to its normal status.

DEFINITIONS: 1. Sensitive Material: Classified or unclassified information or material necessary to the Board, which reflects pertinent data concerning the Apollo 204 accident.

2. Persons Authorized Access to Board Information and Material.

a. Sensitive-Classified: Access will be granted to those appropriately cleared and essential Government and contractor personnel who have been authorized by the Review Board Procedures.

b. Non-Sensitive-Unclassified: As in a above, except these personnel need not be cleated.

3. Secure Area: An area where sensitive, classified or unclassified, material is housed or stored in approved containers or is under continuous control by cognizant, cleared personnel will be categorized as a Secure Area.

PROCEDURE: 1. Storage

a. Sensitive - All unclassified or classified sensitive Board information or material will be stored in a "Secure Area."

b. Non-Sensitive: All unclassified, non-sensitive Board information or material may be stored in the manner normal for official Government material, or as established by other Board Procedures.

2. Access to and Removal of Sensitive Information

Material. Access to sensitive material and removal of sensitive material from a Secure Area will be in accordance with administrative procedures approved by the Chairman of the Board.

3. Regrading. Sensitive information or material will be regraded from sensitive to non-sensitive only by the authority of those persons indicated in paragraph 1,

Policy. Sensitive information or material will be regraded to CONFIDENTIAL or SECRET only by the authority of the Chairman of the Board.

4. Marking of Information or Material

a. Non-Sensitive. All non-sensitive Board information or material will be unmarked, unless classified and marked, originally.

b. Sensitive.

(1) General - All sensitive Board information or material, when removed from a Secure Area, will be identified by use of the Apollo 204 Review Board Material Cover Sheet or stamp as follows:

APOLLO 204
REVIEW BOARD
MATERIAL

Note: The former cover sheet marked "For the Use of Apollo 204 Board Investigation Only" may be used until the supply is exhausted.

(2) Printed or Written Information - All material of this type related to Review Board activities which is susceptible to the secure fastening of a cover sheet need only be identified by the cover sheet in 3a above. Material not susceptible to secure cover sheet fastening should be plainly and conspicuously stamped once on each page.

(3) Photographs, Films, Microfilms.

(a) Negatives - The envelope will be marked.

(b) Slides and Transparencies - The margin will be stamped.

(c) Still Prints - If the quality of the prints will not be reduced, they will be stamped on the lower front of the print. Otherwise, they will be stamped on the back.

(d) Polaroid Prints - As in (c) above.

(e) Microfilm Mounted on IBM Cards - Stamped on front of card.

(f) Motion Picture Film - Reels and reel containers will be individually stamped. Take-up reels will be stamped, unless film is immediately transferred to the original reel following projection.

(4) Magnetic Tapes - The cabinets in which tapes are stored will have cover sheets affixed prominently on the exterior. As tapes are removed for use, the shipping container and the reel will be marked on the labels with the stamp.

(5) Hardware - Parts Tag (KSC Form 4-8 (7/65)) if attached to the hardware will be stamped appropriately on reserve side. Hardware without parts tag will be otherwise tagged and the tag stamped appropriately.

Note: Extreme care must be utilized in properly identifying and marking sensitive information or material lest it fall into the non-sensitive category by merely omitting marking.

5. Transmitting Apollo 204 Review Board Information and Material.

a. Sensitive

(1) External - Apollo 204 Review Board information and material must be transmitted by registered or certified U.S. mail. If hand-carried, it will be securely packaged, and cleared couriers will be used.

(2) Internal - Local mail delivery will require the use of cleared couriers and sealed containers.

Note: Classified-sensitive material will be handled as indicated in Paragraph 3, Policy, Paragraph 7, Procedure, and NASA Security Directives.

b. Non-Sensitive. This information and material may be transmitted in the manner normal for official Government material, unless otherwise specified by Board policies or the sender, or unless classified, when NASA Security Directives pertain.

Note: This material must be forwarded only to those persons indicated in Paragraph 2, Definitions, until released by the Board.

6. Reproduction of Apollo 204 Review Board Information and Material.

a. Sensitive - In this category, it may be reproduced only by authority of Board authorized personnel in areas approved for classified reproduction or on apparatus specifically approved for Board use.

b. Non-Sensitive - If in this category, it may be reproduced only by authority of Board authorized personnel in the manner normal for unclassified reproduction, unless otherwise specified by Board policy or the holder.

7. Board Classified Information and Material Records System.

a. All classified material received by or generated by the Board will be recorded within a system established for the Board by the local NASA Security Office.

b. All classified material will immediately be reported to the Chairman, Security of Operations Panel or his designees who will take steps to assure its proper recording and subsequent handling.

8. Destruction of Apollo 204 Review Board Information or Material.

a. All Sensitive or Non-Sensitive Unclassified Board information or material (including typewriter tapes, carbon paper, notes, etc.) which requires destruction will be destroyed in devices currently approved for classified destruction, unless released by the Board, at which time normal waste procedures may be used.

b. All classified Board information or material will be destroyed by normal classified destruction procedures, but only after being processed through the Board Classified Information and Material Record System for clearance of records.

S Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 8, 1967

Administrative Procedure No. 8

TITLE: Photo Support Service for the Apollo 204 Review Board

SCOPE: This procedure covers the manner by which photo support is requested, prints are delivered, and negatives and prints are stored in a "Central Film Library" for use by the Apollo 204 Review Board.

POLICY: 1. Only Apollo 204 Review Board members and Task Panel members can authorize a request for photo service. For the purpose of this procedure "photo service" means the taking of pictures, developing film and printing photographs.

2. All photo support requirements will be fulfilled by the KSC Photographic Branch, RH-2, unless specifically authorized by the Review Board.

Unless specifically instructed, four sets of color prints will be made during the initial processing.

For reproduction of existing photos, one set will be made unless specified.

3. A Central Film Library is available at MSO Building, Room 1114, 867-2631, 2632, where existing prints are available for review by authorized personnel.

Prints are arranged in books by spacecraft grid areas, identified on library drawing, by date and time sequence so that any particular spacecraft area may be reviewed in detail desired.

Reproduction from existing negatives may be requested at that library.

All prints released from the Central Film Library will be logged out to the requesting Review Board Member or Task Panel Chairman who will be responsible for maintaining proper internal handling and control.

Before initiating any request for the taking of new pictures, the originator should contact the Photo Library to assure himself that his areas of interest have not been photographed previously.

All Task Panel Chairmen are requested to furnish the library with a list of their personnel who will require access for reviewing photographs.

4. Requests for taking pictures should be the requirements of a TPS.

An authorized photographer is available at the spacecraft site for taking pictures on request from authorized personnel as required by the TPS being worked.

For areas where photographers are not continuously available, telephone KSC Photo Operations at 867-6240, stating that the requirement is for the Apollo 204 Review Board and the location where a photographer is required.

5. Before taking any pictures, the photographer must be furnished with the name of the requesting Board or Panel member, Task Panel Number, whether Spacecraft 012 or Spacecraft 014, the description of each view, the date and time the picture is made, and the TPS number and step number for proper photo identification on his "photo caption log".

All prints and negative jackets are to be identified as Apollo 204 Review Board Material in accordance with Administrative Procedure No. 7.

All prints and negative jackets will be captioned on the back giving the applicable spacecraft, view description, TPS number and step number, the date and time at which the picture was made, the cognizant Board member or Task Panel number, and will be serialized with photographic work order number, film pack number, and frame number.

Negatives will be released only to the Photo Branch, RH-2, for reproduction unless specifically requested by the Review Board.

PROCEDURE: 1. Requests for taking new pictures:

a. The requirement for pictures is established by the TPS.

The requirement should be indicated on the TPS and any particular step requiring a picture should include the Task Panel number, or a member's name as a minimum information.

b. Information for the photographer's photo caption log may be given verbally but is required.

c. The responsible on site person should give verbal instruction to the photographer regarding particular views required and the time sequence involved to satisfy the requirements of the TPS.

2. Delivery of Photo Material:

a. After the required pictures have been taken, KSC Photographic Branch, RH-2, personnel will carry the film to their photo labs for processing in order of arrival by film pack number.

b. Four sets of color prints will be made.

c. After processing, the Photographic Branch, RH-2, will prepare the photo material in a sealed envelope identifying the package as Apollo 204 Review Board Material.

d. The Photographic Branch will then contact the Apollo 204 Review Board Central Film Library at the MSO Building, Room 1114, telephone 867-2631, 2632, and request that the authorized Photo Courier pick up the package and carry it to the Central Film Library for proper disposition.

e. The library will contact the Photo Courier at 867-5628; delivery to be made to the Central Film Library.

f. After arrival at the Central Film Library, disposition will be as follows:

(1) One set of prints will be logged out and carried to the requesting Review Board Members or Task Panel Chairman's mail box in the MSO Building.

(2) One set of prints will be sent to Mr. J. Lobb, PK-2, MSC, Houston.

(3) One set of prints will be filed at the Central Film Library numerically by negative number and will be available for release to authorized personnel.

(4) One set of prints will be permanently filed by spacecraft grid area and subject description into appropriately identified books which will be available for review in the library by authorized personnel.

(5) All negatives will be filed numerically by negative number at the library for future reproduction use.

8. Requests for Reproduction of Prints:

a. When it is determined that additional copies of existing prints are required, the file copy may be released.

b. If a file copy will not meet the requirement, the librarian will prepare a work order listing the negative numbers, whether color is required, size of print, quantity of prints, and the name of the authorized person.

NOTE: Since there may be a considerable number of different prints available for a particular spacecraft zone, careful selection of the individual prints from the library file will provide faster service and be less costly.

c. The librarian will prepare the required negatives and a copy of the work order in a sealed envelope marked "Apollo 204 Review Board Material".

d. The librarian will then contact the Photo Courier at 867-5628 and request that the package be carried to the Photographic Branch who will fulfill the request.

e. After processing, the Photo Branch will prepare the package and have delivery made to the Central Film Library as previously described.

f. The librarian will distribute the prints to the appropriate Review Board members or Task Panel Chairman's mail box and will file the negatives.

S—Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure No. 9

TITLE: Transcribing Apollo 204 Review Board Proceedings.

SCOPE: This procedure covers the recording, transcription, review and distribution of Apollo 204 Review Board Procedures for record in the Review Board Meeting Room, MSOB.

POLICY: The proceedings for record of the Apollo 204 Review Board shall be recorded and provided in written form for Review Board use.

PROCEDURES: 1. Upon statement by the Chairman of the Apollo 204 Review Board that the Board actions, testimony, findings, etc., will be stated for record, communications personnel will cue the 1/4 inch magnetic tape voice recorder. The resulting tape is designated the Master Tape.

2. The recorded material will be reproduced, one copy only, onto 4-inch IBM tape by the communications personnel.

3. The Master Tape and the 4-inch IBM tape will be delivered to the Secretarial Support Room, (Room No. 1805) MSOB by the communications personnel.

4. The 4-inch IBM tape will be logged by Secretarial Support personnel with a reference to the Master Tape.

5. The individual 4-inch IBM tapes will be transcribed by the Secretarial Pool into a series of first drafts.

6. The first drafts and the Master Tape will be delivered by the Secretarial Pool to the selected technical personnel for review and correction, and returned to the Secretarial Pool.

7. The Master Tape will be delivered to Task Panel 17, Final Board Report Panel, Room 1806, MSOB, for storage.

8. The Secretarial Pool will prepare a second draft of the combined corrected transcripts for one day's proceedings and will distribute them to the Apollo 204 Review Board Members and the Board Counsel.

9. After the lapse of 24 hours from receipt by the Board Members and Counsel all comments/corrections which may be received by the Secretariat from the Board members will be incorporated into a final copy for record by the Secretariat.

10. The final copy will be reproduced and copies placed in appropriate covers for the Board Members and Counsel. The original will be delivered to Task Panel No. 17, Final Board Report Panel, for filing.

/S/ Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 21, 1967

Administrative Procedure No. 10, Revision A

TITLE: Control of Data and Documents

SCOPE: This procedure covers the control of all documentation and data relative to AS-204 Space Vehicle and associated GSE data.

POLICY: 1. Original copies of all data to include specifications, inspection data, test procedures, test data, drawings relative to all parts, subsystems, and modules in Space Vehicle AS-204 and associated GSE prior to 0600 January 27, 1967, shall be impounded. Access to these data or copies of this data shall not be further restricted than that necessary for normal program control.

2. Original copies of all data to include inspection data, test procedures, test data, tapes, etc., relative to the AS-204 space vehicle and associated GSE after 0600 January 27, 1967, no matter where recorded, as well as duplicates of such data shall be impounded. Access to such data as well as duplicates of such data will be restricted to authorized personnel as included in Attachment 1 or their designees as specified in writing.

3. For purposes of this instruction, impounding means assuring security of such data from alteration or destruction.

4. No release of such information to public sources shall be made without specific approval of the Review Board Chairman.

PROCEDURE: 1. Data will be impounded in areas as follows:

a. Room 3344, MSO Building (Review Room 3343)

b. Rooms 2720-21, MSO Building

c. SCO Tape Library, Room 4410, MSO Building

d. Flight Crew System Lab, Room 3724, MSO Building

e. Complex 37A AGCS - (Launch Vehicle Data)

f. Room 240, Central Instrumentation Facility (CIF)

2. A NASA Security Guard will be posted at the entrance of each impounded area as noted above, except Room 4410, and Room 240, CIF, on a 24-hour basis and shall allow authorized personnel as indicated in Attachment 1 or their designees in writing to have access to impounded area. (Procedures for Room 4410 and Room 240, CIF, are provided in paragraphs 4 and 6 below, respectively.)

3. Control of documentation and data contained in Room 3344, MSO Building, will be as follows:

a. Room 3343 will be used for review of documents contained in 3344.

b. Access to 3344 shall be restricted to people actually assigned to Spacecraft 012 impounded record control. A list of these personnel will be forwarded from the Task Panel No. 6 Chairman to NASA Security.

c. Access to Room 3343 shall be as specified in paragraph 2 above.

d. Removal of original documents from Room 3344 is not authorized without prior approval from the Apollo 204 Review Board (Mr. Geer or his alternate) except to Room 3343 for review. Reproduction of documents located in Room 3344 is authorized for persons having access but shall be accomplished by personnel located in Room 3344.

4. Control of documentation and data as contained in Room 4410 will be as follows:

a. Data tapes for Spacecraft 012 shall be stored in locked/sealed cabinets. No cabinet containing Spacecraft 012 tapes may be opened unless NASA Quality Control personnel are present when the seal is broken.

b. Original data tapes for Spacecraft 012 may only be withdrawn from the SCO Data Handling Facility to make a duplicate copy.

c. At the time that the original request is received, Data Handling personnel shall first check to make sure that a duplicate copy has not previously been made before releasing the original copy of data tapes.

d. Original and duplicate copies of Spacecraft 012 tape may be withdrawn from SCO Data Handling Facility only when authorized by an AVO signed by J. H. Lane or J. H. Weisner, H. N. French, D. E. Perreton, D. E. New, or F. R. Schilling.

5. Control of Documentation and Data contained in Rooms 2720, 2721, 3724 of the MSO Building, and Complex 37, Pad A, will be as follows:

a. Removal of original documents is not authorized without prior approval from the Apollo 204 Review Board (Mr. Geer or his alternate).

b. Access shall be as specified in paragraph 2 above. In addition, it is anticipated that Launch Vehicle Operations will require access to the Complex 37, Pad A, data. An LVO access list will be forwarded to NASA KSC Security by the NASA Launch Vehicle Test Conductor's office (853-9917) which is designated as the cognizant Launch Vehicle Operations Office.

6. Control of documentation and data located in Room 240 of the CIF will be as follows:

a. The control of tapes and data in this room, which pertains to AS-204, is the responsibility of the KSC Data Office (Mr. Jelen).

b. The KSC Data Office will not reproduce data pertaining to AS-204 unless authorized by the Launch Vehicle Test Conductor's Office (Mr. J. Kelly or his alternate), and/or the Spacecraft Test Conductor's Office (Mr. J. H. Lane or his alternate).

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 11, 1967

Administrative Procedure No. 11

TITLE: Categorization and Control of AS-204 Material Required to Support the AS-204 Review Board

SCOPE: This procedure defines the various categories of material associated with the AS-204 incident and establishes controls for the reclassification and/or release of such material by the board. Material as used in this procedure includes components and sample material removed from S/C 012; spacecraft GSE, launch vehicle and its associate GSE; support equipment and facilities.

POLICY: 1. The following direction relative to the release of impounded material from Apollo 204 Review Board control has been established by the Board as quoted from the Board action summary list. All material released by actions of the Board previous to 11 Feb. 1966, have been placed into Category C.

GSE, STE AND FACILITY EQUIPMENT ON LAUNCH COMPLEX 34

Equipment of this type not utilized for checkout or servicing on Spacecraft 012 and the AS-204 launch vehicle on Pad 34 should be released for normal operation.

All equipment of this type utilized prior to plugs in and removed prior to plugs-in which is still in complex area should be statused in terms of configuration and released for further use.

All equipment of this type used during plugs-in or later will require board approval.

GSE, STE AND FACILITY EQUIPMENT OUTSIDE OF LAUNCH COMPLEX 34

All equipment of this type utilized in buildup prior to arrival at Launch Complex 34 of S/C 012 should be released for further use.

All servicing equipment of this type utilized prior to arrival of S/C 012 at L/C 34 should be checked for configuration status and fluids sampled for future records. Equipment then should be released for usage.

2. All material associated with the AS-204 incident will be classified as follows:

Category A - Material which may have a significant influence or bearing on the results or findings of the Apollo 204 Review Board. This material is considered highly relevant and is to be maintained under rigid control.

Category B - All material other than Category A which is considered relevant to the Apollo 204 Review Board investigation.

Category C - Material released from Board jurisdiction.

3. All category A material will be maintained under the control of the Apollo 204 Review Board through the Panel Coordination Committee and the appropriate Panel Chairmen. All work accomplished on Category A will be by the use of the Test Preparation Sheet (TPS) (Reference Apollo 204 Administrative Procedure 18).

4. Category B material will be documented as to the configuration at the time of the incident and maintained under the control of the cognizant program or line organization.

5. The determination of the category and release of any material currently under impoundment in support of the AS-204 investigation is a responsibility of the Apollo 204 Review Board. The attached form, Apollo 204 Review Board Material Release Record (MRR), is to be used by organizations desiring to release or reclassify any material presently under impoundment by the Apollo 204 Review Board. Instructions pertaining to this form are covered in the procedures section below.

6. Category A material which must be sent off-site for testing, analysis or other reasons to satisfy requirements of the review, will be accompanied by a representative (witness) designated by the Board unless otherwise specified by the Board. Appropriate quality control and contractor personnel may also accompany the Board's representative. In addition, at the discretion of the Board, Category A material which will be tested on-site will be accompanied by a Board-appointed representative. Category B material sent off-site need not be accompanied by a Board-appointed representative.

7. All Category A material which requires testing and/or analysis either on-site or at a location other than KSC will be processed in accordance with Apollo 204 Review Board Administrative Procedure 5b.

PROCEDURE: 1. Completion of the MRR - The MRR will be completed as follows:

Item No. - To be filled in by the Panel Coordination Committee of the Apollo 204 Review Board

Description - Include a brief description of the item to be reclassified by the Board.

Relevance to Accident - Include justification for reclassification action to include why the reclassification of the equipment will not affect the final board findings.

Constraint Prior to Release - To be filled in by the Panel Coordination Committee.

Current Category - If equipment has not been released from the Board by some previous action the current category is "A".

Desired Category - Include desired category based on definitions of categories as specified in Paragraph 2 above.

Board Approval - To be filled in by the Board.

2. Flow of the MRR

a. The MRR will be filled in by the individual or organization desiring to reclassify or release equipment currently under impoundment. The forms can be obtained from the DLO Test Supervisor's Office (Room 2121, MSOB - Phone 867-6230) or Apollo Review Board Administrative Procedures Office (Room 1842, MSOB - Phone 867-6706).

b. For material located in all areas except the Pyrotechnic Installation Building (PIB) area, the completed form will be submitted to the Director of Launch Operations (DLO) Test Supervisor's office. For material located in the PIB area, the completed forms will be forwarded to a Panel 4 member.

c. The DLO Test Supervisor or the Panel 4 Chairman as appropriate will submit the form to the Panel Coordination Committee for review and presentation to the Board.

d. The Board decision will be relayed through the DLO Test Supervisor's office or the Panel 4 Chairman as appropriate to the affected individual or organization.

/S/ Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

Item No.	Description	Relevance to Accident (Include Location)	Constraint Prior to Release	Curr. Category	Desir. Category	Board Approval

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure No. 12

TITLE: Access to Apollo 204 Review Board Office

SCOPE: This procedure covers access control to the Apollo 204 Review Board Office, Room 1814, MSO Building, KSC, for the period of time that this space is assigned to the Review Board.

POLICY: 1. Access to the Apollo 204 Review Board Office, Room 1814, MSO Building, shall be limited to the following personnel:

a. Personnel wearing the special Apollo 204 Review Board badges issued in accordance with Administrative Procedure No. 1 (Access to the Apollo 204 Review Board Meeting Room).

b. Other personnel approved by occupants of the Apollo 204 Review Board Office, exclusive of secretaries.

2. Access will be controlled on a full-time basis by a security guard.

PROCEDURES: 1. Personnel will clear through the security guard prior to entering Room 1814, MSO Building.

a. Personnel displaying an Apollo 204 Review Board badge with green or yellow stripes may enter and leave Room 1814 as required.

b. Non-badged personnel desiring to visit occupants of Room 1814 will indicate the name of the occupant to the security guard. Contact will be made with the occupant's office and if approved, the security guard will permit access. Logging in and out is not required.

c. Secretarial support personnel will be permitted access into Room 1814 per secretarial access list. Changes to the secretarial access list may be made by Mr. Dave Allen or his designated representative.

S Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 6, 1967

Administrative Procedure No. 13, Rev. A.

TITLE: Preparation of Apollo 204 Review Board Meeting Agenda

1. Not later than 8:00 p.m. each day, all items desired to be proposed by Board members for inclusion on the following day's agenda should be given in writing to the Secretariat, Attn: Ernest Swieda, MSO Building, Room 1814, telephone 867-6693.

2. The Secretariat will obtain approval or modification from the Board Chairman or his approved representative for this purpose and have the published list of agenda items prior to the next scheduled meeting.

3. In the event there is a modification to or deletion of any item, the Secretariat will so advise the concerned Board member as soon as possible.

4. Distribution to the Board members and other appropriate personnel will be accomplished on an expedited basis.

5. Items not on the published agenda will not be discussed at the Board meeting without approval of the Board Chairman.

S Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure Number 14

TITLE: Access to Spacecraft 012

The Panel Coordination Sub Committee will establish coordination of and priority for all tasks requiring access to the spacecraft. The access to the interior of the spacecraft will be controlled by Colonel Borman or a designated representative.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure No. 15

TITLE: Official File for Apollo 204 Review Board

SCOPE: This procedure covers the accumulation and filing of all documents required for the official Apollo 204 Review Board file.

POLICY: 1. One copy of all Task Panel and Review Board-generated data shall be provided to Task Panel No. 17 (Final Report Panel), except as noted in paragraph 2 below.

2. The negatives and prints of all photographs made as a part of Review Board or Task Panel activities shall be provided to the Apollo 204 Review Board Film Library for disposition in accordance with Administrative Procedure No. 8, "Control of Film"

PROCEDURES: 1. Each Task Panel Chairman will establish a system of controlling all documents generated by his panel in the performance of its functions. (Documents include, but are not limited to, letters, memoranda, reports, plans, procedures, test preparation sheets, logs, statements, and transcripts.)

2. The Apollo 204 Review Board Secretariat will establish a system of controlling all documents generated by the Apollo 204 Review Board. (Documents include, but are not limited to, letters, memoranda, and transcripts of Board proceedings.)

3. The original of all data resulting from paragraphs 1 and 2 above, will be provided to the receptionist, Task Panel No. 17, Room 1806, MSO Building, by each Task Panel Chairman or representative and the Review Board Secretariat as soon as available.

4. The Chairman, Task Panel No. 17, will establish a system of controlling and filing all documents received from other panels and the Review Board Secretariat. The system will permit identification of that material which will be included in the final report and that material which is supporting or reference data.

5. Negatives and prints of all photographs made as part of Review Board or Task Panel activities will be controlled in accordance with Administrative Procedure No. 8, "Control of Film". Negatives will be catalogued and filed by the Apollo 204 Review Board Film Library in Room 1111, MSO Building. Prints will be provided to Task Panel No. 17 upon written request of the Chairman. Upon completion of the Review Board investigation all negatives will be turned over to Task Panel No. 17 for inclusion in the official file.

/S Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 3, 1967

Administrative Procedure No. 16

TITLE: Coordination Policy for Interviewing Witnesses

A statement, substantially as follows, will be addressed to each individual called before the Panel for Task No. 12 to be interviewed or questioned further:

> We appreciate your coming here to assist us further in this investigation in order that the Board may arrive at certain decisions affecting the Apollo Program. The answers you may provide may be a clue to other matters that this Board should look into.
>
> Before we start the questioning, we want you to understand that your appearance is on a voluntary basis and that any statements you make will be kept in strict confidence.
>
> If you are able to answer a question, please do so with language you use with family and friends. It is not necessary to be formal.
>
> If you are unable to answer a question, do not hesitate to say so.
>
> Now, we may proceed.

Where the witness called is deemed by the Panel to have furnished important information in his original statement, Counsel to the Board and cognizant technical personnel in areas to be covered by the interview will be advised beforehand.

Doubtful cases will be resolved by the Chairman, Task 12 Panel, after consultation with cognizant technical personnel and concurrence by Counsel.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 8, 1967

Administrative Procedure No. 17

TITLE: Response to Offers of Assistance or Recommendation

POLICY: Offers of assistance or recommendation submitted as a result of the Apollo 204 Review will be answered by the Chairman, Apollo 204 Review Board.

PROCEDURES: 1. All messages (letters, telegrams, and telecon notes) received by the Apollo 204 Review Board members, Task Panel members, other associated personnel, or the Secretarial Support Office (Room 1805, MSO Building) which are identified as suggestions or offers of help pertaining to the task of the Apollo 204 Review Board shall be forwarded to Task Panel No. 15, Room 1842, MSO Building. Task Panel No. 15 will log all incoming messages and review them for content.

2. Task Panel No. 15 will prepare replies to all messages for the signature of the Chairman, Apollo 204 Review Board, unless they have been properly acknowledged by other organizations. Official NASA Apollo 204 Review Board letterhead will be used.

3. Copies of those messages, which, in the opinion of Task Panel No. 15, appear to be relevant to the activities of one or more task panels will be sent to those panels for consideration. In certain cases, comments or other action may be requested. If acceptance of an offer of assistance or if more information is desired, Task Panel No. 15 will be contacted so that arrangements can be made.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

Administrative Procedure No. 18, Revision C

TITLE: Use and Control of Test Preparation Sheets (TPS)

SCOPE: This procedure covers the plan and control by which AS-204 spacecraft hardware will be removed, inspected, analyzed or otherwise modified.

POLICY: 1. All work, including inspections, on the AS-204 spacecraft hardware and on the spacecraft GSE that is on or was connected to the spacecraft from the Plugs In Overall Test (0006) until after the incident is to be authorized by Test Preparation Sheets (TPS).

2. TPS's written to perform work under the control of the Medical Analysis Panel (Panel No. 11) involving equipment located in Room 106 of the PIB will require only the approval signature of a member of the Medical Analysis Panel.

3. TPS's written to perform work under the control of the Disassembly Activities Panel (Panel No. 4) will be prepared and signed by the applicable NAA Systems Engineer and will be approved by the applicable NASA-KSC-SCO and NASA-MSC Systems Engineers. In addition, approval signatures must be obtained from the appropriate KSC-MAB Engineer, a member of the Origin and Propagation of Fire Panel, a member of the Integration Analysis Panel who will assure that any additional coordination required, such as materials engineers, is accomplished before affixing his signature and a member of the Panel Coordination Committee. Any TPS to be worked at the 012 spacecraft will also be signed by a member of the Disassembly Activities Panel. Any of these listed signatures, except that of the TPS writer, may be obtained per telephone conversation.

4. TPS's written to perform work under the control of the Service Module Disposition Panel (Panel No. 21) will be handled as in Paragraph 3 except that the signature of a member of the Service Module Disposition Panel is required in lieu of a member of the Disassembly Activities Panel.

5. Prior to preparation of TPS's, work plans must be presented to the Apollo 204 Review Board through the Panel Coordination Committee for approval.

6 When a TPS is required to be modified in order to allow continuance of work activity, a TPS mod sheet is required. The TPS mod sheet will be signed by both the Systems Engineers monitoring the work. These engineers will be responsible for proper coordination before signing the mod sheet. (Ref. para. 8h. under procedure.)

7. Work, examination, testing, or analysis that is to be performed at KSC of equipment removed from the spacecraft must be authorized by a subsequent TPS which is to begin with a statement that authorizes removal of the equipment from the bonded storage area, if required. Testing or analysis that is to be performed at sites other than KSC must be authorized and accomplished in accordance with Administrative Procedure No. 5.

8. All equipment or material removed from the spacecraft must be documented on a Parts Installation and Removal Record (PIRR).

9. All equipment or material removed from the spacecraft must be tagged with a parts tag.

10. No task will be initiated until those individuals assigned to accomplish the task are thoroughly briefed by the responsible engineer. No disassembly task will be performed on S/C 012 until the same task has been performed on S/C 014 by the same individual, unless specified on the TPS as "not applicable to S/C 014."

11. Proofing tasks on S/C 014 will be worked to a S/C 012 TPS. These need have only one NAA and one NASA Systems Engineer signature for this task. Work will be authorized by and bought off on a S/C 014 TPS which will state to work the S/C 012 TPS on S/C 014. This TPS will be signed by one NAA and one NASA Systems Engineer. Either one of the above will sign mod sheets. Any of these listed signatures, except that of the writer, may be obtained per telephone conversation.

12. Access to the spacecraft area will be tightly controlled in accordance with applicable administrative procedures.

13. The original of all TPS's will be provided upon completion to Panel No. 17.

14. The Apollo Pre-Flight Operations Procedures Manual (APOP) is the reference document to be used during all work activity on the spacecraft. When differences exist between this procedure and the APOP, this procedure is the ruling document.

PROCEDURE: 1. Flow of the TPS (includes all TPS's except those worked by Panel No. 11)

a. The request for an intended action or work plan will be forwarded to the panel coordination committee which will be responsible for obtaining Board approval.

b. After approval by the Chairman of the Apollo 204 Review Board, the request will be forwarded to the Integration Analysis Panel who will integrate the work into the overall S C 012 effort.

c. The Integration Analysis Panel will direct NAA Engineering to prepare the TPS for the task. The TPS will be signed by the responsible NASA and or NAA Engineers and or panel and committee members, as appropriate.

d. A TPS number will be obtained by the originator from the Apollo Tech Data Services, Room 3197, MSO Building, telephone 867-5365.

e. Original will be taken to Room 1432 for reproduction and distribution. Twenty (20) copies will be taken to Room 2130 prior to the 8:00 a.m. daily meeting.

f. Service Engineering will deliver the buy off copy to the appropriate work area. Modification sheets added to the original TPS will be called into the Apollo Tech Data Services by NAA QC for their records.

g. After the completion of the task, NAA Quality Control will hand carry the original completed bought off copy to Room 3344.

h. QC in Room 3344 will reproduce the completed TPS, place one on file and hand carry 20 copies to Room 2130 prior to 8:00 a.m. daily meeting.

i. Then QC will hand carry the "as worked" buy off copy TPS's to Task Panel No. 17 in Room 1806.

2. Work Support (except as performed by Panel No. 11)

a. Operations Engineering:

(1) The actual removal, disassembly, and analysis work within the local KSC area will be executed through the normal NASA and NAA pad and industrial area organizations.

(2) It is required that NASA KSC-SCO and NAA Operations Engineers be on duty at the spacecraft on the shift and work-week basis specified by the Apollo 204 Review Board.

(3) The Operations Engineers have the responsibility to schedule the daily spacecraft activity in detail. They also have the authority to stop work on the spacecraft when deemed necessary.

(4) The Operations Engineers are responsible to maintain a spacecraft log, which documents all activity on the spacecraft on an hourly basis. A copy of the log is to be provided to the DA Panel and is to be updated on a daily basis.

b. Systems Engineering:

It is required that NASA and NAA Systems Engineering be on duty for all work on their particular system when the work is authorized by a S/C 012 investigation or component analysis TPS. Any deviation to this requirement either must be documented on the appropriate TPS prior to submittal for authorizing signature or authorized by the Chairman of the Disassembly Activity Panel, or his designated representative.

3. TPS Preparation:

TPS's will be prepared as follows: (Note: Only paragraphs a, b, and h apply to Panel No. 11 work.)

a. A specific and complete statement of the "reason for work" is required on each TPS.

b. The TPS's are to consist of step-by-step work items written in a detailed manner that will leave no question as to what is specifically required to be done.

c. No wire bundle electrical connectors are to be disconnected without specific call-out by W/B connector number on the TPS.

d. All work on the spacecraft is to be accomplished by NAA technicians unless otherwise indicated on the TPS.

e. All work is to be witnessed by NASA KSC-SCO and NAA inspection. In addition, it is the responsibility of the Integration Analysis Panel to make sure that the TPS includes the necessary requirements for official observers when required. Upon completion of each TPS work item, the item is to be stamped by NASA/NAA Inspection indicating completion.

f. It is required that TPS's which authorize removal of equipment from the spacecraft while at Complex 34 conclude with the following statement as the last item of work: "Transport equipment to the Pyro Installation Building (PIB) for display or retention in bonded storage."

g. Upon completion of work authorized by a TPS, it is required that a summary statement be made on the last TPS mod sheet by the NASA/NAA Systems Engineer(s). The summary statement is to include all items of a significant nature that were observed during the work activity indicating where follow-up action is needed.

h. When a mod sheet is prepared, a specific and complete statement of the reason for the mod sheet is required on each TPS. Also, the TPS mod sheet must authorize work that is within the intent of the original TPS.

i. Separate investigation (IV), Material Analysis (MA), Component Analysis (CA) TAIR books will be established and all TPS's associated with spacecraft work, including GSE, will be retained in these TAIR books.

4. Parts Installation and Removal Record (PIRR) (Except Panel No. 11)

The information noted on the PIRR consists of a part number (if available or applicable); a description of the equipment or material; and the time and date of removal. The parts installation and removal record will be prepared and used as noted in the APOP with Quality Control required to buy off all entries.

5. Parts Tag:

As stated in paragraph 8 of the policy section above, all material removed from the spacecraft must be tagged with a parts tag (KSC Form 4-8) as follows:

a. The parts tag will be stamped in accordance with Apollo 204 Review Board Administrative Procedure #7.

b. The tag is to be attached to the hardware in such a manner that will not affect the condition of the equipment.

c. The tag is to be attached to the container or bag into which the material is placed.

d. The parts tag is to accompany the equipment or material at all times.

e. It is required that prior to removal of spacecraft hardware, spacecraft system components, disconnect of spacecraft electrical connectors, and disconnect of spacecraft plumbing lines, a short length of silver-gray tape be attached across the mating line between the hardware to be removed and the adjacent hardware remaining in the spacecraft. An indexing line is to be then marked on the tape with a black ball-point pen at right angles to, and across, the hardware mating line. A number correlating to the spacecraft hardware removal form entry is also

to be written on each end of the tape. In order to avoid destruction of valuable evidence, it may be necessary to deviate from this procedure. In these cases, a mod sheet shall be prepared which states the reasons the procedure cannot or should not be followed.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 7, 1967

Administrative Procedure No. 19, Revision A

TITLE: Establishment of the Panel Coordination Committee

SCOPE: This procedure covers the purpose and activities of the Panel Coordination Committee and is applicable to all elements of the Apollo 204 Review Board including Board and Panel members.

POLICY: 1. The Panel Coordination committee is hereby established. The committee shall consist of the following:

Mr. John J. Williams, Chairman
Col. Frank Borman, Member
Mr. Charles W. Mathews, Member
Dr. Maxime A. Faget, Member
Mr. George Jeffs, Member
Mr. John F. Yardley, Member
Mr. R. L. Benner, Member
Mr. John Hodge, Member
Mr. Ted Sasseen, Member

2. The purpose of this committee is to coordinate the actions of the constituted panels and bring to the attention of the Apollo 204 Review Board those actions requiring specific approval of the Board.

3. All needs for coordination of activities and requirements that the various constituted panels and other activities cannot satisfy or resolve by direct action between those involved should be brought to the immediate attention of the coordination committee.

4. All requirements to implement activity that comes under the direct control of the Board (such as photograph examination, or disassembly of S/C 012 or the use or disposition of impounded items) will likewise be brought to the attention of the Panel Coordination Committee.

5. A panel coordination review session will be held daily at 5 p.m. in room 2130 MSOB unless otherwise specified. All Panel Chairmen are required to attend. Daily Reports are required to be submitted by the Panel Chairman at that time. A daily meeting will also be held at 9 a.m. in room 2130. Selected Panel Chairmen will attend by request.

6. Matters which require attention of the Panel Coordination Committee should be addressed to the Panel Coordination Committee, room 2130, MSOB 867-6447.

S/ Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 24, 1967

Administrative Procedure No. 20, Revision A

TITLE: Establishment of Apollo 204 Review Board Panels

SCOPE: This procedure officially documents the Apollo 204 Panels and covers the purpose and activities of such panels. This procedure is applicable to all elements of the Apollo 204 Review Board. Working panels were established at the beginning of the AS-204 Review Board investigation and have been in continuous operation. This procedure revises previous documentation relative to these panels.

POLICY: 1. Panels will be utilized by the Apollo 204 Review Board to perform specialized tasks as identified by the Board. Each panel will have a Chairman appointed and approved by the Review Board and a Board Monitor to whom the Panel Chairman is responsible. The official list of panels is contained in Attachment 1.

2. The panels will provide reports of their activities as required by the Review Board or the Panel Coordination Committee.

RESPONSIBILITIES ACTIONS:

1. The Apollo 204 Review Board will appoint a Chairman and a Board Monitor for each of the twenty-one (21) Task Panels. New panels may be constituted by action of the Review Board to perform additional tasks. Attachment 1 contains the official list.

2. Each Panel Chairman will serve as a manager to direct and coordinate the activities of the Panel within the statement of work prescribed for that Panel as included in attachment 1.

3. Each panel chairman will report directly to the appropriate Board Monitor and will report to the Board, when required, on the progress of work. He will obtain Board approval of work whenever required by other applicable Board Administrative Procedures.

4. Each Panel Chairman is responsible for recommending membership on the Panel which must be approved by the cognizant Board Monitor including any changes thereto. The Board Monitor will initial his approval on the list contained in attachment 1.

5. Each Panel Chairman is responsible to designate an alternate in case of temporary absence. This alternate must be approved by the respective Board Monitor for each Panel.

6. Panel reports of findings and determinations will be required of all panels. These reports will be signed by the Panel Chairmen only and submitted to the Board through the appropriate Board Monitors. Board Monitors will insure that minority positions relative to panel reports are brought to the attention of the Board.

7. All final Panel reports submitted to the Board will be in the prescribed format as included in attachment 2. Reports from Panel #11 will have limited distribution as determined by the Apollo 204 Review Board Chairman.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

Enclosure
1. Apollo 204 Review Board Panels
2. Outline for Panel Reports

ATTACHMENT 1
APOLLO 204 REVIEW BOARD
ADMIN. PROCEDURE NO. 20
FEBRUARY 18, 1967

APOLLO 204
REVIEW BOARD
PANELS

PANEL SUMMARY

NO.	TITLE	CHAIRMAN	BOARD MONITOR
1	S/C and GSE Configuration	J. Goree, MSC	J. Williams, KSC
2	Test Environments	W. Hoyler, MSC	G. White, NASA Hqs
3	Sequence of Events	D. Arabian, MSC	M. Faget, MSC
4	Disassembly Activities	S. Simpkinson, MSC	Col. F. Borman, MSC
5	Origin & Propagation of Fire	F. Bailey, MSC	Dr. Van Dolah
6	Historical Data	J. T. Adams, MSC	G. White, NASA Hqs
7	Test Procedures Review	D. Nichols, KSC	J. Williams, KSC
8	Materials Review	W. Bland, MSC	M. Faget, MSC
9	Design Reviews	R. Williams, MSC	G. White, NASA Hqs
10	Analysis of Fracture Areas	P. Glynn, MSC	B. Geer, NASA LaRC
11	Medical Analysis	G. Kelly, MSC	F. Thompson, NASA LaRC G. Malley, Counsel
12	Witness Statements	N. Vaughn, MSC	Col. C. Strang, USAF G. Malley, Counsel
13	Ground Emergency Provisions Review	G. Page, KSC	Col. F. Borman, MSC
14	Security of Operations	C. Buckley, KSC	Col. C. Strang, USAF
15	Board Administrative Procedures	A. Griffin, KSC	B. Geer, NASA LaRC
16	Special Tests	G. Stoops, MSC	M. Faget, MSC
17	Final Board Report	Lt. Col. K. H. Hinchman, USAF	Col. C. Strang, USAF
18	Integration Analysis	A. Mardel, MSC	M. Faget, MSC
19	Safety of Investigation Operations	J. Atkins	B. Geer, NASA LaRC
20	In Flight Fire Emergency Provisions Review	Capt. J. Lovell	Col. Borman, MSC
21	Service Module Disposition	W. Petynia	J. Williams, KSC

APOLLO 204 REVIEW BOARD
PANEL

Task No. 1

Task Title S/C & GSE Configuration

Task Description:

Establish and document physical configuration of spacecraft and GSE immediately prior to and during fire incident including equipment configuration, switch positions, and non-flight items in cockpit. By deviation, document configuration differences with respect to expected launch configuration and configurations used in previous testing, (Altitude chamber, for example), as pertinent to this problem. To a lower level of detail, document configurational difference between the spacecraft and other spacecraft as pertinent to this problem.

Room 2301 Phone 6558

Panel Members:

J. Goree, MSC, Chairman
C. Haines, MSC
R. Larson, NAA-D
W. Edson, NAA-KSC
C. Gay, KSC
R. Murad, NASA Hqs
C. Rouse, KSC

Cognizant Board Member: J. Williams JJW

APOLLO 204 REVIEW BOARD
PANEL

Task No. 2

Task Title Test Environments.

Task Description:

Provide history of all test environments encountered by this spacecraft on a major assembly total assembly basis which are germain to validation of systems from fire hazard standpoint. Include appropriate qualification testing of systems and subsystems. Particular emphasis should be placed on qualification tests in pure O_2 with regard to pressures, temperature, time of exposure, and simulation of equipment malfunction. Indicate any deficiencies in this test program related to the subject problem. Also, include comparison with previous tests of appropriate flight, house, or boilerplate spacecraft. Any problems encountered related to fire hazard shall be documented.

Room 3431 Phone 5217

Panel Members:

W. Hoyler, MSC, Chairman
F. Key, MSFC
A. Toelicen, NAA-D
H. Dunham, MSC/GE
C. Nolen, MSC/GE

Cognizant Board Member: G. White

APOLLO 204 REVIEW BOARD
PANEL

Task No. 3

Task Title Sequence of Events (anamoly data review)

Task Description:

Analyze data obtained immediately prior to and during the fire incident including digital, analog, voice communications, photography, etc. Data should display significant events as they occurred with precise time tag. Time histories of all continuous or semi-continuous recorded parameters, correlation of parameter variations and events shall be recorded as well as interpretation of the results of said analysis. Where pertinent, normal expected variations shall be compared with those actually obtained.

Room 2721 Phone 6270

Panel Members:

D. Arabian, MSC, Chairman

A. Tischler, NAA-D

H. Creighton, KSC

W. Eckmeier, NAA-KSC

W. Jewel, KSC

Cognizant Board Member: M. Faget

APOLLO 204 REVIEW BOARD
PANEL

Task No. 4

Task Title Disassembly Activities

Task Description:

Develop plans and procedures for progressive disassembly of spacecraft for purposes of inspection and failure analysis. Disassembly should be configured to proceed on a step-by-step basis, in a manner to obtain maximum amount of information prior to disturbing evidence. Contents of testing requirements shall also be considered. Disassembly plans should consider both the cockpit and the area outside the pressure hull. Means for cataloging documentary information within spacecraft and for display of removed items shall be a part of these plans and procedures.

Room 1293 Phone 5497

Panel Members:

S. Simpkinson, MSC, Chairman
P. Hanifin, NAA-D
J. Moore, NAA-KSC
S Beddingfield, KSC
D. Grimm, MSC
H. Shoaf
P. Graf
R. Reed
R. Covel

Cognizant Board Member: F Borman

APOLLO 204 REVIEW BOARD
PANEL

Task No. 5

Task Title Origin and Propagation of Fire

Task Description:

Conduct inspections, chemical analyses, spectrographic analysis of spacecraft, parts or rubble or use any other useful techniques to establish point of fire origin, direction and rate of propagation, temperature gradients and extremes. The nature of the fire, the type of materials consumed, the degree of combustion shall be determined.

Room 3229 Phone 7438

Panel Members:

J. F. Bailey, MSC, Chairman
I. Pinkel, LeRC
T. Horeff, FAA
J. Craig, MSC
J. Yardley, MAC
H. Carhart, NRL
J. Leak, CAB
A. Krupnick

Cognizant Board Member: Dr. Van Dolah, BOM

APOLLO 204 REVIEW BOARD
PANEL

Task No. _____

Task Title Historical Data

Task Description:

Assemble, review, and summarize historical data on spacecraft and associated systems as pertinent to the fire incident. Data to be analyzed shall include records such as included in spacecraft log, failure reports, other quality engineering and inspection documents. Make interpretation on data as to applicability to subject problem.

Room 1237 Phone 3984

Panel Members:

T.J. Adams, MSC, Chairman	J. Hansel, NAA-KSC
D. Buffington, NAA-KSC	
J. Dickinson, KSC	

Cognizant Board Member: G. White

APOLLO 204 REVIEW BOARD
PANEL

Task No. 7

Task Title Test Procedures Review

Task Description:

Document test procedures actually employed during day of incident Indicate deviations between planned procedures and those actually used. Determine from review potential changes that might alleviate fire hazard conditions or that might provide for improved reaction or corrective conditions. Review these changes with respect to applicability to other test sites or test conditions.

Room 2141 Phone 6547

Panel Members:

D. Nichols, KSC, Chairman
K. Cuzzupoli, NAA-D
H. Cahill, NAA-KSC
W. Petynia, MSC
F. Bryan, KSC
R. Swanson, NAA-D
J. Wright, NAA-KSC
H. Luetjen
S. Marshburn, NAA-D
A. Dale, NAA-D
C. Brooks, MSFC

Cognizant Board Member: J. Williams

APOLLO 204 REVIEW BOARD
PANEL

Task No. 8

Task Title Materials Review

Task Description:

Assemble and summarize data and analysis related to flammability of spacecraft materials. Results of other programs as well as Apollo shall be considered. Requirements for additional testing shall be recommended. Review Apollo test conditions for adequacy. Make recommendations for material or configuration changes to alleviate fire hazard. Perform analysis as appropriate to determine overall energy balance, correlations with temperature and pressure build-up, etc.

Room 1800 Phone 5484

Panel Members:

W. Bland, MSC, Chairman
A. Busch, KSC
Archer, NAA-KSC
R. Olsen, NAA-D
E. Welhart, MAC
W. Riehl, MSFC
A. Staklis, MSC

Cognizant Board Member: M. Faget

APOLLO 204 REVIEW BOARD
PANEL

Task No. 9

Task Title Design Reviews

Task Description:

Conduct critical design reviews of systems or subsystems that may be potential ignition sources within cockpit or which might provide a combustible condition in either normal or failed conditions. Areas such as glycol plumbing configuration, electrical wiring and its protection, physical and electrical, other potential ignition sources such as motors, relays, and corona discharge. Other areas of review include egress augmentation and basic cabin atmosphere concept (1 vs. 2 gas). Document where applicable pros and cons of design decisions made. Summarize recommended changes for corrective action.

Room 3301 Phone 3270

Panel Members:

R. Williams, MSC, Chairman
J. McCarthy, NAA-D
J. Janokaitis, KSC
R. Pyle, NAA-KSC
A. Cohen, MSC
Fred Sanders

Cognizant Board Member: G. White, NASA Hq

APOLLO 204 REVIEW BOARD
PANEL

Task No. 10

Task Title Analysis of Fracture Areas

Task Description:

Inspect spacecraft for structural failures resulting from fire. Analyze these failures from standpoint of local pressure - temperature levels, direction of gas flow, etc.

Room 2308 Phone 7870

Panel Members:

P. Glynn, MSC, Chairman
L. Korb, NAA-D.
R. Johnson, MSC
D. Root, NAA-D
N. Koenig, NASA - KSC

Cognizant Board Member: Geer

C-3

APOLLO 204 REVIEW BOARD
PANEL

Task No. 11

Task Title Medical Analysis

Task Description:

Medical Analysis. A summary of medical facts together with appropriate medical analysis which would be of interest to the investigation. Examples would be cause of death, pathological evidence of overpressure, and any other areas that might be of technical value in determining the cause of accident or in establishing corrective action.

Room 3849 Phone 3541

Panel Members:

G. Kelly, MSC, Chairman
A. Harter, KSC
N. Pincock, KSC
R. Thompson, PAA
P. Hoffman, USAF
E. Ferguson, Jr., USAF
T. Spann
R. Parrish

Cognizant Board Member: Dr. Thompson

G. Malley, Counsel

APOLLO 204 REVIEW BOARD
PANEL

Task No. 12

Task Title Witness Statements

Task Description:

An orderly process to collect all data from witnesses (includes eye witnesses as well as concole monitors). This includes a determination of who to interview, arranging for competent people to conduct the interviews, recording data, and collecting it into a form suitable for publication as an appendix to the formal report. Included also in this task is an analysis of the pertinent sequence of events as reported by the bulk of the witnesses together with a summary of that testimony which is contradictory to the main data.

Room 3238 Phone 7438

Panel Members:

N. Vaughn, MSC, Chairman
J. O'Donnell, KSC
C. McNamara, NAA-KSC
C. Netherton, KSC
Lt. Col. Rawers, USAF
H. Blackwood, NASA Hq.

Cognizant Board Member: Col. C. Strang, USAF

G. Malley, Counsel

APOLLO 204 REVIEW BOARD
PANEL

Task No. 13

Task Title Ground Emergency Provisions Review

Task Description:

This task involves an orderly review of planned ground emergency procedures relative to their adequacy, as well as a review to determine that emergency procedures, in fact, exist for all appropriate activities. This review should concentrate on activity at the launch site, and should include recommendations to the board for changes in existing procedures and for the creation of new emergency procedures if deemed necessary.

Room 2121 Phone 6230

Panel Members:

G. Page, KSC	, Chairman	H. Russell,	NASA Hq.
		W. Cunningham	MSC
G. Smith, NAA-D		R. Sayers	MSC
		L. Barnett	KSC
J. Chappée, MSC		R. Rochester	NAA-GSE
		M. Carlson	KSC-LVO
K. Wishon, NAA-KSC		H. Luetjen	

Cognizant Board Member: F. Borman

APOLLO 204 REVIEW BOARD
PANEL

Task No. 14

Task Title Security of Operations

Task Description:

This group shall review existing security practices for adequacy. This includes such things as access control, personnel sign in requirements, buddy systems, background investigation requirements, etc. They shall also make responsible recommendations to the board on changes to existing practices.

Room 1239 Phone 2350

Panel Members:

C. Buckley, KSC, Chairman	R. Gaines Lewis
H. Maines NASA Hq. Vice-Chairman	W. Horner KSC
S. Ellis, MSFC	Col.W. Dugan USAF
C. Buckel, MSC	

Cognizant Board Member: Col. C. Strang, USAF

APOLLO 204 REVIEW BOARD
PANEL

Task No. 15

Task Title Board Administrative Procedures

Task Description:

This group shall establish and document administrative procedures for the board to use. This includes activity such as procedures for the control of spacecraft work, logging and filing of exhibits, maintenance of log of board activities, schedulingof meetings, preparation of agenda for board meetings, arrangements for secretarial services, reporduction of material, etc.

Room 1842 Phone 6706

Panel Members:

A. Griffin, KSC, Chairman
W. Moody KSC
G. Huffines, MSC
P. Reed, NAA-KSC

Cognizant Board Member: Geer

APOLLO 204 REVIEW BOARD
PANEL

Task No. 16

Task Title Special Tests

Task Description:

This task involves the coordination of desired tests generated by other groups into an overall integrated test plan. For example flammability testing will probably be done at several locations. This group will assure proper coordination of this activity. Major tests such as mockups of actual configuration, boiler plate destructive combustion tests, etc. would be considered by this group, and appropriate action recommendations would be made to the board. Test results would be collected, reviewed, and edited in a form suitable for inclusion in the final report.

Room 3431 Phone 5371

Panel Members:

G. Stoops, MSC, Chairman

J. Jeter, KSC

E. Gunn, NAA

J. Saunders, NASA Hq.

Cognizant Board Member: M. Faget

APOLLO 204 REVIEW BOARD
PANEL

Task No. 17

Task Title Final Board Report

Task Description:

This activity involves the organization of the report, the delegation of responsibility to other assigned task groups, the review and editing of submitted material, and the final preparation of the report.

Room 1806 Phone 6505

Panel Members:

Lt. Col. K.H. Hinchman Chairman

J. Ross

R. Smith

Cognizant Board Member: Col. Strang

APOLLO 204 REVIEW BOARD
PANEL

Task No. 18

Task Title Integration Analysis

Task Description: .

This task involves the review of inputs from all task groups, the correlation of all pertinent information, feedback for further study, and the final technical integration of the evidence.

Room 2130 Phone 6722

Panel Members:

A. Mandel, MSC	, Chairman	S. Jones	MSC
D. Levine, NAA-D		H. Taylor	MSC
R. Pyle NAA-MSC		D. Moyhew	MSC
C. Mars, KSC		A. Cohen	MSC
		J. Lobb	MSC
		E. Walters	MSC

Cognizant Board Member: M. Faget

APOLLO 204 REVIEW BOARD
PANEL

Task No. 10

Task Title Safety of Investigation Operations

Task Description:

This group is charged with the responsibility of reviewing all operations performed during the investigation to assure that all personnel safety requirements are adequately maintained.

Room 1427 Phone 7390

Panel Members:

John Atkins, KSC, Chairman

D. Karl, PAA Pad Safety

Ralph Walker, Bendix System Safety

John McGough, TCC Operations Safety

Lt. Col. Jim Rawers, AFETR

Cognizant Board Member: B. Geer

APOLLO 204 REVIEW BOARD
PANEL

Task No. 20

Task Title In-Flight Fire Emergency Provisions Review

Task Description:

This task involves an orderly review of planned in-flight fire emergency procedures and other provisions relative to their adequacy, as well as a review to determine that emergency procedures, in fact, exist for all appropriate activities. This review should include recommendations to the board for changes in existing procedures and other provisions and for the creation of new emergency provisions if deemed necessary.

Room 3431 Phone 6666

Panel Members:

Capt. J. Lovell MSC, Chairman

Lt. Col. R. Evans MSC

R. Warren

R. Glover

T. Loe

N. Shyken.

J. Swigert, Jr.

Cognizant Board Member: F. Borman

APOLLO 204 REVIEW BOARD
PANEL

Task No. 21

Task Title Service Module Disposition

Task Description:

This task involves the planning and execution of necessary SM activity beginning at the time of Board approval for CM demate. This task will be performed mainly by appropriate Apollo line organizational elements in accordance with a Board approval plan which identifies the Board requirements for documentation and control of this activity.

Panel Members:

W. W. Petynia, MSC, Chairman

R. D. Carothers, KSC

B Haight, NASA-KSC

Cognizant Board Member: J. Williams

Attachment 2
Apollo 204 Review Board
Admin. Procedure No. 20
February 18, 1967

OUTLINE FOR PANEL REPORTS

This review, as in all accident investigations, will determine a primary or most probable cause of the mishap. Once the primary, or most probable cause has been determined, a recommendation as to corrective action(s) to prevent a recurrence is then agreed upon. Each task panel pursues its course of action and submits a report through the Board Monitor to the Review Board with one (1) copy. This report, while it might not relate to the determined primary cause, could be data that exposes contributing causes to this accident. Each panel, be it test environments, historical data, test procedures review or any other panel has a most important function within the structure of the Apollo 204 Review Board. In addition to determining what caused the accident, a good review board determines what existing designs, technical data, test procedures, etc., did not contribute to the mishap. In other words, a validation process runs concurrently with the accident investigation as a beneficial by-product. It is conceivable that these task panel reports will be referred to in the future for information as to systems operations and/or reliability during adverse conditions.

Certain task panel reports will provide the basis for the "Narrative" of the accident, as well as the input to the Board for the "Investigation and Analysis" portion of the final report.

The desired format of the task panel reports is attached.

FORMAT FOR TASK PANEL REPORT

Part VII - Apollo 204 Review Board

Task Panel Report

Section A. This is the work statement assigned the panel by the Review Board. (Charter of task to be accomplished)

Section B. Proceedings (How assigned work statement was accomplished)

Section C. Findings and Determinations

Findings and determinations should not only be addressed to the proximate cause(s) of the accident. They should also cover any condition discovered which could have caused the accident or which, in any way, could improve the mission of the Apollo Program.

1. Finding:

   No overall evaluation . . . . . .(Fact).

   Determination:

   It is concluded that . . . . . .(Assumption; logical conclusion; considered opinion, etc.)

2. Finding:

   Determination:

Section D. Supporting Data

This section will include identified photographs, if appropriate, test results, diagrams, consultant statements, recitals, copies of data, etc.

APOLLO 204 REVIEW BOARD
FEBRUARY 19, 1967

Administrative Procedure No. 21

TITLE: Access Control to Service Module Disassembly Area

SCOPE: This procedure covers access control to the Service Module Disassembly Area (herein after called Controlled Areas) located in High Bay of the MSOB. This procedure is effective from the time of entry of the Service Module into the Controlled Areas until release by the Apollo 204 Review Board Chairman.

POLICY: 1. In order not to restrict other concurrent operations taking place in the High Bay of the MSOB, the Controlled Areas will move as the vehicle is processed through the High Bay. The 3 Controlled Areas will be as follows: (see attachment).

a. CONTROLLED AREA NO. 1: Integrated Stand No. 1.(Duration of control will be approximately 2 days).

b. CONTROLLED AREA NO. 2: H14 - 124 Stand (Duration of control will be approximately 1 day).

c. CONTROLLED AREA NO. 3: H14 - 134 Stand (Vehicle will remain on this stand until release by Apollo 204 Review Board Chairman).

2. Limited access to the Controlled Areas shall be maintained on a full time basis (24 hours per day) by a security monitor.

3. A log of all personnel not on the access list that are permitted entry into the Controlled Areas will be maintained by the security monitor.

4. Persons authorized to sign in visitors and or add to the access list are noted by appropriate asterisk(s) on the list.

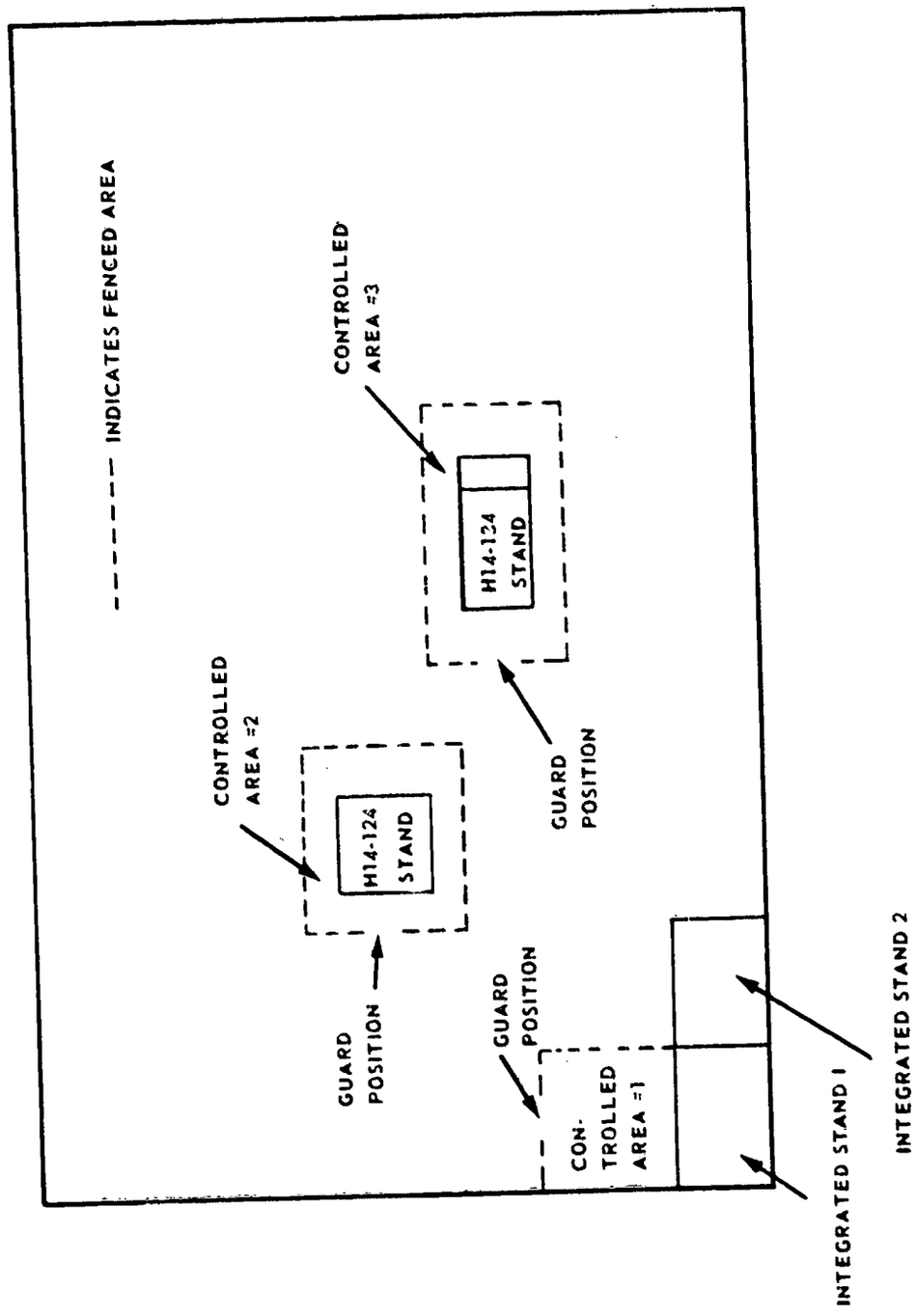
PROCEDURE: 1. Personnel will clear through the security monitor prior to entering the Controlled Area. No special badging will be provided.

2. Personnel will enter and leave the Controlled Areas as shown in the attached sketch.

S Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

ATTACHMENT
APOLLO 204 REVIEW BOARD
ADMINISTRATIVE PROCEDURE NO. 21
FEBRUARY 19, 1967

MSOB HIGH BAY



APOLLO 204 REVIEW BOARD
FEBRUARY 23, 1967

Administrative Procedure No. 22.

TITLE: Control of Audio Magnetic Tapes

SCOPE: This procedure covers the control of all voice transmission recordings relative to spacecraft 012 during the Plugs Out Test on January 27, 1967.

POLICY: 1. All original and duplicate voice recordings on 1 4" magnetic tape relative to S C 012 after 0600, January 27, 1967 shall be included in this procedure.

2. Access to these voice tapes as well as duplicates shall be restricted to Board Members, Panel Chairmen or their designees as specified in writing.

3. All tapes will be located in a controlled central tape library. Playback of these tapes will be in accordance with the procedure as specified below.

PROCEDURE: 1. All original and duplicate voice tapes will be impounded in Room 2721B, MSOB, Phone: 867-6270.

2. Original tapes will be played back only to make a duplicate.

3. Playbacks will be from a duplicate only.

4. A duplicate can be made from an original only when authorized in writing by a Board member.

5. All originals and duplicates will be maintained in a central tape library located in Room 2721B where recorders will be available for authorized personnel.

6. Mr. G. Huffines or his alternate is the central tape library manager and is responsible for maintaining the tapes in a locked safe and for ensuring that only authorized personnel have access to the tapes. He will schedule and coordinate playbacks to assure efficient use of tapes and recorders. Hours of the library will normally be daily from 8 am to 1630 p.m. Arrangements for use of the library at times other than normal duty hours can be made by contacting the manager.

7. Original tapes containing the time interval 23:25 Z – 23:35 Z will be duplicated in two parts with this time interval or any part thereof being on a separate tape. This time interval requires written AS204 Review Board approval to be played back.

8. Any original may be duplicated at the request of an authorized person, but the duplicate will be retained in the central tape library.

S Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
FEBRUARY 25, 1967

Administrative Procedure No. 23

TITLE: Disposition and Storage of Physical Evidence

SCOPE: This procedure covers the disposition and storage of Command Module 012 following the completion of the on site investigation by the Apollo 204 Review Board.

POLICY: Except for further testing of components deemed necessary by the Apollo 204 Review Board, the physical evidence, comprised of the Command Module of Spacecraft 012 together with its various components and systems installed therein at the time of the accident occurring on January 27, 1967, shall be placed in the custody of the John F. Kennedy Space Center. When approved by the Board, the systems requiring no further tests shall be reinstalled, as practicable, in the spacecraft. The spacecraft, together with all items, systems and components showing evidence of damage caused by the incident of January 27, 1967, shall be placed in a weather tight, secured container with appropriate locks and seals. Access to the locks and seals shall be controlled by an individual delegated custodial responsibility for the evidence by the Board.

PROCEDURE: 1. In the event it becomes necessary or desirable to reexamine any system or component within the spacecraft, or the spacecraft itself, Board approval for such access shall be obtained, and in accordance with such reasonable precautions as may be necessary to preserve the evidentiary nature of the module, the Custodian shall permit such access.

2. In the event it becomes necessary to remove from the module any item, system or component for further testing, a receipt shall be tendered to the custodian of the module, together with a reference to the test to be performed, and the place of performance. As a necessary part of any further testing procedures, the condition of the item, system or component shall be noted; the exact nature of the test to be performed shall be described; the time, date and place of testing shall be listed; the results of the test shall be documented and the item, system or component shall be returned to the module custodian. Upon receipt of the item, system or component, with documentation in accordance with this procedure, the item, system or component shall be reinstalled, as practicable, in the module, and the documentary results of the test shall be forwarded by the module custodian to the Board's depository at Langley Research Center, Hampton, Virginia; Attention: Apollo 204 Records Custodian.

3. Bonded and sealed storage of the module and its items, systems and components shall be continued for a period of 10 years, unless sooner ordered released from storage by the Board. At the end of a 10 year period of time, providing no further use of the module then appears, the module, its items, systems and components shall be disposed of in accordance with the instructions of the Board.

4. During all times the module and its related equipment is in sealed and bonded storage, efforts shall be maintained to prevent its examination by curiosity seekers and others not having a bona fide interest in the module and its equipment. Final disposition of the module shall be in accordance with such procedures as to prevent its exploitation as a commercial exhibit, or its use as a curiosity.

/S/ Dr. Floyd L. Thompson, Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
MARCH 10, 1967

Administrative Procedure No. 24

TITLE: Environmental Control System (ECS) Investigation

SCOPE: This procedure is applicable to all elements of the AS 204 Review Board and authorizes and initiates an investigation of the Spacecraft 012 Command Module ECS. The ECS will be tested, disassembled, and analyzed to the fullest extent to determine:

a. Possible fire initiators

b. Possible fire propagators

c. Suitability and safety of design and fabricated hardware for use in S/C applications.

POLICY: 1. This task will be conducted utilizing existing AS 204 Review Board Procedures.

2. A Board designated agent is herein appointed and is to be supported as required by the S/C Prime Contractor, the pertinent Subcontractors, KSC - Materials Analysis Branch and appropriate quality and support elements.

3. After approval of pertinent general test plans, the designated Board Agent is responsible for the generation, control, and implementation of the detailed plans and activities.

PROCEDURE: 1. This procedure establishes the S/C 012 ECS Investigation Committee and delineates the Committee's authority.

2. The ECS Investigation Committee will consist of:

a. D. Hampton, Chairman (Board Designated Agent)

b. Robert A. Bruce (Alternate Board Designated Agent)

c. E. Wright, KSC - ECS

d. D. Evans, KSC - MAB

e. W. Hunter, NAA - Downey

f. E. Griffith, NAA - F. F.

g. D. Nell, Air Research

3. The Board designated Agent will act as Chairman of this Committee and is granted the same authority and privileges as has been defined for Panel Chairman in the existing Administrative Procedures.

4. Each member of this Committee may, at his discretion, call a temporary hold to the operation. An immediate appraisal will be provided with all attempts made to reach a mutually agreeable solution. If such cannot be achieved, work will not progress beyond the point of no return until the Board designated Agent has obtained resolution from higher authority.

5. MAB will act as staff advisors in the Investigation and conduct specialized investigations as required.

6 Air Research will provide engineering advice, planning Procedures, testing and disassembly as required on Air Research supplied subassemblies and components.

7. North American Aviation will provide those normal services such as system level engineering, TPS generation, GSE preparation, testing, QC inspection, etc.

REPORTING: 1. Periodic progress reports will be made at pertinent intervals.

2. A final integrated report will be published upon completion of the effort.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

APOLLO 204 REVIEW BOARD
MARCH 13, 1967

Administrative Procedure No. 25

TITLE: Continuation of Testing in Support of Apollo 204 Review after recess of Board

SCOPE: This procedure is applicable to all elements of the Apollo 204 Spacecraft Program Office, Kennedy Space Center, and Manned Spacecraft Center that require testing and analysis of subsystems, components, and materials of Spacecraft 012 command module in support of the Apollo 204 investigation. This procedure becomes effective when the Apollo 204 Review Board completes its on-site investigation and recesses.

POLICY: The policy and procedures set forth in Administrative Procedures 5, 11, and 23, not inconsistent herewith, are applicable. Unless otherwise approved, only non-destructive testing is permissable.

PROCEDURE: 1. When a requirement exists for testing, the custodial agent shall be informed thereof.

2. Laboratory tests and analyses in support of the investigation of the Board will be continued by the appropriate Panel or Panels after recess of the Board, and the results of such tests shall be incorporated serially in Appendix G of the Final Report of the Board and appropriate distribution made.

/S/ Dr. Floyd L. Thompson
Chairman
Apollo 204 Review Board

REPORT OF PANEL 16
SPECIAL TEST
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

SPECIAL TESTS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Special Tests Panel, 16. The task assigned for accomplishment by Panel 16 was prescribed as follows:

This task involves the coordination of desired tests generated by other groups into an overall integrated test plan. For example flammability testing will probably be done at several locations. This group will assure proper coordination of this activity. Major tests such as mockups of actual configuration, boilerplate destructive combustion tests, etc., would be considered by this group. Test results would be collected, reviewed, and edited in a form suitable for inclusion in the final report.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Special Tests Panel:

Mr. G. J. Stoops, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. J. D. Jeter, Kennedy Space Center (KSC), NASA
Mr. J. F. Saunders, Office of Manned Space Flight (OMSF), NASA
Mr. M. E. Gunn, North American Aviation, Inc., KSC

2. COGNIZANT BOARD MEMBER:

Dr. Maxime Faget, Manned Spacecraft Center (MSC), NASA, Board Member, was assigned to monitor the Special Tests Panel.

C. PROCEEDINGS

1. INVESTIGATION APPROACH:

a. The request for special tests were generated by Members of the Board, Panel Chairmen, or Panel members. It was the responsibility of Panel 16 to review these requests to assure that:

(1) Test duplication did not exist
(2) The test was relevant to the AS-204 Review.
(3) The test would contribute significant and meaningful technical results.

b. The Special Test Panel was also responsible for:

(1) Securing appropriate hardware or materials to accomplish the test.
(2) Proposing the test facility and/or agency to perform the test.
(3) Scheduling the test.
(4) Securing the appropriate approval to implement the test.
(5) Assuring that test data and reports were submitted by the test agency and delivered to the requester.
(6) Maintaining a test status.
(7) Publishing a periodic test summary and status.

c. Panel 16 served as a separate Panel from January 31, 1967, through February 23, 1967. The Panel was dissolved on February 23, 1967, and merged with Panel 18. This merger was accomplished to better support the Apollo 204 Review. The work statement of Panel 16 remained virtually unchanged and at that time continued as a responsibility of Panel 18.

2. SUMMARY OF ACTIVITIES:

a. The accomplishment of the assigned task required that Panel 16 establish a system to receive, maintain status of, and implement special testing. A Request for Special Test (RST) form was devised and issued to all Panel Chairmen on February 13, 1967. The purpose of this form was to permit the requestor of a special test to do so with minimum effort and maximum speed. The RST form also displays the test approval signature, the test location, and the originator.

b. Panel 16's test files were set up using Special Test Number (STN) as the file index and tracking number. The RST and the STN are synonymous. All correspondence, data, reports and other incidental information was filed by this number.

c. The Special Test Panel reviewed each test request to establish hardware/material requirements and to determine the test agency or facility who could best accomplish the test. Panel responsibility also required that the procurement or shipment of hardware necessary to perform the test be accomplished. The Special Test Panel fulfilled this responsibility through the use of appropriate contractual channels.

d. Panel 16 presented the test request with the recommendation of approval or disapproval to Integration Analysis Panel, 18. This recommendation included the proposed test facility, the availability of hardware, and the priority of the test relative to other AS-204 Review testing being done in the same facility.

e. Test approvals were acquired from either the Review Board or Panel 18. Board approval was required on all tests which utilized Spacecraft 012 hardware or spares or "one of a kind" hardware whose use required control. This assured its availability for AS-204 Review Board usage. Board approval was secured through Panel 18 and the Panel Coordinating Committee. All other testing was approved by Panel 18 prior to implementation.

f. Implementation of the test was accomplished by either a Test Preparation Sheet (TPS) or an Apollo Spacecraft Hardware Utilization Request (ASHUR). The latter is described in Apollo 204 Administrative Procedure Number 5C (Appendix D-15). The TPS was used for defining the test requirements and procedures for all Kennedy Space Center (KSC) and Manned Spacecraft Center (MSC) testing. The ASHUR defined the test requirements and was used for all Spacecraft 012 hardware testing accomplished at any location other than KSC.

g. Test data and reports resulting from special tests were submitted to Panel 16. Panel 16 distributed the test results to the originator for his technical evaluation and subsequent inclusion in his final report. Panel 16 was not responsible for performing a technical evaluation of the test data. However, it was responsible for assuring that the data and reports were submitted by the test organization immediately following completion of the test. A summary of pertinent test evaluations resulting from Special Tests is included in the Panel 18 final report.

h. Panel 16 test files were closed out individually as the tests were completed. Test reports and data were distributed to the test originator. The total file, including originals and working paper, was officially transmitted to Panel 17 for filing.

i. The first test summary was published on February 4, 1967. Starting on February 14, 1967, the status summary was published each Tuesday and Thursday and has continued through the Apollo 204 Review. The Special Test Summary was distributed to each Panel Chairman and the members of the Panel Coordinating Committee.

D. FINDINGS AND DETERMINATIONS

This section is not applicable to Panel 16. Technical evaluations of tests were performed and reported by other Panels.

E. SUPPORTING DATA

Enclosure	Description
16-1	Special Test Statistical Summary
16-2	Special Test Synopsis

SPECIAL TEST SUMMARY

MARCH 14, 1967

SPECIAL TEST REQUESTS (TOTAL)			50
DISAPPROVED			11
IN PROCESSING			1
APPROVED			38
IN TEST (TOTAL)			11
KSC		9	
MSC		1	
OTHER		1	
COMPLETED TESTING (TOTAL)			27
RESULTS NOT RECEIVED		7	
RESULTS RECEIVED		20	
RESULTS IN PANEL REVIEW	8		
CLOSED OUT	12		

ENCLOSURE 16-1

SPECIAL TEST SYNOPSIS

STN	TEST TITLE	TEST PURPOSE
1.	TV SIMULATION	Substantiate visual resolution expected from a TV monitor system. Test completed on Spacecraft 008 per TPS V16-002-068. Evaluation by Panel 18.
2.	CLEANING FLUID SQUEEZE BOTTLE ANALYSIS	Assure that bottle contents had no causitive relationship to the accident. Analysis per TPS S/C 012-MA-003. Evaluation by Panel 18.
3.	COBRA CABLE — SPARK IGNITION SOURCE	Determine if connecting or disconnecting cobra cable could cause spark or ignition. TPS S/C 012-MA-016 complete. TPS S/C 012-MA-018 waiting parts. Evaluation by Panel 8.
4.	NORTH AMERICAN AVIATION MOCK-UP NUMBER 2 SHIPMENT	Required as a visual reference to support investigation. Arrived February 8, 1967 - No evaluation required.
5.	ONE-HALF SCALE MOCK-UP SHIPMENT	Required to Depict S/C 012 Cabin Interior. Arrived February 8, 1967. No evaluation required.
6.	S/C 014 SHIPMENT	Spacecraft 014 required as a practice and procedure verification vehicle for S/C 012 disassembly activities - Arrived February 1, 1967. No evaluation required.
7.	EMERGENCY EGRESS TEST	Determine force required to break hatch seal at various cabin pressures. Test disapproved because of hatch redesign. No evaluation required.
8.	SPECIAL HANDLING PROCEDURE - S/C 012	Develop procedure to assure proper handling, testing, and disposition of S/C 012 hardware. Administrative Procedure 5B released February 8, 1967; revised to 5C on March 3, 1967.
9.	SPACE SUIT TEST	Determine response of demand regulator to various movements of a suited crew member. Completed on MSC Portable Life Support System (PLSS) console per TPS EC44-0120 and TPS EC44-0121. Evaluation by Panel 3.
10.	BECKMAN OXYGEN ANALYZER - GAS ANALYSIS	Determine whether any clue to the cause of the fire could be found in the gas analyzers - Completed in KSC Materials Analysis Branch (MAB) per TPS S/C 012-S/C 007 - Evaluation by Panel 18.
11.	OXYGEN FLOW RATE SENSOR TEST	Attempt to simulate S/C 012 oxygen flow rate data by subjecting a spare transducer to varying loads - TPS S/C 012-CM-CA 028. Evaluation by Panel 3.
12.	ANALYTICAL STUDY OF FLAMMABILITY OF MATERIAL IN OXYGEN	Provide a basis for a comprehensive fire control program in the spacecraft. Four week study contract awarded to Atlantic Research on February 16, 1967. Evaluation by Panel 8.

13.	QUALIFICATION-TYPE TEST ON LITHIUM HYDROXIDE (LiOH) CANISTER	Determine ability of LiOH canister used during OCP FO-K-0021-1 to meet qualification of flight hardware - Test Disapproved. Information available to verify that canister did not qualify as flight hardware.
14.	GAS CHROMATOGRAPH CABLE ARCING TEST	Determine if connector would arc when dropped onto a metal surface with power applied. Completed on S/C 008 per TPS V16-001-073. Evaluation by Panel 18.
15.	DECOMPOSITION PRODUCTS OF LiOH CANISTER	Determine the composition of the gases generated from the combustion of a LiOH canister. Test requirements incorporated into Special Test No. 50.
16.	GAS CHROMATOGRAPH CABLE: WATER/GLYCOL TEST	Determine reaction of powered gas chromatograph connector to water/glycol vapor and liquid - to be accomplished in KSC-MAB per TPS S/C 012-CM-MA-016. Evaluation by Panel 18.
17.	CHROMATOGRAPH AND ALTERNATING CURRENT (AC) BUS SWITCHING TEST	Attempt to determine spacecraft configuration and operations which could produce conditions found in S/C 012 data accomplished on S/C 008 per TPS V16-006-064. Evaluation by Panel 3.
18.	MULTIPLE KEYING TEST	Attempt to simulate S/C 012 communications anomalies by performing multiple keying operations on S/C 008. Test cancelled because of questionable value of information that would be obtained.
19.	SMOKE AND FIRE GLOW SIMULATION ON TELEVISION MONITOR	Symbolically simulate the accident by providing smoke and fire glow as described by witnesses. Test disapproved as providing no meaningful information beyond that obtained in the first TV test.
20.	VERIFY PROCEDURES USED TO CLEAN CONNECTORS EXPOSED TO WATER/GLYCOL	Verify adequacy of procedures used to clean connectors on S/C 012 exposed to water/glycol. Combined with special test No. 33 because of similarity. To be accomplished in KSC-MAB. Evaluation by Panel 8.
21.	FLOW MEASUREMENT IN SUIT LOOP UNDER VARYING CONDITIONS	Attempt to duplicate high suit flow rates and possible suit hose disconnect seen in S/C 012 data - accomplished at MSC on breadboard per TPS STB-A-167. Evaluation by Panel 3.
22.	SPACECRAFT ELECTRICAL TESTS	Attempt to simulate electrical anomalies indicated on S/C 012 data at the time of the accident - accomplished on S/C 008 per TPS V16-001-073. Evaluation by Panel 3.
23.	GAS CHROMATOGRAPH CONNECTOR: TREATED VELCRO ARCING TEST	Determine if energized connector rubbing over Velcro treated with glycol and methyl-ethyl-ketone (MEK) would cause ignition. Test disapproved as not providing meaningful information.

24.	ELECTROSTATIC TEST - SPACE SUIT	Determine electrostatic charge that can be developed by a suited crewman in spacecraft atmospheres. Part 1 - TPS Pressure Garment Assembly (PGA) 152 complete - Part 2 - TPS S/C 014-CM 038 pending spacecraft availability. Evaluation by Panel 8.
25.	S/C 012 ATMOSPHERE - RELATIVE HUMIDITY	Calculations of S/C 012 atmosphere relative humidity entered in Special Test Log because of its potential use. Technical evaluation not required.
26.	VENT VALVE OPERATION	Determine maximum cabin pressure at which vent valve fails to operate. Test disapproved because vent valve was not designed for use in over-pressure conditions.
27.	GAS CHROMATOGRAPH CABLE PROCUREMENT	Procurement action to assure availability of spare gas chromatograph cables for test usage. Cables received February 25, 1967.
28.	SUIT FLOW TESTS	Obtain additional information for evaluation of S/C 012 suit flow data - test constrained by lack of a properly configured spacecraft. To be performed at MSC. Evaluation by Panel 3.
29.	ANALYSIS OF S/C 012 GAS CHROMATOGRAPH CABLE	Determine damage to and involvement of gas chromatograph cable in cause of accident - analysis in progress in KSC-MAB per TPS S/C 012-CM-IV088. MAB report MAB 238-67. Evaluation by Panel 18.
30.	ANALYSIS OF LIQUID FROM QUAD ENGINE	Analyze liquid from Quad B, Engine No. 3 to determine composition and source - analyzed in KSC-MAB per TPS S/C 012-SM-MA 001, MAB Report Number MAB-232-67. Evaluation by Panel 18.
31.	ANALYSIS OF CONTENTS OF GAS MELON	Attempt to gain further information on contents of melon sampler used to analyze suit gases on January 27, 1967 - analysis performed in KSC-MAB per TPS S/C 012-S.C 017, MAB Report Number MAB 259-67. Evaluation by Panel 18.
32.	FLAME RATE OF ETHYLENE GLYCOL WATER MIXTURES	Determine concentrations of ethylene glycol/water mixtures which could have supported combustion on S/C 012. Accomplished in KSC-MAB. Evaluation by Panel 8.
33.	WATER GLYCOL EFFECTS	Determine if procedure used to clean connectors exposed to water glycol on S C 012 was adequate, and effects upon connectors of exposure to water, glycol - to be performed in KSC-MAB. Evaluation by Panel 8.

34.	INERTIAL MEASUREMENT UNIT (IMU) TEMPERATURE CONTROL TEST	Determine changes in IMU Heater and Blower current as a function of Bus voltage changes, for correlation with S/C 012 data - Test cancelled.
35.	PROCUREMENT OF ENVIRONMENT CONTROL UNIT (ECU) CABLE ASSEMBLIES	Supply twenty-five (25) cable assemblies to support Special Test No. 33. Twenty-three (23) assemblies available March 10, 1967; three weeks lead time on remaining two. Evaluation not required.
36.	LiOH CANISTER TEST	Measure temperature and flow characteristics of LiOH canister same as those used on S/C 012 during OCP FO-K-0021-1. Test Requirements incorporated into Special Test No. 50. Evaluation to be made as part of that test.
37.	SOOT COMPARATIVE ANALYSIS	Comparative analysis of soot from near cabin relief valve inlet and from steam duct to verify cabin relief valve operation. To be analyzed in KSC-MAB per TPS S/C 012-CM-MA-008. Evaluation by Panel 10.
38.	ANALYZE DEPOSIT ON COMMAND PILOT FOOT PAN	Analyze deposit on Command Pilot's foot pan to determine its composition and aid in determining its origin. Performed in KSC-MAB per TPS S/C 012-CM-MA-007, MAB Report Number MAB 311 67. Evaluation by Panel 18.
39.	ELECTRICAL SHORT TEST	Provide data to support investigation of alternating current (AC) anomaly noted on S/C 012 prior to the accident. Accomplished on S/C 008 per TPS V-16 001-083. Evaluation by Panel 3.
40.	COLDPLATE LEAK CHECK	Isolate sources of water glycol leakage which may have contributed to the accident. Included in plan of action for Board Action Item 0107. Evaluation by Panel 18
41.	SPECIAL ECU WITH LiOH CANISTERS	Obtain accurate thermal and chemical performance data on LiOH canister under conditions nearly identical to S/C 012-Requirements incorporated into Special Test No. 50. To be evaluated as part of that test
42.	CABIN RELIEF VALVE AND VENT LINE FLOW	Determine flow characteristics through vent line with vent valve in abort entry mode for correlation with S/C 012 data - accomplished on Mockup SMD 2B. Evaluation by Panel 10
43.	DIFFERENTIAL PRESSURE (ΔP) vs COUPLING DATA UNIT (CDU) GIMBAL ANGLES	Obtain plot of CDU Gimbal Angles at various cabin pressures for comparison with S/C 012 data - accomplished on S/C 008 per TPS V16 001 080 Evaluation by Panel 10

44.	CHROMATOGRAPH CABLE TEST	Reproduce copper flow found on S/C 012 Chromatograph Cable following accident. Performed in KSC-MAB per TPS S/C 012-CM-MA-011. MAB Report Number MAB 297-67. Evaluation by Panel 18.
45.	WEIGH LiOH CANISTERS	Determine extent to which canisters had reacted with the surrounding atmosphere during storage. Incorporated into Special Test No. 50. To be evaluated as part of that test.
46.	ELECTRICAL SHORT TEST	Conduct electrical shorting tests on a vehicle configured similar to S/C 012 to obtain information relative to cause of ignition. Request withdrawn by originator.
47.	AC BUS 2 SHORT ON PHASE A	Provide additional data to support investigation of S/C 012 AC anomaly prior to the accident. Performed on S/C 008 per TPS V16-001-093. Evaluation by Panel 3.
48.	OCTOPUS CABLE TEST - S/C 008	Acquire positive data to determine if MDAS would evidence anomalies due to short duration grounding of direct current (DC) Main Bus B. Authorized per ASHUR 012-501 - accomplished on S/C 008 per TPS V16-001-093. Evaluation by Panel 3.
49.	ELECTRICAL SHORT TEST	Determine effects of hard shorts on various gage wire circuits within the DC systems. Test to be accomplished March 15, 1967, on S/C 008 at MSC. Evaluation by Panel 3.
50.	LiOH CARTRIDGE TEST	Combination of requirements of Special Tests 15, 36, 41, and 45. To be accomplished in KSC-MAB. Evaluation by Panels 2, 5, 8, 11, and 18.

REPORT OF PANEL 17
FINAL BOARD REPORT
APPENDIX D-17
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Final Board Report Panel, 17. The task assigned for accomplishment by Panel 17 was prescribed as follows:

> This activity involves the organization of the report, the delegation of responsibility to other assigned task groups, the review and editing of submitted material, and the final preparation of the Report.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Final Report Panel:

Lt. Col. K. H. Hinchman, U. S. Air Force, Chairman
Mr. R. D. Smith, Kennedy Space Center (KSC), NASA
Mr. J. G. Ross, Langley Research Center (LaRC), NASA

2. COGNIZANT BOARD MEMBER:

Colonel Charles F. Strang, U. S. Air Force, Board Member, was assigned to monitor the Final Report Panel.

C. PROCEEDINGS

In response to the direction of the Apollo 204 Review Board, the Panel derived detailed objectives. These objectives were: preparation of the Apollo 204 Review Board Final Report; review of Panel reports; and the establishment and maintenance of an Apollo 204 Review Board General File.

1. FINAL REPORT PREPARATION:

The Apollo 204 Review Board immediately recognized the Final Report would serve important functions. These functions included: the detailed documentary of the investigation process; the presentation of the rationale which supports the findings and recommendations; and the presentation of validating data used to eliminate specific systems and procedures as possible causative factors. With these functions in mind, the Final Report Panel was designed to document findings, determinations, and recommendations for submission to the Administrator, National Aeronautics and Space Administration (NASA).

To accomplish this objective effectively, it was initially determined that the Final Report Panel would establish a system to insure that every Board proceeding, statement, text, analysis, disassembly action, etc., was documented. Original copies (wherever possible) of each supporting document were obtained by the Panel. Those identified for enclosure in the Final Report were then reviewed, edited, and assembled. The Final Report would lose its readability and effectiveness if every document created during the review was included in the report proper. Therefore, only those documents, photographs and test results considered pertinent to the findings of the Review Board are contained within the covers of the Report. All other references are retained in the General File. Enclosure 17-1 is the outline used in the preparation of the Final Report.

2. PANEL REPORT PREPARATION - APPENDIX D TO THE FINAL REPORT:

Enclosure 17-2 illustrates the procedures employed in the preparation of the Final Panel Reports. Panel Chairmen consulted Panel 17 to obtain detailed requirements for Final Panel Report preparation. Format, enclosures, findings and determinations were discussed, and recommended improvements defined. Each draft of the Panel Reports was edited by Panel 17 and simultaneously, technical reviews were made. Copies were prepared and distributed to Board Members, Counsels to the Board and cognizant Panel Chairmen for individual study. The Apollo 204 Review Board, through meetings with the Panel Chairmen, reviewed the completeness, coordinated the contents with other Panels, and judged the acceptability of the reports. Panel Chairmen advised Panel 15 of their photographic selections for

Sheet 1 of 2)

inclusion in the Final Panel Report. Services for the preparation and reproduction of text, charts, drawings, photographs, and binding of the Final Report were obtained by the Final Report Panel, 17.

3. GENERAL FILE:

The Apollo 204 Review Board General Files were established in accordance with Review Board Administrative Procedure 15. The Final Report is dependent upon this file for much of the supporting documentation. Data relative to fire propagation, materials, systems operation at high temperatures, system and component testing and validation, etc., are some of the by-products of the review and are available in the file. The composition and functions of the Review Board, as well as task assignments of the Panels, are also available therein. The file system is designed to insure that every item entered in the file is reviewed, logged, indexed and cataloged. Major classification is by Panel with specific reference data pertaining to the Panel Report filed in the front of each Panel's file. Test Preparation Sheets (TPS), prepared for each test, disassembly task, investigation technique, etc., are identified by the spacecraft system to which they apply and are cross indexed by TPS number.

All Review Board General Sessions were recorded on tapes designated "original" (Review Board Administrative Procedure 9) and are in the General File. These tapes were then used in transcribing minutes of General Sessions. Verbatim transcripts of these sessions are incorporated in Appendix A along with minutes of the Executive Sessions. Edited copies of original tapes were made and designated "master". The editing process removed extraneous information and periods of silence. Other items in the General File include photographs, diagrams, T.V. tapes and motion picture films.

In accordance with the direction of the Administrator, NASA, February 27, 1967, the Final Report and General File will be maintained by the Director, Langley Research Center, Langley Station, Virginia, for the National Aeronautics and Space Administration, to provide a source of information to inquiries and for research projects of the future.

D. FINDINGS AND DETERMINATIONS

Not applicable.

E. SUPPORTING DATA.

Enclosures

17-1. Final Report Outline
17-2 Task Panel Report Flow Chart

FINAL REPORT OUTLINE

Letter of Transmittal to Administrator, NASA

Preface

Table of Contents

Part 1 - Purpose and Authority
- a. Narrative of Board History
- b. NMI 8621.1 and memoranda of January 28 and February 3, 1967.
- c. Dr. Seaman's letters on appointment of Dr. Van Dolah; letters on deletion of Dr. Long and Mr. Jeffs.

Part 2 - Biographical background on each board member and Counsel to the Board.

Part 3 - Board:
- a. Organization Letter from Board Chairman on appointments of Representatives, Consultants, Liaison to the Board and Task Panels.
- b. Procedures - Explanation of how Board functions, i.e., daily General and Executive Sessions, Task Panel participation, decisions and requests for Panel accomplishments enacted in Executive Session.
- c. Summary of Activities - Record of Board proceedings.
- d. Spacecraft and data custodial responsibilities
- e. Interim Reports from Deputy Administrator, NASA to the Administrator, NASA

Part 4 - History of Accident
- a. Background of Spacecraft 012 together with description of test objectives and sequences up to start of T-10 hold.
- b. Time line from T-10 hold through medical determination of death (summarize events as they occurred).

Part 5 - Investigation and Analysis — a detailed descriptive narrative of the investigation which provides an analysis of the causes or probable causes.

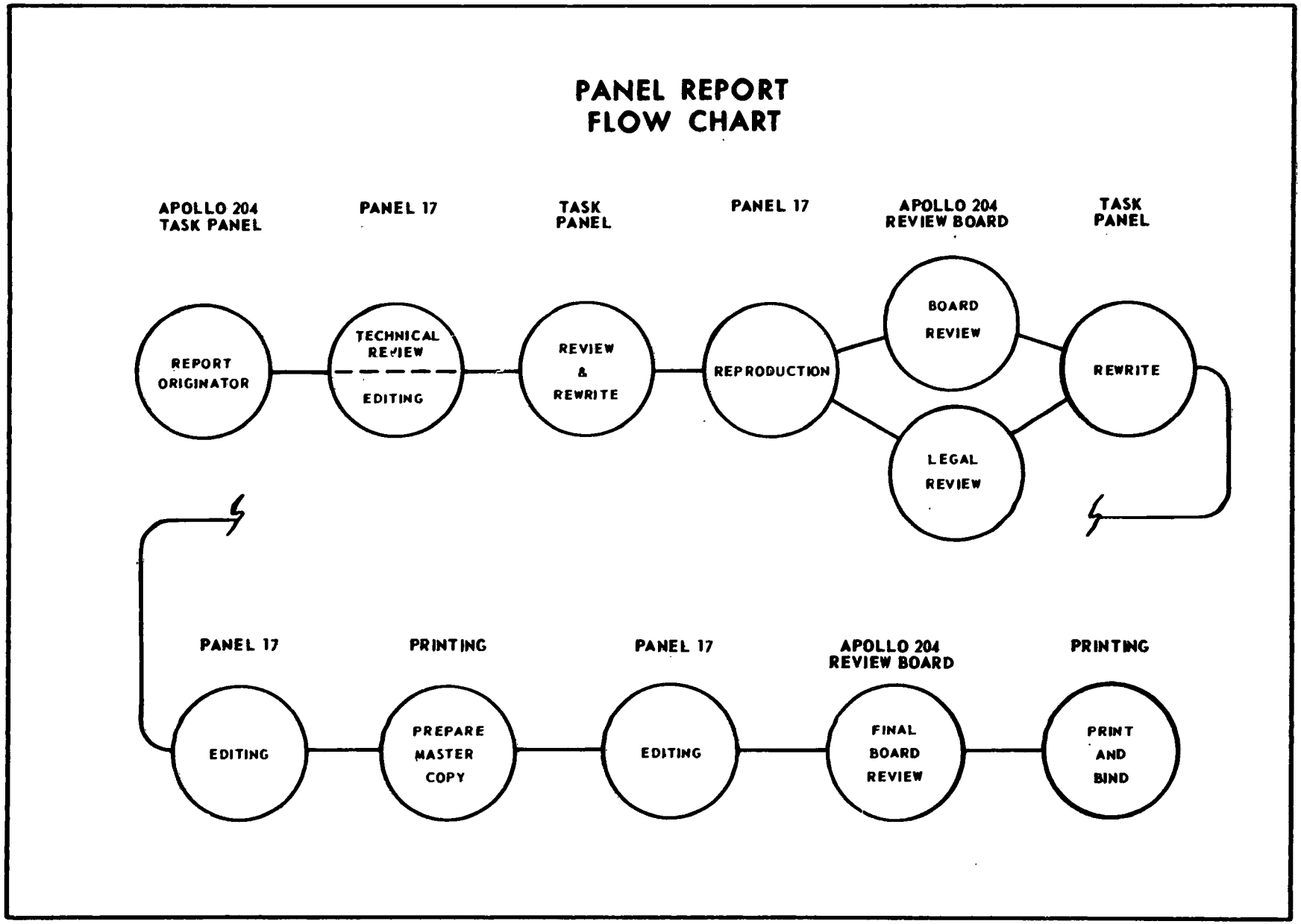
Part 6 - Findings, Determinations, Recommendations

Appendices.
- a. Board Minutes.
- b. Witness statements (with releases).
- c. Apollo Operations Handbook, dated 12 November 1966.
- d. Panel Reports.
- e. Organization and Management.
- f. Schedule of Physical Evidence.
- g. Addenda and Corrigenda

Board Files not part of report

General File.
1. Witness statements not relevant.
2. Photographs not used in report.
3. Supplementary analysis and data used in preparation of Report
4. Working papers
5. Voice and medical records (filed at MSC).
6. Correspondence from General Public
7. Miscellaneous papers.

ENCLOSURE 17-1



ENCLOSURE 17-2

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANEL 18

REPORT OF PANEL 18

INTEGRATION ANALYSIS PANEL

APPENDIX D-18

TO

FINAL REPORT OF

A P O L L O 2 0 4 R E V I E W B O A R D

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Integration Analysis Panel, 18. The task assigned for accomplishment by Panel 18 was prescribed as follows:

> This task involves the review of inputs from all task groups, the correlation of all pertinent information, feedback for further study, and the final technical integration of the evidence.

B. PANEL ORGANIZATION

1. Membership

The assigned task was accomplished by the following members of the Integration Analysis Panel:

Mr. A. D. Mardel, Chairman, Manned Spacecraft Center, NASA
Mr. R. W. Pyle, North American Aviation, Kennedy Space Center
Mr. C. B. Mars, Kennedy Space Center, NASA
Mr. D. S. Levine, North American Aviation, Downey, California

2. Cognizant Board Member

Dr. M. A. Faget, Manned Spacecraft Center, NASA, Board Member, was assigned to monitor the Integration Analysis Panel.

3. Panel Consolidation

Panel 16 and 3 served as separate Panels from January 31, 1967, through February 23, 1967. These Panels were dissolved on February 23, 1967, and merged with Panel 18.

C. PROCEEDINGS

1. General

In response to the direction of the Board, the Panel discharged its responsibilities to the Board by planning and executing the following major activities:

a. Coordination of all phases of hardware inspection, disassembly, test and analysis requirements, and presentation of periodic status and summary of results to the Board.

b. Correlation, validation, and determination of each significant finding, and presentation of periodic status and summary of results to the Board.

2. Hardware Inspection, Disassembly and Analysis

Inputs were solicited from all Panels with respect to hardware inspection, disassembly, test and analysis requirements. A special form, "Disassembly and Post-Disassembly Requirements," (Enclosure 18-1), was used for the logging of all requirements.

In keeping with the analysis activity, priorities for the various requirements were established. Items were then selected twice daily to be approved by the Board for proceeding with that activity of work. Board approval information was fed by the Panel back to the systems engineers so that a "Test Preparation Sheet," TPS, (Enclosure 18-2) would be originated to accomplish this work. This Panel approved all TPS's, kept current TPS files, and reported on the status of all approved requirements by means of a "Board Action Summary" prepared each Wednesday. A sample page of the latest "Board Action Summary" is attached as Enclosure 18-3. All three enclosures relate to the same item: "Removal of a cover over the junction box in the lower left-hand equipment bay."

Significant findings from hardware inspection were then correlated with the analysis effort to determine further courses of activity so as to culminate all research and work on an item and enable a determination to be made. This hardware activity was completed on March 27, 1967. All of the equipment has been removed from the spacecraft.

An examination of the electrical wiring harnesses remaining in the spacecraft in the most probable zone of fire initiation was completed on March 24, 1967. The most probable zone of fire initiation is defined as the area on the Command Pilot side of the Command Module. Looking forward through the main hatch, this area starts at the Environmental Control Unit (ECU) and progresses forward to the gas chromatograph compartment, and covers the volume from the floor to the top of the ECU and to the top of the gas chromatograph compartment. All wiring in the lower

equipment bay was also examined. The ECU wiring has been examined while the unit was in the spacecraft and after removal from the spacecraft.

Electrical Power System wiring inspection and analysis is still continuing. Work items that are active are as follows:

a. Determination of the cause for each circuit breaker and fuse that was found open or blown after the accident. All open circuit breakers have been identified. The identity of all blown fuses has not yet been established. All circuit breakers that were to be closed but were found open after the accident are listed in Enclosure 18-4.

b. Conduct of additional continuity checks to establish that suspect wiring was installed as required by manufacturing drawings.

The only evidence of arcs, shorted and suspicious wiring that has been found is listed below:

(i) DC wiring completely burned through in harnesses providing power to Environmental Control System instrumentation.

(ii) Arc between a DC wire and the cover of J-Box C15-1A52.

(iii) Shorted AC wires providing power to the gas chromatograph connector.

(iv) Shorted DC wires providing power to scientific equipment bay 2.

(v) Two shorted AC phases in cabin air fan 1 wiring.

(vi) Crushed DC harness in Environmental Control Unit providing power for instrumentation.

(vii) Shorted DC wires providing power to the biomed recorder.

(viii) Shorted AC wires in Environmental Control Unit providing power for suit compressor 2.

(ix) Command Pilot suit wiring shorted.

(x) Arc on structure by side of switch S11 in back of panel 8.

All removed parts and assemblies were thoroughly reviewed by NASA and Contractor design engineers, metallurgists and Panel 5 members. Based on these reviews, they were classified either as a possible or as an improbable ignition source. A written justification was required for each item, and each item was approved by three design engineers representing NASA KSC, NASA MSC, and NAA, by the three members of the Screening Committee, by the Head of the KSC Materials Analysis Branch, and by a member of Panel 5 before it could be classified as an improbable ignition source.

The listing of all equipment totals 299 parts and assemblies. No attempt was made to list or to remove from suspicion as a possible ignition source the spacecraft wiring or devices integrally a part of that wiring such as terminal boards.

The 299 parts and assemblies were categorized as follows:

System	Number of Parts and Assemblies	Improbable Ignition Source (Cat. B)	Possible Ignition Source (Cat. A)	Remarks
Communications	17	17		
Instrumentation	22	12	10	9 ECS related transducers 1 harness assembly
Guidance and Navigation	16	16		
Stabilization and Control	14	14		
Environmental Control System	48	3	45	
Electrical Power System	32	30	2	Static Inverter 2 Panel C15-1A52 (LEB J-Box Cover)

Continued

System	Number of Parts and Assemblies	Improbable Ignition Source (Cat. B)	Possible Ignition Source (Cat. A)	Remarks
Displays and Controls	30	29	1	Switch 11, Panel 8
Sequencers	6	6		
Reaction Control System	12	12		
Structure	18	18		
Earth Landing System and Recovery Aids	5	5		
Crew Equipment	61	59	2	Command Pilot Cobra Cable, Command Pilot Torso Harness
Experiments	4	3	1	Octopus Cable
Pyrotechnics	14	14		
TOTALS	299	238	61	

The details of the Screening Committee review are contained in the "Screening Committee Final Report," dated March 24, 1967 (Reference 18-1). Analyses of the remaining Category A items are contained in other sections of this report. Special laboratory investigations of spacecraft wiring, the ECS and Static Inverter 2 are reported in this document.

3. Correlation, Validation and Determination of Investigation Items

Inputs were received periodically from daily Panel meetings, daily Panel reports, special Panel reports, hardware inspection and disassembly, brainstorming sessions, technical discussions, etc.

The more significant inputs, defined as those that (a) could possibly contribute to the cause of ignition, or (b) could contribute to the propagation of the fire, were listed as investigation items. Each investigation item was

correlated with other items, studied to establish validity and meaning, and finally a determination was made as to whether the item did not cause the accident or whether it may have contributed to the accident.

To better illustrate the mechanics, the process for one investigation item will be summarized:

Investigation Item 42 - Elapsed Time Indicator burned on Spacecraft (S/C) 014. This unit was associated with the Caution and Warning System. Data were received from Panel 6 that an Elapsed Time Indicator (a non-flight item) for the Caution and Warning System was overheated as a result of a noise suppression capacitor short during factory checkout on S/C 014 at North American Aviation, Downey, California. The Command Module filled with smoke during this incident.

The following validation actions were taken:

(a) Action to Panel 1 to determine the exact configuration of the Elapsed Time Indicator installed on S/C 012 and compared to the S/C 014 installation, and knowledge on whether this unit was installed during the accident.

(b) Action to Panel 2 to determine the level of qualification with respect to oxygen and pressure environments. Because this unit was to be removed before flight, it was believed that the unit would not have been qualified, but this still had to be confirmed.

(c) Action to Panel 3 to review all data from S/C 014 during the time that the incident occurred to determine if there were any electrical transients or if any circuit breakers opened, for correlation with indications during the accident.

Closure of these actions disclosed that no changes were made to the unit following the incident on S/C 014, that the unit installed on S/C 012 during the accident was of the identical configuration, and that the unit was not qualified for the environment during the time of the accident. A Board action was then requested to examine the installation on S/C 012 (Board Action No. 0035). A TPS was written (TPS 053) and an examination of the unit was made the next day. The physical

examination disclosed that the unit was in a satisfactory condition with no evidence of burning or damage. The item was then closed in the category of "did not cause the accident."

A "Status of Investigation Items" was prepared for the Board each Wednesday. The latest "Status of Investigation Items" is attached as Enclosure 18-52. Whenever an item was closed, an "Integration Analysis Summary" was prepared and presented to the Board (all are attached as Enclosure 18-53).

Output data from selected Panel activities were reviewed in detail. Examples of these outputs were discrepancy reports and open difficulties provided by Panel 6, and incomplete work or open "Engineering Orders" (EO's) and configuration differences provided by Panel 1. These outputs were reviewed by NASA and Contractor system engineers to determine which could be related to the cause of the accident. Those that could have some bearing on the cause of the accident were entered as investigation items.

4. Special Reports to the Board

Formal and informal reports were prepared and presented to the Review Board. The more significant of these included:

Review of Spacecraft Power Status
Supplement to Review of Spacecraft Power Status
Structural Assessment Report
Explanation and Discussion of ECS Water/Glycol Circuit Prior to and After the Fire Report
Spillage of Ethylene Glycol/Water (RS89-a) as a Possible Cause of Fire in S/C 012
ECS Oxygen System Description and Interim Data Evaluation
Communications Analysis Report
Mock-up 2 Mobility Evaluation Test Results

These reports are briefly summarized below.

Review of Spacecraft Power Status

This is a summary of internal and external power descriptions and configurations applicable to S/C 012. It contains a sequential history of the DC power system. The sequential history is fully verified by data indications and S/C and Ground

Support Equipment (GSE) switch and control positions. This report was used to establish the DC power system configuration at the time of the accident, and to show that it was proper. (Enclosure 18-54a)

Supplement to Review of Spacecraft Power Status

This is a summary of minor internal and external power supplies applicable to S/C 012 in addition to the main DC supplies. (Enclosure 18-54b)

Structural Assessment Report

This is the first summary of the visual inspection of the interior of the S/C to determine the extent of damage to the structure, plastic control knobs and glass dials. (Reference 18-2).

Explanation and Discussion of ECS Water/Glycol Circuit Prior to and After the Fire Report

This is a summary of the internal and external water/glycol system configuration throughout the test. It also contains a sequential history of significant system parameters. (Reference 18-3)

Spillage of Ethylene Glycol/Water (RS89-a) as a Possible Cause of Fire in S/C 012

This report presents laboratory results on the properties of water/glycol and its inhibitor agents. It points out that the residue remaining from any spillage or leakage is hygroscopic and corrosive. It postulates a theory that fire can be produced from electric short circuits caused by glycol/water residue in electrical insulations. (Reference 18-4)

ECS Oxygen System Description and Interim Data Evaluation

This is a summary of the internal and external oxygen system configuration throughout the test. It also contains a sequential history of significant system parameters. (Reference 18-5)

Communications Analysis Report

This report covers the configuration of the complete voice communications system - the Spacecraft, Spacecraft/Ground Interfaces and Ground Systems. It includes detail transmission information during the last ten minutes of the test. (Reference 18-6)

Mock-up 2 Mobility Evaluation Test Results

This report presents the results of a crew mobility test conducted at KSC. This test was conducted to determine the capability of a crew to see certain areas of the spacecraft and to perform certain actions with respect to time. (Reference 18-7)

5. Brainstorming Meetings

When the initial review of data and hardware failed to disclose an obvious source of the fire, a series of brainstorming meetings was held with participation by test engineers, design engineers, astronauts, etc. The purpose of these meetings was to initiate and critique possible fire initiation and propagation theories.

A large number of potential fire initiation and propagation theories were proposed and evaluation sheets were established to build up the supporting factors for the theory, negative factors to refute it, and to delineate additional physical examinations or tests required to support or to eliminate the theory. A total of 47 potential initiation theories have been proposed and evaluated. All of these are attached as Enclosure 18-55.

Of the 47 potential initiation theories, 46 are closed as not considered likely ignition sources, and one is closed as a probable potential ignition source.

The one probable ignition source is the DC wiring completely burned through in harnesses providing power to Environmental Control System instrumentation. Two potential initiation theories of a more general nature were also considered. These are described below.

a. Cold flow characteristics of Teflon insulated wire.

Teflon wire was selected for the spacecraft because of excellent resistance to high temperature, good dielectric properties, lightweight characteristics, etc.

It has, however, in common with other plastic materials, cold flow characteristics which permit the insulation to flow away from localized high pressure points over long periods of time. It is possible that localized high pressure points, either between wires or between a wire and structure, could ultimately result in breakdown of the insulation. All wire bundles in the spacecraft which showed damage were carefully inspected for signs of arcing. Only those locations delineated in other sections of this report showed such signs.

b. Failure of electrical connectors due to water/glycol spillage:

The characteristics of the inhibitor used in the coolant water/glycol fluid leaves a residue that is electrically conductive, hygroscopic, and flammable. Leaks of water/glycol occurred in the lower equipment bay and Environmental Control Unit area during earlier tests on S/C 012. These leaks were mopped up and connectors and accessible wire harnesses were washed with distilled water and alcohol, and dried with nitrogen.

After the accident, all connectors were carefully disconnected, photographed, and inspected for any signs of internal burning or arcing. No evidence of internal arcing or burning was found which indicated a fire source. A few isolated cases of pin arcing were found, but these appeared unrelated to the fire since all surfaces in the vicinity were clean and without any indication of a combustion path.

6. Data Indications

The purpose of this section is to summarize briefly the recorded data indications that were unusual and unexpected prior to the crew report of fire, and significant data indications following the crew report of fire.

a. Gas Chormatograph Telemetry Indication

Gas chromatograph channel output variation occurred at 23:30:50 GMT. The gas chromatograph was not installed for this test and the connector that carries the telemetry data signals and the required AC power was placed on the gas chromatograph shelf prior to the test. Power to the AC line in the connector was turned on during the test, as required by the test procedure.

A careful examination of records showed activity on this channel seven times prior to 23:30:50 GMT.

Following is a summary of the seven periods of activity (see Enclosure 18-7):

Trace A - 22:04:45 GMT - Gas Chromatograph (GC) trace changed in exact correlation with a rise in the VHF/FM RF output when transmitter was turned on. GC output change was 2 to 3 per cent.

Trace B - 22:06:54 GMT - This trace correlates with middle gimbal angle stabilization loop, responding to fine align mode.

Trace C - 22:19:23 GMT - This change in the gas chromatograph trace correlates to the Guidance and Navigation System (G&N) going to coarse alignment.

Trace D - 22:20:09 GMT - Change correlates with G&N going to fine align. The large current drawn by this change in the G&N mode also caused transients on DC bus A and DC bus B.

Trace E - 22:34:46 GMT - Pilot turned updata link to UHF.

Trace F - 22:53:13 GMT - Environmental Control System monitor reported high oxygen flow. He asked crew if the face plates were opened. Crew said "No." Much noise in background of Spacecraft.

Trace G - 22:55:40 GMT - Command Pilot changed cobra cable and was in process of communication check at this time. Location of Pilot was not known. Pilot did get cobra cable and may have still been in the lower equipment bay.

Trace H - 23:30:50 GMT - Variation just prior to the accident.

The telemetry data line in the connector has the characteristics of an antenna, and consequently can detect changes in the electromagnetic field within the spacecraft.

b. AC Bus 2 Voltage Variation

A momentary increase in AC bus 2 voltage was noted at approximately nine seconds before the crew report of fire, and at the same time the recorded parameters monitoring the equipment powered from AC bus 2 showed abnormal indications. Enclosure 18-3 shows the parameters and changes, with the times of sampling by the telemetry system. These were:

(1) Rise in AC bus 2 voltage phases A, B and C

(2) 1.7 second dropout of C-band decoder and transmitter outputs

(3) Momentary dropout of VHF-FM carrier

(4) Fluctuation of rotation controller null outputs

(5) Gas chromatograph telemetry signal transient

Other equipment connected to AC bus 2 at this time had no telemetry monitoring capability that would detect effects of voltage variation.

The associated changes which occurred at the time of the AC bus variation are individually discussed:

(1) The C-band beacon parameters dropout occurred for approximately 1.7 seconds. The 1.7 second dropout observed is the minimum recovery time of the protective circuit internal to the beacon to prevent magnetron damage. Possible causes of the C-band beacon dropout are:

(a) Interruption of AC bus 2 power would cause the C-band beacon dropout as verified by special tests on a C-band beacon similar to the one used in S/C 012.

The test indicated that interruptions of the AC power, all three phases, or phases A and B, or phases B and C, for 10 milliseconds or more created a dropout.

(b) Momentary drop of range interrogation; however, the range C-band station log shows no report of interrogation dropout at this time.

The most probable cause of the beacon dropout was a momentary loss of AC input power to the beacon, particularly since the transponder dropout was coincident with the variation of the AC bus and the beacon performed normally after the recovery from the dropout until loss of the data.

(2) VHF-FM transmitter signal dropout occurred for approximately 30 milliseconds. A dropout of this nature has been duplicated by special tests conducted by Collins Radio Company with a transmitter under similar conditions. These tests show that the received video signal during the noted time can be matched very closely by a momentary dropout on the AC supply (all three phases) to less than 50 volts, or a dropout of DC supply to less than 6.5 volts for a period of 15 to 20 milliseconds. Since the VHF-FM transmitter recovered, as did the C-band beacon, the most likely cause of the dropout was a momentary interruption of the AC input power.

(3) Rotation controller null outputs showed momentary transients in each of the three control axes. The rotation controller outputs which were reading slightly off null just prior to the voltage variation (the controller was pinned) are supplied by phase A of AC bus 2. Special tests have shown that the null

output transients can be duplicated by a momentary interruption of AC bus 2 phase A input power.

(4) The gas chromatograph telemetry signal showed a sharp transient coincident with the voltage variation. The character of the transient is indicated in Enclosure 13-7.

The AC bus 2 voltage increase appeared on all three phases momentarily. The AC bus voltages are sampled ten times a second by the instrumentation system. It is, therefore, impossible to determine the actual variation of AC bus 2 voltages for 100 milliseconds prior to or after the observed voltage increase. In addition, special tests indicate that there is an inherent delay and stretching of the AC voltage signal conditioner output due to rectification and filtering. Consequently, an AC voltage transient occurred several milliseconds prior to the time indicated in the S/C 012 data. However, the AC bus voltages are connected to an overvoltage and undervoltage sensor which will trip if the voltage on any phase exceeds 135 volts AC or drops below 90 volts AC for 32.5 $\pm$ 7.5 milliseconds. Main bus A and B voltages are also monitored by an undervoltage sensor which will trip if the voltage drops below 26 volts DC for 70 $\pm$ 30 milliseconds. Any one of these conditions would cause a master alarm. The master alarm did not occur during the period of the AC bus 2 voltage variation.

e. High Oxygen Flow Rate

At 23:30:59 GMT the oxygen flow rate measurement went to a saturated condition of 1.03 pounds per hour. Fifteen seconds later the caution and warning system master alarm was triggered. The oxygen (O_2) flow stayed in a saturated condition until loss of signal (LOS). Oxygen flow rate and associated data are shown in Enclosure 18-9.

There were 10 other periods during this test in which an unexplained saturated flow rate condition existed. A correlation of relevant data for these unexplained periods is shown in Enclosure 18-10. The actual flow rates for several of the times listed were computed using measured surge tank pressure.

Four possible conditions can cause a high oxygen flow indication. These are:

(1) H_2O Cyclic Accumulator Activation - The cyclic accumulator is actuated every 10 minutes for a ten second duration by the Spacecraft Central Timing Equipment (CTE). The diaphragm pump is actuated when the CTE triggers the circuit. During the 10 seconds in which the solenoid is open, the O_2 flow transducer will saturate and energize circuitry which could trigger the Caution and Warning System high-O_2 flow indication; the system is, however, equipped with a 15 second time delay to prevent the 10 second high flow condition from triggering the system.

(2) Suit Leakage - Crew suits are not designed for the very low delta pressures that were present during this test. The joint seals, etc., are not adequately effective at low differential pressures and therefore crew movements can induce suit leakages which result in high-O_2 flow rates.

(3) Open Helmet Visor - Enclosure 18-12 shows that with an open helmet visor (23:19:13 GMT), Surge Tank Pressure responds within about 5 seconds. For this condition the surge tank pressure decayed from 739 to 480.6 psig (see Enclosure 13-13 which shows the history of surge tank pressure for the entire test). During the last high-O_2 flow condition the surge tank does not start decreasing for 12 seconds.

(4) Crew Movement - During five of the ten unexplained high oxygen flow rates, listed in Enclosure 13-10, the voice tapes indicate the crew was troubleshooting the communications problems. During the last three high-O_2 flow rates the Guidance and Navigation System gimbal angle movements have been correlated with crew motion and biomed data. Of particular interest is the time period of 23:24:03 to 23:24:06 GMT. Five seconds prior to start of high-O_2 flow the biomed data indicates a deep breath and possible talking by the Senior Pilot. Biomed data are available from the Senior Pilot only. The slope at the start of high-O_2 flow correlates with the characteristics of the data when the Command Pilot opened his face plate at 23:19:13 GMT. Another significant period is at 23:30:59 to LOS, where the middle gimbal torque motor input shows response to motion at 23:30:24 GMT. At this time the O_2 flow starts a gradual rise. At 23:30:39 GMT the gimbal torque motor inputs reflect a distinct vehicle motion. The biomed data from the Senior Pilot, shown in Enclosure 18-14, show the start of motion which is

also reflected in the continued increase of O_2 flow. At 23:30:59 GMT the O_2 flow rate reached saturation with motion still being indicated on the inner gimbal.

d. Live Microphone Condition

Voice tape analysis and instrumentation data records show that a live microphone constant-keying condition existed from the Command Pilot position during a considerable portion of the final test period.

The live microphone condition was evidenced in a real time during the test at 22:25:53 GMT, when the crew selected the VHF/AM T/R mode. Data analysis using the Merritt Island Launch Area Open-Loop Communication (MOLC) tape (S-band and VHF/AM voice) showed that the first indication of the live microphone was at 22:18:49 GMT.

However, a review of the Mission Control Center-KSC (MCC-K) tape showed that the MOLC tape recorder was stopped between 20:57:19 and 22:13:49 GMT. Further analysis of the MOLC tape established no evidence of the live microphone condition prior to 20:57:19 GMT. It is concluded therefore that the live microphone condition began between 20:57:19 and 22:13:49 GMT.

The crew became aware of the live microphone condition at 22:26:48 GMT, and started a series of troubleshooting exercises. These exercises, plus voice tape analyses and data records, indicated that the live microphone condition existed in the Command Pilot communication system. The known exercises were:

(1) The Command Pilot switched from the "normal" connector to the "emergency" connector of his cobra cable.

(2) The Command Pilot and Senior Pilot interchanged cobra cables.

(3) The Command Pilot and Senior Pilot placed their cables back in the original configuration.

(4) The Command Pilot replaced his cobra cable with a flight spare.

(5) Various audio control panel modes were tried.

The live microphone condition continued to exist after the above exercises and was in evidence through the crew report of fire.

e. Crew Movement

Crew activity was evident for about the last 30-second period just before the crew report of fire. The data that indicates movement is shown in Enclosure 18-14 where several parameters support the indications. The crew was not required to perform any operation or function during this time. The Enclosure shows changes in the torquing voltage to the gimbal torque motors indicating significant spacecraft motion.

Activity of the Senior Pilot was interpreted from respiration rate, heart rate and phonocardiogram data. The Senior Pilot was essentially at a resting baseline until 23:30:21 GMT, when slight increases in pulse and respiratory rate was noted. At 23:30:30 GMT, there was a 4.5 second burst of noise on the electrocardiogram trace indicating some muscle activity. A similar burst occurs at 23:30:39 GMT accompanied by maximum noise on the phonocardiogram. The data are consistent with increased activity, but are not indicative of an alarm response. By 23:30:45 GMT all biomed parameters have begun to revert toward baseline levels.

The Command Pilot's live microphone condition on the S-band voice loop indicated considerable amounts of brushing and tapping-type noises during the 30 second time period prior to the crew report of fire. Noises on the S-band voice loop prior to this time were not of this magnitude or density.

Additional indication of crew activity was the onset of increasing oxygen flow to the suit circuits during this relative time span.

f. Cabin Pressure Rise

A determination of the pressure the cabin attained and the approximate time of structural rupture is included in this section. The analysis is based on observations from previous tests and certain known facts of the hardware design.

The installation of the optics system and INERTIAL MEASUREMENT unit on the navigation base is shown in

Enclosure 13-15. The navigation base is shock mounted on the Command Module structure. The optics system penetration through the pressure vessel is a set of bellows which forms the crew compartment seal. Navigation base displacement is most significant in the spacecraft pitch axis. The inertial reference and spacecraft axes are not coincident, therefore, gimbal angles must be transformed to reflect navigation base motion (refer to Enclosure 13-16).

A finer detail of the navigation base is shown in Enclosure 13-17. The single lower shock mount acts as a pivot point. The optics bellows mounted at the upper extreme end of the navigation base allows motion of the base about that pivot. A pressure differential across the optics and bellows assembly results in a force which will tend to rotate the upper end of the navigation base outboard. Any rotational motion or angular displacement of the navigation base will be reflected in the Inertial Measurement Unit (IMU) gimbal torque motor currents and gimbal angles. Deflection of the navigation base has been correlated with differential pressure across the optics and bellows assembly through data acquired during the altitude chamber test of S/C 012. The results are shown in Enclosure 13-18. With the cabin pressurized to 5.5 psig, the upper navigation base was deflected outboard. An approximate linear movement of the navigation base was noted as a function of decreasing cabin pressure.

Variations of temperature on the Command Module RCS "A" engine, CR 4561T, and on the Aft Heat Shield thermocouple, CA 5493T, are displayed in Enclosure 13-19 during the time of the accident. Cabin pressure and the three gimbal angles are also included for correlation. The variation of cabin pressure is shown from telemetry data which reached saturation at 21.3 psia. For comparison a second curve is shown which was developed from results of a digital simulation performed at AC Electronics, Milwaukee, Wisconsin, which determined the cabin pressure required to attain the gimbal angles observed during the accident.

The gimbal angles in Enclosure 13-19 change with the cabin pressure and reach an apparent maximum at 21:31:20 GMT, then reverse direction, indicating a decrease in cabin pressure. Because of the low sample rate of these measurements, the actual peak deflection and time of gimbal angle reversal is unknown. The RCS

thruster chamber temperature CR 4561T displays a sharp rise in temperature starting at 23:31:19.86 GMT. Assuming the sharp rise in temperature is the result of hot gas impingement, a rupture in the pressure vessel must have occurred prior to start of temperature rise because of the insulation surrounding the RCS thruster transducer and the response time of the transducer. Therefore, the rupture must have occurred between 23:31:18 and 23:31:19.86 GMT. The time of rupture was estimated at 23:31:19.4 GMT by Panel 10. The time of 23:31:18 GMT was the last gimbal angle data point prior to the sharp temperature rise at 23:31:19.86 GMT. Following the rupture, the cabin pressure would decrease allowing the navigation base to move toward its initial position. Results of a digital simulation indicate the cabin pressure reached at least 29 psia.

g. Suit Flow Dropout

At 23:31:09.62 GMT the suit flow rate of the Senior Pilot was at the upper limit of the transducer (saturated) of 25.27 lb/hr. The flow rate per man was actually higher and was approximately 64 lb/hr per man. One-tenth of a second later, at 23:31:09.72 the flow rate had dropped to the lower limit of the transducer (6.15 lb/hr) and stayed there until 23:31:11.82 GMT. It then returned to the upper limit at 23:31:11.92 GMT. The other two suit flow rates remained at the upper limit during this period (see Figure 18-18).

There are three possibilities that could explain the suit flow drop-off. These are:

(1) A momentary short in the suit flow transducer wires would explain the suit flow transducer going to the lower limit and returning to saturated flow again. However, the suit delta pressure and compressor delta pressure show a marked change coincident with the drop in suit flow, indicating that the suit flow in fact changed.

(2) If the suit outlet hose was disconnected, the suit outlet has a check valve in the suit which stops the flow to the suit giving an indication of no flow. The suit delta pressure and suit compressor delta pressure should increase and, in fact, did as shown in Enclosure 18-20. The decrease in these parameters within about 2 seconds after the increase can only be interpreted as suit burn-through

and/or subsequent reconnection of the outlet hose. Disconnection and reconnection of the outlet hose within a 2 second time period is highly unlikely. If this argument is to hold, the suit must have burned through to re-establish flow and sometime later the outlet hose was reconnected to the suit. The outlet hose was found connected after the accident, which tends to weaken the argument in light of possibility (3) which follows.

(3) The suit inlet hose was found disconnected from the Senior Pilot's suit. An explanation of this could be that the Senior Pilot disconnected his suit inlet for emergency egress.

h. Water/Glycol System Integrity

Pressure and temperature measurements in the water/glycol system were examined to determine if any line rupture or leak might have occurred prior to or during the early phase of the fire.

No indications of a leak were found. It should be recognized that very slight leakages (less than about 0.5 cubic inches) could not reliably be determined with the information available.

7. Data Analysis and Correlation

The purpose of this section is to treat each data indication prior to the crew report of fire in combination with engineering tests and analyses, and correlate with other available information to provide an integrated technical evaluation.

a. Gas Chromatograph Data Interpretation

In the preceding section it was reported that the gas chromatograph measurement output varied seven times in the 22:00 to 23:00 GMT time period. It then remained totally quiescent for approximately 35 minutes, and at 23:30:50 GMT approximately 14 seconds prior to the crew report of fire, it again produced an output.

The last output is considered to have a special meaning with respect to the accident, because the trace was quiet for so long a period, and because an output occurred within seconds of the fire.

Tests were conducted at MSC and at the Contractor's facility to determine what physical phenomena can cause an output to be produced from a powered and open gas chromatograph electrical connector. Enclosure 18-21 shows the variations from two of these tests compared with the output from S/C 012. Trace A shows the output from a S/C 008 test at MSC, during the period of time when a plastic bag was being removed from the connector, where the wiring and connector were touched with bare hands. Trace C shows the output from a North American Aviation, Downey, California, test during the period of time when the wiring and the connector were subjected to an external flame. The composite data from all special test indicate that an output from the connector can be produced by the following:

(1) Physical movement or disturbance of the wiring and/or the connector

(2) Application of external heat to the wiring and/or the connector

(3) Changes in the electro-magnetic field, affecting the antenna characteristics of the wiring and/or connector

Tests are being conducted in which a wire will be sparked with a gas chromatograph connector nearby to determine if any output can be produced.

b. AC Bus 2 Transient

The AC bus 2 over-voltage condition observed at approximately nine seconds before the crew report of fire is a characteristic inverter response attributable to one of the following conditions:

(1) Momentary short or interruption of DC bus B input power to inverter 2

(2) Momentary short on one or more phases of inverter 2 output

(3) Removal of a major portion of the load from inverter 2

Enclosure 18-22 shows the basic AC and DC power distribution system configuration at the time of voltage variation. Power was in a standard configuration at the time.

Special tests have been conducted on S/C 008 at MSC and at the Contractor facilities to reproduce the telemetry voltage characteristic and the associated changes in C-band beacon, VHF-FM transmitter and rotation controller outputs. These tests show that the time relationship between the over-voltage indication and associated changes can only be duplicated by a momentary short or interruption of DC bus B input power to inverter 2. The results for all three conditions are shown in Enclosure 18-23. In this figure test AC bus 2 voltages versus time have been plotted with zero time as the time of VHF-FM transmitter and C-band beacon changes. The time that AC bus 2 voltages were sampled on S/C 012 is also indicated for each test condition. The data for the output of the AC bus 2 voltage signal conditioner was available only for the inverter DC input shorting test, but the plot of the bus voltages for the other conditions shows that the over-voltage occurs earlier and for a shorter time duration.

Voltage regulation tests were run on the ground power supply at Launch Complex 34. These tests were run under similar load conditions (30 amps) to that existing on DC bus B in S/C 012 at the time of the accident

Short circuits of 0.25 ohm resistance were applied across the bus for periods of 5 to 25 milliseconds. Measurements of voltage at the umbilical interface, voltage and current at the power supply were made using a CEC recorder with response characteristics good to 5000 cps. In addition, the ACE equipment was set up to monitor power supply voltage and current in a similar manner to that used for OCP FO-K-0021-1.

These tests indicated that a short circuit in the range of 5 to 25 milliseconds drawing approximately 75 amps caused an immediate drop in bus voltage of 13 to 15 volts, recovering to about 3.6 volts below steady state conditions after 1 to 1.5 milliseconds. The voltage remained constant until the short cleared at which time it overshot steady state conditions by about 10 volts recovering to steady state by 1 to 1.5 milliseconds.

The ACE indications of voltage and current were sporadic, depending on the time of the short relative to the ACE sample time (sample rate 1 per second). Several current measurements were obtained for the 20 and 25 milliseconds duration shorts. These current indications were quite low, from 1 to 6 amps, apparently because of the transient response characteristics of the current measurement system.

It is concluded that the probable cause of the AC bus 2 transient and associated indications was a momentary short (2 to 25 milliseconds) of DC bus B affecting the input voltage to inverter 2.

c. High Oxygen Flow Rate

Telemetered data indicate that the high oxygen flow rate conditions for the last 30 seconds before the crew report of fire can be attributed to the apparent high level of prime crew suit leakage at low suit-to-cabin differential pressure, magnified by apparent crew activity. An analysis of S-band audio data also indicates that a face plate may have been open. An analysis was also conducted to determine if the high flow could be indicative of a sensor and/or associated wiring difficulty.

It was considered improbable that any short circuit between the signal lead and a 28 volt DC supply lead could occur.

Single failures could exist within the bridge circuitry controlling the flow sensor which would indicate high flow rates on both the PCM output and the signal to a high flow alarm relay. A preliminary examination disclosed shorts to ground in the flow sensor; shorts to ground will produce a zero or no flow output indication. It should also be noted that the location of the oxygen flow sensor was a high fire damage area, and that the sensor would be expected to be damaged by the fire.

Based on the above, it is concluded that the high oxygen flow data indication was valid, and that there was no malfunction of the sensor prior to the crew report of fire.

d. Command Pilot Live Microphone

The live microphone connotation means that the microphone amplifier in the audio center has received a ground, allowing 28 volts DC to energize the amplifier electronics, and the diode gates in the audio center on the S-band audio output have been grounded, allowing audio signals to modulate the S-band transmitter. These two conditions are normally effected by a crewman pressing his Push-to-Talk (PTT) button on the cobra cable, or in the Command Pilot's case, by pressing his translation controller PTT or his cobra cable PTT button. The PTT button, in addition to the above function, provides a ground for the VHF/AM Transmitter keying relay through the audio control panel VHF/AM T/R select switch. These VHF/AM T/R switches are connected together for all three astronaut positions which would cause a ground to be transferred among all positions in VHF/AM T/R mode. See Enclosure 18-24 for logic detail.

An analysis of this problem has isolated the cause to the PTT or keying line that runs between the cobra cable, translation controller, Command Pilot audio control panel, and the audio center (circuitry shown in Enclosure 18-24). The following has been determined:

(1) The separate components have been checked for resistance to ground. All lines measured open which is correct.

(2) The S/C wiring was checked and a 3000 ohm resistance was measured to ground. This 3000 ohm resistance could account for the keyed microphone. However, this resistance could be a result of the fire damage to

wire bundles. Later, when an attempt was made to locate the cause of the 3000 ohm resistance, a recheck did not produce the same results. The circuit now measures open, which is normal.

(3) The translation controller PTT button was pushed and released ten times. On the fifth try the button stuck down. If the button had stuck during the S/C 012 test the microphone would remain keyed.

The audio center has successfully completed qualification testing with this line grounded for twenty-eight days.

A review of switch positions in the Command Pilot audio control panel indicates that all switches were in the positions expected. When in this configuration, current drawn by the keying line is limited to 20 milliamps at 28 volts. Tests run with a cobra cable show that no sparks were generated with 28 volts and 150 milliamps.

Based on all of the above, it is concluded that the live microphone condition was probably not a source of ignition.

e. Crew Movement

Crew movement was indicated during the last minute preceding the crew report of fire, most prominently by the torquing voltage to the gimbal torque motors. An attempt was made to determine what type of activity by the crew could produce these torquing signals by reviewing all available data from previous tests with the proper guidance mode selected. There was no consistency in the effects of crew activity such that repeatability could be shown for presumably similar activities. This may be expected since the combination of crew actions for a particular operation may never be the same. Similarly, the vigor with which an action is performed can vary. Even though the crew activity cannot be defined, the fact remains, crew motion can be detected.

f. Analysis of Tape Recorded Transmissions

The voice transmissions shown in Enclosure 18-5 were analyzed with the use of MOLC RF voice recorder tapes, oscillographs of the MOLC tapes and PCM data. This

enclosure shows the VHF/AM and S-band voice tracks oscillograph readout from 23:29:42.5 GMT to LOS.

(1) 23:29:42.5 to 23:30:14 GMT

(a) The Command Pilot was transmitting on S-band. The Senior Pilot made a voice transmission on S-band and VHF/AM. There was no voice transmission by the Pilot.

(b) The ground personnel were transmitting to the S/C on S-band. The voice of the Command Pilot was being turned around by the CAST (Astro Communicator Console) system and retransmitted to the S/C on VHF.

(c) The live microphone noises were not evident, probably because of the higher noise level caused by the uplink S-band being patched to the MOLC RF recorder.

(2) 23:30:14 to 23:31:00 GMT

(a) There were no voice transmissions from the S/C.

(b) The ground personnel were not transmitting to the S/C on VHF.

(c) There was no change in the live microphone condition. Considerable amounts of noise similar to those obtained when a microphone is brushed or tapped, including breathing sounds, were evident. Some of the louder noises appear to have had sufficient amplitude to trigger the uplink VHF/AM via CAST.

(d) There is evidence of an open visor.

(3) 23:31:00 GMT to LOS

(a) There were two series of voice transmissions on S-band. The times for these two transmissions are detailed in Enclosure 18-5. No voice communications on VHF were made from the S/C during this time period.

(b) The ground personnel were not transmitting to the S/C on VHF. The voice transmissions

from the S/C were being turned around by the CAST system and were retransmitted to the S/C on VHF.

(4) Analysis of Voice Tapes During the Period of Fire

The tape transcripts of the voice tapes from the C/M during the time period of the fire (referred to as the first and second transmission, on Enclosure 18-6), have been extensively analyzed. This analysis included a review of all transmissions prior to the fire that were made by the crew during the test in an attempt to aid in the determination of who made these last two transmissions and what was said. This analysis was made by NASA personnel familiar with the communication systems, the crew and their voice characteristics, the sequence of events before, during and after the fire as determined during the accident investigation. Experts at the Bell Telephone Laboratories performed extensive analysis of the tape record. The Board also reviewed these transmissions. Review by other experts is currently in progress. Any new findings from these additional reviews will be included in Appendix G of the Final Report.

Except for a portion of the first transmission, which is quite clear, it is impossible to define exactly what was said by the crew. Two points made by the Bell Telephone Laboratory experts, however, should be noted:

(a) The present state-of-the-art of analyses of voice records is such that little, if anything, can be determined as to what was said if the recording is not sufficiently clear to be intelligible by listening alone. Analyses under these circumstances can provide some clues to determine which crew member initiated the transmission. These clues cannot however establish definite identity.

(b) When the recording of the transmission is not clear, there will be nearly as many interpretations of what was said as there are qualified listeners. Many interpretations of what was said have been made. A summary of these interpretations is made in the following paragraphs.

The analysis of the first voice transmitted is as follows:

This transmission began at 23:31:04.7 GMT with an exclamatory remark. This transmission is not clear. Most listeners believe this initial remark was one of the following:

"Hey"

"Fire"

"Break"

Most listeners believe, and laboratory analysis supports this belief, that this transmission was made by the Command Pilot. This remark is followed by a short period of noise (bumping sounds, etc.).

The second portion of this first transmission begins at 23:31:06.2 GMT with an unclear word. Most listeners believe the first to be one of the following:

"I've"

"We're"

The remainder of this transmission is quite clear and is: "....Got a fire in the cockpit", followed by a clipped word sounding like "vheh", which ended at 23:31:10 GMT. Many listeners believed this transmission to have been made by the Pilot. Some believe it could have been made by the Command Pilot or the Senior Pilot. However, laboratory analyses indicate the greatest probability that it was made by the Pilot, but the results of the analyses do not negate the possibility that one of the other crew members could have made the transmission.

The analysis of the second voice transmission is as follows:

Following a 6.8 second period of no transmission, the second transmission began at 23:31:16.8 GMT and ended at 23:31:21.8 GMT.

The entire second transmission is somewhat garbled. This second transmission, therefore, is subject to wide variation of interpretation as to content and as to who was making the transmission or transmissions. The general content is what appears to be three separate phrases and it has been interpreted several ways by many listeners. The following is a list of some of the interpretations that have been made:

1. "They're fighting a bad fire - Let's get out....Open'er up."

2. "We've got a bad fire - Let's get out .... We're burning up."

3. "I'm reporting a bad fire....I'm getting out....Oh, aah."

Many listeners believe this transmission was made by the Pilot. It should be noted that:

a. The total time duration of these two transmissions was brief, lasting 17.1 seconds; the first lasted 5.3 seconds and the second lasted 5.0 seconds, with a 6.8 second period of no transmission between.

b. The transmissions provide evidence only of the time the crew first transmitted a report of the existence of the fire and do not provide any direct information as to the cause of the fire.

Two analyses of tape recorded transmissions were completed. The detailed findings are contained in references to this document. The first, Reference 18-8, is a report prepared by Bell Telephone Laboratories. The second, Reference 18-9, is a report prepared by NASA MSC.

g. Related Tests and Analyses

The purpose of this section is to cover special tests, analyses, additional data and other information that is essential to complete the investigation of the accident.

A brief summary of significant special test results is attached as Enclosure 18-56.

(1) Onboard Records Analysis

Items of onboard procedures, log books, switch lists, etc. found in S C 012 after the accident were delivered to the Federal Bureau of Investigation for reconstruction and spectrographic examination. All of the items have been positively identified. Written remarks were either changes to the OCP switching lists or crew comments in the crew log books. None of the comments are significant with respect to the accident and no other information was found pertinent to the cause of the fire.

(2) Status of Inverter 2 Investigation

Inverter 2 (Part No. ME 495-0001-0004, serial No. 88) was returned to Westinghouse facility in Lima, Ohio, for investigation relating to the S C 012 accident.

The results of the initial electrical tests conducted on the inverter disclosed that a pair of transistors in the booster stage was shorted and a fuse was open. The other four transistors in the inverter's booster stage were removed and checked out satisfactorily. The good transistors and new replacements were reinstalled. The inverter was again electrically checked and operated satisfactorily. Replacement of the fuse was not required for this check.

It is concluded that the inverter was not the source of the fire and that the transistors failure was due to thermal stresses induced by high temperatures external to the inverter. The fuse was probably damaged during the effort to remove the foam in order to gain access to the internal test points. It is also concluded that the inverter could not have caused the AC bus 2 transient at 23:30:54:86 GMT for had the transistors failed at that time the inverter would have dropped out and stayed out.

(3) Status of ECS Parts and Assemblies Investigation

The Screening Committee Report listed 54 Environmental Control System parts and assemblies as possible ignition sources. Further investigative work has placed 52 of these into the improbable ignition source

category. The two remaining suspect items are still being analyzed and are identified as follows:

Electrical Cable Assembly P/N 836599-1-1
Electrical Cable Assembly P/N 836602-1-1

The two cables assemblies are connected in series. Both carry DC power to an instrumentation temperature sensor power supply. The power supply then provides power to five signal amplifiers.

Both DC bus A and DC bus B power wires were contained in these cables and both were protected by 5 amp circuit breakers. The circuit breakers were found open after the accident. Anomalies were not observed on the data from the five measurements. A short in one of the above cables would not show an anomaly on the data since the redundant power would continue to supply power necessary to maintain the integrity of the measurements.

Post-fire tests did establish a grounded condition in both harnesses and visual inspection revealed that a considerable amount of one of the cables was completely consumed by fire. These harnesses are covered in more detail in section 8-A of this report.

8. Technical Discussion of Possible Ignition Sources

The specific cause or the trigger that initiated the fire in S C 012 has not been determined. A number of potential causes have been identified and actions have been implemented to validate each one, so as to determine which will remain as likely possibilities.

The family of possible sources of ignition that apply to the Command Module includes:

(a) Spacecraft electrical power
(b) Overheating of mechanical equipment
(c) Electrostatic spark discharges
(d) Spontaneous combustion

The most likely cause of ignition is in the Spacecraft Electrical Power System. This may provide an ignition source from electric arcs that can be produced by making or breaking electric circuits, or by physical failure of a current-carrying wire. This most likely supposition is supported by the fact that the AC bus 2 power system exhibited a transient ten seconds prior to the crew report of fire, indicating an electrical power abnormality just prior to any awareness of fire by the crew.

Spontaneous combustion has been considered extensive series of test involving all know combustible materials in the spacecraft in combination with all known contaminants has been completed. The spontaneous ignition temperatures of these materials were all found to be in excess of the maximum test temperature of 400°F. All areas in the S/C should be well below this temperature unless there is a malfunction or electrical short. Therefore, the possibility of spontaneous combustion is ruled out.

Chemicals that are highly reactive can produce sufficient heat to start a fire. There are two sources of highly reactive chemicals in the spacecraft. These are the batteries and the lithium hydroxide for the Environmental Control System. Analysis of data and post-fire examination of these objects indicates that they were probably not involved in the start of the fire.

Electrostatic discharge from one of the suits to adjacent material, initiating a fire in Velcro pile or other easily combustible material, has been considered a source. Tests conducted in S C 014 indicate that insufficient energy is generated for ignition to occur. (refer to Panel 8 Report).

The probable cause of ignition follows:

a. DC Wiring for Environmental Control System Instrumentation Burned Through

Three separate harnesses providing DC power for Environmental Control System instrumentation have been found burned through. Two of these harnesses are shown in Enclosure 18-25 as they appeared before the accident. The harness lying over the Waste Management System bare stainless steel line contained both DC bus A and DC bus B power wires. The harness lying on the floor under the plumbing contained DC bus B power wires only. The total complement and identification of all wires in each of these two harnesses is shown in Enclosure 18-26.

The third harness that was burned through provided DC bus A and DC bus B power for an instrumentation sensor power supply. The power supply then provided power to five signal amplifiers. The harness that mates with this harness at an electrical panel near the ECU also is suspect at this time. The total complement and identification of all wires in each of these two harnesses (both similar because connected in series) is described below:

(1) Twenty-three wires total
(2) All wires were 24 gauge
(3) Wires were identified as:

28 volt DC bus A and bus B power leads (2 wires)
28 volt DC return (1 wire)
5.4 volt DC. power supply output (5 wires)
18 volt DC. power supply output (5 wires)
-0.5 volt DC, power supply output (5 wires)
common returns, power supply output (5 wires)

Enclosure 18-27 illustrates the nature of the installation of two of the harnesses on S/C 014. The lower edge of the aluminum access door to the lithium hydroxide holders contacts one of the harness when the door is opened and closed. It is inferred that the installation in S C 012 was similar to that in S/C 014. Enclosure 18-28 shows the remains of these two harnesses after the accident. Sections six to twelve inches in length of each harness are missing. If a short occurred in either of the harnesses, the evidence is gone. In this same enclosure, the third harness that was burned through is shown. This third harness is located within a one inch radius of the center of the photograph, connected to the lower electrical connector on the panel shown at the left.

Splices were made at KSC in the wires of the harness lying over the steel line in the DC bus B power and return wires on September 12, 1966. These splices were made in the wires about four inches away from the point at which the harness ran over the line. The splices are still contained in the harnesses. They have been examined, and all are in a satisfactory condition.

Debris netting lay over the harnesses traversing the complete left side of the Command Module at the floor. If a short did occur in these harnesses, ignition and fire propagation could take place.

The harness lying over the line contained instrumentation power for two measurements, Oxygen Flow Rate and Oxygen Regulator Outlet Pressure. DC bus A and bus B 28 volt power was provided to each instrumentation sensor. Twenty-two gauge wires were used throughout this harness. Two 5 amp circuit breakers were provided for these circuits. Bus B power for both sensors was protected by one breaker, and bus A power by the second breaker. Both circuit breakers were found in an open condition after the accident. Both measurements provided proper output signals until the loss of all data, some 17 seconds after the crew report of fire.

The harness lying under the plumbing contained instrumentation power for the CO_2 Absorber Outlet Temperature. It also carried power to a discontinued measurement. DC bus B 28 volt power was provided for both measurement circuits. Twenty gauge wire was used for all power circuits in this harness. Each circuit was protected by a 1/4 amp fuse. Both fuses were found in a blown condition following the accident. Since the one active measurement circuit provided proper output signals until the loss of all data, some 17 seconds after the crew report of fire, it is concluded that the fuse for this circuit did not blow until after this time. Because no data exists from the discontinued measurement, it cannot be concluded when this fuse blew.

The third and fourth harnesses at the electrical panel contained power for five temperature measurements. Two 5 amp circuit breakers were provided for these circuits; bus B power was protected by one breaker, and bus A power by the second breaker. Both circuit breakers were found in an open condition after the accident. All five measurements provided proper output signals until the loss of all data some 17 seconds after the crew report of fire.

A momentary shorting condition could have occurred in any of the power wires in any of these harnesses without being seen in the telemetered data and without affecting the measurement circuits.

Indications of copper have been found on the bottom of the lithium hydroxide access door. Indications of copper and pit marks have also been found on the stainless steel line over which one of the harnesses lay. The stainless steel line has been examined in the Metallurgical Laboratory at KSC and it has been determined that there are no pit marks indicative of arcing. Two modes of copper deposits were evident. One was apparently caused by molten copper dropping onto a heated line resulting in alloying and diffusion between the copper and stainless steel elements. The other was due to dropping of molten copper onto a relatively cool stainless steel line indicated by molecular diffusion at the bead-tube interface.

It has been determined that the harness containing DC bus B power wires protected by fuses was probably not the fire initiator, as current flow is very limited prior to the fuses blowing. The other three harnesses, each containing both DC bus A and DC bus B power wires, remain as probable causes of ignition.

9. Technical Discussion of Other Suspicious Wiring

A physical examination of wiring and equipment for arcs, shorted and suspicious wiring has disclosed ten specific items, as mentioned in section C-2 of this report. The first was covered in the preceding section as the probable cause of ignition. The remaining nine are not considered probable ignition sources, and each one is discussed in this section.

a. Arc Between a DC Wire and the Cover of J-Box C15-1A52

An arced point was discovered between a wire in a bundle and a metal cover at the lower left corner of the lower equipment bay just to the left inverter 3. The installed cover is illustrated in Enclosure 18-29. The back side of the cover showing the arced point on the cover and the wire is illustrated in Enclosure 18-30.

It was determined that the arc occurred between a wire in the Reaction Control System/Stabilization Control System (RCS/SCS) and the cover protecting the C15-1A52 J-Box. The wiring was traced to a circuit from DC bus A, a 16 gauge wire, protected by a 20 amp circuit breaker. The wire supplied 28 volt DC power to the RCS plus-yaw engine solenoids. The circuit breaker was not opened by the short circuit.

Enclosures 18-31 and 18-32 illustrate the arced point on the cover and the wire magnified many times.

An arc was produced in this bundle when a technician was removing J-Box C15-1A52 on January 17, 1967, and the wire was repaired. The wire which arced against the cover at the time of the accident is a different wire in the same bundle. The wire harness installation had obscured access to two cover plate mounting bracket screws. This was corrected on January 19, 1967, by separating the harness into two bundles for a short distance. With this slight relocation, one of the bundles was adjacent to a portion of the cover not protected by a nylon grommet edging. This is also illustrated by Enclosure 18-30.

An additional interesting point for this cause possibility is that the gas chromatograph wiring harness and the bus B 28 volt DC power harness for the biomed recorder, which might be associated with pre-accident data variations, are attached to the harness that contained the arced wire.

Supporting factors for this ignition cause possibility include the definite evidence of an arc, previous water/glycol spillage in the general area three months before, the flammability of the adhesive for the nylon grommet edging, and the proximity of debris trap netting.

Negative factors include the preventative washing and drying of the wire bundles in the area after the water/glycol spillage and the lack of any telemetry transient indication on that function prior to the crew report of fire. A measurement sampled 200 times per second, which would show a drop below approximately 10 volts, shows no change until shortly after the pressure shell rupture, at which time some evidence of a short is indicated.

Preliminary tests have been conducted on the flammability characteristics of water/glycol and the water/glycol inhibitor at Kennedy Space Center (KSC), Manned Spacecraft Center (MSC), and Raychem Corporation, Redwood City, California. These tests support the possibility of a fire propagation path along wiring that has been exposed to water/glycol spillage or leakage.

A test was conducted at MSC on a simulated cover plate with adjacent flammable materials configured as in S/C 012 with the same oxygen/pressure environment. When the adhesive/nylon grommet edging was ignited with a nichrome wire at the arced point, there was a fire propagation along the adhesive/nylon grommet edging spreading above to the Velcro on the flight qual recorder and to the left to the debris netting in the lower left-hand equipment bay corner.

A test was conducted on a duplicate cover plate at KSC to determine if an electrical arc would ignite the adhesive/nylon grommet edging in the oxygen/pressure environment as existed in S/C 012 at the time of the accident. During this test, ignition from an arc did occur, the fire progressed faster along the adhesive than along the nylon edging, and a section of debris netting on the opposite end of the nylon edging ignited in approximately 9 seconds.

In all tests of flammability of adhesive/nylon grommet edging combinations conducted to date, there was a complete burning of the nylon grommet edging material to the point where it was indistinguishable after the fire. A review of Enclosure 18-30 shows clearly

that all of the nylon material in S/C 012 did not burn, but that a decomposition took place. A test applying external flame to the front face of the panel more closely duplicates the melting characteristic of the nylon edging as illustrated in the same photograph. This test indicates that if this arc was the ignition source, then the fire propagation path would not be along the adhesive/nylon grommet edging; the fire propagation path would thus be inferred to be along wiring that had previously been exposed to water/glycol.

A hardness analysis conducted on the aluminum cover disclosed that the left edge was exposed to much higher temperatures than the right edge. The cover was fabricated from 2024-T6 aluminum alloy. The extreme left edge was in a T3 aged condition, while the right edge was in the original T6 condition. The left edge was, therefore, subjected to a temperature in the range of 800 to 885 degrees Fahrenheit. A physical examination also disclosed that the fire progressed from the left side to the right side of the panel cover.

The Velcro on the "flight-qual" recorder panel does not appear to have sufficient fire damage to indicate that the fire was initiated at this point. A hardness and conductivity analysis was performed on this panel. The analysis disclosed that all areas of the panel were exposed to the same level of external heating.

A simulated flight-qual recorder panel used during a special fire propagation test conducted at MSC was sent to KSC for comparison with the S/C 012 panel. It was determined that this panel was of a lighter guage, and that the Velcro was applied with a different adhesive. The MSC results are therefore considered inconclusive.

Special tests were conducted at KSC in an oxygen/pressure environment to determine the current required to produce a similar arc on a wire and cover as that evident from S/C 012 hardware. A test conducted on March 28, 1967, disclosed that the nylon edging/adhesive combination was ignited when an arc was produced approximately 1-1/2 inches away.

It is highly probable that the nylon edging/adhesive combination would be totally burned away if this arc was the initiator of the fire.

b. Shorted Gas Chromatograph AC Wiring

The gas chromatograph was not installed on S/C 012 at the time of the accident. The gas chromatograph connector was placed on the shelf of the gas chromatograph (GC) compartment. The connector was not bagged, and AC bus 1 phase A power was applied to the connector through a closed circuit breaker. Twenty-two gauge wire was used, protected by a 2 amp circuit breaker. The circuit breaker for the GC was found to be open following the accident, with a heavily sooted condition. It cannot be determined when the circuit breaker opened. The harness was not tied down in a flight configuration because the GC was not installed.

Two physical peculiarities were noted concerning the GC wiring and the connector. After the accident, the harness and connector were found on the floor. This is illustrated by Enclosure 18-33. It should be noted that the GC connector lay on a big harness. Enclosure 18-35 shows two spot ties that were unblackened as a result of being protected by the GC connector. Enclosure 18-35 shows the side of the connector that lay against the big harness and protected the two spot ties. This side appears burned and the potting at the back of the connector is melted. The GC connector was stuck to the big harness and had to be pried loose with a tool. It is concluded that the connector was burning in a different location, but fell or otherwise moved to its final location prior to the time the fire swept across that portion of the floor. It can also be concluded that the connector either protruded beyond the GC compartment shelf and was burned in that location, or that it was burned while it lay inside the gas chromatograph compartment before it fell to the floor.

Secondly, the two GC AC wires exhibited peculiar melting characteristics. The output signal leads from the connector were fed through a fiberglass sleeve. One hundred fifteen volt AC power was carried to the connector through a twisted pair of Teflon-insulated conductors. These power conducting wires were run along the signal leads and were occassionally tied together. The power wires show a number of copper balls attached to their surfaces. This condition is illustrated in Enclosures 18-36 and 18-37.

All attempts to simulate this condition by either short circuits or by application of external heat have not resulted in a similar appearance of the AC wires. It is concluded that the beading was caused by localized

external heating, with Teflon insulation degradation followed by shorting of the wires, causing molten copper to flow through defects in the wire nickel plating. It has been estimated that the external heat to produce this condition was in the order of 2500°F for less than one second. It is inferred that this condition resulted as the harness fell through the flame to the floor.

X-rays and continuity tests of the connector pins and input wiring showed no evidence of arcs or short circuits. For this reason, this is not a suspect fire initiator.

c. Shorted DC Wires to Scientific Equipment Bay 2

Wires providing DC bus B power to scientific equipment were found to be shorted. These are 22 gauge wires protected by a 20 amp circuit breaker. The circuit breaker was found to be open following the accident and to be in a heavily sooted condition. The scientific equipment was not installed, therefore, no information is available as to when the circuit breaker was opened.

The wires that are shorted are located at the edge of a compartment shelf directly over the entry batteries. The location of the wires is illustrated in Enclosure 18-38.

The pattern of battery swelling and the scorching of the batteries indicates that they were exposed to a source of considerable heat centered at the face of Battery B, and that very high heat flow occurred in front of and in the spaces between the three batteries.

Tape was applied to protect the battery terminals during this test. The spots of scorched residue on the batteries was determined to be similar in all respects to the tape. The burning of this tape could have burned the wiring insulation off, and thereby caused the shorted condition.

Enclosure 18-39 illustrates the shorted wires projecting beyond the shelf. It is concluded that these wires shorted as a result of the fire from the floor (the same heat source that affected the batteries). Tests in the Metallurgical Laboratory at KSC have substantiated that the shorting was the result of external heat.

d. Cabin Air Fan 1 AC Wiring Shorted

The cabin air fan 1 circuit breakers for phases A and C were found to be open after the fire, and electrical tests of the fan circuitry in the spacecraft indicated shorted phases. Cabin air fan 2 was in a satisfactory condition. Cabin air fan 1 is powered by AC bus 1 and fan 2 by AC bus 2. Twenty-two gauge wires are used and each phase is protected by a 2 amp circuit breaker. The circuit breaker for AC bus 1 phase A was found with a very light-sooted condition, and the AC bus 1 phase C circuit breaker was found with a sooted condition.

Enclosure 18-40 shows the location of the cabin fans. They are located on the Command Pilot side of the Command Module. It is not known whether the short circuit occurred before or after initiation of the fire. However, because there is a lack of fire propagation material, it is inferred that the shorting occurred as a result of the fire. A physical inspection of the fan and the fan area for fire damage does not indicate this to be a fire initiation area. Enclosure 18-41 shows the conditions of the fans following the accident.

An inspection of the fans after removal from the S/C shows that both rotors were frozen as a result of melting of epoxy on the stators. No shorted condition has been found in fan 1. The electrical harness was examined and insulation was found burned off in one area. The electrical harness is being checked to verify that the damage was an effect and not a cause of the fire.

e. Crushed DC Instrumentation Harness in Environmental Control Unit

A wire harness for the Compressor Differential Pressure and Glycol Accumulator Quantity instrumentation transducers has been found in a crushed condition. This is an Environmental Control Unit harness that was crushed between a lithium hydroxide canister and the cyclic accumulator control during the assembly process. The harness contained ten 24 gauge wires, and contained both DC bus A and DC bus B power.

The circuit breakers for these circuits were found closed following the accident. The sleeving is intact and does not indicate any ruptures. For these reasons the harness is not considered an initiating source of the fire.

f. Shorted DC Wires Providing Power to the Biomed Recorder

Short circuits have been found on the octopus cable near connector J185. This connector is located directly above the gas chromatograph compartments, and is illustrated in Enclosure 18-42. This wiring has been identified as 28 volts DC bus B power for the biomed Medical Data Acquisition System (MDAS) recorder. Twenty-two gauge wires were used, protected by a 20 amp circuit breaker. The circuit breaker was found to be open following the accident, with a heavily sooted condition. The MDAS recorder provided satisfactory data until after pressure shell rupture, therefore, the circuit breaker opened after this time. The octopus cable was not in a flight configuration as the connectors were not potted.

Enclosures 18-43 shows a closeup of the connector, and Enclosure 18-44 illustrates the shorted condition of the DC wires.

Enclosure 18-45 illustrates the layout of the power wiring to the J185 connector. This wiring runs down a channel alongside the right edge of the chromatograph compartment, then along the edge of the floor of the chromatograph compartment, then down to the floor along the left edge of inverter 3. At the floor, it is tied to the same harness that shows the presence of an arc with the cover of J-Box C15-1A52. This power wiring to the J185 connector is also adjacent to the gas chromatograph harness at all locations from the arced point to the channel entry point. This harness and the gas chromatograph harness were tied together but were not tied down in a flight condition; they were laid up against the gas chromatograph compartment. Both harnesses were found on the floor after the accident.

In addition to the shorted condition on the octopus cable between the J185 connector and MDAS recorder, the DC wires are also shorted at a point near the left end of the gas chromatograph compartment floor. The shorted condition at this location does have a bubbled copper appearance, similar to that noted on the gas chromatograph AC wires.

Preliminary examination of both sets of harnesses have been made in the Metallurgical Laboratory at KSC. The shorting on the octopus cable was found to be superficial and the result of fire damage. The DC power harness to the J185 connector, because of the similar appearance to the gas chromatograph wires, was also the result of fire damage; it is concluded that the harness was subjected to both a short and to external heating from the fire.

g. Shorted AC Wires Providing Power for Suit Compressor 2

Wiring in the four conductor wire harness to suit compressor 2 appeared shorted, with suspected evidence of arcing.

AC power to each of two suit compressors is provided by 24 gauge wires. Each phase for each suit compressor is protected by a 2 amp circuit breaker. The harness for each compressor can provide either AC bus 1 or AC bus 2 power, dependent on the switch position selected by the Pilot.

The switch position following the accident shows that the suit compressor switch was in the compressor 1, AC bus 1 position. The circuit breakers for phases A and B for compressor 1 were found open with heavy soot on the breaker stems. Telemetry data indicates that a compressor was operating until loss of data; therefore the circuit breakers opened after this time.

Enclosure 18-46 illustrates the location of the wiring and suit compressors in the Environmental Control Unit on Spacecraft 012 after the accident.

Suit compressor 2 was not to be operated during the test. A re-examination of the harness disclosed that the connectors for compressors 1 and 2 were reversed from the expected interconnect. With the connectors being reversed, compressor 2 would then have power and the wires could short, and the compressor 1 circuit breakers would open when the shorting would occur. Enclosure 18-47 illustrates the harness for compressors 1 and 2. The connector for compressor 1 was disconnected, and the wires were cut at the connector for compressor 2. Note the metal band with the number "2" for the wires providing power for compressor 1.

A closer examination of the wires disclosed that the shorted appearance was the result of fire damage.

h. Command Pilot Suit Wiring Shorted

Short circuit damage has been found in the Command Pilot's suit wiring. No shorts were noted either in the Senior Pilot or Pilot suit wiring.

Four shorted wires were found in the communications wiring between the suit connector and the helmet communications connector. The wire insulation was discovered to be brittle, discolored and cracked. The wires were identified as microphone signal, microphone signal return, earphone signal and earphone return. Enclosures 18-48 and 18-49 illustrate the shorted condition of the wires.

An intermittent condition was also noted in the 16.8 volt DC biomed power wire in the torso harness between the suit connector and the biomed connector. This condition is considered to be not relevant to the cause of the accident, in that no biomed power was being supplied to the Command Pilot's suit.

The vendors of the torso harness materials have provided the following information:

(1) The nylon sock around the ribbon cable melts at 480 degrees Fahrenheit.

(2) The silicone, of which the ribbon is made, melts at 600 degrees Fahrenheit.

(3) The Milene insulation around the wires cracks at 430 degrees Fahrenheit and melts at 480 degrees Fahrenheit.

From the above information, it is probable that the exterior of the ribbon cable around the area of the damaged wiring was subjected to localized and superficial heat. This would cause damage to the internal wiring insulation without damaging the silicone ribbon.

i. Arc on Structure by Side of Switch S11 in Back of Panel 8

On removal of panel 8 from S/C 012 it was observed that there was an area of damaged conformal coating on wire terminal 2 of switch S11. Continuity checks showed that a potential short existed from the wiring through the damaged conformal coating to the substructure behind the panel. Supplemental examination of the substructure

was made to determine the extent of any arcing from panel 8 switch S11 to the substructure. Minute arc pits were found in the substructure which indicate that low power arcing did occur, and could more properly be described as sparking. The lack of silicone dioxide deposits indicates that the temperature generated by the arcing was not high enough to cause significant deterioration of the silicone rubber conformal coating material.

The panel and switch location and substructure appearance is illustrated in Enclosures 18-50 and 18-51. Switch S11 serves as an enable function for Service Module Quads A and C Roll. The wire terminal in the area of damaged conformal coating carried DC bus B power. An analysis of circuit conditions disclosed that this circuit was not powered before or during the fire. It was determined that the switch was in the "OFF" position before and after the fire. Continuity checks have been performed to confirm that the switch was wired properly. Refer to Enclosure 18-41 for a schematic description of switch wiring.

Examination of the wire terminal and pit on the bracket are inconclusive as to existence of an arc and indicate that the observed damage most likely occurred from a mechanical abrasion while the panel was being installed. From the appearance of the area surrounding the pit on the bracket, and the contact area on the wire terminal, it is deduced that any possible sparking generated by the short circuit current was confined under the conformal coating.

From the above it is concluded that, while an arc or short circuit current may have occurred in the contact area of S11 wire terminal and bracket V16-335126-85, this circuit was not energized during this test, and this condition must have resulted from a prior test. Further the evidence indicates that the potential current level through any such fault would have been so low that it would not have caused any significant disturbance on the power bus.

10. Technical Summary

For the last few minutes of the test all recorded test data indicated that all systems were operating satisfactorily with no indication of any malfunctions, with one expection - the communication system. Communications were poor between the ground and the Spacecraft and a live microphone condition was present in the Command Pilot voice loop.

The cause of the live microphone has been atributed to picking up a ground somewhere in the Command Pilot Push-to-Talk circuit in the Spacecraft. The specific source of the ground has not been established. This malfunction, electrical in nature, is not considered to be a fire initiation source.

The overall inputs and outputs of Spacecraft systems were measured and recorded. There is no reason to believe that possible malfunction or abnormality would have been indicated had more detailed measurements been obtained from each system.

For approximately the last thirty seconds prior to the crew report of fire many measurements reflect crew motion in the Spacecraft. There is no way in which crew activity can be derived from these measurements.

An electrical power system abnormality was indicated at approximately ten seconds prior to the crew report of fire. This electrical abnormality occurred in the AC bus 2 power portion of the system. All AC bus 2 voltage measurements were affected. The data from equipment powered by AC bus 2 shows that they were also affected. The composite of these data and special tests conducted after the accident point to the conclusion that the AC bus 2 problem was caused by a momentary loss of inverter 2 output.

The momentary loss of inverter 2 output should not be implied to constitute an inverter failure. The inverter was returned to the supplier for teardown and analysis to positively establish whether it could or could not have malfunctioned in a manner reflected by the data. This has been completed and it has been concluded that the inverter did not cause the AC bus 2 dropout, and that it was not the cause of the fire.

It is believed that the momentary loss of output to inverter 2 was caused by an interruption in the DC power being supplied to inverter 2. This DC power was being supplied from DC main bus B. The most likely cause of an

interruption in DC bus B power is a momentary short in a conductor carrying this power or by a malfunction of equipment being supplied from this power source.

The most likely phenomena that would produce such a momentary short is an inadvertant electric arc either within electrical equipment or between a power conductor and the Command Module structure. Such an arc is nominally the result of electrical insulation failure.

No data recorded during the interval of the electrical abnormality shows any variance that could be interpreted as a momentary short in DC bus B power, or DC bus A power. Tests show that a drop in DC voltage to a level below 19 volts for as short a time as two milliseconds is sufficient to affect the inverter and the AC bus. Because all telemetry date is sampled at discrete intervals, a short of two milliseconds duration probably would not appear in the data.

All equipment and wiring has been examined for any and all evidence of arcs, shorts and suspicious appearance, to help explain the electrical abnormality. All items of equipment, except for specific wiring, have been placed into an improbable ignition source category.

Ten cases of arced, shorted and/or suspicious looking wiring have been identified. Tests and analyses are being conducted on a number of these at this time. From this listing, however, only one is considered suspect as being the cause of the electrical abnormality. It can also be the trigger or source of ignition that caused the accident.

The one suspect is wiring providing instrumentation power for some Environmental Control System instrumentation. This wiring contains both DC bus A and DC bus B power, and is located on the Command Pilot side of the Command Module in the vicinity of the Environmental Control Unit and the Lithium Hydroxide Units.

A momentary short could occur in any of four DC bus B or four DC bus A power wires in this wiring. A short would not affect the equipment being powered by these wires, and would not be reflected in any of seven measurement outputs of transducers being provided power because of redundant power with diode isolation for each equipment.

Tests have shown that a short in any of the four DC bus B wires could cause a drop in DC bus B voltage to a level low enough to cause an interruption to inverter 2. A test

has been conducted at Launch Complex 34, with an inverter, to simulate this shorting.

Debris netting traversing the floor on the left side of the C/M was within inches of the wire harnesses. If ignited, the netting would burn along the floor toward a vertical flammable material. The vertical material on the left was the polyurethane foam on the Environmental Control Unit evaporator, approximately 7 inches away from the wires. The vertical material on the right, was the debris netting in the corner of the S/C by the water panel, approximately 13 inches away from the wires. The average burning rate of debris netting in a 14.5 psi oxygen environment in a horizontal direction has been determined to be 2 inches per second.

Assuming that this burning rate is valid, it can be postulated that the polyurethane foam on the evaporator would ignite at about 4 seconds and the vertical debris netting in the corner at about 8 seconds after the initial netting ignition. The front cover of the ECU was not installed and the netting on the floor was a couple of inches away from the polyurethane foam on the evaporator. Because of this, it is inferred that the vertical netting in the corner would be the first instance of vertical burning. Vertical burning would occur at about 23:31:03 GMT. Allowing one second for the flames to reach the couch level, the first voice transmission of trouble from the Command Pilot at 23:31:04.7 GMT occurs at the proper time. Unfortunately, there is no physical evidence to support a conclusive determination. This wiring was located in the area where burning was at the highest intensity. Sections of these wires, six to twelve inches long, in the suspect location have been completely burned away.

D. FINDINGS AND DETERMINATIONS

1. Findings:

Several arcing indications were observed in the Command Module -Y +Z sector and a voltage transient was noted in all three phases of AC bus 2. This transient was most closely simulated by a power interruption or short circuit on DC bus B.

Physical evidence and witness statements indicated the progress of the fire to be from the left side of the Spacecraft.

Simulations and tests indicate that combustion initiation due to electrostatic discharge or chemical action is not probable.

No physical evidence of pre-fire overheating of mechanical components or heating devices was found.

Determinations:

No single ignition source could be conclusively identified.

The most probable initiator is considered to be electrical arcing or shorting in the sector between the -Y and +Z Spacecraft axis.

The location best fitting the total available information is that where ECS instrumentation power wiring runs into the area between the ECU and the oxygen panel.

2. Finding:

All Spacecraft records have been reviewed by the various Panels and the results were screened by Panel 18.

Determination:

No evidence has been found to correlate previously known discrepancies, malfunctions, qualification failures or open work items with the source of ignition.

3. Finding:

At the time of the observed fire, data including telemetry and voice communications indicate no malfunctioning Spacecraft systems (other than the live microphone).

Determination:

Existing Spacecraft instrumentation was insufficient by itself to provide data which would identify the source of ignition.

E. SUPPORTING DATA

List of Enclosures

Enclosure	Description
18-1	Sample of Disassembly and Post-Disassembly Requirements Form
18-2	Sample of Test Preparation Sheet
18-3	Sample of Board Action Summary Page
18-4	Listing of Open Circuit Breakers
18-5	VHF/AM and S-Band Voice Recordings
18-6	Transcript of Voice Channel for Last 27 Seconds
18-7	Gas Chromatograph Trace
18-8	AC Bus 2 Data and Associated Changes
18-9	Oxygen Flow Rate and Associated Data
18-10	Oxygen Flow Rate Correlation
18-11	Not used
18-12	ECS Data Correlation
18-13	Surge Tank Pressure Profile
18-14	Motion Indications
18-15	Navigation Base Installation
18-16	Spacecraft and IMU Stable Member Axes
18-17	Navigation Base Installation Detail
18-18	Navigation Base Pitch Angle Change Versus Cabin Pressure

Enclosure	Description
18-19	Selected Temperature, Pressure, and Inertial System Measurements Versus Time
18-20	Suit O_2 Flow Rates
18-21	Gas Chromatograph Trace Comparison
18-22	Electrical Power System
18-23	AC Bus 2 Special Tests
18-24	Audio Key Lines
18-25	Environmental Control System Instrumentation Harnesses Before Accident
18-26	Environmental Control System Instrumentation Harness Wiring Identification
18-27	Spacecraft 014 Environmental Control System Instrumentation Harnesses
18-28	Environmental Control System Instrumentation Harnesses After Accident
18-29	Cover of J-Box C15-1A52
18-30	Arced Point on Wire and Cover of J-Box C15-1A52
18-31	Arc Point on Cover of J-Box C15-1A52
18-32	Arc Point on Wire Related to Cover of J-Box C15-1A52
18-33	Undisturbed Location of Gas Chromatograph Connector
18-34	Area Under Gas Chromatograph Connector
18-35	Side of Gas Chromatograph Connector Which Protected Spot Ties on Harness on Floor

Enclosure	Description
18-36	Copper Droplets on Gas Chromatograph Wires
18-37	Copper Flow and Nickel Pipe Effect on Gas Chromatograph AC Wires
18-38	Shorted DC Wires Above Entry Batteries
18-39	Detail of Shorted Wires Above Batteries
18-40	Location of Cabin Fans
18-41	Main Display Console Panel Number 8 Switch S-11 Wiring
18-42	Location of Octopus Cable J185 Connector
18-43	Detail of J185 Connector
18-44	Shorting on Octopus Cable
18-45	Power Harness to J185 Connector
18-46	Suit Compressor Wiring After Accident
18-47	Not Used
18-48	Command Pilot's Suit Wiring
18-49	Detail of Command Pilot's Communication Harness
18-50	Location of Switch S11 on Panel 8
18-51	Short to Structure by Terminal of Switch S11
18-52	Complete "Status of Investigation Items" dated April 1, 1967
18-53	"Integration Analysis Summary" for each investigation item as available on April 1, 1967
18-54a	"Review of Spacecraft Power Status", dated February 6, 1967, prepared by Panel 18

Enclosure	Description
18-54b	"Supplement to Review of Spacecraft Power Status", dated February 23, 1967, prepared by Panel 1.
18-55	Complete set of "Potential Initiation Theories Evaluation Sheets", dated March 28, 1967.
18-56	Brief Summary of Significant Special Test Results
18-57	List of References

SAMPLE OF DISASSEMBLY AND POST-DISASSEMBLY REQUIREMENTS FORM

No. 0060 REMOVE COVER C15-1A52 JUNCTION BOX

DESCRIPTION of TASK 2/9

REMOVE MECHANICAL COVER ON C15-1A52 JUNCTION BOX

INSPECT WIRING WHERE SCREWDRIVER INCIDENT OCCURRED

SUBSYSTEM

ELECT.

PRIME REASON

INSPECTION

URGENCY RATIONAL

MAY HAVE CONTRIBUTED TO CAUSE

CONSTRAINTS

NONE

ENCLOSURE 18-1
D-18-57

ORIGINAL PAGE IS
OF POOR QUALITY

INVESTIGATION

NON-CONFIGURATION CHANGE
B | NON-CONFIGURATION & DOWNEY OPERATIONS

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

TR NO. SC012-SC-022
S/C | CAT. | NO.

MOD. SHEET NO. ____

TEST PREPARATION SHEET

PAGE 1 OF 1

INITIATING ORGANIZATION Systems Engineering
AGE / MOD. NO. V14-3 | DATE 2-10-67 | TIME 1300 | NEED DATE AS SCHEDULED
DRAWING(S), DOCUMENTS, OTP(S), & PART NO.(S) V16-880225
PARTS WITHDRAWN REQ. N/A | S/N:
SYSTEM EPS
TPS SHEET TITLE Remove Cover
REASON FOR WORK To Inspect Area Behind Closeout Panel Over C15-1A52

	DESCRIPTION (Print or Type)	TECH	INSP. NAA	INSP. NASA
	VERIFY EO NO. EO LOG RECORD CLEARED			
	Not Req'd To Be Worked On SC014			
	Constrained By SC012-SC-049			
1.	Pantograph C15-1A52 Pnl Lower Equ. Bay.			
2.	Carefully Backout 4 Mtg. Screws And Washers From C15-1A52 Holding Panel V16-441802 (Esl V16-880225), To Prevent It From Falling.			
3.	Place Panel And Mounting Hardware In Plastic Bag. Identify Bag As To Contents.			
4.	Send Bag To PIB Bond Room For Storage.			

PARTS WITHDRAWN & RECORDED, IF REQUIRED
PREPARED BY J. Linares | FINAL ACCEPTANCE DATE

Reference to local procedures for specific approvals

1 [illegible] 2-10-67
2 [illegible] 2-10-67
3 [illegible] 2/10/67
4 [illegible] 2-10-67

ENCLOSURE 18-2: SAMPLE OF TEST PREPARATION SHEET

BOARD ACTION SUMMARY

ACTION	DESCRIPTION	REASON	BRD APP DATE	TPS #	RESULT SUMMARY
0057 CLOSED B	Remove Pyro Batteries	Only active power source still in C/M	2/8	109	TPS complete 2/15/67. C/M batteries removed. Terminals in good condition. Slight coating of soot.
0058 CLOSED B	Disconnect SM Jettison Controller Batteries.	Remove Active power source on S/M.	2/8	087	TPS complete 2/10/67. Electrical power was removed and battery terminals insulated.
0059 CLOSED A	Inspect ECU Wiring (Non-destructive)	Routine check. Summary required for each S/C entry.	2/8	062	Inspection indicated burned and bare wires. Low level continuity checks and engineering analysis will be performed under Action #0179.
0060 CLOSED	Remove mechanical cover on C15-1A52 Junction Box ENCLOSURE 18-3:	Inspect wiring where screwdriver incident occurred. SAMPLE OF BOARD ACTION SUMMARY	2/8	082	TPS complete 2/12/67. See Action 0037 for summary and/or analysis. Reference Investigation Item 47.

LIST OF OPEN CIRCUIT BREAKERS

PANEL 22 RIGHT-HAND CIRCUIT BREAKER PANEL

No.	Identification	Rating	Condition
CB18	Master Event Seq. Controller Arm B	5 Amp	HS
CB15	DC Sensor Signal Main A	5 Amp	HS
CB117	Scientific Equipment Bay 1 (J185)	20 Amp	HS
CB118	Scientific Equipment Bay 2 (above batteries)	20 Amp	HS
CB77	Battery Charger Batt B	10 Amp	BS
CB116	Gas Chromatograph AC1	2 Amp	HS
CB45	Telecommunications Group 5	7.5 Amp	HS
CB94	ECS H_2O Accumulator Main A	5 Amp	NS
CB76	Cabin Air Fan 1 AC1 Phase A	2 Amp	VLS
CB74	Cabin Air Fan 1 AC1 Phase C	2 Amp	S
CB33	ECS Suit Compressor AC1 Phase A	2 Amp	HS
CB32	ECS Suit Compressor AC1 Phase B	2 Amp	HS
CB92	ECS Waste and Potable H_2O Main A	5 Amp	HS
CB91	ECS Waste and Potable H_2O Main B	5 Amp	S
CB43	ECS Transducer pressure group 2 Main A	5 Amp	B
CB34	ECS Transducer pressure group 2 Main B	5 Amp	VLS
CB11	ECS Temperature Main A	5 Amp	MS
CB10	ECS Temperature Main B	5 Amp	LS

PANEL 21 RIGHT-HAND SIDE CONSOLE BUS SWITCHING PANEL

CB8	Sensor Unit AC Bus 2	5 Amp	NS

PANEL 25 LEFT-HAND CIRCUIT BREAKER PANEL

CB33	SCS B and D Roll Main B	20 Amp	VLS
CB39	SCS Pitch Main B	20 Amp	NS
CB31	SCS Yaw Main B	20 Amp	MS
CB26	Gimbal Motor Control 1 Pitch Battery A	15 Amp	HS
	Gimbal Motor Control 1 Yaw Battery A	15 Amp	HS
CB16	RCS Propellant Isolate Main A	15 Amp	LS
CB15	RCS Propellant Isolate Main B	15 Amp	MS
CB52	EDS 1 Battery A	5 Amp	MS
CB53	EDS 3 Battery B	5 Amp	MS

PANEL 203

CB3	Inverter Power No. 2 Main B	70 Amp	NS

PANEL 150

CB14	Pyro A Seq. A	20 Amp	NS
CB17	Pyro B Seq. B	20 Amp	S
CB20	Battery Charger Battery C	5 Amp	NS

PANEL 204 INSTRUMENTATION POWER CONTROL

CB3	Essential Instrumentation	7 Amp	

Condition Code:

B - BURNED

S - SOOTY

NS - NO SOOT

MS - MEDIUM SOOT

HS - HEAVY SOOT

LS - LIGHT SOOT

BS - BURNED SOOT

VLS- VERY LIGHT SOOT

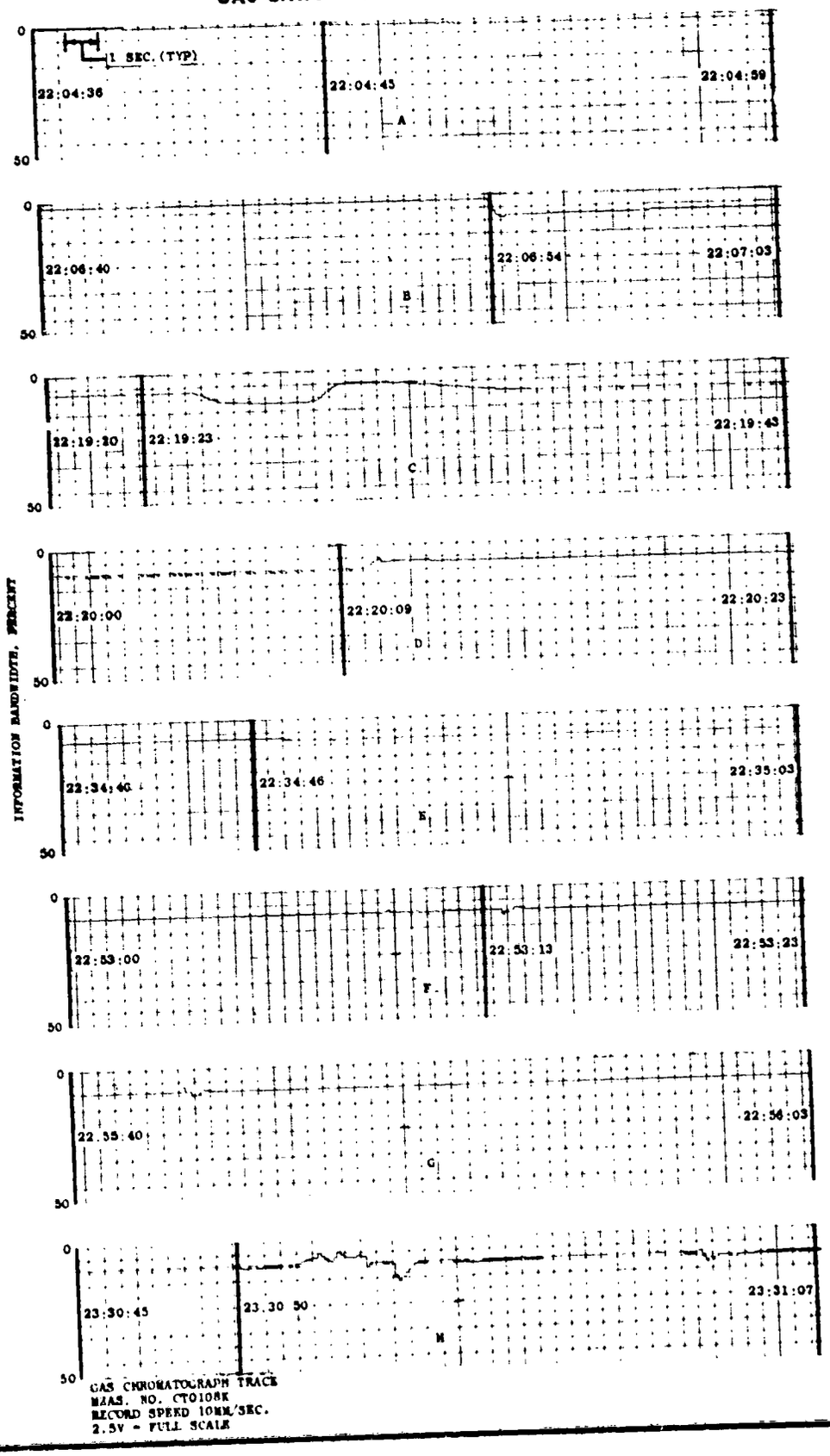
ENCLOSURE 18-6

D-18-65

TRANSCRIPT OF VOICE CHANNEL FOR LAST 27 SECONDS

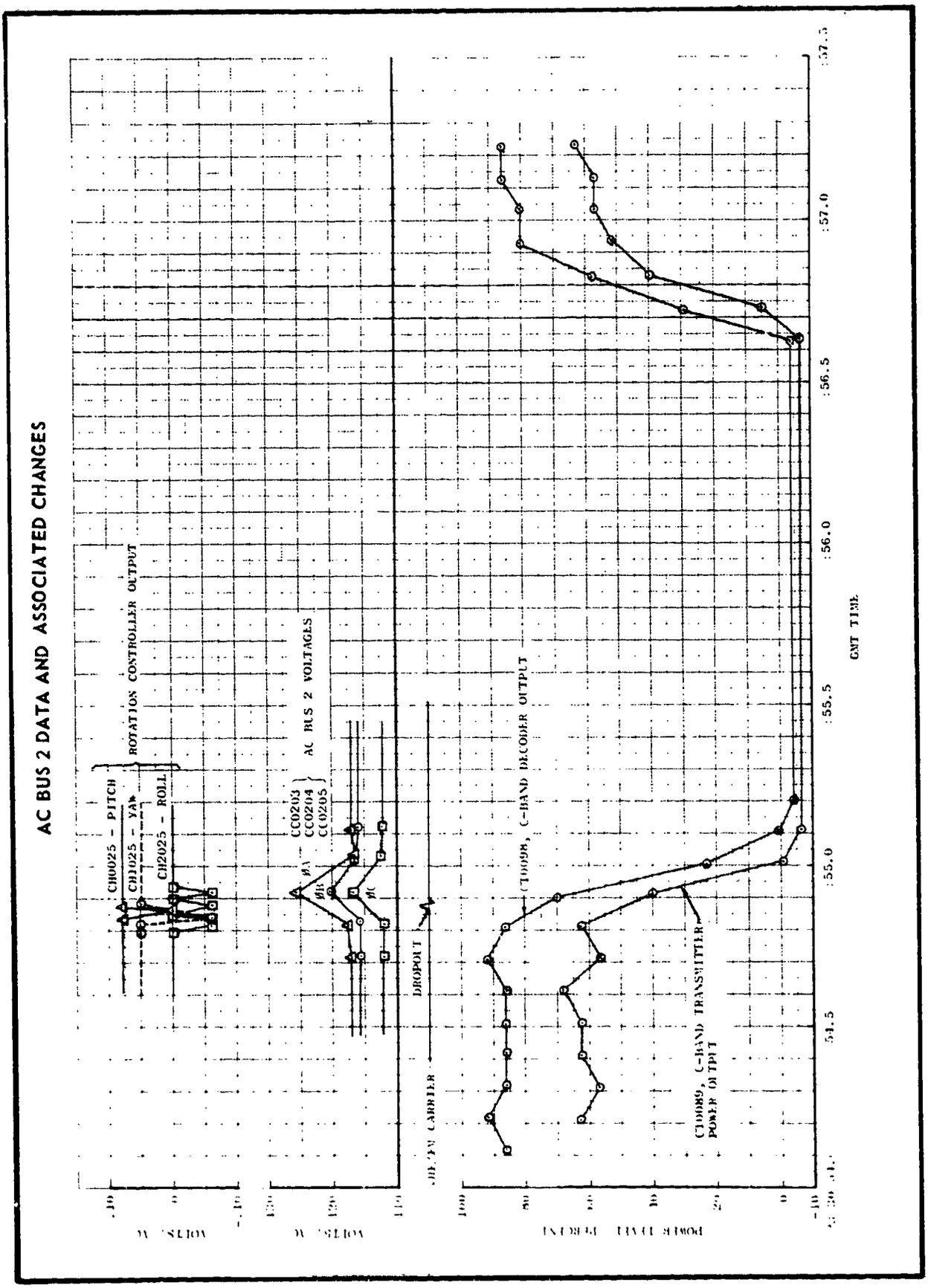
MOLC VHF/AM TRACK TRANSCRIPT		MOLC S-BAND TRANSCRIPT	
		23:30:55.5	(Noise)
		23:30:56	(Breathing sound)
		23:30:56.5	(Noise)
		23:30:58.1	(Noise)
23:30:58.5	(Short noise 0.6 sec.)		
		23:31:04	(Breathing sound)
23:31:10.0	(First voice transmission)	23:31:04.7	(First voice transmission of Spacecraft problem)
23:31:10.0	(End of first transmission)	23:31:10.0	(End of transmission)
		23:31:16.8	(Second voice transmission of Spacecraft problem)
23:31:17.1	(Second voice transmission)		
23:31:21.8	(End of second transmission)	23:31:21.8	(End of second transmission)
		23:31:22.4	(LOS)

GAS CHROMATOGRAPH TRACE

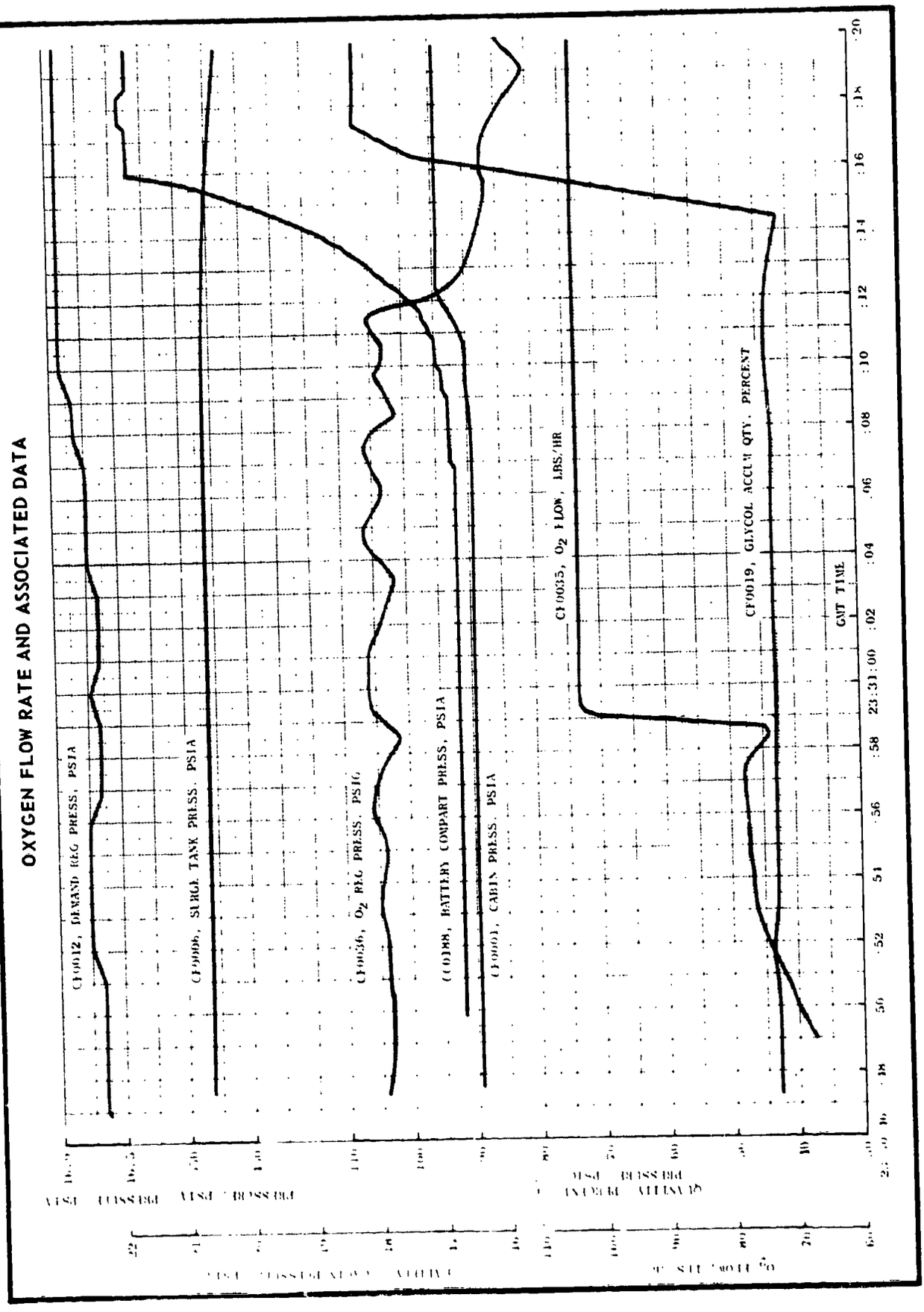


GAS CHROMATOGRAPH TRACE
MEAS. NO. CTO108K
RECORD SPEED 10MM/SEC.
2.5V = FULL SCALE

ENCLOSURE 18-7



ENCLOSURE 18-8



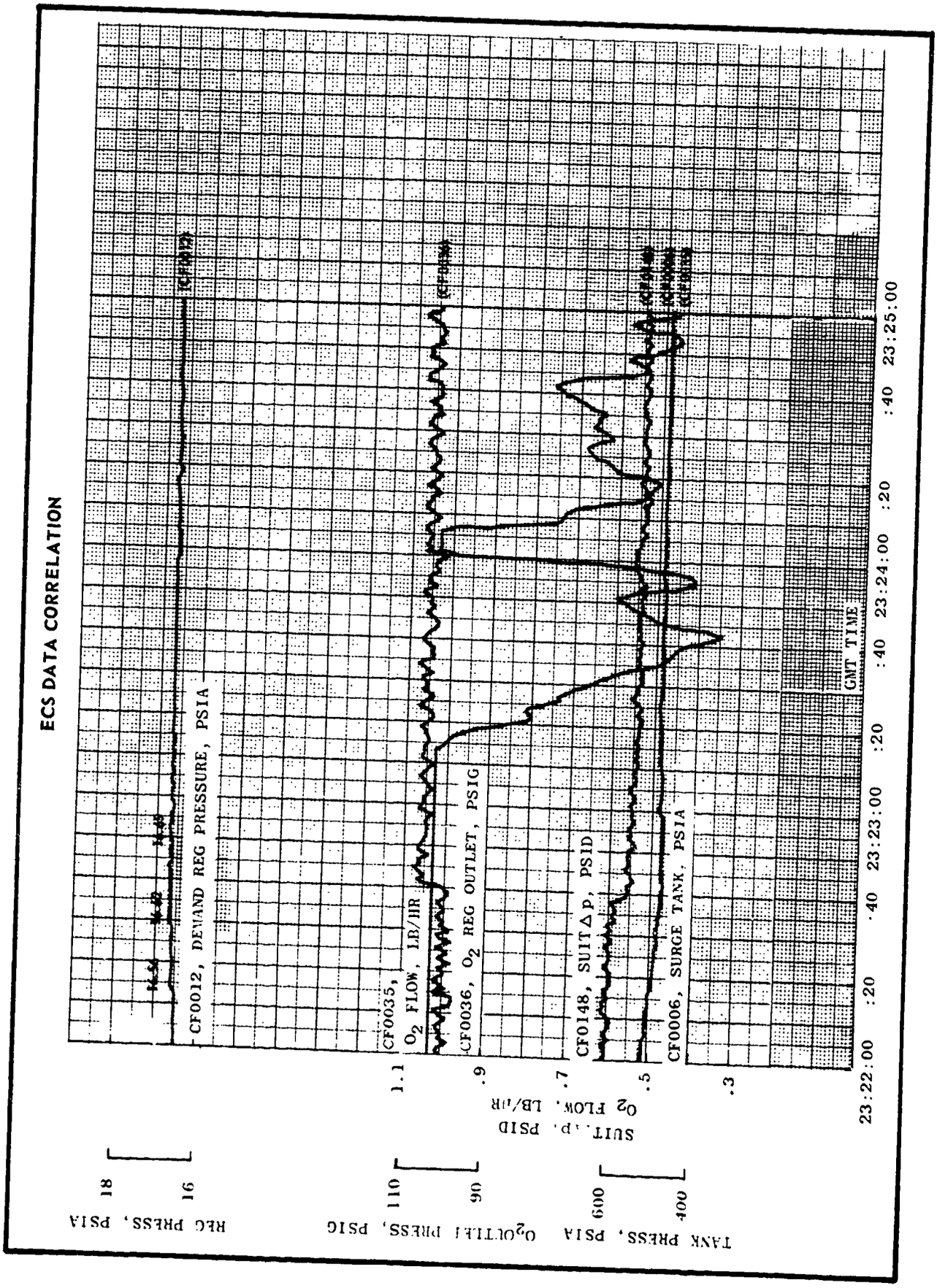
ENCLOSURE 18-9

OXYGEN FLOW RATE CORRELATION

(Correlation of relevant data for unexplained periods when oxygen flow rate (CF0035R) indicates maximum value of 1.033 lb./hr.)

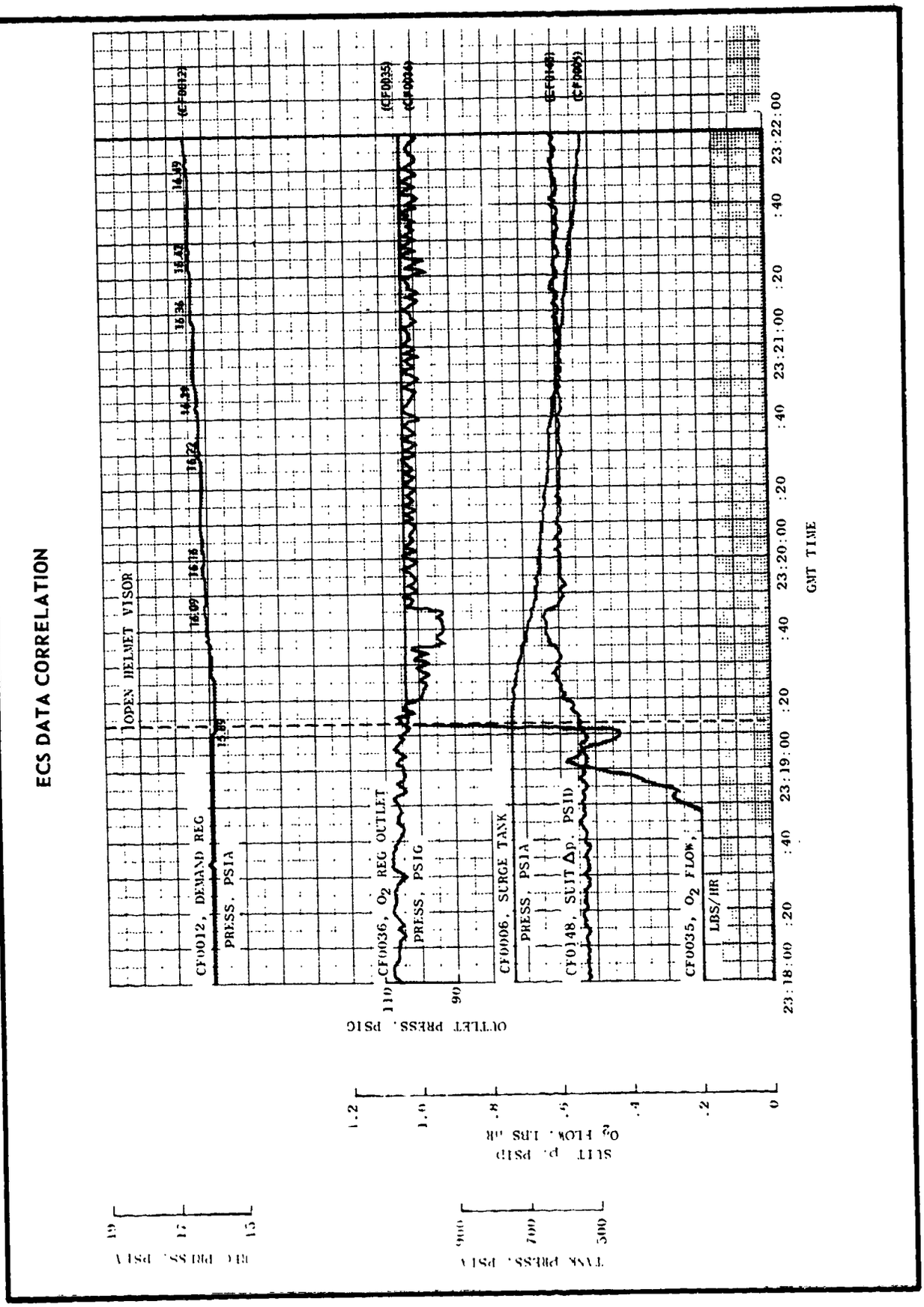
TIME (start/end)	DURATION (min:sec)	C&W INDICATION (on/off)	SURGE TANK PRESSURE CHANGES (psia-start/end)	AVERAGE FLOW (lb./hr.)	MAX RATE OF FLOW INCREASE (lb./hr./sec.)	SUIT PRESSURE CHANGES
1. 20:20:30 20:20:41	00:10	None	None	≥1.033	0.09	Yes
2. 21:27:43 21:27:51	00:08	None	None	≥1.033	0.12	Yes
3. 21:28:34 21:28:40	00:06	None	None	≥1.033	0.14	Yes
4. 21:45:54 21:46:29	00:35	21:46: 21:46:26	None	≥1.033	0.11	No
5. •22:46:07 22:46:24	00:17	22:46:22/ 21:46:24	None	≥1.033	0.24	Yes
6. •22:52:07 22:53:18	01:11	22:52:22/ 22:52:48	734.7/730.5	3.80	0.09	Yes
7. •22:53:47 22:54:16	00:29	22:54:01/ 22:54:05	None	≥1.033	0.06	Yes
8. •22:54:24/	00:16	None	None	≥1.033	0.03	Yes
9. ••23:19:13 23:23:14	04:01	23:19:28/ 23:19:34	739/480.6	≥22.28	0.33	Yes
10. 23:24:03/ 23:24:06	00:03	None	None	≥1.033	0.33	Yes
11. •23:30:59/LOS		23:31:15/LOS	514.5/484.8	64.3	0.29	Yes

NOTE: Average flows computed from surge tank pressure data. •Voice tape indicates crew activity. ••Command Pilot face plate open.

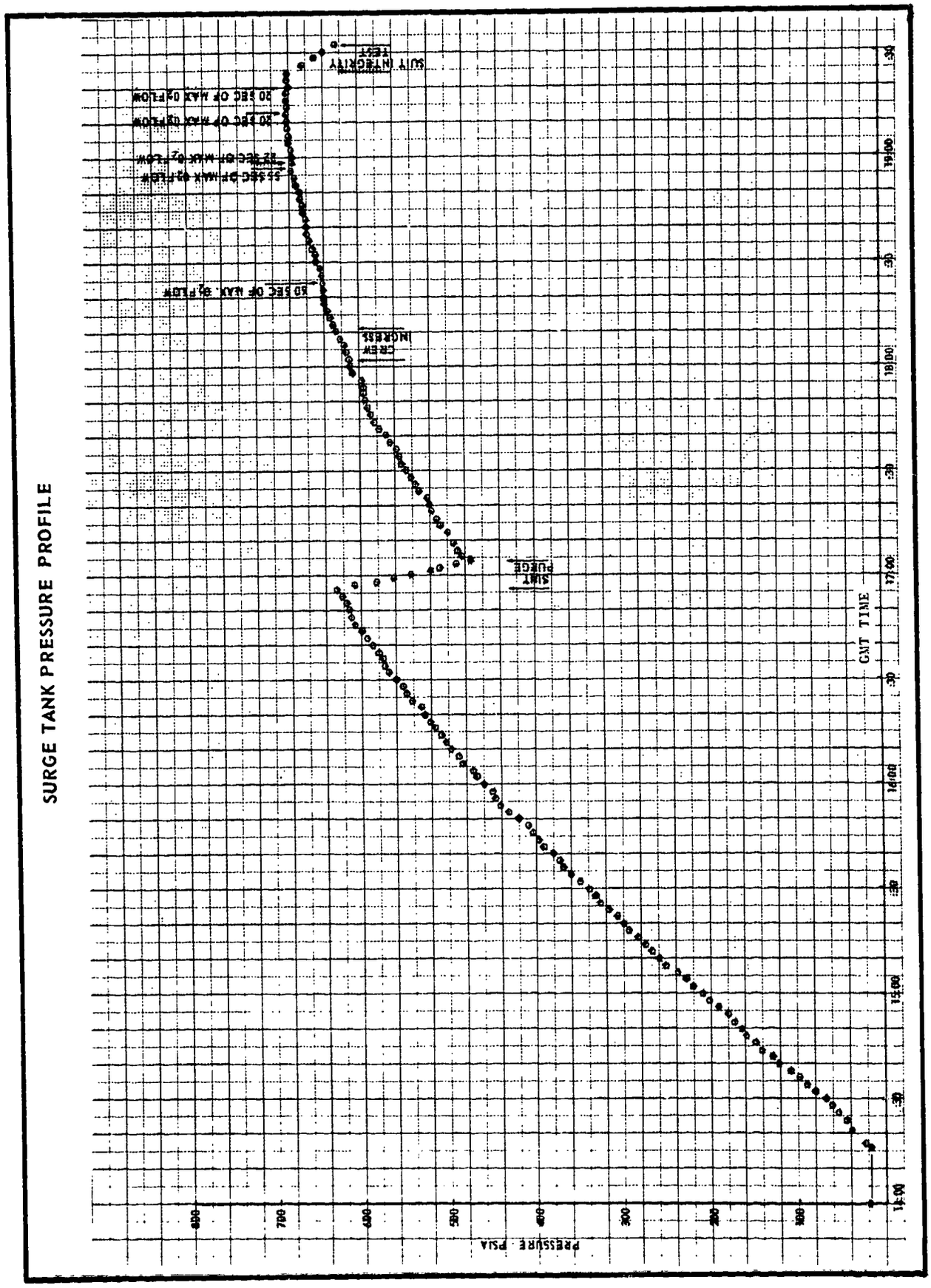


ENCLOSURE 18-12

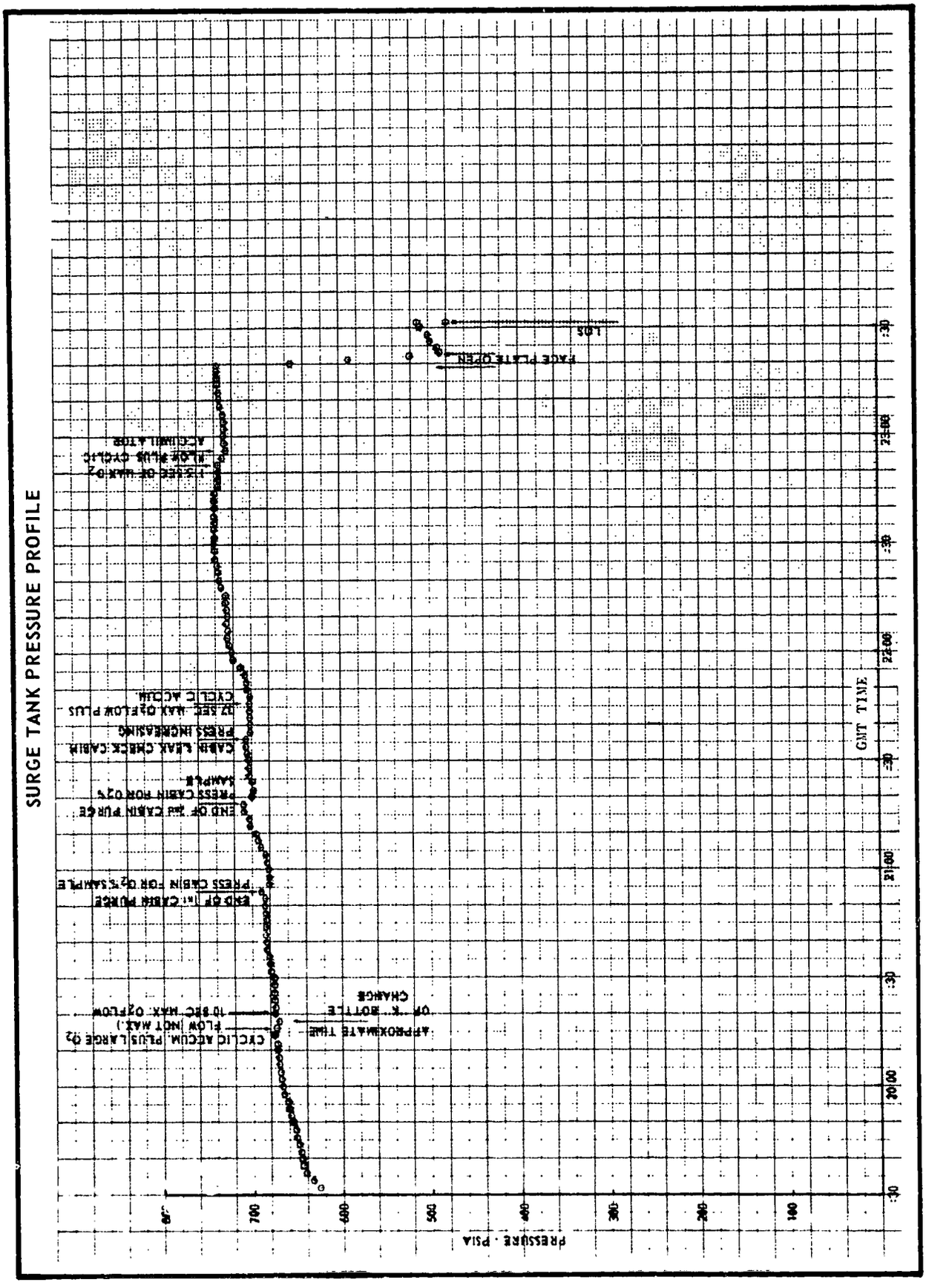
ECS DATA CORRELATION



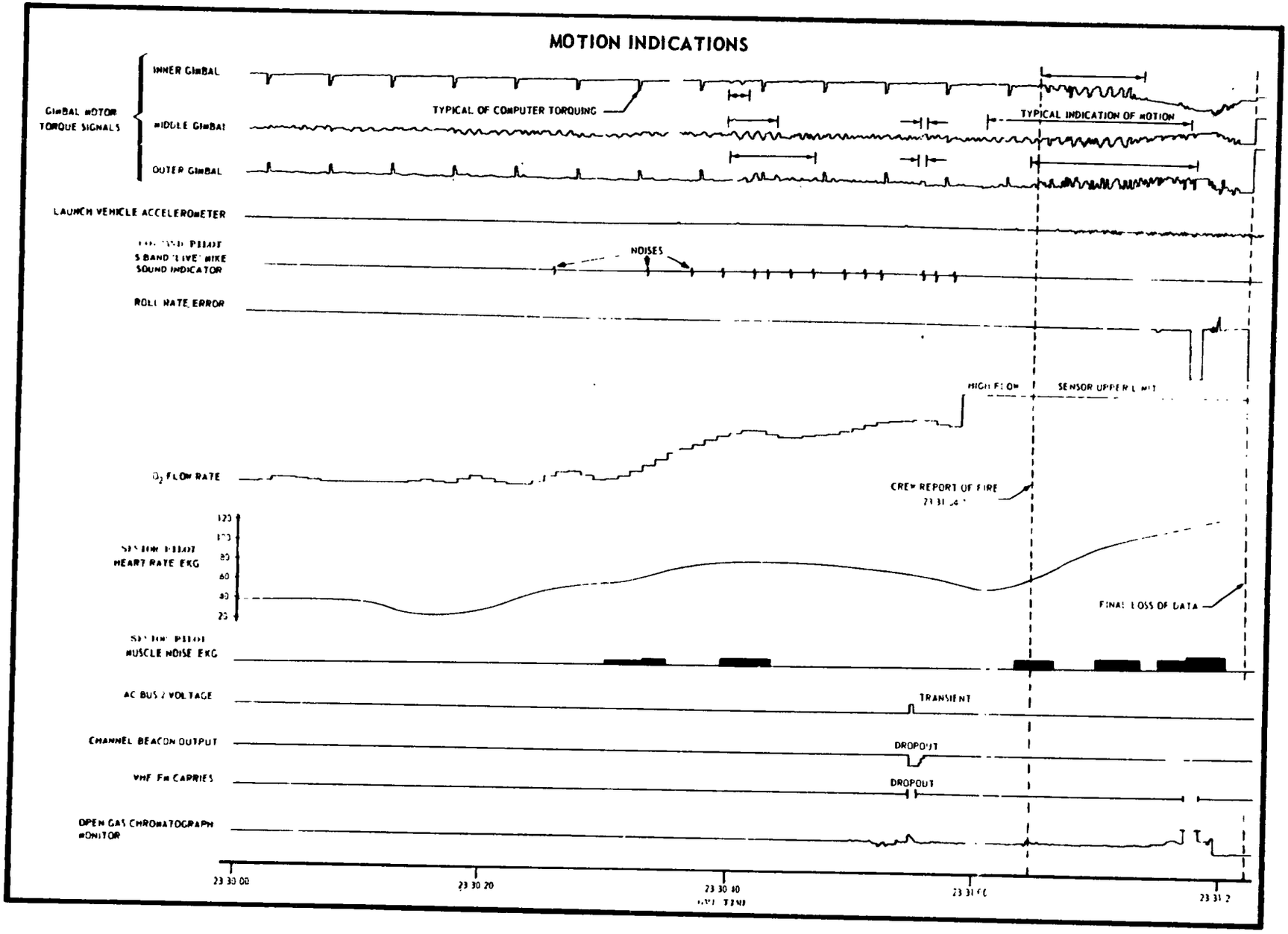
ENCLOSURE 18-12



ENCLOSURE 18-13



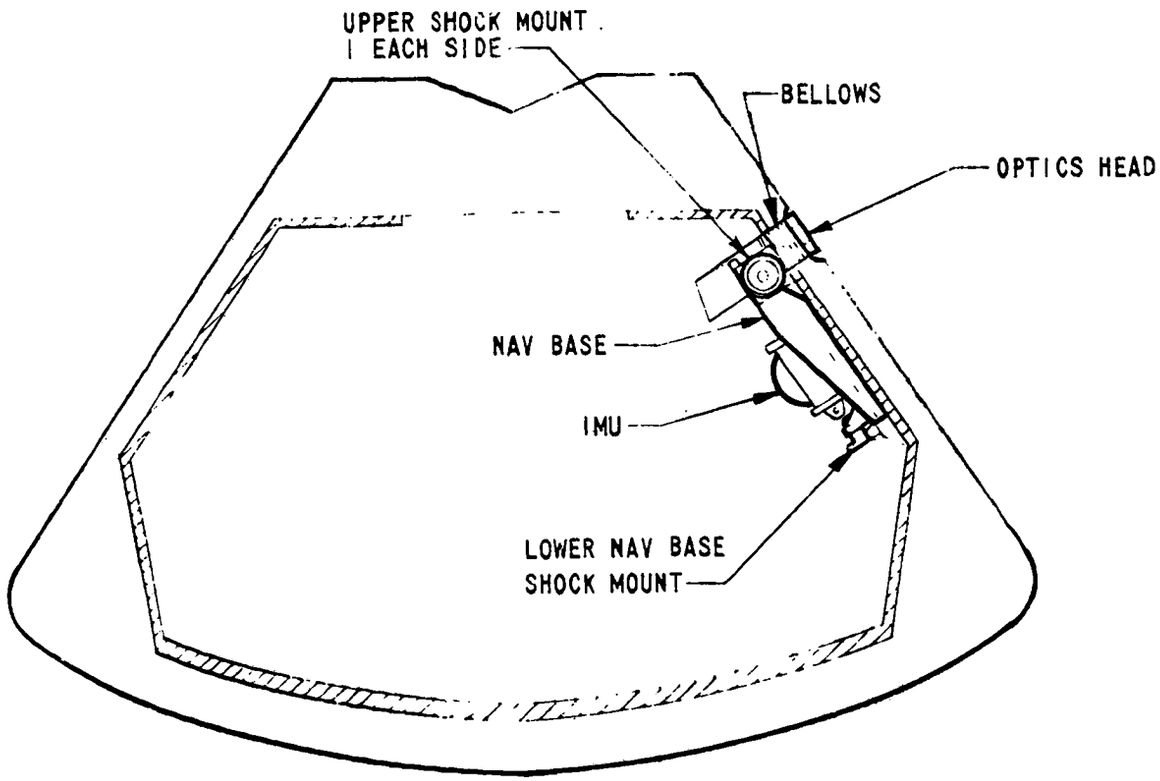
ENCLOSURE 18-13



ENCLOSURE 18-14

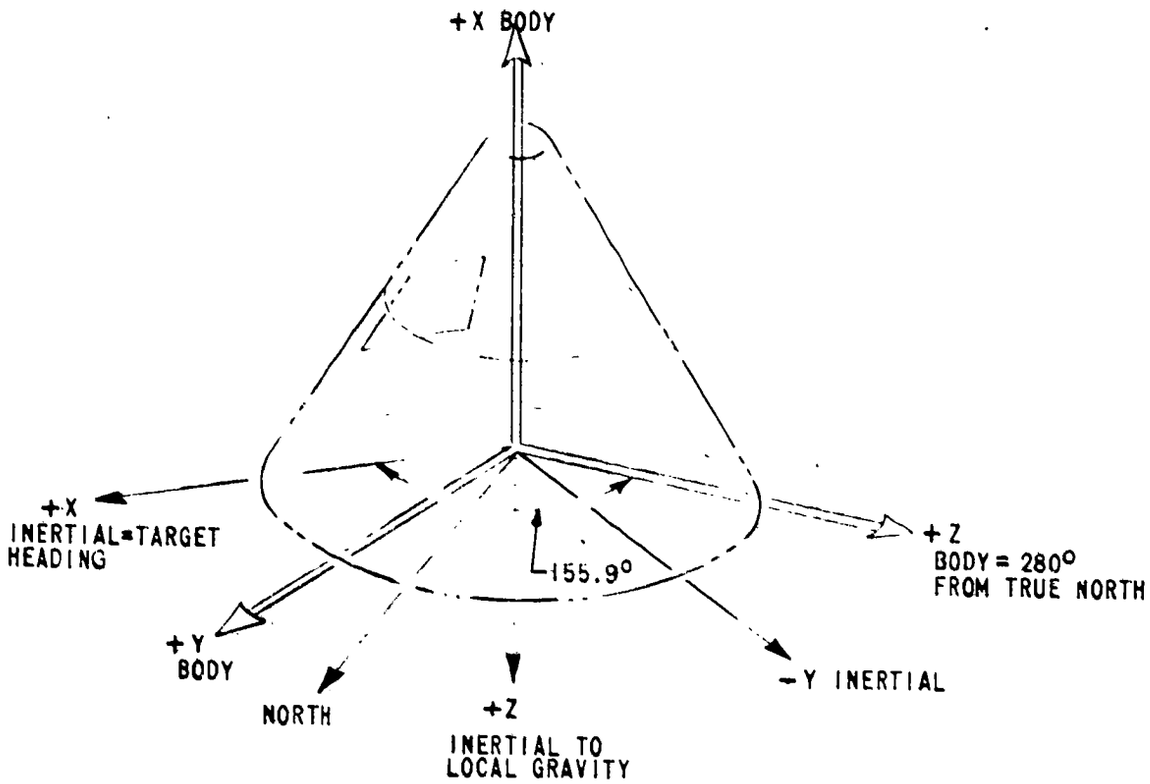
D-18-74

NAVIGATION BASE INSTALLATION



ENCLOSURE 18-15

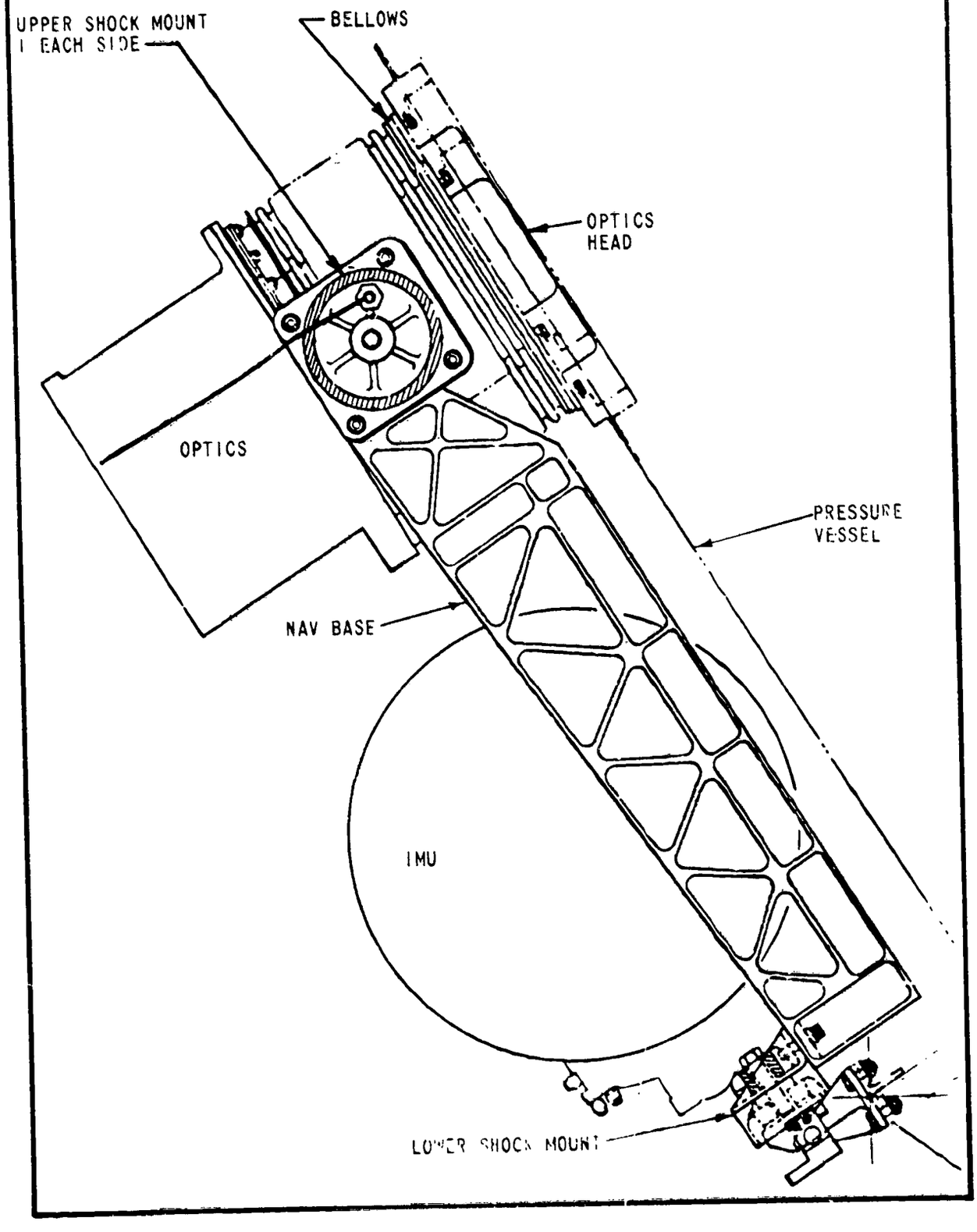
SPACECRAFT AND IMU STABLE MEMBER AXES



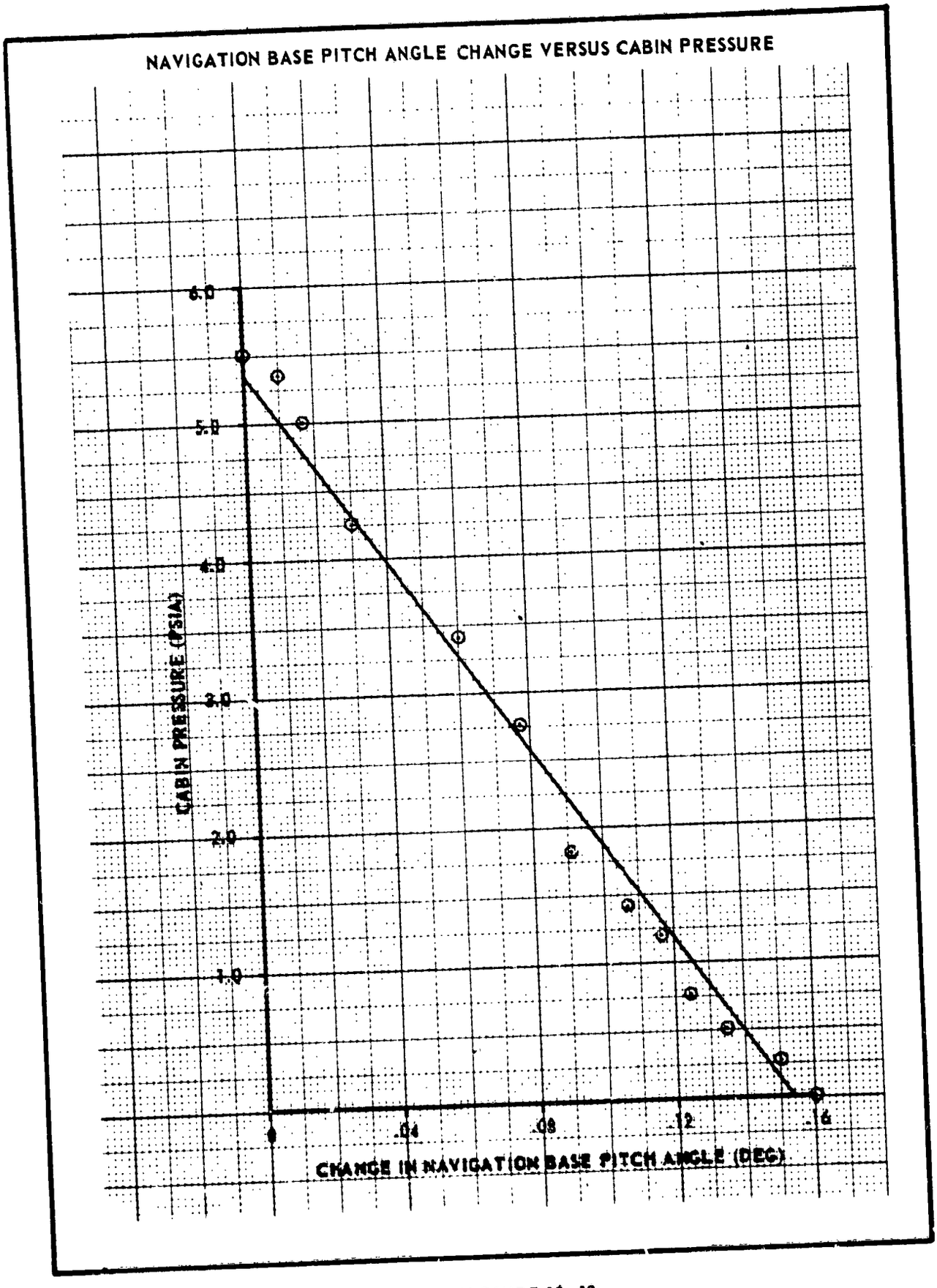
ENCLOSURE 18-16

D-18-76

NAVIGATION BASE INSTALLATION DETAIL



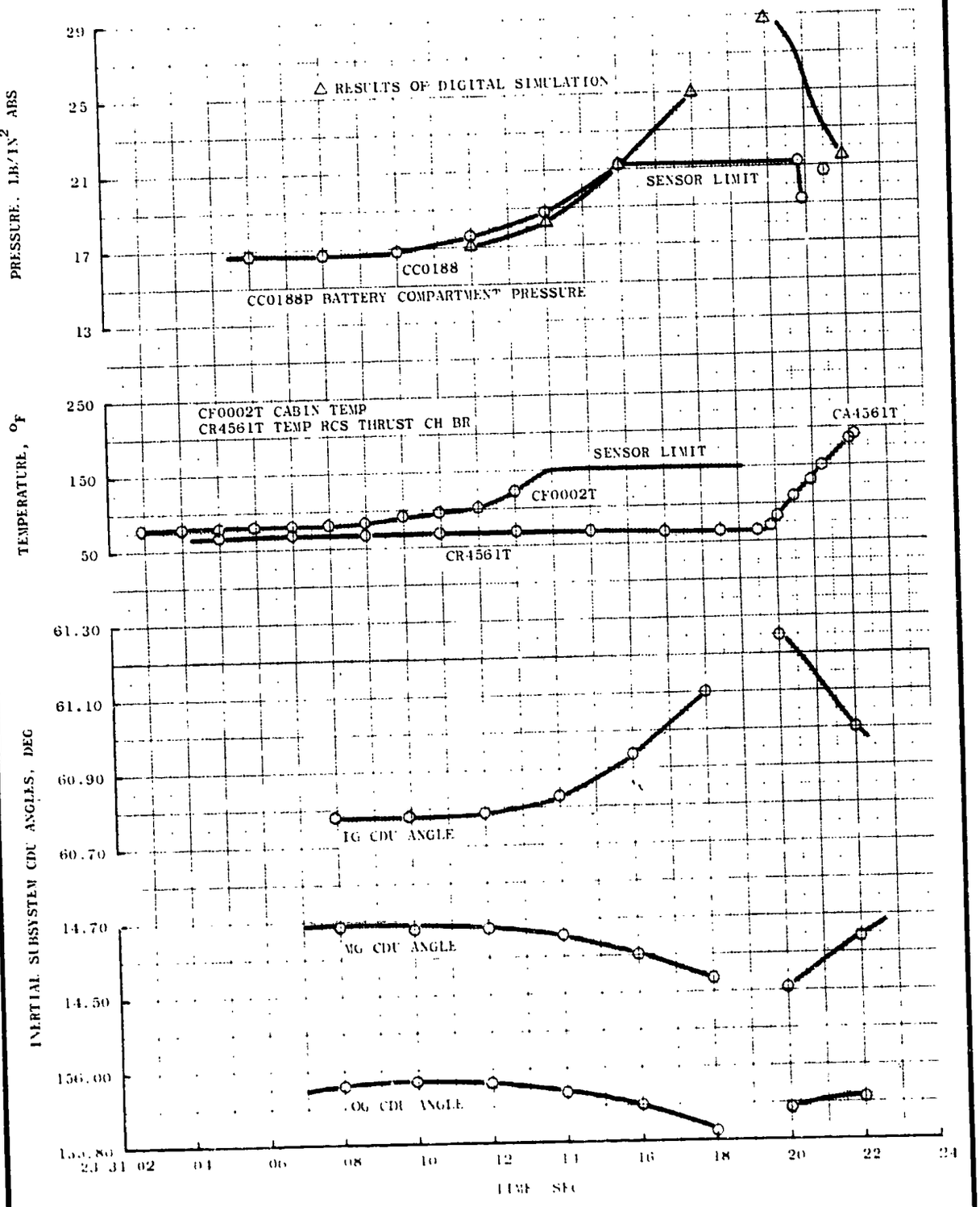
ENCLOSURE 18-17



ENCLOSURE 18-18

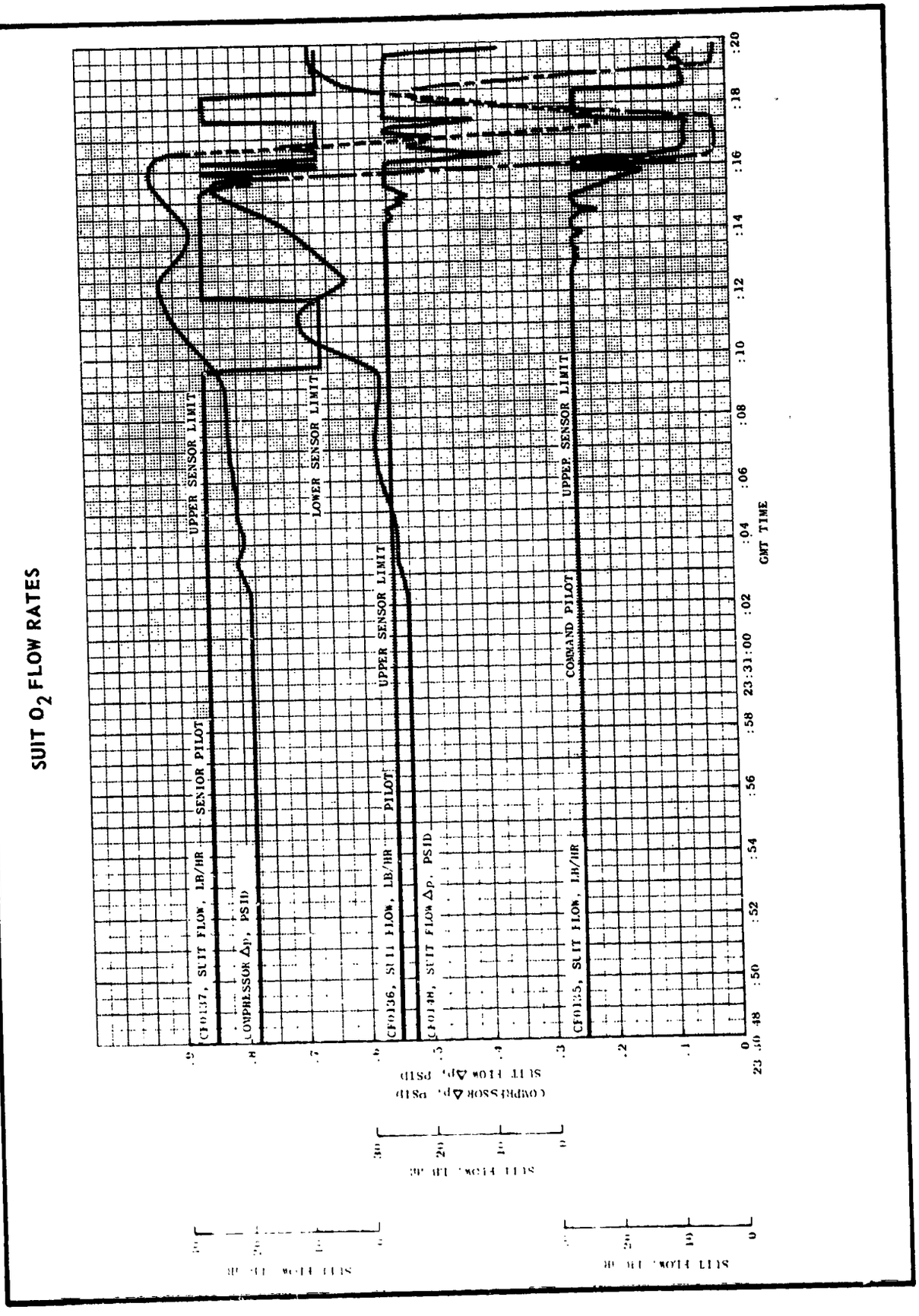
D.13.78

SELECTED TEMPERATURE, PRESSURE, AND INERTIAL SYSTEM MEASUREMENTS VERSUS TIME



ENCLOSURE 18-19

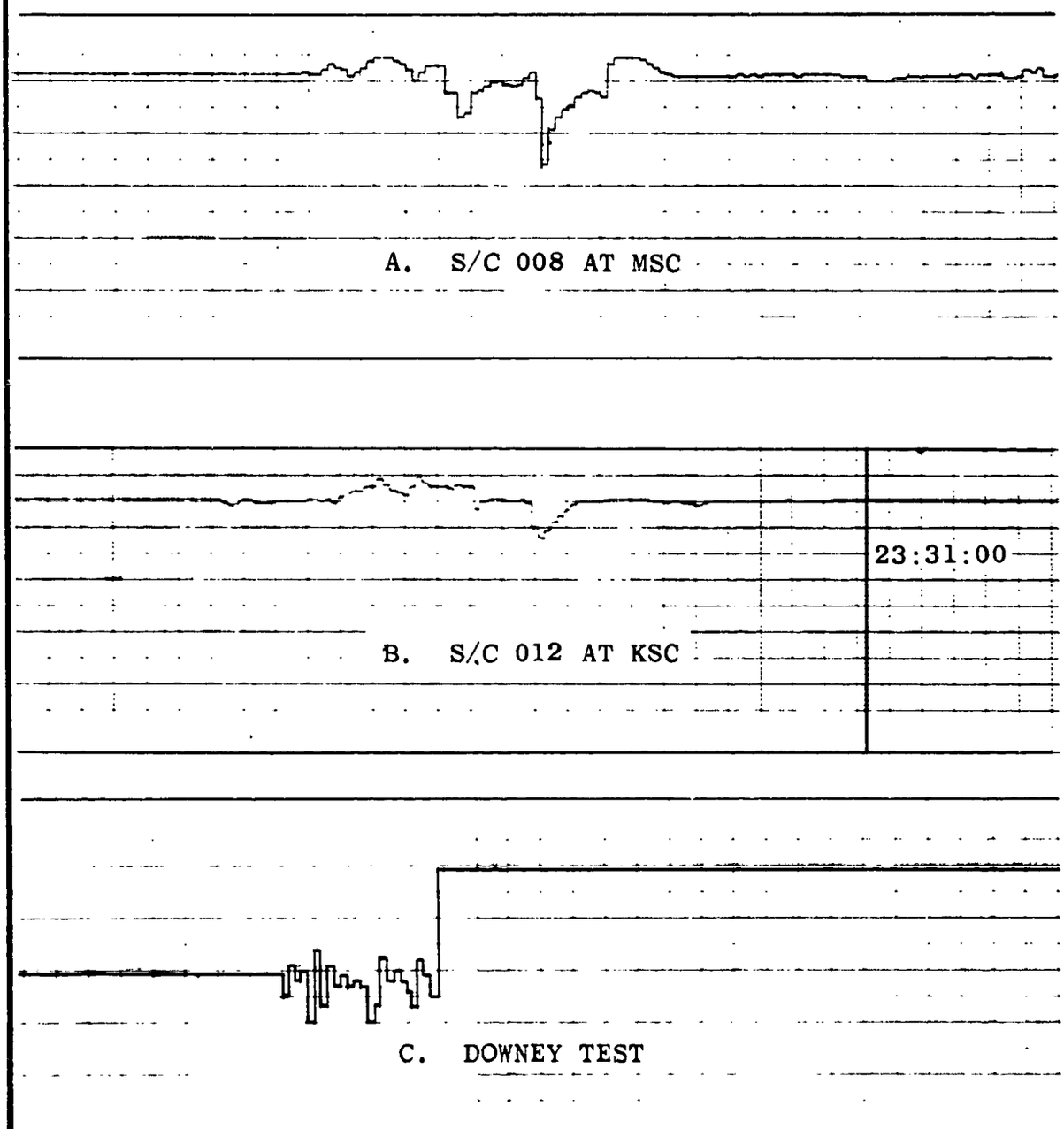
SUIT O_2 FLOW RATES



ENCLOSURE 18-20

D-18-80

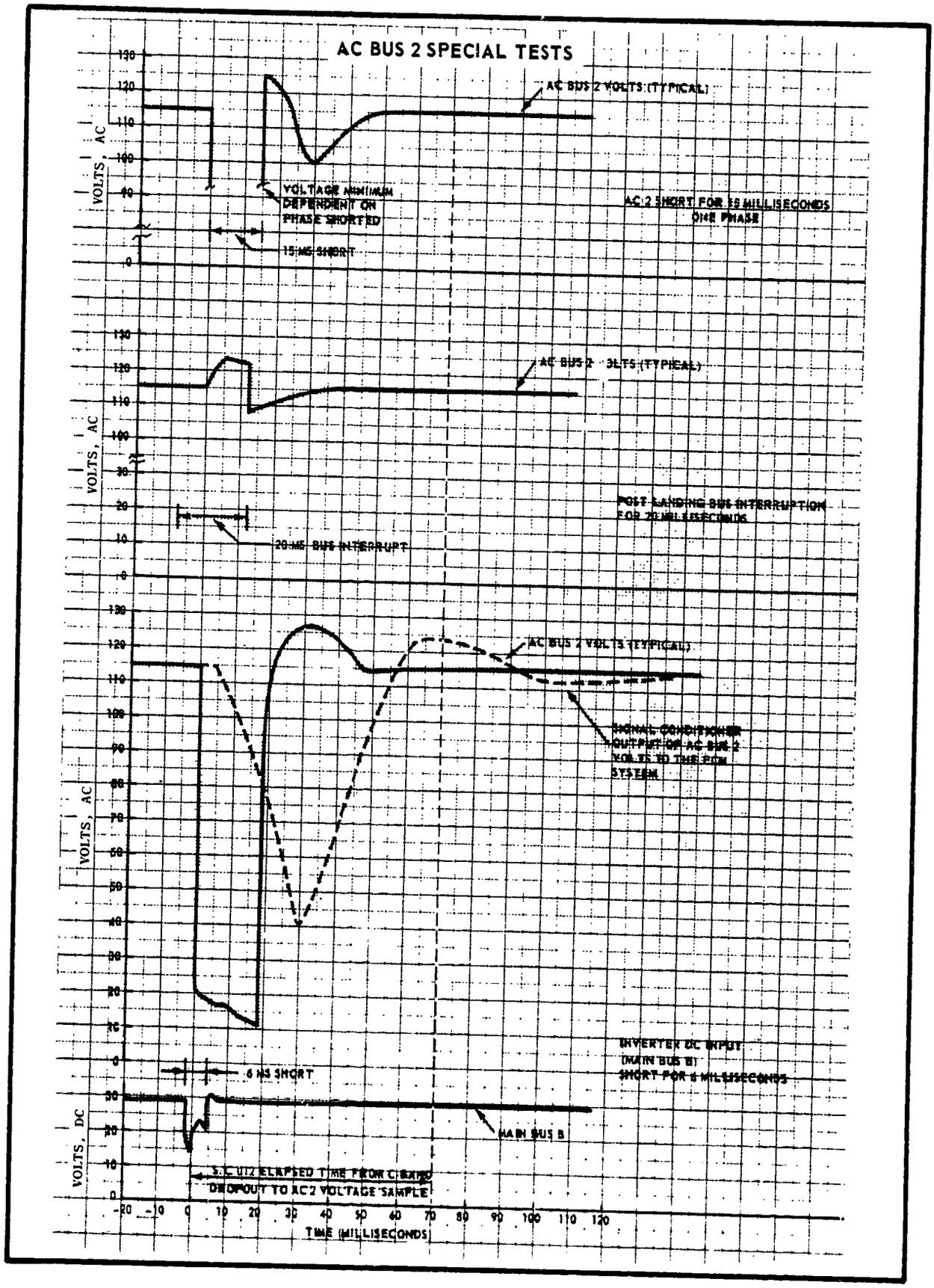
GAS CHROMATOGRAPH TRACE COMPARISON



GAS CHROMATOGRAPH TRACE
MEAS. NO. CT0108K
RECORD SPEED 10MM/SEC.
2.5V = FULL SCALE

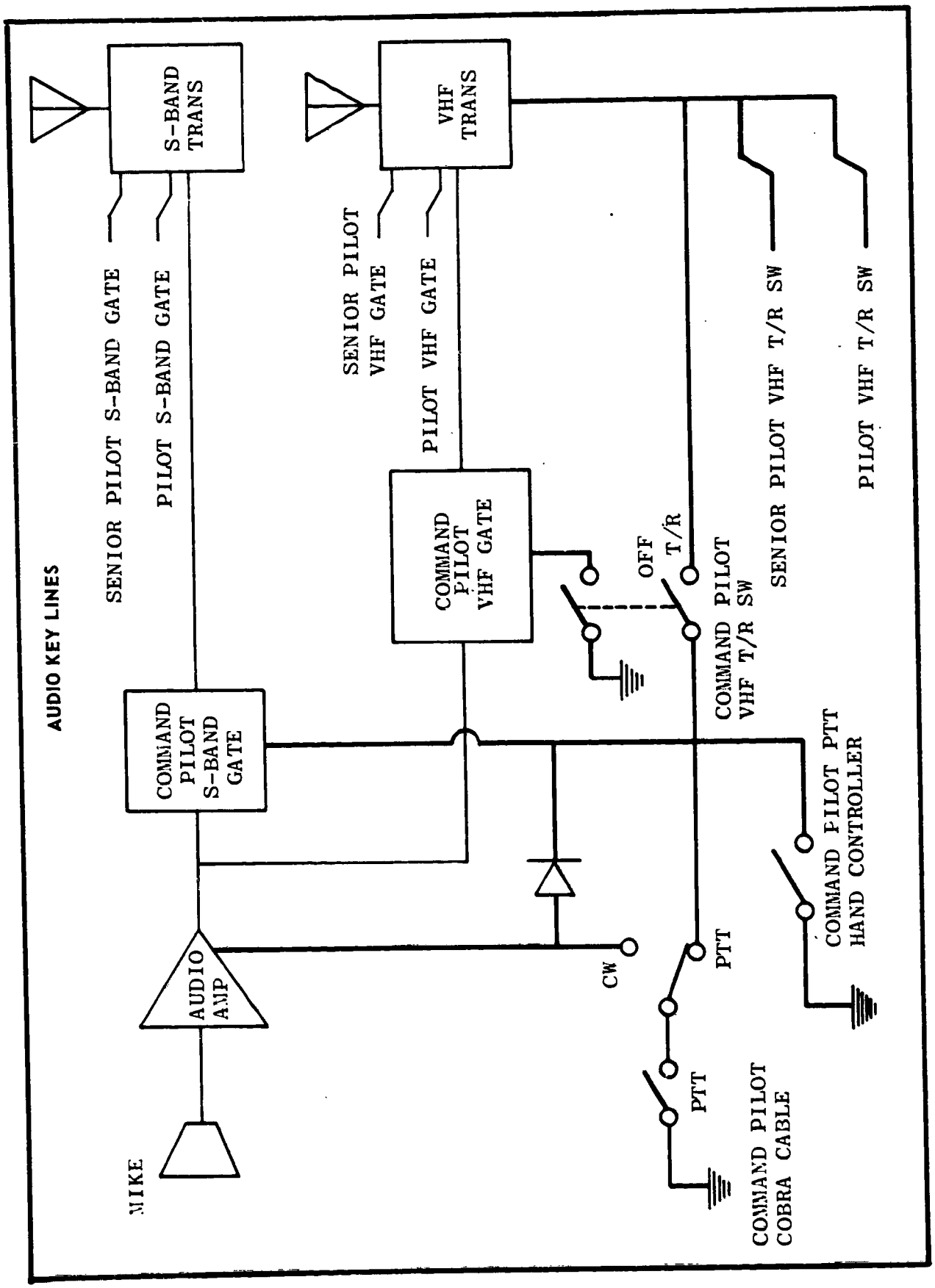
ENCLOSURE 18-21

D-18-81

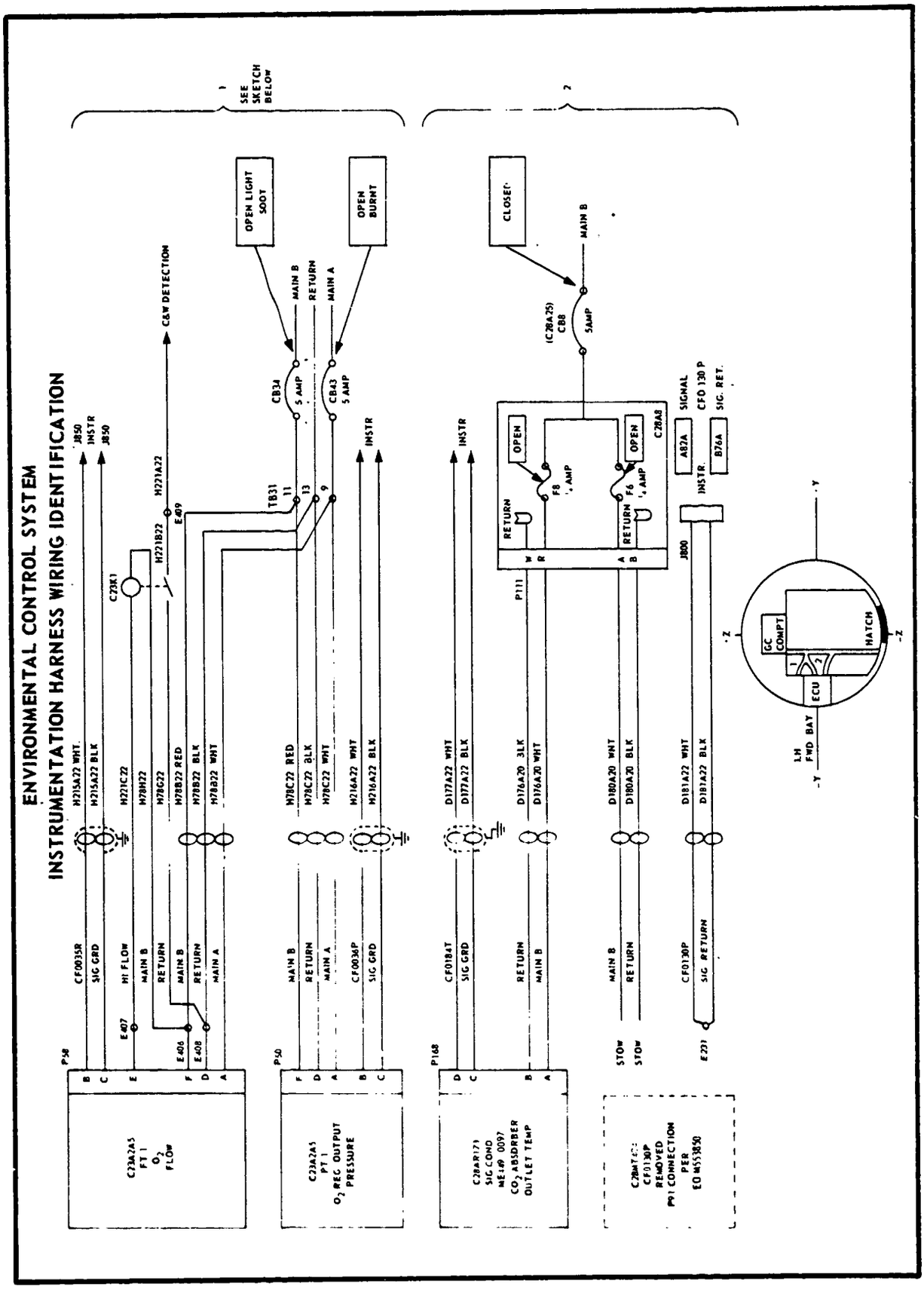


ENCLOSURE 18-23

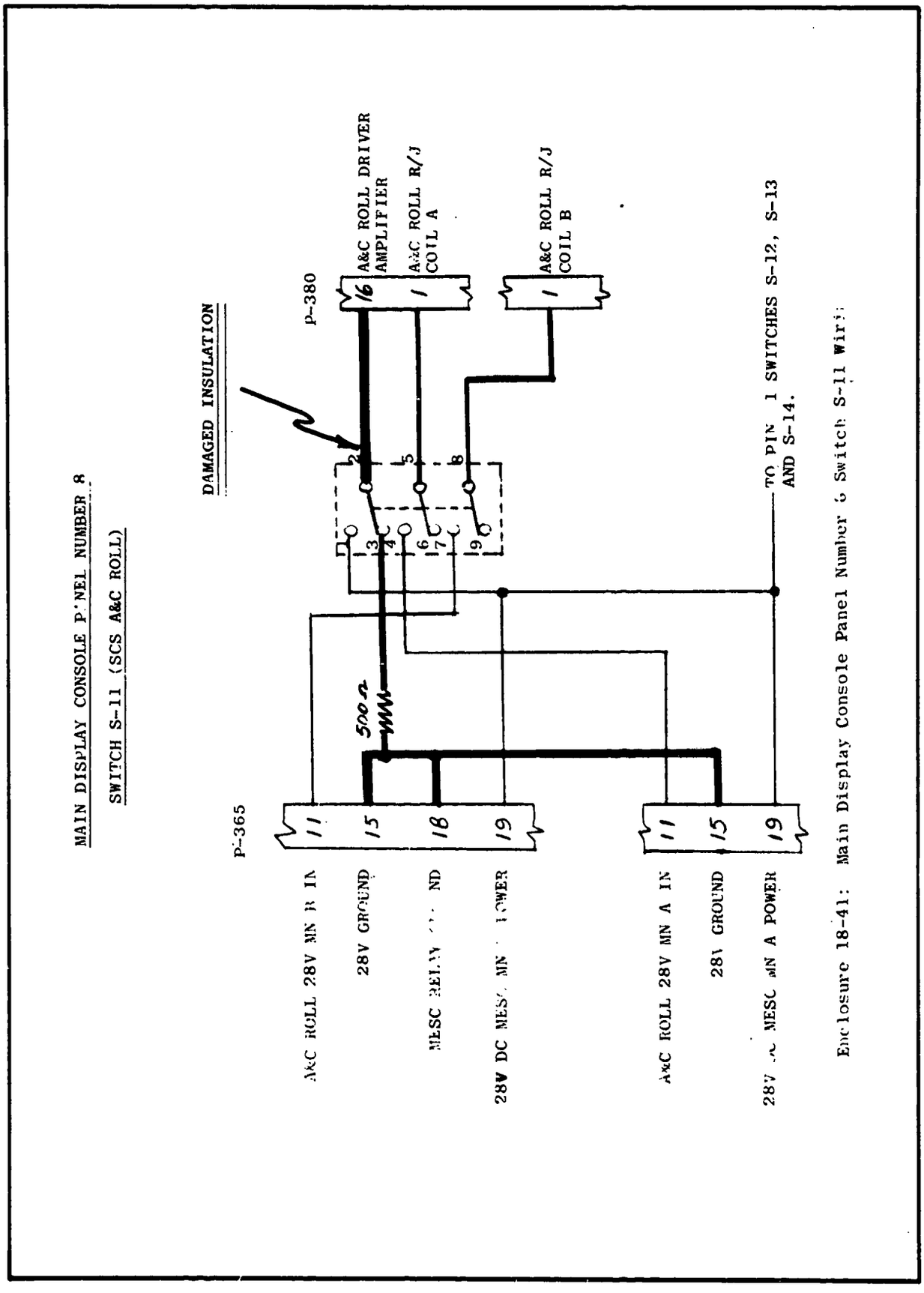
D-18-85



ENCLOSURE 18-24



ENCLOSURE 18-26



Enclosure 18-41: Main Display Console Panel Number 8 Switch S-11 Wiri

ENCLOSURE 18-52
D-18-139

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
1	Last voice from crew before fire 2330:03 Baseline information only. No Analysis Summary required.	3-3	3-14	3-14	
		Bell Labs preliminary report received. Information of significance will be covered under appropriate items. ITEM CLOSED			
2	Noise on S-Band voice channel 2330:39.5 to 2330:58.5	3-20	3-31	3-31	
		Bell Labs and MSC preliminary reports received. Their determination on these noises is inconclusive. However, the sounds were similar to those of tapping and brushing a microphone. ITEM CLOSED			
3	IMU gimbal angle data indicates movement: 2330:39 to 2330:44, 2330:54.9 2331:00 to Loss of Data	3-3	3-21	3-21	
		Data have been reviewed to determine if correlation of definitive movement can be established from gimbal torque mortor signals. It was determined that no repeatability or consistancy could be established other than gross indications of motions. ITEM CLOSED			
4	Ground DC power supply number 2 shows a 4 amp increase for a one second sample 2326:30.5	3-3	3-16	3-17	
		An analysis of the data has been completed. It has been concluded that power supplies A and B may have momentarily shifted their shared loads or another load may have been added at this time. Considering the time, it has been concluded that this event could not have contributed to the cause of the accident. ITEM CLOSED			

ENCLOSURE 18-52

D-18-140

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
5	Gas chromatograph output starts movement from this time to loss of data 2330:50	3-5	3-20	3-21	
		The gas chromatograph (GC) was not installed in S/C 012 at the time of the accident. It has been determined, however, that the GC cable acted as an electromagnetic radiation detector. Changes in the GC data trace are an indication of changes of state in the Command Module. ITEM CLOSED			
6	VHF-FM video drops out for 30 milliseconds 2330:54.85	2-10	2-10	2-10	
		Tests conducted showed that the received video signal will drop out if the AC supply drops to less than 50 volts or the DC supply drops to less than 6.5 volts for a period of 15 to 20 milliseconds. This is an effect of an AC bus 2 power interruption. ITEM CLOSED			
7	AC bus 2 voltages transient on all three phases 2330:54.85	3-20	4-1	4-1	
		The AC voltage transient appeared as a rise of 5 to 8 volts for one data sample. Testing has determined that a momentarly interruption of bus B DC power to inverter 2 will cause this type of AC transient. ITEM CLOSED			
8	C-band transponder drops to zero volts for two seconds 2330:54.85 to 2330:56.9	2-10	2-10	2-10	
		AC drop out for very short intervals of time causes the C-Band transponder to go to a protective mode. Normal recovery time is approximately 1.7 seconds. This is an effect of an AC bus 2 power interruption. ITEM CLOSED			

ENCLOSURE 18-52
D-18-141

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
9	O_2 flow rate increases to measurement limit 2330:59.4	2-20	3-20	3-20	
		Telemetered data and engineering analysis of failure modes and circuitry, and an inspection of the flow sensor, leads to the conclusion that the high oxygen flow indication was valid, and that there was no malfunction of the sensor and/or associated wiring prior to the crew report of fire. ITEM CLOSED			
10	Voice data "fire" 2331:04.7 Baseline information only. No Analysis Summary required.	3-21	3-27	3-27	
		Bell Labs and MSC preliminary reports received. Details of their analyses are contained in Section C-7 of the Panel 18 Final Report. ITEM CLOSED			
11	Witnesses report bright glow moving from left to right after fire call Baseline information only. No Analysis Summary required	2-13	2-14	3-17	
		A TV simulation test was performed utilizing S/C 008 Video tape playbacks were shown to the primary witnesses to verify their observation and time correlations, and no changes in statement resulted. The only positive summary statement is that after the fire call observation of the TV monitor showed flame progressing inside the crew compartment from the left corner of the porthole to the upper right area. ITEM CLOSED			
12	Data indicates the initial cabin temperature increase at 2331:06.4	2-14	4-1	4-1	
		Test conducted by the transducer's vendor(AiResearch) showed that the sensor response time was approximately 300 milliseconds. It is concluded that the time of cabin temperature rise is accuracte to within ±1 second. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
13	Cabin pressure increase began at 2331:06.818 (battery pressure transducer)	2-10	2-14	2-14	
	Response time of the transducer has been determined. Response time plus measurement sampling rate defines the accuracy of this data to be within ± 100 milliseconds. ITEM CLOSED				
14	Cabin pressure increase began at 2331:08.417 (measurement CF0001P)	2-10	2-14	2-14	
	Response time of the transducer has been determined. Because this measurement is sampled only once per second, the battery pressure transducer (Item 13) should be used for cabin pressure data. ITEM CLOSED				
15	IMU gimbal angle data shows ramp starting at approximately 2331:10	2-10	2-10	2-15	
	The IMU gimbal ramp is attributed to an increase in Command Module pressure. This data has been substantiated by data obtained during the second vacuum chamber test on Spacecraft 012 and on special tests performed on Spacecraft 008 at MSC. ITEM CLOSED				
16	Entry battery B transferred to Main Bus B 2331:12.4	2-10	2-10	2-10	
	Two ground and six PCM measurements showed that the entry battery B was transferred to the Main Bus B. Also post test investigation substantiated the position of switch S-10 on panel 22 which is indicative of Pilot action. Refer to Item 17 for corollary information on Battery A. ITEM CLOSED				

ENCLOSURE 18-52
D-18-143

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
17	Entry battery A transferred to Main Bus A 2331:13.6	2-10	2-10	2-10	
		Four PCM measurements showed that the Entry Battery A was transferred to Main Bus A. This was further substantiated by the post test inspection of switch S-9 on panel 22 which is indicative of Pilot action. ITEM CLOSED			
18	Master caution warning light came on 2331:14.7	2-10	2-10	2-10	
		This light was the result of a high oxygen flow rate indication. Whenever the oxygen flow rate increases to its maximum and stays at a mixmum transducer saturated level for 15 seconds, the master alarm will come on. ITEM CLOSED			
19	Temperature of oxygen supply began to increase 2331:16.0	2-10	2-14	2-14	
		Post test observations indicate that loss of pressure suit circuit integrity occurred in the Command Pilot's pressure suit and/or return hose. Such an opening would allow warm cabin air to be drawn into the suit compressor. The CO_2 absorber outlet temperature indicates that the CO_2 absorber acted as a heat sink until this time, when it and the suit manifold temperature began to increase. ITEM CLOSED			
20	Momentary interruption in VHF-FM and S-Band data 2331:17.398 to 2331:17.659	2-10	3-10	3-10	
		This loss of data is attributed to soft short circuits occurring in the communications system wiring. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
21	Biomed recorder timing trace inspection for DC dropout.	3-3	3-16	3-16	
		Tests showed that the timing trace amplitude changes were caused by imperfections and dust on the tape. There were no interruptions indicative of a short on DC bus B, on Biomed recorder data from the accident.			
		ITEM CLOSED			
22	Additional (seven) gas chromatograph data variations 2204:45 to 2255:43	3-6	3-16	3-16	
		An analysis of the data at these times has been conducted and correlations with other systems changes were seen. It has been concluded that the gas chromatographs cable acted as a electromagnetic radiation detector.			
		ITEM CLOSED			
23	Loss of all communications data 2331:21.0 to 2331:22.42	2-14	3-10	3-10	
		This is due to the burning and shorting of wire harnesses during the fire, attributed to a loss of power or loss of a coax cable.			
		ITEM CLOSED			
24	MTVC Pitch Rate Command observed at 2330:54.847	2-14	2-23	2-23	
		This happened at the same time as the AC Bus 2 transient. A re-analysis disclosed this was a one bit change in the data which occurred frequently. No significance is therefore attributed to this item.			
		ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
25	Senior Pilot suit flow dropped to lower limit then returned to normal flow indication 2331:09.6 to 2331:11.9	3-6	4-1	4-1	
	It is inferred that the Senior Pilot disconnected his suit inlet hose for emergency egress (Reference Item No. 102).				
	ITEM CLOSED				
26	O_2 surge tank pressure started to decrease 2331:12.4	3-3	3-20	3-20	
	It is concluded that the oxygen surge tank pressure decay was the result of high O_2 flows into the suit loop.				
	ITEM CLOSED				
27	Command Pilot suit flow started fluctuating at 2331:12.9 and Senior Pilot suit flow started fluctuating at 2331:15.4	2-13	2-27	2-27	
	Characteristic of suit flow indications with restricting caused by Command Pilot movements or physical activity. The time period for fluctuations in the Senior Pilot suit flow coincides with increase muscular activity indicated by physiological data.				
	ITEM CLOSED				
28	Suit compressor inlet temperature starts increasing 2331:13.2	2-13	2-14	2-14	
	Post-test observations indicate that loss of pressure suit circuit integrity occurred in the Command Pilot's pressure suit and/or return hose. Such an opening would allow warm cabin air to be drawn into the suit compressor.				
	ITEM CLOSED				

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
29	RCS jet action, data questionable 2329:40	2-14	2-23	2-23	
		A more detailed analysis of the data during this period has been completed. The indicated RCS action was found to be erroneous. ITEM CLOSED			
30	Rotation controller output transient of 1.5° 2330:54.85	3-2	3-31	3-31	
		This happened at the same time as the AC Bus 2 transient. Special tests have shown that the null output transients can be duplicated by a momentary interruption of AC Bus 2 Phase A input power. This is therefore an effect of the AC Bus 2 transient. ITEM CLOSED			
31	Electrical short due to cold flow characteristics of Teflon wire insulation	2-24	4-1	4-1	
		All wire bundles in the spacecraft which showed damage were carefully inspected for signs of arcing. Due to the considerable fire damage and the possibility that shorting could have been a result, evidence of Teflon "cold-flow" is considered inconclusive. ITEM CLOSED			
32	SCS roll rate oscillations starting at 2331:03.85	2-19	2-23	2-23	
		Indicates movement in the command module during this period. Nothing more can be inferred from the data other than movement. ITEM CLOSED			

ENCLOSURE 18-52
D-18-147

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
33	Launch Vehicle pitch and yaw accelerometers start oscillation 2331:04 to loss of data	2-14	2-15	2-15	
		No indications in data during cobra cable change (crew movement). Data shows slight oscillations starting at 2331:04 with maximum activity at 2331:20 ITEM CLOSED			
34	Arcing noted on Junction Box cover plate	3-14	4-1	4-1	
		No positive identification has been made to indicate that this arc occurred prior to the fire. Burning noted in this area does not appear as severe as would be expected had the fire started due to this arc. ITEM CLOSED			
35	Suit differential pressure begins to increase 2331:06.4	2-13	3-20	3-20	
		The oxygen demand regulator senses cabin pressure. An increase in cabin pressure will cause the diaphram of the regulator to be opened allowing oxygen flow into the suit loop. ITEM CLOSED			
36	Saturn I engine 8 anomaly 2052:23.039	2-22	3-31	3-31	
		All launch vehicle data pertaining to this circuit has been reviewed and no anomalies have been found. An intermittent condition could exist somewhere within this system to cause this anomaly. Based on the time of this happening, it has been concluded that this is unrelated to the accident. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
37	Water-glycol accumulator quantity starts decreasing 2331:13.0	2-13	2-13	3-14	
		Attributed to increasing cabin pressure, since accumulator diaphragm is vented to cabin pressure. The water-glycol accumulator transducer sensed the increase in cabin pressure and interpreted this as a decrease in water-glycol quantity. ITEM CLOSED			
38	Pilot suit flow starts to fluctuate 2331:14.3, but violently at 2331:16.2	2-13	2-13	2-27	
		Characteristic of suit flow indications with restrictions caused by Pilot movements or physical activity. ITEM CLOSED			
39	GSE DC power commanded off 2332:46.4	2-10	2-10	2-10	
		ACE data shows that the ground DC power was commanded off at 2332:46.4 and that the power was off at 2332:47.7. This is in accordance with the emergency procedures. ITEM CLOSED			
40	Glycol pump discharge pressure starts increasing 2331:14.4	2-13	3-14	3-14	
		Attributed to boiling of water-glycol within the lines when subjected to intense heat. ITEM CLOSED			

ENCLOSURE 18-52
D-18-149

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
11	Use of loose equipment in chromatograph compartment	3-3	3-10	3-14	
		The storage of loose items has been established prior to crew ingress and all were found still in the compartment after the test. However, some of the equipment may have been moved but there is no evidence to support this belief. No films were contained in any of the cameras. ITEM CLOSED			
12	Elapsed time indicator burned on Spacecraft 014 at Downey (unit associated with caution warning system).	2-10	2-10	2-10	
		The elapsed time indicator was physically examined on Spacecraft 012 and found to be satisfactory with no evidence of burning. (Reference TPS 053). ITEM CLOSED			
13	Internal-external power history during entire test --- Baseline information only. No Analysis Summary required.	2-22	2-23	2-23	
		A supplement to the electrical power history has been completed and was presented to the Board on 2-24. ITEM CLOSED			
14	Bottle of MEK found in White Room.	3-3	3-22	3-22	
		Chemical analysis of the bottle has been obtained and it was determined to be MEK. Also a history of cleaning, painting and bonding in Spacecraft 012 has been completed. Use of the bottle on the day of the last test cannot be determined. (Reference Board Action 0147 and TPS MA-003) ITEM CLOSED			

ENCLOSURE 18-52
D-18-150

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
		2-22	3-31	3-31	
15	Two broken pressure transducers on ECU	The two transducers have been identified (suit supply inlet pressure and water glycol pump outlet pressure). Radiographic examination indicated no evidence of damage within these units. Also there were no visual fire paths from within the transducers. ITEM CLOSED			
		2-10	2-10	2-14	
16	Couch resistance measurements and status of bonding straps	Two bonding straps from the floor to the S/C wall were installed but the two from the Z struts to the center couch were not installed due to parts shortage. Resistance checks were made on the crew couches which indicated an 1 ohm resistance. While this is high (normal 0.03 ohms) it is low enough to prevent any static charge buildup. ITEM CLOSED			
		3-4	3-16	3-16	
17	Screwdriver caused arc in wire harness (Ref. DR 0917 dtd 1/23/67)	Inspection of the arced wire (No. 1C50A16 RCS Quad B + Roll Normal Control) has been completed and nothing suspicious was noted. However, an arc spot was noticed on the cover plate which is located in a different area. Reinspection of the area in which the screwdriver drew an arc has shown that it did not contribute to the fire. (Ref: Item No. 34) ITEM CLOSED			
		2-18	2-10	2-10	
48	ACE control and computer room configuration	The ACE Control Room No. 1 and Computer No. 1 configuration have been defined. All indications are that the system operated properly, that no spurious commands were transmitted and in no way contributed to the accident. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
49	Review of past floodlight failures and floodlight examination and testing.	3-3	3-10	3-14	
		The exact configuration of floodlights during the last test has been reviewed. All six floodlights have been removed and have been examined and tested. and were found to be satisfactory. (Reference TPS 028. 029. 032. 033 and 059).			
				ITEM CLOSED	
50	H_2 tank fan motor variation P 20:30.4	2-10	3-10	3-10	
		GSE access connector J 22 which normally carries this measurement has been verified as not connected during the accident. Re-analysis of this data variation has been completed. The variation is attributed to random noise in the ACE station.			
				ITEM CLOSED	
51	Hole in translation controller	2-10	2-15	2-15	
		The Fire Analysis Panel has completed their investigation of the translation hand controller. There is no evidence that an explosion occurred inside the controller. It was probably hit by a foreign object. (Reference TPS 022).			
				ITEM CLOSED	
52	Waste management system blower motor failure on Spacecraft 008	2-13	2-15	2-15	
		The WMS blower selector switch has been determined to have been in the OFF position immediately prior to the incident (T-10 min.) per OCP. Post test switch list shows the selector switch in the OFF position. Examination of the blower motor showed no evidence of any electrical difficulty.			
				ITEM CLOSED	

ENCLOSURE 18-52
D-18-152

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
53	Review of heater failures and hardware examination.	3-1	4-1	4-1	
		History data has been received and has been evaluated. There are six different uses for heaters. The review of the failure history of the heaters concluded that no significant problem could be associated with the 204 accident. ITEM CLOSED			
54	Review of FCS water-glycol leakage on 012	3-3	4-1	4-1	
		A detailed survey of all leakage has been completed. After the accident all connectors subject to past water-glycol spills. No evidence of internal arcing was found that could be attributable to prior water-glycol contamination. ITEM CLOSED			
55	RCS thruster temperature sensor indicates cabin rupture. 2331:19.8	2-10	2-10	2-14	
		This time correlates with the time indicated by the G&N and cabin measurements for the pressure shell rupture. (Response time for this measurement system being obtained.) ITEM CLOSED			
56	Lithium hydroxide canisters non-flight type	2-17	3-8	3-10	
		A detailed analysis of the data associated with the oxygen suit loop indicates normal temperatures until approximately 10 seconds after the fire call. It has been concluded that the canister damage was a result and not a cause of the accident. ITEM CLOSED			

ENCLOSURE 18-52

D-18-153

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
57	Analysis of gas from 2 Beckman oxygen analyzers	2-13	2-15	2-15	
		Neither of the 0_2 analyzers contained significant gaseous materials (more than 500 ppm) of anything other than air components. Trichloroethylene was found in the silica gel of the analyzer used for the last sample. This could result from any previous use. (Ref. TPS 007). ITEM CLOSED			
58	On board recording equipment and electrical connector configuration.	3-6	3-14	3-14	
		Post test physical verification indicates that the DSEA (LEM recorder) was not connected electrically; however, the cable was "hot" per the switch configuration. Electrical wiring has been inspected and no indications of arcing or other damage were noted. (Ref. Board Action No. 0153 and TPS CM-IV-081). ITEM CLOSED			
59	Spectral assessment report --- Baseline information only. No Analysis Summary required.	2-10	2-10	2-19	
		The results of Panel 10 preliminary visual inspection have been prepared and forwarded to the 204 Review Board. ITEM CLOSED			
60	History of all Apollo Program fires --- Baseline information only. No Analysis Summary required.	2-13	4-1	4-1	
		Data received and has been reviewed for applicability. No correlation with past fires and the AS-204 accident were noticed. ITEM CLOSED			

ENCLOSURE 18-52
D-18-154

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
61	Spark ignition possibility	3-20	4-1	4-1	
		Electrostatic spark ignition testing determined that ignition by electrostatic discharge is not probable explanation of a ignition source. For details see Panel 8 final report. ITEM CLOSED			
62	Water glycol pump failure on Spacecraft 008	2-22	3-16	3-17	
		Pump cap configuration on S/C 008 was plastic. It has been determined that the configuration S/C 012 utilized an inconel cap. This has been validated during teardown of the ECU. Inspection showed that the inconel cap allowed no leakage into the pump motors and that the pumps were in satisfactory condition. ITEM CLOSED			
63	Oxygen flow rate sharp increase to measurement limit 2324:03	2-13	2-23	2-23	
		Tests and data have determined that 0_2 flow rates are affected by crew activity. Crew activity has been correlated to the rise in 0_2 flow. ITEM CLOSED			
64	Oxygen flow master alarm time excessive, 27 instead of 15 seconds 2145:54	2-13	2-23	2-23	
		It can be inferred that this was not a malfunction because this period of high 0_2 flow was interrupted by cyclic accumulator action, and because the time delay worked properly at all other times including during the accident. ITEM CLOSED			

C-2

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
65	ECS water glycol system history during test --- Baseline information only. No Analysis Summary required.	2-10	2-10	2-19	
		Input provided to Board. Action completed. ITEM CLOSED			
66	Oxygen system history during test --- Baseline information only. No Analysis Summary required.	2-13	2-15	2-15	
		Input provided to Board. Action completed ITEM CLOSED			
67	Communication System history during test. --- Baseline information only. No Analysis Summary required.	2-14	2-15	2-15	
		Input provided to Board. Action completed. ITEM CLOSED			
68	Review of all elapsed time indicators used on S C 012 of type to be removed before flight.	2-10	2-15	2-15	
		A check was made of all of these indicators on S/C 012 and found to be satisfactory with no evidence of short circuits or burning. (Ref. TPS S/C 012-054). ITEM CLOSED			

ENCLOSURE 18-52
D-18-156

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
69	ECS Fire at AiResearch	2-19	3-7	3-7	
		The fire which occurred on April 28, 1966 during the mission life qualification test of the ECS was attributed to ignition of electrical heater tape which was installed as part of the test equipment. No such commercial grade tape was used on Spacecraft 012. ITEM CLOSED			
70	VHF-AM Receiver failure encountered on Spacecraft 008	2-13	2-15	2-17	
		This was not a transceiver failure but was caused by a cut in a wire. This failure has no applicability to S/C 012. ITEM CLOSED			
71	Suit loop return valve leak encountered on Spacecraft 008	2-13	3-6	3-7	
		Failure data obtained from NAA and applicability of failure reviewed with respect to 204 accident. It has been determined that the leakage problem encountered on S/C 008 cannot be associated with the cause of S/C 012 accident. ITEM CLOSED			
72	MTVC (Manual Thrust Vector Control) engage came on during earlier tests of Spacecraft 012 (Ref. DR 0868 dated 12 28 66).	2-10	3-6	3-6	
		After an inspection of the SCS wiring schematics associated with the MTVC mode and a review of all its associated data, it is concluded that the MTVC signal was a "False" signal. The malfunction was probably in the harness between the SCS and the PCM system. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
73	Identify all AC wires going to ECU --- Baseline information only. No Analysis Summary required.	2-10	3-3	3-3	
		All wires identified for two interface connectors. ITEM CLOSED			
71	AC Bus 2 phase C short during prior test on spacecraft 012 (Ref. DR 0903 dated 1-13-67)	2-10	3-19	3-19	
		This short occurred while obtaining a voltage measurement. A 1/8 amp fuse was blown in the instrumentation circuits. It was determined that the fuse protected the AC 2 instrumentation system and this short had no relation to the accident. ITEM CLOSED			
75	Relay terminal wires exposed on 15 second timer on Spacecraft 012 (Ref DRS 692 dated 11-27-66)	2-23	2-24	2-24	
		Permanent Installation and Removal Record shows relay was potted and properly reinstalled. Post test evaluation shows potting on relay is intact and relay was properly installed. Test data shows relay performed its function properly. ITEM CLOSED			
76	Review of Panel 24 difficulties on 012	3-3	3-14	3-14	
		Thirteen DR actions were noted. The major problem was wire insulation damage because of the very tight envelope allotted to this panel. Tests have shown that electrical continuity was present after the fire and that no damage of any significance has been incurred by the switches, panel wiring or connectors. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
77	Three Saturn S-IVB measurement anomalies 2325:44	2-14	4-1	4-1	
		The reason for this data change has not been found, but at this time, 2325:44, it is considered to be unrelated to the incident. ITEM CLOSED			
78	"Buttermilk Odor" in Suit Circuit G s 1810	2-14	3-7	3-7	
		An evaluation of the reported odor has been completed. No impurities were noted from the K-bottle source; also no particular suspect item was identified as emitting a "sour milk" odor, although some RTV potting compounds have a pungent odor that may fit this odor description. ITEM CLOSED			
79	SCS Yaw ECA Female Connector J95 Blackened Areas	3-3	3-14	3-14	
		Other ECA connectors and mating connector show no similar damage. Pins 4, 42, 80, 81, 82 have a blackened area. The area around pins 80, 81, and 82 has been shown to be a previous repair. The mating connector was perfectly clean. Pins 4 and 42 were spares. It was concluded that the connector had nothing to do with the fire. ITEM CLOSED			
80	+Roll Output 2331:14.5 to 2331:15.0	2-13	2-23	2-23	
		Tests at MSC have shown that the rotational controller will produce an output when hit, even though the handle is pinned and locked. The handle was found pinned and locked, and the data therefore indicates a physical blow to the controller by one of the crew members. ITEM CLOSED			

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STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
81	Gassing characteristics of Pyro batteries	3-6	3-7	3-9	
		Preliminary tests have been completed at MSC. Results indicate that is only a 2 psi pressure increase at normal room temp. during a 16 day period. Another battery was tested at 105 ± 5 degrees F. and under worst conditions, H_2 venting would occur after approximately four days. Post test inspection of batteries showed them to be in satisfactory condition. (Ref. Board Action 0112). ITEM CLOSED			
82	VTVC was changed at 2331:18.	2-14	2-23	2-23	
		For some unknown reason, the T-handle of the translation controller was turned to a full clockwise position. There can be much speculation as to how and why it was turned, but the answers are not considered significant. ITEM CLOSED			
83	Start Senior Pilot activity (slight increase in heart rate and change in respiration) 2330:22	2-23	3-1	3-1	
		A moderate increase in heart and respiratory rates at this time. These data do not indicate the degree of activity that would be expected had the Senior Pilot been aware of an emergency situation. ITEM CLOSED			
84	Senior Pilot heart rate increase, aware of danger 2331:01	2-23	3-1	3-1	
		A marked change in the Senior Pilot's respiratory and heart rate was seen at this time and continued until loss of signal. This physiological response is compatible with the realization of an emergency situation. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
85	Shorting in MDAS octopus cable and connectors	2-25	4-1	4-1	
		Shorts were found on the octopus cable which provided power to the MDAS The MDAS was still operating until LOS. The shorting was found to be superficial and a result of the fire. ITEM CLOSED			
86	Astronaut shocked during Spacecraft 101 Crew Compartment Fit and Functional Check	2-24	2-27	3-7	
		The short circuit experienced in Block II S/C 101 at Downey occurred because the torso harness utilized was of Block I configuration and in poor condition due to previous usage. If the same type short occurred in S/C 012, the voltage could not have been transferred to the crewman because of the differences in the overall Block I hardware. ITEM CLOSED			
87	Accumulator quantity and glycol pump inlet pressure start increasing to upper limit 2331:15.1	2-13	3-14	3-14	
		Accumulator quantity change attributed to change in water-glycol pressure. Pressure change attributed to boiling of water-glycol within the lines when subjected to intense heat. ITEM CLOSED			
88	CO_2 absorber outlet temp. starts increasing 2331:16.0	2-13	2-14	2-14	
		Post test observations indicate that loss of pressure suit circuit integrity occurred in the Command Pilot's pressure suit and/or return hose. Such an opening would allow warm cabin air to be drawn into the suit compressor. The CO_2 Absorber Outlet Temp. indicates that the CO_2 Absorber acted as a heat sink until this time when it and the suit manifold temp. began to increase. ITEM CLOSED			

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D-18-161

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS: Investigation/ Validation Action In Work	STATUS: Validation Completed	ANALYSIS: Did Not Cause Accident	ANALYSIS: May have Contributed to Accident
-9	Q Ball circuit integrity	3-6	4-1	4-1	
		The Q-Ball was not electrically mated for the plugs-out test (OCP-0021). However, the cable was "hot" up to the Q-Ball connector. Resistance checks revealed no anomalies in the Q-Ball cable. ITEM CLOSED			
90	Suit flow indication at low limit for Command Pilot from 2331:18.5 through LOS, Senior Pilot from 2331:18.5 through LOS, and Pilot from 2331:19.6 through LOS.	2-22	4-1	4-1	
		When cabin pressure rises rapidly, the increase pressure results in restricting or stopping the flow. In addition, loss of integrity of inlet side of the suit circuit causes a drop in suit flow indication. ITEM CLOSED			
91	Accumulator quantity reached upper limit 2331:17.1	2-22	3-14	3-14	
		Indicates beginning of overpressurization in the water-glycol circuit due to thermal expansion of the fluid. ITEM CLOSED			
92	Glycol evaporator liquid temperature increasing 2331:17.5	2-22	3-14	3-14	
		Heating in the area to the left of, or within, the ECU. Supported by water-glycol pump inlet and outlet pressure and accumulator quantity. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
93	Command Pilot's Live Mike from approximately 22:18 to some time during the incident	2-23	3-18	3-18	
		Data indicates that the live mike condition began at approximately 22:18 and continued through the time the fire was first reported. An investigation on the Command Pilot's audio circuit has been completed. Based on the findings, it has been concluded that the live mike condition cannot be considered a source of ignition. ITEM CLOSED			
94	Initial investigation determined that cabin air fan no. 1 shorted.	2-22	4-1	4-1	
		Post test inspection of Cabin Fan No. 1 has indicated shorting in Phase A and C circuits. Continuity checks of the cabin fan were satisfactory. The shorts were determined to be in the power cable. Due to the lack of fire propagation material and physical inspection, it is concluded that these shorts were not the cause of the accident. ITEM CLOSED			
95	Etching of Teflon wire insulation a. ECI harness b. Gas chromatograph connector	3-17	4-1	4-1	
		All teflon insulated wiring is required to be etched before potting Pretest records were examined to determine whether they show that these cable connectors were etched as required. Etching of the gas chromatograph wires was accomplished. Etching of the ECI harnesses was not required as it was the latest configuration. ITEM CLOSED			
96	Salt current limiter panel short to teleflex cable	2-22	3-13	3-14	
		Terminal board 61 to be examined for evidence of shorting and 82556 resistors and conformal coating for overheating. A more detailed examination disclosed that there was no actual contact between the teleflex cable and the terminal board, and that there was no evidence of shorting or overheating. ITEM CLOSED			

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
97	Panel 150 not installed and lying loose	2-22	3-14	3-14	
		Panel 150 has been inspected for arcing as part of the Spacecraft disassembly plan. (Reference Board Action Item 0120). There was no evidence of arcing or material outflow from any components on the panel. ITEM CLOSED			
98	Command Pilot cobra cable and PGA connectors suspect	2-22	4-1	4-1	
		Cobra cable connector and pressure garment assembly (PGA) connectors have been examined for arcing and condition of pins. No arcs were found. Tests were conducted simulating the disconnections of these connectors while "hot". No ignition occurred in a gaseous mixture of oxygen and methyl ethyl ketone (MEK). ITEM CLOSED			
99	BMAG Power Switch Position During Accident Indeterminate	2-22	3-8	3-14	
		BMAG switch was examined to determine position during test, when position was changed, possibility of false detent position, and effect of this switch being in test position and also being in false detent position. Switch determined to have been in proper position before crew report of fire. ITEM CLOSED			
100	Close-out found on battery terminals and other equipment	2-22	4-1	4-1	
		The flash and firepoint of this polyvinyl chloride tape was established as 485°F. Inspection of the areas in which the tape was used has determined that the tape did not start the fire but did support combustion. ITEM CLOSED			

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STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
		2-22	3-21	3-21	
101	ECU back pressure controller	Back pressure controller examination revealed that motor rotates satisfactorily, and that all electrical continuity was within spec limits. ITEM CLOSED			
		2-24	4-1	4-1	
102	Senior Pilot inlet hose disconnected	The inlet hose of the Senior Pilot was found disconnected. Investigation by Panel 11 revealed a sooting pattern which could have been made if the Senior Pilot's inlet hose was disconnected. It is inferred that the Senior Pilot disconnected his hose in preparation for emergency egress. ITEM CLOSED			
		2-22	3-18	3-18	
103	Service propulsion system chamber pressure data DC drop	The service propulsion system SPS chamber pressure is sampled 100 times a second. The circuitry has been reviewed to determine if this data would show any significant DC power changes. No significant change was noticed during the period of the AC glitch at 2330:54.85. ITEM CLOSED			
		2-22	3-2	3-9	
101	Battery B Loading	Battery B Loading was indicated at 3.52 amps compared to 1.76-1.9 amps for batteries A and C and 2 amps. A detailed evaluation of the data showed the difference was due to a PCM zero shift and not real data. ITEM CLOSED			

ENCLOSURE 18-52

D-18-165

STATUS OF INVESTIGATION ITEMS

ITEM NO.	ITEM	STATUS		ANALYSIS	
		Investigation/ Validation Action In Work	Validation Completed	Did Not Cause Accident	May have Contributed to Accident
105	Suit wiring short circuit	3-8	3-28	3-28	
		Short circuit damage has been uncovered in part of the communications cabling on the Command Pilot's suit. Detailed inspection of the shorted wires revealed that the shorting and damage was due to external heat and burning.			
					ITEM CLOSED
106	DC wiring for the Environmental Control System instrumentation was found burned through	3-23	3-31		3-31
		The probable cause of the accident is in the wiring providing instrumentation power for some of the ECS instrumentation.			

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

March 21, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communications Subsystem

Item [illegible]
TPS N/A

Observation: Between [illegible] to [illegible] GMT noise sounds were received on S-band

Discussion and Analysis:

The noise sounds were analyzed by Bell Labs and MSC. The results are not conclusive as to what caused the sounds. The sounds were similar to those of tapping and brushing a microphone. During the time period the microphone was "live," noises of this nature occasionally were received; however, the frequency of the noises during the period of [illegible] to [illegible] GMT was much higher. A relaxed breathing cadence was superimposed on the sounds. The sounds were recorded on both the S-band and VHF voice tracks, although the crew was on S-band. This is as expected, due to the ground communication system which retransmits the S-band through a VOX controller circuit over a VHF transmitter. These transmissions are received by the VHF receiver on the ground and are recorded. The ground receiver does not differentiate between transmissions from the spacecraft VHF transmitter and the ground VHF transmitter. The proof that the noises were generated through the S-band is the fact that the noise sounds appear on the S-band track first and, with a short delay, then appear on the VHF track. The delay is the time required for the retransmissions through the VOX controller circuit. Further, some of the sounds were not of sufficient level to trigger the VOX and, therefore, were not recorded on the VHF voice track

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 21, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Guidance and Navigation Subsystem Item #3
TPS N/A

Observation: Gimbal angle data indicates movement just prior to fire call

Discussion and Analysis:

Analysis of telemetered data from past testing of S/C 012 has shown the following signals are indicators of torque or angular disturburances of the G&N Navigation Base with respect to an inertially stabilized IMU:

1. Gimbal Torque Motor Input
2. Gimbal Angle Resolvers
3. AGC Registers Recording Gimbal Angles.

The recordings of the ten (10) sample per second gimbal torquer input from S/C-012 OCP's 0034, 0034A, 0005 and 0021 were reviewed by personnel from NASA G&N - ACED-MIT in an attempt to correlate individual crew member movement within the S/C to disturbances noted on the gimbal torquer inputs.

The analysis indicated that definite individual crew movement could not be determined.

The gimbal torquer input indicated S/C disturbance but cannot distinguish between left, right or center crewman caused motion, and/or disturbances caused by forces external to the spacecraft.

The AGC CDU registers are telemetered once every two seconds and can only be used to indicate the angular relationship which existed at the sample time. Changes which take place faster then the sampling rate will not be indicated.

Item 95 (Cont'd)

Based on the above, it has been concluded that only gross indication of Command Module motion can be determined and correlated.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1 , 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem — Item #4. TPS N/A

Observation: Increase on Ground Power Supply B at [illegible] GMT

Discussion and Analysis:

The four bit increase (4 amps) was observed on the ACE Control Room real time recorder and also on a playback from track 5. The interim output is recorded also on track 8. Track 8 did not show the 4 bit increase. Analysis of the interleaver wave train output at this period of time indicate that the magnitude of the wave train (track 8) output did decrease slightly at this time although the bit stream was readable and the 4 bit increase on power supply B was there.

During this period of time, there was VHF/AM transmitter keying which draws 1.1 amps with no modulation and an additional 4 amp with modulation. The VHF/AM transmitter is powered from the Post Landing Bus which is powered from both Main A and B buses in the CM thru isolating diodes. There was no other activity going on in the S/C at this time that could be detected from the data. Although the data is questionable, there are several factors that could have caused this indication

(1) The power supplies A & B could have momentarily shifted their shared load (Post Landing Bus Load) due to the power supply regulation characteristics. This could have occurred

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Item #. (Cont'd)

without being detected in the data since PSA current is sampled [illegible] milliseconds prior to Power-Supply B current. This phenomenon had been seen for longer periods of time where one power supply current would show a few bits increase and the other decrease.

(*) Another load could have been placed on at this time but since the data shows no other parameter activity during this period, there is no way this can be verified.

With the analysis that has been made and considering the time ([illegible] GMT) of this happening, it is concluded that this event could not have contributed to the cause of the fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

March 1 [illegible]

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #:
TPS N/A

Observation: Gas Chromatograph output started to change from [illegible] GMT until loss of data

Discussion and Analysis:

It has been determined that the gas chromatograph (GC) cable acted as an electromagnetic radiation detector (Ref. Item No [illegible]).

The gas chromatograph (GC) was not installed in Spacecraft 1 at the time of the accident. The GC connector was placed on the shelf of the gas chromatograph compartment. The connector was not bagged, and AC bus 1 phase A power was applied to the connector through a closed circuit breaker. Twenty-two gauge wire was used, protected by amp circuit breaker. The circuit breaker for the GC was found to be open following the accident, with a heavily sooted condition which is indicative of opening during the early portion of the fire. The harness was not tied down in a flight configuration because the GC was not installed.

Two physical peculiarities were noted concerning the GC wiring and the connector. After the accident the harness and connector were found on the floor with the GC connector laying on a big harness. Two spot ties of this harness were found unblackened as a result of being protected by the GC connector.

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Item #5 (Cont'd)

The side of the connector that lay against the big harness and protected the two spot ties is badly burned and the potting at the back of the connector is melted. The GC connector was stuck to the big harness and had to be pried loose with a tool. It can be inferred that the connector was burning in a different location but fell or otherwise moved to its final location prior to the time the fire swept across that portion of the floor. It can also be inferred that the connector protruded beyond the GC compartment shelf and was burned in that location before it fell to the floor.

Secondly, the two GC AC wires exhibited peculiar melting characteristics. The output signal leads from the connector were fed through a fiberglass sleeve. One hundred-fifteen volt AC power was carried to the connector through a twisted pair of teflon-insulated conductors. These power conducting wires were run along the signal leads and were occasionally tied together. The power wires show a number of copper balls attached to their surfaces. This is the only instance that wires in this condition have been found in Spacecraft 3L2. The shorted DC wires to the J185 connector do show a couple of droplets; these are still being examined.

All attempts to simulate this condition by either short circuits or by application of external heat have not resulted in a similar appearance of the AC wires. It is inferred that these wires were subjected to both a short and to external heating from the fire. It is also inferred that this condition resulted as the harness fell through the flame to the floor.

X-ray and continuity tests of the connector pins and input wiring showed no evidence of arcs or short circuits. For this reason, this is not a suspect fire initiator.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 1[illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communications Subsystem

Item #
TPS N/A

Observation: VHF-FM video drops out for [illegible] milliseconds at [illegible] GMT

Discussion and Analysis: Tests completed at Collins Radio Company on a similar VHF-FM transmitter (reference Collins Radio Company report dated [illegible]) show that the received video signal during the noted time can be matched very closely by a momentary dropout of the AC supply (all three phases) to less than 50 volts or a dropout of DC supply to less than [illegible].5 volts for a period of [illegible] to [illegible] milliseconds. Comparison with Investigation Items 7 and 8 leads to the conclusion that this was an effect of an AC bus [illegible] power interruption.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem — Item #7, TPS N/A

Observation: The instrumentation system detected a transient on all three phases of AC bus 2 at 23:30:54.85 GMT

Discussion and Analysis:

An AC bus 2 voltage transient was observed approximately nine seconds before the crew report of fire. There are three reasons this condition could have existed:

(a) Momentary short or interruption of DC bus B input power to inverter number 2.

(b) Momentary short on one or more phases of inverter number 2 output.

(c) Removal of a major portion of the load from inverter number 2.

Special tests were conducted on spacecraft 008 at MSC to show the time relationship between the over-voltage indication and associated changes of other equipment outputs from the spacecraft.

Voltage regulation tests were run on the ground power supply at Launch Complex 34 under similar load conditions (30 amps) to that existing on DC bus B in spacecraft 012 at the time of the accident.

These tests indicated that a short circuit in the range of 5 to 25 milliseconds drawing approximately 75 amps caused an immediate drop in bus voltage of 13 to 15 volts, recovering to about 3.5 volts below steady state conditions after one to 1.5 milliseconds. The voltage remained constant until the short cleared at which time it over shot steady state conditions by about 10 volts recovering to steady state by 1. to 1.5 milliseconds.

Item #7 (Cont'd)

It is concluded that the probable cause of the AC bus ' transient and associated indications was a momentary short (' to ' milliseconds) of DC bus B affecting the input voltage to inverter '.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 1 , 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communications Subsystem

Item #17
TPS N/A

Observation: C-band transponder drops to zero volts for approximately two seconds from 233:54.8 to 233:57.0 GMT .

Discussion and Analysis:

Tests by Collins Radio Company (reference TWX dated 1-30-67) indicate that the transponder output characteristics can be matched by a drop in 3 phase AC voltage or phases A and B, or B and C. One phase loss would not cause the effect.

Dropout for very short intervals causes the C-band transponder to go to a protective mode to prevent magnetron damage. Normal recovery time for the C-band transponder is approximately 1.7 seconds.

Comparison with Investigation Items 6 and 7 leads to the conclusion that this was an effect of an AC bus 2 power interruption.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March [illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #:
TPS N/A

Observation: Oxygen Flow Rate increased to off-scale high at [illegible] GMT

Discussion and Analysis:

Telemetered data indicate that the high oxygen flow rate conditions for the last 30 seconds (/330:30.4) before the fire call can be attributed to the apparent high level of prime crew suit leakage at low suit-to-cabin differential pressure, magnified by apparent crew activity.

There has been considerable speculation as to whether the high flow could be indicative of a sensor and/or associated wiring difficulty.

The oxygen flow sensor circuit includes two separate outputs. The signal circuit going to the Pulse Code Modulation Telemetry System (PCM) is conducted to the PCM system through a twisted shielded pair of wires. A short circuit between the signal lead and either the return wire or the shield braid would cause a zero output (no flow) reading on the oxygen flow indication. It is highly improbable that any short circuit between the signal lead could occur without a prior short circuiting to the ground lead or shield lead.

Item #9 (Cont'd)

The second output from the oxygen flow sensor circuit goes to a time delay relay to indicate high flow alarm. It is on the ground circuit return side of the relay. A ground circuit completion is required to indicate high oxygen flow. This is supplied from a separate circuit from that going to PCM, and a ground on this line could not affect the PCM flow rate indication.

Single failures could exist within the bridge circuitry controlling the flow sensor which would indicate high flow rates on both the PCM output and the signal to the relay. These, however, will require examination of the oxygen flow sensor box to confirm or deny this possibility. A preliminary examination disclosed shorts to ground in the flow sensor; shorts to ground will produce a zero or no flow output indication. The flow sensor box is being torn down at the present time. It should also be noted that the location of the oxygen flow sensor was a high fire damage area, and that the sensor would be expected to be damaged by the fire.

Based on the above, it is concluded that the high oxygen flow data indication was valid, and that there was no malfunction of the sensor and/or associated wiring prior to the fire call.

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IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control System

Item #12
TPS N/A

Observation: Data indicate initial cabin temperature increase at 2331:0[illegible] GMT

Discussion and Analysis:

The initial cabin temperature increase (measurement CF0002T) was observed at 2331:0[illegible] GMT.

This measurement is sampled one time per second on PCM.

Preliminary data determined that the cabin temperature transducer response time is approximately 5 seconds to 63.3 percent of full scale for a step increase; however, initial response time was unknown.

Tests conducted at AiResearch determined that the cabin temperature sensor would show an initial response of .25°F within 200 to 300 milliseconds when subjected to air at 130°F. In addition, the sensor output increased to 63.3 percent of full scale (125°F) in four seconds when subjected to an air temperature of 130°F.

It is, therefore, determined that the time of cabin temperature increase start is accurate to within ± 1 second.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #13, TPS N/A

Observation: Cabin pressure increase began at 2331:06.818 GMT (battery pressure transducer)

Discussion and Analysis:

This measurement, CC0188P, was not installed in its final configuration since the flight batteries were not installed. The transducer lay on the floor of the cabin and, therefore, sensed cabin pressure instead of battery compartment manifold pressure.

The transducer has a 0 to 20 psia range and a response time of 1 millisecond. No additional filtering occurs on its PCM input circuit.

The measurement is sampled ten times a second on PCM.

It is, therefore, determined that the time of cabin pressure increase start is accurate to within ±100 milliseconds.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

February 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #14
TPS N/A

Observation: Cabin pressure increase began at 2331:08.417 GMT (measurement CF0001P)

Discussion and Analysis:

The transducer has a 0 to 17 psia range and a response time of 100 milliseconds. The measurement is sampled once a second on PCM.

Because of the low sampling rate and limited range of this measurement, the most accurate time and value of cabin pressure increase should be from measurement CC0188P (Item #13).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 1 , 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Guidance & Navigation Subsystem — Item #1, TPS N/A

Observation: The inertial guidance gimbal angles measurements showed a change starting at approximately 2331:15 GMT to a maximum value between 2331:18 and 2331:19 GMT.

Discussion and Analysis: It has been determined that the change in gimbal angles data is attributed to the increase in command module pressure. Following 2331:19 GMT, the gimbal angles data started to return to their original levels. This change in the data traces is determined to be the relief of the pressure or rupture of the pressure vessel. This determination has been substantiated by data obtained during the vacuum chamber test.

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IN REPLY REFER TO:

February 1[illegible], 196[illegible]

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #1:
TPS N/A

Observation: Entry battery B power transferred to main bus B and simultaneously entry battery C power transferred to main bus A at [illegible] GMT

Discussion and Analysis:

Two ground measurements and six PCM measurements show that the above occurred. These data are further substantiated by the position of switch S[illegible] on panel [illegible]. The switch position is indicative of pilot action to place the batteries on the buses. This action took place approximately eight seconds after the fire call.

It is conjectured that pilot action may have resulted from smoke obscuring the floodlights, giving the impression of loss of ground power, or the desire to keep power on the suit compressors in the event of loss of ground power because of the fire.

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IN REPLY REFER TO

February 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem — Item #17
TPS N/A

Observation: Entry battery A power transferred to main bus A and simultaneously entry battery C power transferred to main bus B at 0331:13.6 GMT

Discussion and Analysis: Four PCM measurements show that the above occurred. These data are further substantiated by the position of switch S9 on panel 22. The switch position is indicative of pilot action to place the batteries on the buses. This action took place approximately nine seconds after the fire call.

It is conjectured that pilot action may have resulted from smoke obscuring the floodlights, giving the impression of loss of ground power or the desire to keep power on the suit compressors in the event of loss of ground power because of the fire.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #18 TPS N/A

Observation: The master caution warning light came on at 2331:14.7 GMT

Discussion and Analysis: This light was the result of a high oxygen (O_2) flow indication. The oxygen flow rate measurement increased to the upper band limit of 1.06 lbs./hr. or five volts at 2330:59.4 GMT. Whenever the O_2 flow rate instrumentation voltage reaches 5.3 volts or greater and stays at this voltage level continuously for 15 seconds, the master alarm will come on. A time delay was added to inhibit the alarm because of periodic action of the cyclic accumulator every 10 minutes for a 10-second interval.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #1[illegible]

TPS N/A

Observation:

Suit Supply Manifold Temperature began to increase at 23[illegible] GMT

Suit Compressor Inlet Temperature began to increase at 23[illegible] GMT

CO_2 Absorber Outlet Temperature began to increase at 23[illegible] GMT

Discussion and Analysis:

The configuration of the pressure suit circuit was such that the crew would be isolated from the cabin at the time fo the fire. Post-test observations of the end of the Command Pilot 's pressure suit umbilical hose segments indicate that the hose returning from the suit to the ECS was "very sooty" and dark. The corresponding hose segment for the Pilot's hose was white and clean. This information would indicate that the loss of pressure suit integrity occurred in the Command Pilot's pressure suit and/or return hose. Such an opening would allow warm cabin gas to be drawn into the suit compressor. The suit compressor inlet temperature (CF0153T, range 50 to 150°F) began increase from 77°F at 2331:13.0 GMT. The CO_2 absorber outlet temperature (CF0154T, range 90 to 200°F) indicates that the CO_2 absorber appears to have acted as a heat sink until 2331:[illegible] GMT at which time this temperature and suit supply manifold temperature (CF[illegible]T, range 50 to 95°F) began to increase.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communications Subsystem — Item #20, TPS N/A

Observation: A momentary interruption was observed in VHF-FM and S-Bank data between 2331:17.398 and 2331:17.659 GMT

Discussion and Analysis: The momentary interruption in VHF-FM and S-Band between 2331:17.398 and 2331:17.659 GMT is attributed to a soft short circuit occuring in the communication wiring.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 16, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Crew Biomedical Equipment

Item #21
TPS(s) S/C-011
S/C-056
S/C-076
S/C-085

Observation: Inspection report of Biomed Recorder

Discussion and Analysis:

The Medical Data Acquisition System (MDAS) was removed from the spacecraft and physically inspected. MDAS was found to be in exceptionally good condition with only minor smoke damage.

The data tape was reduced and valid data obtained except for several noise glitches which appeared on the biomed data channels. These glitches occurred randomly. The first one at 1828:02 GMT and the last one at 2324:00 GMT. These glitches or noise spikes are believed to be caused by RFI which has been duplicated by post test bench checks.

From the MDAS data playbacks, time code amplitude variations were noticed. Representatives from the MDAS tape recorder and tape vendors stated that these variations may be caused by handling (fingerprints, etc.) and by dust.

The MDAS time trace was also inspected for indications of a DC dropout. No dropouts were found. From the time the MDAS was turned on and the timer reset (1738:02 GMT) until LOS of the timer (2331:21.? GMT), the timer operated normally with no loss or change in timing. Special tests were conducted to determine the effect on the timer from a main DC bus voltage transient. Voltage

transients from 24 volts to 8 volts and 5 volts for 1.5 ms to 8.8 ms showed no effects on the timing. The only transient that effected the timing was a voltage drop from 28 volts to zero for a duration of 10 ms to 25 ms.

Based on the PCM and the MDAS data, there are no indications that the MDAS contributed to the cause of the fire.

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IN REPLY REFER TO

March 1[illegible], 1[illegible]

INTEGRATION ANALYSIS SUMMARY

System Affected: Gas Chromatograph

Item [illegible]
TPS N/A

Observation: Seven gas chromatograph variations observed in the time period [illegible] to [illegible] GMT.

Discussion and Analysis:

The gas chromatograph (GC) was not installed for this test (OCP-K-0021). The connector which carries the telemetry data signals and the required AC power was open ended and was placed on the GC shelf prior to the test. Power to the AC line in the connector was turned on during the test per the test plan.

Examination of records show variations on the GC trace seven (7) times prior to [illegible] GMT. Further investigation of SC-[illegible] data measurements showed that the GC trace variations correlated with power changes in various SC systems

It was determined that the telemetry data line in the connector has the characteristics of an antenna, and consequently can detect changes in electromagnetic radiation within the spacecraft

This phenomenon was verified by tests conducted in SC-[illegible] CM at MSC.

The time of the aforementioned trace variations and correlation to system power changes are listed below:

1. [illegible] GMT. GC trace changed in exact correlation with a rise in the VHF/FM RF output (CT-[illegible]V) when the transmitter was turned on. The GC output change was 2 to [illegible]

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2. 2200:54 GMT. This trace variation correlates with middle gimbal angle stabilization loop, GC 2147, responding to a fine align mode.

3. 2219:23 GMT. This change in the GC trace correlates to G&N going to coarse align.

4. 2220:90 GMT. This change in GC trace correlates with G&N going to fine align.

5. 2234:40 GMT. The Pilot turned updata link to UHF.

6. 2253:13 GMT. ECS reported high O_2 flow and asked the crew if their face plates were open. The crew reported "No".

During their transmissions much SC background noise was encountered.

7. 2255:40 GMT. Spacecraft commander (CMD) had just changed cobra cables and was in the process of communications check at this time.

Conclusions drawn from the above data is that GC telemetry data line acted as an electromagnetic radiation detector.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communication Subsystem

Item #23
TPS N/A

Observation: Final loss of all spacecraft data observed 2331:21.0 to 2331:22.42 GMT

Discussion and Analysis: The final loss of all spacecraft data is attributed to a loss of power or loss of a coax cable due to the burning and shorting of wire harnesses during fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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IN REPLY REFER TO

February 23, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization & Control Subsystem — Item #24, TPS N/A

Observation: MTVC Pitch Rate Command observed at 2330:54.847 GMT

Discussion and Analysis: This command was seen on CH0074 (MTVC pitch rate) and CH1074 (MTVC yaw rate) as a one (1) bit change-of-state. The SCS frequently sees one (1) bit changes on measurements which are attributed to noise.

All data indicated that the SCS operated normally at the above time and did not contribute to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #25
#102
TPS N/A

Observation: The Senior Pilot's suit flow dropped to lower limit at 2331:09.618 GMT and then returned to normal flow indication at 2331:11.918 GMT. The Senior Pilot's hose was found disconnected.

Discussion and Analysis: At 2331:09.618 GMT the suit flow rate of the Senior Pilot was at the upper limit of the transducer (saturated) of 25.27 lb/hr. The flow rate per man was actually higher and was approximately 64 lb/hr per man. One-tenth of a second later, at 2331:09.718 GMT the flow rate had dropped to the lower limit of the transducer (6.15 lb/hr) and stayed there until 2331:11.818 GMT. It then returned to the upper limit at 2331:11.918 GMT. The other two suit flow rates remained at the upper limit during this period.

There are three possibilities that could explain the suit flow drop-off. These are:

(a) A momentary short in the suit flow transducer wires would explain the suit flow transducer going to the lower limit and returning to saturated flow again. However, the suit delta pressure and compressor delta pressure show a marked change coincident with the drop in suit flow, indicating that the suit flow in fact changed.

(b) If the suit outlet hose was disconnected, the suit outlet has a check valve in the suit which stops the flow to the suit giving an indication of no flow. The suit delta pressure and suit

compressor delta pressure should increase and, in fact, did increase. The decrease in these parameters within about 2 seconds after the increase can only be interpreted as suit burn-through and/or subsequent reconnection of the outlet hose. Disconnection and reconnection of the outlet hose within a 2 second time period is highly unlikely. If this argument is to hold, the suit must have burned through to re-establish flow and sometime later the outlet hose was reconnected to the suit. The outlet hose was found connected after the accident, which tends to weaken the argument in light of possibility (c) which follows.

(c) The suit inlet hose was found disconnected from the Senior Pilot's suit. An explanation of this could be that the Senior Pilot disconnected his suit inlet for emergency egress at the dropout of the suit flow.

Testing at MSC has confirmed that disconnecting a suit inlet hose will produce a dropout in suit flow similar to that which occurred at 2331:09.618 GMT. In addition the Senior Pilot's inlet hose was found disconnected and sooting was found on the inlet hose connector which infers it was disconnected during the fire.

Based on the above it is concluded that the Senior Pilot's hose was disconnected at 2331:09.618 GMT and caused the dropout in suit flow.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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IN REPLY REFER TO

March [illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #2, TPS N/A

Observation: Oxygen surge tank pressure started to decrease at [illegible] GMT

Discussion and Analysis: High oxygen flow rates were encountered for 60 seconds prior to the report of fire. These flow rates are attributed to suit leak rates and crew activity which placed a demand on the suit pressure regulator to supply oxygen at a rate causing a decay in the surge tank pressure.

Test data have shown that flows in excess of [illegible] will result in a decay in the surge tank pressure.

It is concluded, therefore, that the oxygen surge tank pressure decay at [illegible] GMT was the result of high oxygen flows into the suit loop and did not contribute to the initiation of the fire

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IN REPLY REFER TO

February 27, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #[illegible]

TPS N/A

Observation: Suit flow indications begin to fluctuate for the Command Pilot at 2331:12.9 GMT, for the Senior Pilot at 2331:[illegible] GMT, and for the Pilot at 2331:14.3 GMT. At 2331:[illegible] GMT the Pilot's suit flow began to fluctuate violently

Discussion and Analysis: Fluctuations in suit flow indications are characteristic results of restrictions in the suit flow caused by movements of the man

The time period for fluctuations in the Senior Pilot's suit flow coincides with the increased muscular activity indicated by Physiological Data

Increase in cabin pressure against the suit could increase the indication

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IN REPLY REFER TO

February 23, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stablization & Control Subsystem — Item #29, TPS N/A

Observation: Indication of RCS action at 2329:40 GMT

Discussion and Analysis: The data during this period has been reviewed in detail and indicated RCS action was found to be erroneous. The variation does not appear on the digital data from CIF VHF-FM which is best at this time.

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IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization and Control System

Item #30
TPS PIB-004
CM-IV-077

Observation: Rotation Controller output data indicates a transient of 1.5% at 2330:54.85 GMT

Discussion and Analysis:

The Rotation Controller (R/C) was charred, and the pistol grip handle badly burned. The boot at the pistol grip input to the device was partially burned away. The cover of the lid was buckled outward between the attachment screws on each side, evidently due to thermal stresses. The lower left rear corner (nearest astronaut's right knee) of the cover was disfigured and cracked.

A dark residue, apparently foreign to the pistol grip, was observed sticking to the right side of the grip. This residue was removed and determined to be a mixture of nylon and a terephthalate ester by chemical analysis.

The locking pin visually appeared to be intact; however, about one-sixteenth of an inch of unsooted pin was observed at the pin's exit point from the device which indicated that the pin had been slightly pulled out subsequent to soot deposition.

On the bundle, the polyethylene zipper tubing and the silicone rubber shrink sleeving were burned through from the cable egress point for approximately one foot. The cable and zipper tubing were not as badly burned over the remaining length left attached to the unit.

The insulation of four wires approximately one inch from the egress point of the cable from the device was nicked or split for about one quarter of an inch, or had the insulation burned and/or blasted away. Magnified examination of the exposed wiring indicated no arcing or shorting. Functionally these four wires are associated with the R/C direct rotation switch outputs and were not armed with 28 VDC for at least twenty minutes prior to the accident. Also the locking pin was installed at least twenty minutes prior to the accident which would not allow these switches to be actuated.

The radiographs indicated no anomalies in the R/C internal metal parts. In particular, the locking pin was determined to be intact.

The R/C cover was removed and no evidence of foreign material inside the device was observed. The potting on the terminal board in the lower rear corner of the device was darkened and appeared melted on both sides. Charring and crystalization of spot ties, and sooting of internal wire bundles was observed in the lower rear and middle rear of the device. The internal heat pattern appeared to be most intense in the lower rear left side of the device and then progressed upward and to the rear right side through the wires and components. Examination of the cover, which was bulged out (by thermal expansion) when attached to the controller, indicated that a hot gas flow pattern came from above the controller into the case through the cover bulges. The inside of the cover showed very definite indications of a hot gas flow

pattern where the hot gas came in from outside the controller, was deflected by heavy internal components, and then flowed through the wires and components to the other side of the mechanism.

The review of the data, the continuity check and the insulation check have shown no evidence that the rotation controller or the associated wiring were a cause or propagator of the fire.

Special tests have shown that the null output transients can be duplicated by a momentary interruption of AC Bus 2 Phase A input power. It is therefore concluded that the AC interruption caused the rotation control transient. Information concerning AC interruption is contained in Integration Analysis Summary Item #7.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem — Item #31, TPS N/A

Observation: Due to the "cold flow" characteristics of the teflon insulation, it is possible to have a breakdown of the spacecraft wiring insulation and resultant electrical shorts.

Discussion and Analysis: Teflon wire was selected for the spacecraft because of excellent resistance to high temperature, good dielectric properties, lightweight characteristics, etc. It has, however, in common with other plastic materials, cold-flow characteristics which permit the insulation to flow away from localized high pressure over long periods of time. It is possible that localized high pressure points, either between wires or between a wire and structure, could ultimately result in breakdown of the insulation. All wire bundles in the spacecraft which showed damage were carefully inspected for signs of arcing.

From all the investigation of arcs and shorted wires, there is no reason to believe that any of these can be attributed to "cold-flow".

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IN REPLY REFER TO

February 23, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization & Control Subsystem

Item #32
TPS N/A

Observation: SCS roll rate oscillations starting at 2331:03.85 GMT.

Discussion and Analysis: The SCS roll rate oscillations at 2331:03.85 GMT are an indication of crew movement in the spacecraft. This item correlates with launch vehicle accelerometer data, IMU gimbal angle data, and nothing more can be gained from additional study to try to determine the degree of crew movement.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Launch Vehicle

Item #33
TPS N/A

Observation: Launch Vehicle (LV) pitch and yaw accelerometers (DP1AOV-01-02 and CP1BOV-01-04) showed slight oscillation starting at 2331:04 GMT and increasing with maximum oscillation at 2331:20 GMT.

Discussion and Analysis: The LV pitch and yaw accelerometers output data were reviewed to determine relationship with crew movements during the conduct of OCP-K-0021 (i.e., changing of cobra cables). No correlation was seen except during the above period. It is, therefore, determined that these data only indicate movement of the spacecraft after the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power System

Item #34

TPS CM-CA-358

Observation: During an inspection of the S/C harness between inverter #3 and the Junction Box in the LEB, a suspect arc spot was found on the cover plate and wire where it would have been in contact with the plate. The wire has been identified as 28 volt Bus A power in the SCS subsystem.

Discussion and Analysis: No positive identification has been made to indicate that this arc initiated or occurred prior to the fire. The following facts have been determined.

The location of this arc is within the area selected by the Fire Panel as the probable source of the fire.

Water glycol which has been shown by tests to support and propagate fire when spilled on wires was known to have been spilled in this area in an earlier checkout.

The wire bundle was not protected from the sharp edge of the junction box cover plate by the nylon grommet edging.

Several possible propagation paths for the fire, had it been initiated at the junction box, have been found.

Item #3-(Cont'd)

The glycol spillage had been corrected by washing.

No change was noted in high sample rate data (200 samples per second), which should have indicated such a short, until after the time of spacecraft rupture.

Burning noted in the area of the junction box does not appear as severe as would be expected had the fire started here.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

March [illegible], 196[illegible]

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control System

Item #35
TPS N/A

Observation: Suit differential pressure begins to increase at 2331:0[illegible].4 GMT

Discussion and Analysis:

The cabin pressure began to increase at 2331:0[illegible].4 GMT.

The oxygen demand regulator senses cabin pressure. An increase in cabin pressure or a decrease in suit pressure will cause the diaphragm of the O_2 demand regulator to be opened allowing O_2 to flow into the suit loop.

The suit differential pressure (ΔP) also began to increase at 2331:0[illegible].4 GMT since it tends to follow the trend of cabin pressure. Crew movement at this time will also add to the increase in suit ΔP.

It is determined that the general rise in suit differential pressure was caused by increased cabin pressure and crew movement.

The rapid rise in the slope of suit ΔP curve at 2331:09.6 GMT is attributed to the dropout of the Senior Pilots (SPLT) suit flow.

The drop in the suit ΔP at 2331:11.5 GMT is attributed to the resumption of flow in the SPLT's suit inlet hose. The rapid rise in the suit ΔP starting at 2331:12.4 GMT was caused by the rapid increase in cabin pressure.

Item #3 (Cont'd)

Information concerning the drop of crew suit flow to lower limits at 233l:l.:.4 GMT is discussed in Integration Summary Analysis Item #9.

It is concluded that the initial crew suit differential pressure increase was caused by crew activities and the latter increase was caused by the rapid rise in cabin pressure.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 31, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Sequential System

Item #36
TPS N/A

Observation: Emergency Detection System (EDS) "Engine 8 out" light went out and came back on 8 seconds later, during the EDS tests at 20:52:23 GMT

Discussion and Analysis: During the time of the anomaly the launch vehicle "attitude reference fail" check was being performed. EDS bus 1 was turned off and the astronaut was to verify no change in the panel 5 status light. However, he stated that the "Engine 8 out" light went off. This light came back on 8 seconds later as reported by the astronaut and verified on the voice tape. Data review showed no switching in the cockpit from the time the EDS bus 1 went off for approximately 39 seconds. No further information is available since this is the "B" side of the light and is not instrumented. The "Engine 8 out" light wiring has been checked for continuity both in the spacecraft and the launch vehicle with no abnormalities detected. An intermittent condition of this nature could be located anywhere in the system, however, the event could not have caused the fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Items #37, 40, 87, 91, 92

TPS N/A

Observation: Water-glycol accumulator quantity starts decreasing at 2331:13.0 GMT. Glycol pump discharge pressure starts increasing at 2331:14.4 GMT. Accumulator quantity and glycol pump inlet pressure start increasing to upper limit at 3231:15.4 GMT. Accumulator quantity reached upper limit 2331:17.1 GMT. Glycol evaporator liquid temperature increasing at 2331:17.5 GMT.

Discussion and Analysis:

A decrease in the water/glycol (W/G) accumulator quantity was noted at 2331.13 GMT. The quantity indication continued to decrease until 2331.14 GMT.

During the time period 2331:06.4 to 2331:12.4 GMT, the cabin pressure increased from 16.40 to 16.94 and the battery compartment pressure transducer registered an increase from 16.70 to 18.05. Refer to Integration Analysis Summary #13.

The quantity measurement for the W/G accumulator is obtained from a transducer which monitors both the W/G and cabin pressure. The transducer W/G pressure is taken upstream of the accumulator bellows which are also vented to the cabin atmosphere. The bellows are designed to maintain a 7-9 psi differential pressure at the pump inlet and compensate for changes in cabin pressure. After the start of the fire the initial rate of cabin pressure increase was greater than the rate of pressure increase in the W/G lines. The W/G accumulator transducer, accordingly, sensed the

increase in cabin pressure and interpreted this as a decrease in W/G quantity in the same manner as if the cabin pressure had remained constant and the W/G pressure had decreased.

The accumulator quantity continued to show a decrease until the W/G pressure (recorded at the pump inlet) began to increase at a very accelerated rate (2331:15.4 GMT).

The W/G accumulator quantity transducer again sensed the change in pressure differential and interpreted this as an increase in W/G quantity.

The accelerated rise of W/G pressure is attributed to boiling of the liquid within the lines when subjected to the intense heat of the fire. This phenomenon has been duplicated by testing.

A pressure rise at a slow rate was initially detected at both the inlet and outlet sides of the W/G pumps at 2331:14.4 GMT.

The rate of pressure increase and final pressure measurement for the outlet side of the W/G pumps were less than those recorded at the inlet side. This is attributed to the pumps acting as a restrictor since they are only designed to supply a 29 to 30 psi pressure to the system.

The late sensing of a temperature increase at the glycol evaporator (2331:17.5 GMT) is attributed to system lag. The normal flow sequence of the W/G subsystem during this test is from the pumps through the SM glycol radiators, GSE cooling equipment, W/G reservoir and finally to the glycol evaporator.

In summary, none of the above findings are considered to have contributed to the original cause of the fire but were initiated as a result of the fire. Data indicate that the W/G subsystem continued operating as an integral unit until after CM and line rupture at which time the glycol then acted as a fuel for the fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Ground Support Equipment — Item #39, TPS N/A

Observation: Ground DC power commanded off at 2332:40.4 GMT

Discussion and Analysis: ACE data show that the ground DC power was commanded off at 2332:40.4 GMT and that power was off at 2330:47.4 GMT. This is in accordance with the emergency procedures.

ENCLOSURE 18-53

D-18-212

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Crew Equipment — Item #41, TPS N/A

Observation: Loose equipment which was stowed in the gas chromatograph compartment

Discussion and Analysis:

TPS 583 (checkout TPS) on S/C 012 specified that the following loose items were to be stowed in the gas chromatograph compartment at crew ingress:

1. 2 each - 16 mm seq. cameras
2. 1 each - 16 mm power cable
3. 1 each - hygrometer control unit
4. 1 each - hygrometer sensor cable and sensor
5. 1 each - hygrometer power cable

These items were stowed in plastic bags. The bags were removed by the Spacecraft Technician and passed out of the spacecraft after Command Pilot ingress and prior to hatch close-out.

The six items listed above were still in the Gas Chromatograph Installation Area as of February 10, 1967. The aforementioned spacecraft technician believes that the items have been moved within the area, but there is no evidence to support this belief. The cables were still neatly coiled as they were before the test.

In addition to these six items, the gas chromatograph pyro cable connector and power/sensor cable

connector are believed to have been placed on the floor of the compartment. After the incident, the pyro cable connector was in place on the floor of the compartment; however, the power/sensor connector was found on the aft bulkhead.

The primary area of interest was to determine if the crew had utilized any of the above equipment thereby causing the gas chromatograph cable and connector to fall on the aft bulkhead, therefore providing an explanation for the final location of the chromatograph connector.

Follow-up investigation showed that cameras' lenses and film had not been stowed for this test. It is therefore concluded that no final determination can be made as to crew activity into this compartment.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Caution and Warning Subsystem

Item #42
TPS S/C 053

Observation: Elapsed time indicator failure on S/C 014 and ETI inspection on S/C 012

Discussion and Analysis:

The elapsed time indicator for the Caution and Warning System was overheated and charred as a result of a capacitor short during a test on S/C 014 during factory checkout at NAA/Downey.

This time indicator and associated noise suppression capacitor for the Caution and Warning System were physically examined on S/C 012 and found to be satisfactory with no evidence of burning.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 22, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: None

Item #44
TPS MA-003

Observation: Bottle of MEK foun in white room

Discussion and Analysis:

A chemical analysis of the Methyl-ethyl Ketone (MEK) bottle found in the white room was completed in accordance with Board Action 0147.

The analysis determined that the material in the squeeze bottle was a very high quality MEK. The vaporization rate through the neck of the squeeze bottle in a controlled environment similar to the white room was established as seven millograms per hour.

Use of the MEK bottle on the day of the accident could not be determined.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 31, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control System

Item #45
TPS CM-CA-136
CM-CA-137

Observation: Two broken pressure transducers were noted on the ECU during post fire inspection

Discussion and Analysis:

The two transducers were identified as the suit inlet pressure and water glycol pump outlet pressure transducers. Both transducer connectors and associated wiring were damaged and electrical continuity checks showed all circuits open. No visual evidence of a fire path from within the transducers was found following removal of the covers. In addition, radiographic examination indicated no evidence of damage within the units

The cabin pressure and water glycol outlet pressure transducer data indicated normal operation both before and after the fire.

The cabin pressure exceeded maximum operating range (17 psia) of the cabin temperature sensor transducer at 23:31.13.4 GMT while the water glycol loop exceeded the transducer maximum operating range (-- psia) at 23:31.15.4 GMT.

It is concluded that the transducer damage did not contribute to but was the result of the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

February 15, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Crew Equipment

Item #40
TPS N/A

Observation: Bonding Straps on Crew Couches missing

Discussion and Analysis:

There are four crew couches grounding straps in the spacecraft, two from the floor to the spacecraft wall and two from the Z-strut to the center couch. The two from the floor to the wall were installed, and the other two were missing. They had not been installed due to parts shortage.

Bonding checks on the crew couches made after the test indicate resistances in the order of 1 ohm. While this is high compared with normal bonding requirements of [illegible] ohms, it is low enough to prevent any static charge buildup. It is thus determined that lack of bonding straps did not increase the possibility of a static charge buildup on the couch relative to the command module structure.

ENCLOSURE 18-53

D-18-218

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 15, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #47
TPS S/C-082

Observation: Screwdriver caused an arc in wire harness (Ref. DR 0917 dated January 23, 1967)

Discussion and Analysis: Investigation of this item was performed in accordance with Board Action 0060.

Discrepancy Report (DR) 0917 dated 1-23-67 states, arc drawn on technicians screwdriver during removal of cover panel for C15-1A52 J-Box.

Panel C15-1A52 is a wire junction panel located in the LEB, just left of the #3 inverter and below the gas chromatograph installation.

The technician was requested to remove the panel to allow for trouble shooting behind it. He removed the cover and the two holding screws on the left side of the panel and the bottom screw on the right side. To gain access to the top right screw, he removed bundle spot ties, separated the wires, and inserted the screwdriver between them. In the process of trying to remove the screw, the screwdriver drew an arc. An inspection was made of all the wires in the immediate bundle and one temporary wire repair was made with "mystic" tape. Since the screw head was so badly wollowed out, the screw was finally removed with a pair of vise grip pliers. Because of the offset of the plier jaws, it was not necessary to go between the wires for the screw removal. After the panel was unfastened, it was left ajar for access to accomplish the original purpose of the removal.

The next day a permanent fix of the damaged wire was made with heat shrinkable teflon tubing. The technician then redressed the wire bundle. He then re-installed the panel with the two screws on the left side of the panel plus the left bracket which holds the cover. The technicians on the next shift installed the two screws on the right side, plus the cover holding bracket, and the cover. Because new screws were used and the way the wires were dressed, it was possible to tighten the screws with the screwdriver at a slight angle without going between wires. No tests or reverification checks were made on the wires in the affected bundle.

To get a better understanding of the work which took place, a simulation was made on SC 014 with the same technicians who did the initial work on SC 012.

Inspection February 12, 1967 of SC 012 cover on C-15-1A52 J-Box revealed the following:

1. One wire adhered to the melted plastic on the bottom of the cover plate.

2. The unprotected bottom of the harness badly burned.

3. The portion of the harness behind the cover plate was in good condition.

4. The relay wires were scorched.

5. Nothing suspicious was noted at this time of the wire associated with screwdriver arcing incident.

Re-examination of the cover plate on March 3, 1967 revealed signs of possible arcing caused by another wire.

A final inspection on March 4, 1967 of the wires in the area involved with the screwdriver arcing incident found no evidence which can be attributed to initiation of the fire.

It is concluded that the area in which the wire was damaged by the screwdriver incident during the removal of the cover on C-15-1A52 did not contribute to the accident. However, the splitting of the wire bundles into two bundles and consequent rerouting of part of this bundle created the possibility for damaging adjacent wires in the wire bundle.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Ground Support Equipment — Item #48, TPS N/A

Observation: Configuration of ACE Control Room #1 and ACE Computer Room #1

Discussion and Analysis: ACE configuration established.

The ACE Control Room #1 and Computer Room #1 configurations have been defined and studied. All of the data indicate that the system operated properly, that no spurious commands were transmitted, and in no way contributed to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: CM Floodlights

Item #49
TPS(s) CM-CA-054
CM-CA-053

Observation: Review of past floodlight failures and floodlight examination and testing.

Discussion and Analysis:

Board Action 0169 directed the removal and investigation of the SC CM floodlights.

Removal and inspection of the floodlights were conducted in accordance with TPS CM-CA-053. Testing and evaluation of test results were conducted in accordance with TPS CM-CA-054.

Six qualified CM Interior Light Circuits were installed in SC 012 CM. These included the Left Hand Overhead (LHOH), Right Hand Couch (RHC), Left Hand Couch (LHC), Right Hand Strut (RHS), Left Hand Strut (LHS) and Right Hand Overhead (RHOH).

All interior lighting floodlights gave physical indications of having sustained extensive fire damage.

Of the six circuits that were known to be operating prior to the fire, three survived and functioned normally within the specification current limits following removal from the SC. The secondary circuits were not energized during the fire. All six of these circuits survived and functioned normally within specification current limits.

The three non-functioning circuits were the LHOH, RHOH and RHS primary circuits. These circuits were open and did not draw an imput voltage up to 28 VDC.

Item #49 (cont'd)

Visual examination of the aforementioned 3 lights indicated that they had been exposed to higher external temperatures than the other lights.

Tests performed by the vendor indicate that the inverter circuit of the lights will cease commutation at temperatures between 230 and 250°F. Failure of the circuit to commutate results in approximately 10 amps current drain and opening of a fuse is approximately 500 microseconds at six amps. After fuse opening, the circuit is open and does not draw current.

Since the lights that contained the non-functioning circuit were the same ones which sustained the higher heat damage it is deduced that their circuits reached temperatures above 230°F and decommutation caused their associated fuses to open.

In summary it is concluded that the floodlights were not an initiator or major propagator of the fire. In addition, the damage to their exterior surfaces and opening of the three primary circuits were caused by exposure to the CM fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 10, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Cryogenic Gas Storage Subsystem Item #50
TPS N/A

Observation: H_2 tank fan motor variation at 2326:30.4 GMT

Discussion and Analysis:

Variations similar to those noted at 2326:30.4 GMT appeared periodically prior to the accident.

Test Procedure for OCP-K-0021 requires that all GSE access connectors be disconnected during this test.

It was verified that GSE access connector J22 was not connected at the time of the accident. Connector J22 normally carries the H_2 Fan Motor measurement (SF0363V).

Verification was accomplished by physical checks at LC34, 2030 GMT, February 2 and by review of Quality Control LC34 checklist, FO-K-10011, for OCP-K-0021.

The H_2 tank fan motor variation noted at 2326:30.4 GMT is attributed to random noise. This incident did not contribute to the S/C 012 accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 15, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization Control Subsystem

Item #51
TPS S/C-022

Observation: Hole in the translation hand controller

Discussion and Analysis:

The translation control was mounted on CM 012 at the L/H side of the L/H couch and was noted after the accident to have a relatively large part of the upper R/H rear corner missing.

The translation control was inspected for fire damage at the MAB laboratory with the following results:

a. In general, the damage due to fire and intensity of charring and sooting is most evident at the upper right rear corner. Charring and sooting diminishes from that corner in general toward the bottom front area and the bottom rear area where little evidence of soot or heat searing is visible.

In this initial inspection, it did not appear that heating came from within the device. It also appears that the missing cover corner has been caused by a blow from the outside after the cover had heated above an embrittling temperature (greater than 1000°F). (Ref. Summary Report of TPS PIB-002)

b. The translation control was functionally tested and verified to be functioning normally. This indicates that the fire damage did not degrade the functional performance of the device. (Ref. Summary Report of TPS PIB-005.)

It is determined that the hole in the translation controller did not result from an action which may have contributed to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 15, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Waste Management Subsystem — Item #52, TPS N/A

Observation: Waste Management Subsystem blower failure (S/C 008)

Discussion and Analysis:

The Waste Management Subsystem (WMS) blower motor failed on S/C 008 after approximately three hours of continuous operation. Normal operation of the blower is for short periods (approximately five minutes or less) to provide gas flow only for the vacuum cleaner. Previously, the blower was used to provide gas flow during collection of urine and feces. Due to a design change, the WMS blower is no longer utilized during these operations and the hard lines involved connecting the blower to the selector valve have been disconnected and plugged. However, the electrical control of the blower by the selector valve has not been changed. Therefore, when the selector valve is moved to either the urine or feces position, the blower is started and forced to operate against a dead headed system. S/C 012 Waste Management Subsystem configuration was the same as S/C 008.

The WMS blower selector switch per recorded configuration was off at pre-ingress of the crew. Review of the OCP-K-0021 shows that the WMS blower selector switch was off immediately prior to the accident. Also, post test switch check list shows the WMS selector switch in the off position. Therefore, it is determined that WMS blower did not cause the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control System
Guidance and Control System

Item #53
TPS CM-CA-220

Observation: A survey should be made of the failure history of heaters of the types used on the spacecraft to determine if any failure modes can be related as a cause of the accident.

Discussion and Analysis: The following heaters were on board the spacecraft:

(a) Potable water heater - not powered for the Plugs Out Test
(b) IMU Heaters - no electrical short or burn-up type failures have occurred for this type of heater. These heaters were in sealed units.
(c) Eyepiece Heaters - one reported failure due to broken heater cable caused by insufficient cable length. The cable was lengthened.
(d) Gyro Heaters - two "out-of-spec" failures reported (tolerance $\pm 2^{\circ}$F). No electrical short or burn-up type failures. These heaters were in sealed units.
(e) Steam Duct Heater - not powered for the Plugs Out Test
(f) Urine Dump Heater - not powered for the Plugs Out Test

The review of failures on the S/C 12 heaters and of these generic types of heaters show no evidence of problems which could be associated with the accident.

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APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #54
TPS N/A

Observation: Leakage of Water/Glycol

Discussion and Analysis:

There has been a history of water/glycol leakage and spillage in spacecraft 012. Some of this occurred during tests at the factory and some occurred before and during the removal of the ECU at KSC. The characteristics of the inhibitor used in the coolant water/glycol fluid leaves a residue that is electrically conductive, hygroscopic and flammable. Leaks of water/glycol occurred in the lower equipment bay and Environmental Control Unit area during earlier tests on Spacecraft 012. These leaks were mopped up and connectors and accessible wire harnesses were washed with distilled water and alcohol, and dried with nitrogen.

After the accident, all connectors were carefully disconnected, photographed, and inspected for any signs of internal burning or arcing. No evidence of internal arcing or burning was found which indicated a fire source. However, if the leakage or spillage had not been adequately cleaned up, it would provide a flame propagation path.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: CM Reaction Control Subsystem — Item #55, TPS N/A

Observation: CM Reaction Control Subsystem (RCS) thruster temperature indicates pressure shell rupture

Discussion and Analysis: Measurement CR 46-1T CCW engine wall "A" system CM RCS showed nominal outside air temperatures (67.7°F) until 2331:19.8 GMT.

This time matches well the time indicated by G&N measurements and pressure measurements for pressure shell rupture (approximately 2331:18 to 2331:19 GMT). It is determined that the high temperature indicated by the RCS engine is an effect of the release of flame in the area by the pressure shell rupture.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 21, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #56
TPS S/C-061
CM-MA-005
CM-MA-006

Observation: Lithium Hydroxide Canisters utilized were non-flight configuration

Discussion and Analysis:

The lithium hydroxide (LiOH) canisters utilized during the conduct of OCP-0021 were unqualified, non-flight configuration and did not contain the 50% bypass provisions incorporated in the improved flight canisters.

A detailed review of the data associated with the crew oxygen suit loop indicates normal temperatures and circuit integrity until approximately 10 seconds after the "fire" call. At 2331:10 GMT both the suit supply temperature and LiOH canister outlet temperature started increasing which indicates loss of pressure suit circuit integrity, thus allowing warm gasses to be drawn into the suit compressor and thru the LiOH canister.

From the above it has been concluded that integrity of the LiOH canister remained until after the start of the fire. Also damage to the canisters was a result and not the cause of the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

February 15, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #57, TPS S/C-007

Observation: Analysis of gas from the two Beckman Analyzers

Discussion and Analysis:

Two (2) Beckman Oxygen Analyzers were located in the Pad 34 S/C White Room to extract cabin and suit gas samples. Serial No. 4 analyzer was utilized in extracting the first cabin gas sample after a twenty (20) minute purge. S/N 3 analyzer was utilized in extracting the suit gas sample and the second cabin gas sample after a ten (10) minute additional purge.

The MAB performed a lab analysis of gas samples taken from the analyzers to determine the presence of contaminants which would be indicative of cabin contamination (reference TPS S/C 012-007).

The determinations of the MAB lab analysis are as follows (reference Report MAB-[illegible], dated February [illegible], 1967):

1. Neither of the analyzers contained significant gaseous materials (more than 500 ppm) of anything other than air components. The S/N 3 analyzer did contain trichlorethylene, most of which was absorbed in the gel cartridge.

2. The air in the analyzers can be accounted for by one and probably both of the following:

a The bulbs were squeezed by someone before being impounded.

ENCLOSURE 18-53

D-18-233

Item #57 (cont'd)

b. The time delay (approximately one week) between use and analysis resulted in air leakage into the system and/or sample loss.

Upon completion of the lab analysis, both analyzers were checked by measuring their response to ambient air, 100% aviators breathing oxygen and 100% nitrogen. The results are as follows:

1. Serial No. 3 analyzer

   a. Ambient air - 20% O_2 reading

   b. 100% O_2 - 100% O_2 reading

   c. 100% N_2 - 0% O_2 reading

2. Serial No. 4 analyzer

   a. Ambient air - 14% O_2 reading

   b. 100% O_2 - 100% O_2 reading

   c. 100% N_2 - Below O_2 reading

It is determined that the analysis of gas samples taken from the two (2) Beckman Oxygen Analyzers has given no indication of cabin contamination which may have contributed to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communication Subsystem — Item #58, TPS N/A

Observation: On-board recording equipment and electrical connector configuration

Discussion and Analysis: The following recording devices were on-board S/C 012 at the time of the incident:

a. FQ Recorder, V16-75410Z, S/N Flt 12
This recorder was loaded with tape, the cover was installed and the recorder was electrically connected. The recorder was not on at the time of the incident and would not have been turned on until into the mission run section of the test.

b. DSE Recorder, V16-714385, S/N BAD0003
This recorder was loaded with tape, the cover was installed and the recorder was electrically connected. The recorder was not on at the time and would have been turned on immediately prior to liftoff.

c. MDAS, Part #511076, Serial #6721A
This system was connected to the Senior Pilot, after crew ingress and was in operation from ingress through the incident.

d. DSEA Recorder S/N 104
Note that only one DSEA recorder was installed on the spacecraft. This recorder was installed in the #2 slot, the alternate slot, and existing paperwork indicates the recorder was connected. Physical verification on 4 February indicated that a DSEA recorder was located in the

alternate position, but that neither the power cable was connected to the recorder nor was the adapter cable connected to the recorder. The power cable at the DSEA end was not capped. Due to the activation of S13 and CB49 on Panel 22 AC power was present at the DSEA end of the cable and DC power was present due to the activation of CB 96 on Panel 22.

Inspection of the DSEA cable showed no evidence of arcing.

There is no indication that any of the on-board recording equipment was the cause of the fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Crew Equipment

Item #61
TPS N/A

Observation: A survey should be made to evaluate the potential magnitude of electrostatic energies in the Command Module.

Discussion and Analysis:

Exploratory tests with suit materials and other nonconducting materials used in the spacecraft indicated that large electrostatic energies could be generated, retained and discharged. As a result of the exploratory tests a detailed test program was generated to evaluate the potential magnitude of electrostatic charge buildup and the possibility of a discharge igniting materials or gases in the area of the discharge. Details of these tests can be found in the Panel #8 Final Report.

The electrostatic testing determined that ignition of solid materials by electrostatic discharge is not a probable explanation of an ignition source for the accident.

It is concluded that electrostatic energies from the Command Module non-conducting materials did not contribute to or cause the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 17, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #62
TPS CM-CA-121

Observation: Investigate water glycol pump failure on S/C 008 and inspect S/C 012 pumps

Discussion and Analysis:

The plastic pump cap configuration on S/C 008 water glycol pump allowed leakage which contributed to the pump motor failure.

The S/C 012 water glycol pumps utilized an inconel cap between the magnet side and the magnetic motor side.

Investigation of the ECU water glycol pump was conducted in accordance with Board Action Item #0168.

Tear-down of the pumps revealed that the inconel caps had allowed no leakage and that the motors were in satisfactory condition. It is noted that the water glycol pumps operated satisfactorily before, during and after the fire.

It is concluded the S/C 008 water glycol pump failure was not duplicated on S/C 012 and that the S/C 012 water glycol pumps did not contribute to the initiation of the fire.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

March [illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control System

Item [illegible]
TPS N/A

Observation: Sharp increase in oxygen flow rate, to measurement limit at 2324:03 to 2324:[illegible] GMT.

Discussion and Analysis: Communications and bio-medical data indicates crew activity at this time.

It has been determined from previous tests and early in this test that oxygen flow rates are affected by crew movement and activity.

It is concluded that the sharp increase in oxygen flow rate was caused by crew activity.

ENCLOSURE 18-53

D-18-239

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 13, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #64
TPS N/A

Observation: Excessive alarm time observed following high oxygen flow indication at 2145:54 GMT

Discussion and Analysis:

The oxygen (O_2) flow transducer assembly, C23A2A5, has two outputs; an analog to the data system (PCM and cabin meter), and an event to the 15 second time delay associated with the input to the caution and warning system. The PCM system saturates (reads full scale) at a transducer output of 5.0 volts. Information from AiResearch acceptance testing of this particular transducer assembly indicates the event output does not trigger until the analog output reaches 5.3 volts.

At 21:46:21.5 GMT the master caution was triggered by the 15 second time delay. This was 15 seconds after the H_2O cyclic accumulator assembly had cycled. It is assumed that the accumulator step O_2 flow (the PCM input was saturated at 5 volts as previously noted at 21:45:54 GMT) and was sufficient (above 5.3 volts with a step requirement) to immediately close the "reed" relay (event output) in the O_2 flow transducer assembly. The original high O_2 flow was at a sufficient level or had increased to a sufficient level during the H_2O accumulator cycle to hold the "reed" relay in when the accumulator cycle was complete.

Item #64 (Cont'd)

It can be inferred that this was not a malfunction because this period of high O_2 flow was interrupted by cyclic accumulator action, and because the time delay worked properly at all other times including during the accident. It is concluded that this delay system had nothing to do with the cause of the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 1., 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Instrumentation Subsystem

Item #. 6
TPS 054

Observation: Elapsed Time Indicators, post test inspection

Discussion and Analysis:

All Elapsed Time Indicators (ETI's) used on S/C 012 which are not qualified as flight hardware and were to be removed prior to flight were inspected after the accident. (Reference TPS S/C 012-054).

Excessive external heat indications were observed on all ETI's but there were no visual indications of short circuits. There wereno ETI's installed on the C-band transponder, VHF-FM transmitter or HF transceiver and covers were not installed on the connectors. There were no shorting indications observed in the open connectors.

It is determined that the ETI's inspected did not cause or contribute to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 7, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item #50
TPS N/A

Observation: ECS Fire at AiResearch

Discussion and Analysis:

A fire occurred on April 28, 1966 in the AiResearch altitude chamber used to simulate the Command Module while the Apollo Environmental Control System (ECS) was undergoing a mission-life qualification test. The incident took place after completing [illegible] hours of a scheduled [illegible] hour test.

The most probable cause of the fire was a failure of the commercial-quality strip heater used to add heat to the steam duct to preclude freezing of water in the duct. A number of commercial grade electrical heater tapes were wrapped around a number of lines as part of the test or support equipment. Heating tape was being used to raise the steam duct temperatures when the incident occured. The heater tape wire was demonstrated to extrude through the insulation and a fire was initiated under simulated conditions.

It is determined from the above that the ignition source encountered during the ECS qualification incident cannot be associated with the cause of the S/C 012 accident.

ENCLOSURE 18-53

D-18-243

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 17, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communications Subsystem

Item #70
TPS N/A

Observation: VHF-AM receiver failure encountered on S/C 008

Discussion and Analysis:

The VHF-AM receiver #1 failed during a thermal vacuum test on S/C 008. The receiver was returned to Collins Radio Company for checkout and found to function normally. Additional investigation of the spacecraft circuitry revealed that the wire harness between the MDE panel 20 receiver select switch and receiver 1 and 2 had been partially cut and some corrosion was noted on the bared conductors. The harness was spliced and additional tests run.

It is determined that this failure has no applicability to S/C 012 and the cause is attributed to a cut wire rather than a system or component.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 7, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #71, TPS N/A

Observation: Suit loop return valve leak encountered on S/C

Discussion and Analysis: During performance of Test #3 on S/C 008, it was noticed that there was atmospheric air in the suit loop (nitrogen contamination) following crew ingress. It was determined that the cabin air entered into the suit loop through the Suit Circuit Return Air Check Valve due to a low Δ-P across this valve assembly. A check of the leak specification on the valve assembly showed that the rate of increase of N_2 in the suit loop was within the allowable leakage. A procedure change was made for S/C 012 which required cracking of the Direct O_2 Valve to maintain positive pressure in the suit loop after crew insertion.

It is determined from the above that the leakage problem encountered on S/C 008 cannot be associated with the cause of S/C 012 accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March , 196

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization & Control Subsystem — Item #12, TPS N/A

Observation: Manual Thrust Vector Control (MTVC) Engage came on for five seconds on earlier tests of S/C 012.

Discussion and Analysis: The MTVC Engage (CH11.04) Event Light was seen to come on without actuating the translation control on the following occasions:

1. During Chamber Pump-Down (4.,000 ft.) for unmanned altitude run of OCP-K-0034A on December 28, 196 . Extinguished after eight seconds.

2. During OCP-K-0034A, apparently while the crew couches were being moved. The light went out with no activity after two seconds.

3. During OCP-K-0034A with no activity in the spacecraft. Light went out when SSRP moved the crew couches.

On the first occasion, the SCS was in the monitor mode with the Delta V Switch "ON". The two other times the light was seen, the SCS was in SCS Attitude Control (Delta V switch - OFF).

An attempt was made to activate the MTVC Engage while in the SCS Attitude Control Mode by turning the Translation Hand Controller (THC) clockwise without success. This action showed that MTVC could not have accidentally been activated to cause the two indications in OCP-K- 0034A (2 and above).

Connectors were wiggled, partially demated and wiggled, and then reconnected in an effort to make the MTVC Mode light come on, but the light stayed out.

With the SCS in the same configuration as it was in OCP-K-0034A (Monitor Mode and the Delta V switch ON), the THC was rotated to MTVC (CW). Observations were made which showed the switch could be detected by other SCS measurements (CH0074 and CH1074 and BMAG outputs). OCP-K-0034A data were reviewed and no activity on CH0074, CH1074 or the BMAG outputs was seen.

Later the Yaw ECA was removed for another problem and the MTVC Engage Signal Conditioner was tested in the Bench Maintenance area and proved to be within specifications. This ECA was then sent to Honeywell for evaluation and the spare Yaw ECA was installed in S/C 012. Threshold level of the PCM system signal conditioner was also tested and found to be in tolerance.

Based on troubleshooting data, the following conclusions have been reached:

1. The MTVC Engage indications in the three instances above were "FALSE" indications since none of the data from OCP-K-0034A or OCP-K-0005A indicated any actual engagement of MTVC (no activity on CH0074, CH1074, or the BMAG outputs.)

2. The malfunction is probably in the harness between the SCS and the PCM system. An intermittent open in a wire or connector would cause the indications.

3. The indication received during the accident in OCP-K-0021 was real. Data review showed activity on CH0074, CH1074, and the BMAG outputs which correlates with the indications received during troubleshooting.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO:

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #[illegible]
TPS N/A

Observation: AC Bus phase C short during prior test on Spacecraft [illegible]

Discussion and Analysis: AC Bus [illegible] phase C shorted during troubleshooting of IDR [illegible]. The short was J[illegible]9/GSE Pin V to ground and happened while trying to make a voltage measurement on AC Bus [illegible] phase C. The shorted instrumentation circuit contains a 1/8 amp instrumentation fuse (F[illegible], C14A1[illegible]). The blown fuse was removed and replaced with a like unit.

Blowing fuse F[illegible] (1/8 amp) in the instrumentation circuit is not considered to be harmful to the AC[illegible] power system. Therefore, it is concluded that this prior concurrence has no correlation with the accident.

ENCLOSURE 18-53

D-18-248

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 24, 1967

INTEGRATION ANALYSIS SUMMARY

Systems Affected: Sequential Subsystem

Item #75
TPS N/A

Observation: DRS692 dated 11-27-66 indicated that the terminal wires were exposed on the 15 second timer C23K1 relay

Discussion and Analysis:

The permanent installation and removal record shows that the time delay module was removed from the C15-1A52 panel; and, without violating electrical connections, the exposed wires were potted, and the module remounted. Since the electrical connections were not violated functional retest of the unit was not required.

Post accident evaluation of the relay has shown that the potting on the relay is intact and that the relay was properly installed.

Data review shows that the relay performed its function (15 second time delay from the time of Oxygen High Flow Rate to Caution and Warning Light Function) properly several times during OCP K-0021-1.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Displays and Controls Subsystem

Item #76
TPS(s) CM-CA-030
CM-CA-031
CM-IV-041

Observation: Review of Main Display Console (MDC) Panel 24 difficulties on S/C 012

Discussion and Analysis:

The investigation of MDC Panel #24 was carried out as directed by Board Actions 0145, 0153 and 0160 and in accordance with TPS (s) CM-CA-030, CM-CA-031 and CM-IV-041.

Review of the summary of difficulties which were encountered during fabrication and installation showed that all had been properly dispositioned.

When the MDC Panel #24 was removed and inspected, two areas were observed to require special investigation. These areas were the wire bundles between the Emergency Detection Subsystem (EDS) Power Switch and the Sequence Arm Switches, which showed heat damage and the positioning of the Body-Mounted Attitude Gyro (BMAG) Switch. Discussion and analysis of the BMAG Switch is contained in Integration Analysis Summary Item #99.

Inspection of the wire bundles revealed no visible damage from the burned area to the connectors.

Continuity tests of the panel in the as-found condition showed all normal continuity and circuit resistances. The continuity tests in all other switch positions for Panel 24 also showed normal continuity and circuit resistances.

Analysis of these tests showed that electrical continuity was present after the fire and that no damage of a significant nature had been incurred by the switches, panel wiring or connectors.

It is concluded, accordingly, that the charring of the EDS switch and associated wiring was caused by an external flame source and not by heat generated internally in the switch. In addition, the components of the panel were not a source or a major propagator of the fire.

C-3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Launch Vehicle

Item #17
TPS N/A

Observation: Three Saturn S-IVB measurement anomalies were noted at [illegible]

Discussion and Analysis:

The measurements were:

(1) LOX tank ullage pressure. EDS #2
(2) External aft skirt pressure, POS #2
(3) 5 volt excitation voltage aft

The level of (1) and (2) increased to 100%. (3) increased to the 100% level more rapidly

The reason for this data change has not been found, but at this time it is felt to be unrelated to the incident. One of the Meas., LOX tank ullage pressure, EDS #2, does interface with the IU and is terminated and open ended in the IU/Spacecraft interface plug

Due to the large time difference between the time of these transients and the Fire Report, it is unlikely that they have any relation to the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March [illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem

Item [illegible]
TPS S/C-[illegible]

Observation: "Buttermilk Odor" was detected in the Suit Circuit

Discussion and Analysis:

The evaluation of the "buttermilk odor" involved the review of the K-bottle analyses of the source, the Beckman Analyzer analyses, the gas sample (Watermelon 1-1) taken at the crew mouthpiece and earlier sample analyses from [illegible] to [illegible].

The review of the K-bottle analyses revealed no unusual impurities and the gas analyses met specifications as required.

The analyses of gas from the two Beckman Oxygen Analyzers revealed no significant information on "buttermilk odor" and the gas was essentially air.

The gas sample taken at the crew mouthpiece (Watermelon 1-1) had two analyses. The first analysis revealed approximately [illegible] ppm of unidentified hydrocarbons which could contribute to an odor condition. A second analysis of the same Watermelon 1-1 sample was run by the Materials Analysis Branch (KSC) in an effort to identify the hydrocarbons with hopes of isolating suspect materials. This second analysis revealed no useful information due to the dilution of the sample and time span since the sample was taken.

ENCLOSURE 18-53

D-18-253

Item #18 (cont'd)

A summary of previous analyses, including earlier manned altitude testing samples, revealed no significant information to identify any "buttermilk odor".

No particular suspect item was identified as emitting a "buttermilk odor" although some of the RTV potting compounds have unique, pungent odors that probably come closest to fitting this odor description. These materials are RTV [illegible], 577, and [illegible] which have been used in the spacecraft.

None of the reports of olors discloses any area of suspicion relating to the origin of the odor.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

March 15, 196[illegible]

INTEGRATION ANALYSIS SUMMARY

System Affected: Stabilization and Control Subsystem — Item [illegible] TPS CM-IV-0[illegible]

Observation: SCS Yaw ECA female Connector J[illegible] had Blackened Areas

Discussion and Analysis:

Spacecraft connector J[illegible], which attached to Yaw ECA mating connector P[illegible], had blackened areas around the receptacles for pins [illegible], [illegible] and [illegible] which appeared to have resulted from arcing. None of these pins saw voltage at the time of the accident.

Connector J[illegible] has been closely examined and the receptacles show to be perfectly clean with no indications of soot.

Mating connector P[illegible] has been closely examined and the interior around the pins shows to be perfectly clean with no indications of soot, arcing burned spots or degradation of the rubber humidity seal

The history of connector J[illegible] was investigated and it was found that the section which appears to be blackened had been chipped and potted prior to the fire. This potting was done only to continue the humidity seal and was not required electrically.

It has been determined that the potting compound used on connector J[illegible] became heated and discolored during the fire, thus appearing to have been the result of an arcing condition. Two (2) other pins indicated hot spots around the receptacles. These pins were [illegible] and [illegible] which are both spares and see no voltage.

The suspected connector had nothing to do with the fire.

ENCLOSURE 19-53

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 23, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Stablization & Control Subsystem — Item #80, TPS N/A

Observation: Plus roll output observed at 2331:14.5 to 2331:15.0 GMT

Discussion and Analysis: A plus roll output was indicated at 2331:14.5 to 2331:15.0 GMT. A special test was conducted at MSC which showed that the rotation controller will give an output when hit even though the handle is pinned and locked. The handle was found pinned and locked, and the date therefore indicates a physical blow to the controller by one of the crew members.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March [illegible], 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #81
TPS N/A

Observation: Gassing characteristics of the pyrotechnic batteries

Discussion and Analysis:

The battery complement in the command module consists of three entry batteries and two pyrotechnic batteries. The entry batteries have their individual vents manifolded to an overboard vent line while the pyrotechnic batteries vent into the cabin through their relief valves (cracking pressure set at [illegible] psi).

A preliminary test has been conducted utilizing two pyro batteries, one at normal room temperatures and one at 105±5°F. Pressure increase data indicated only a two psi rise during a sixteen (16) day period on the battery at room temperature. The pressure increase on the battery at 105±5°F had an estimated worst case rise of approximately 21 psi. (This pressure increase had to be estimated due to an instrumentation malfunction during the first 24 hours of the test.) Based on the above pressures increase and adding 15 psi to simulate flight conditions (15 psia ground level to 5 psia in orbit), only the battery at 105±5°F would have vented

Post test inspection of S/C 012 batteries showed they were electrically functional and there was no physical evidence to indicate the existence of an electrical defect, arcing, or self-provided hot spots.

As the cabin temperature in Spacecraft 012 during the conduct of OCP-K-0021-1 was normal throughout the test until the fire, it is concluded that the pyrotechnic batteries relief valve did not relieve and therefore did not cause the incident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 23, 1967

INGEGRATION ANALYSIS SUMMARY

System Affected: Stabilization & Control Subsystem

Item #82
TPS N/A

Observation: MTVC engaged: 2331:18.5 GMT.

Discussion and Analysis: MTVC (manual thrust vector control) is initialed by a clock-wise rotation of the translation controller T-handle. For some unknown reason, the MTVC was engaged at 2331:18.5 GMT. There has been speculation as to how and why it was turned, but the answers are not considered significant. Nothing more can be gained from a study of this item.

ENCLOSURE 18-53

D-18-259

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Crew Station

Item(s) #83 & 84
T.P.S. N/A

Observation: Moderate increase in the Senior Pilot's heart rate at 2330:22 GMT followed by a high increase rate starting at 2331:04 GMT

Discussion and Analysis:

At 2330:22 GMT there was some change in the respiration pattern and a moderate increase in heart and respiratory rates. These data are consistent with some increase in the Senior Pilot's activity, but do not indicate the degree of activity that would be expected had the Senior Pilot been aware of an emergency situation. At 2330:50 to 2330:55 GMT this data had started returning toward baseline levels.

At 2331:04 GMT there was a marked change in the Senior Pilot's respiration and heart rate. There was also evidence of muscle activity in the EKG trace and evidence of motion in the phonocardiogram. The heart rate continued to climb until loss of signal. This physiological response is compatible with the realization of an emergency situation.

The data obtained from the on-board MDAS tape correlates with the above.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power System and Scientific Equipment

Item #85
TPS V16-001-023(MSC)
CM-CA-074

Observation: Shorting in the MDAS octopus cable and connectors.

Discussion and Analysis: Short circuits were found on the octopus cable near connector J 185. The wiring to this connector provides power and biomedical instrumentation signals to the Medical Data Acquisition System (MDAS). This cable was subjected directly to the flame within the command module and therefore was badly burned. The power circuit breakers were found open after the fire, however, the MDAS was still operating until cabin rupture. The shorted condition on the octopus cable was between the J 185 connector and the MDAS recorder. The DC wires were also shorted near the left end of the gas chromatograph compartment floor. The shorting on the octopus cable was found to be superficial and a result of the fire.

ENCLOSURE 18-53

D-18-261

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 7, 1967

INTEGRATION ANALYSIS SUMMARY

Systems Affected: Crew Biomedical - Communications

Item #86
TPS N/A

Observation: Astronaut shocked during S/C 101 Crew Compartment Fit and Functional (C^2F^2)

Discussion and Analysis: The subject short circuit experienced in S/C 101 C^2F^2 at Downey occurred within the crewman's biomedical communications torso harness rather than the cobra cable assembly. This failure occurred because of the following conditions:

1. The torso harness used was of Block I configuration and was in poor condition due to previous usage.

2. The electrical wiring of the Block I harness was not compatible with the Block II biomedical conditioners used. Although the two systems (harness and signal conditioners) will operate properly, a short such as the one which occurred will cause the 16.8 VDC biomed power to be routed to the chest ground electrode on the crewman.

3. The condition of the harness caused a shield to short 16.8 VDC power due to a break in the shield wiring and the ribbon encasing the wiring.

If the same short had occurred in the S/C 012 configuration, the voltage could not have been transferred to the crewman's chest electrode due to these shields not being carried through the harness and signal conditioners on Block I hardware. The only shields on Block I hardware are floating at the DC-DC converter signal conditioner inputs (16.8 VDC power).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Sequential Events Subsystem

Item #89
TPS S/C - 088

Observation: The integrity of the Q-Ball circuit should be evaluated

Discussion and Analysis: The Q-Ball was not electrically mated for the plugs-out test (OCP-0021), however, the cable was powered up to the Q-Ball connector. Pin to pin and pin to ground resistance checks revealed no anomalies in the Q-Ball cable. Physical evaluation revealed that the connector of the Q-Ball was mated with the storage connector.

Based on the above data it is concluded that the Q-Ball circuitry did not contribute to or cause the accident.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Subsystem — Item #90, TPS N/A

Observation: Suit flow indication at low limit for Command Pilot from 2331:18.5 GMT through loss of signal (LOS), Senior Pilot from 2331:18.5 GMT through LOS, and Pilot from 2331:19.6 GMT through LOS

Discussion and Analysis:

Initial review of suit flow PCM data indicated that the final suit flow for the crew members dropped to the lower limit at 2331:18.5 GMT and 2331:19.6 GMT. Further review of the data has revealed that a LOS occurred from 2331:17.4 to 2331:18.4 and that actually all the crew suit flows dropped to the lower limit starting at 2331:16.2 GMT. All suit flows remained at these lower readings until total loss of all S/C communication data. Information concerning crew suit flow indications from 2331:12.9 GMT to 2331:16.2 GMT is contained in Integration Analysis Summary Items #27 and 38.

S/C telemetry data and analytical analysis has determined that the cabin to ECS suit loop differential pressure had increased to 2 psid. This was caused by extremely rapid rate of rise in cabin pressure between 2331:12.4 GMT and 2331:16.2 GMT.

The high differential pressure between the cabin and the suit loop caused the Command Pilot's and Pilot's suit material to be forced against their bodies thereby stopping suit flow.

The Senior Pilot's suit inlet hose was found disconnected following the accident. (Refer to Integration Analysis Summary Items #25 and 102). The aforementioned differential pressure caused cabin atmosphere to reverse the normal flow path and flow back into the ECS suit loop via

the Senior Pilot's disconnected suit inlet hose.

The arresting of suit flow in the Command Pilot's and Pilot's suit and the reverse flow in the Senior Pilot's suit inlet hose caused the suit loop differential pressure (measurement CF 0148) to drop to zero and the suit compressor differential pressure (measurement CF0137) to drop to a low telemetry reading.

The suit loop differential pressure is measured from a point on the suit supply line above the suit flow limiters to a point on the suit return line above the suit compressor. Telemetry data indicated a sharp rise in suit loop differential pressure starting at 23:31.12.4 GMT until 23:31.15 GMT at which time the restricted suit flow caused the suit loop differential pressure to drop to zero.

Based on the above it is concluded that the ECS system continued to operate in the abnormal environment and that the suit flow telemetry data is valid.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 18, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Communication Subsystem

Item #503
TPS N/A

Observation: Command Pilot had a live microphone

Discussion and Analysis:

The actual cause of the open microphone is not known at this time. Analysis was made of voice recordings taken during on-board troubleshooting by the crew and compared with schematic diagrams. This analysis has isolated the cause to the push-to-talk (PTT) or keying line that runs between the Cobra Cable, translation controller, Command Pilot audio control panel and audio center

1. The separate components have been checked for resistance to ground. All lines measured "open" which is correct.

2. The spacecraft wiring was checked and a 3000 ohm resistance resistance was measured to ground. This 3000 ohm resistance could account for the keyed microphone. However, this resistance could be a result of the fire damage to wire bundles. Later, when an attempt was made to locate the cause of the 3000 ohm resistance, the measurement could not be duplicated. The circuit now measures "open", which is normal.

3. The translation controller PTT button was pushed and released ten times. On the fifth try the button stuck down. If the button had stuck during the S/C-[illegible] test the microphone would remain keyed.

Item #93

Post incident review of switch positions in Command Pilot's audio control panel indicate that all switches were in the positions expected. When in this configuration current drawn by the keying line is limited to .50 milliamps at 28 volts. Tests run with a cobra cable show that no sparks were generated with 28 volts and 150 milliamps.

The cause of the live microphone has been attributed to picking up a ground somewhere in the Command Pilot Push-to-Talk circuit in the Spacecraft. The specific source of the ground has not been established. This malfunction, electrical in nature, is not considered to be a fire initiation source. This malfunction may have contributed to the accident, by prompting the crew to be doing some activity to assist in clearing up the overall communications problem.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Environmental Control Sybsystem

Item #94
TPS. S/C-116
CM-CA-179

Observation: Initial investigation determined cabin air Fan No. 1 shorted

Discussion and Analysis:

The cabin air Fan No. 1 circuit breakers for AC phases A and C were found to be open after the accident. Also electrical tests of the fan in the spacecraft indicate the shorted phases. Cabin air Fan No. 2 was found to be in satisfactory condition.

Cabin Fans No. 1 and No. 2 are powered by AC bus 1 and AC bus 2, respectively. Twenty-two gauge wires are utilized, and each phase is protected by a 2 amp circuit breaker. The fans are located in the left-hand forward equipment bay.

Continuity tests of the cabin air Fan No. 1 after removal verified that all pin to pin and pin to ground readings at nominal values. The suspected shorts were determined by tests and inspection to be in the power on plug cable.

Based on the above it is concluded that the cabin air Fan No. 1 did not contribute to the cause of the fire. This determination is based upon the lack of fire propagation material in the area. The physical inspection of the fan itself does not indicate it to be the fire initiation source.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

Systems Affected: Electrical Power Subsystem — Item #95
Environmental Control Subsystem — TPS N/A

Observation: Determine if the teflon wire insulation for the Environmental Control Unit harnesses and the gas chromatograph connector had been etched.

Discussion and Analysis: All teflon insulated wiring is required to be etched prior to potting. Pre-test records were reviewed of the gas chromatograph connector and Environmental Control Unit (ECU) harnesses to determine if they contained teflon wires and if the required etching had been accomplished.

It was determined that etchirg of the gas chromatograph wires was accomplished. The ECU harness had the latest configuration harnesses which did not require etching.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #96
TPS CM-IV-110

Observation: Suit current limiter panel short to teleflex cable.

Discussion and Analysis: An early inspection report disclosed that the teleflex cable may have contacted and shorted the suit current limiter panel. Terminal board 61 was then examined in more detail for evidence of shorting, and the 82556 resistors and conformal coating for overheating. This more detailed examination disclosed that there was no actual contact between the teleflex cable and the terminal board, and that there was no evidence of shorting or overheating.

ENCLOSURE 18-53

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 14, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem

Item #97
TPS CM-IV-149

Observation: Panel 150 was not properly installed, but lying loose in the Lower Equipment Bay (LEB)

Discussion and Analysis: Spacecraft panel 150 was electrically mated but not physically installed for the conduct of OCP-K-0021. The panel was inspected as part of the spacecraft disassembly plan (Reference Board Action #0120). The inspection showed that the panel was exposed to high heat as evidenced by considerable sooting and burned wiring. The first three or four inches of wiring from the circuit breakers was burned with exposed conductors on some of the smaller gage wires. The wiring beyond the proximity of the circuit breakers was in good condition, indicating the absence of any sustained overloads. Two wire lugs were bent slightly. There was no evidence of arcing anywhere on the panel or of any material outflow from the components. All physical damage appears to have been caused by the fire. TM data (battery voltages and currents) indicate nominal conditions with the battery system, of which Panel 150 is an integral part. There is, therefore, no evidence which indicates that this panel was a fire cause or propagator.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

Subsystem Affected: Communications Subsystems

Item #98
TPS CM-CA-002
005
61
65

Observation: Examine cobra cable and pressure garment assembly connectors for arcing and condition of pins.

Discussion and Analysis: The following cobra cables (V16-601623) were in the spacecraft for OCP-K-0021-1

V16-601623 - 41 S/N 8238 Command Pilot
- 41 S/N 7384 Senior Pilot
- 51 S/N 7389 Pilot
- 51 S/N 0806 Stowed at start of test
- 51 S/N 0807 Stowed at start of test

During the test cables S/N 0806 and 0807 were unstowed and one was used by the Command Pilot. After the accident one cable was in use at each crew position, one was between the Senior Pilot and Pilot's couches, and one was on the Command Pilot's leg pan. The S/N's cannot be read.

After the accident, the condition of the cable connectors near the dust covers and lanyards was relatively the same condition as the surrounding areas. Connector shells and pins were not fused or otherwise distorted.

A post test check of the cobra cable in use by the command pilot at the start of the test showed that all wiring was in accordance with the drawing and wire list. A microscope examination of the pins showed them to be pitted and corroded.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Biomed-Communications Suit Wiring — Item #105, TPS CM-CA-034

Observation: Four shorted wires were found in the communications wiring between the Command Pilot's suit connector and the helmet communications connector.

Discussion and Analysis: Four shorted wires were found in the communications wiring between the suit connector and the helmet communications connector. The wire insulation was discovered to be brittle, discolored and cracked. The wires were identified as microphone signal, microphone signal return, earphone signal and earphone return. Enclosures 18-48 and 18-49 illustrate the shorted condition of the wires.

An intermittent condition was also noted in the 16.8 volt DC biomed power wire in the torso harness between the suit connector and the biomed connector. This condition is considered to be not relevant to the cause of the accident, in that no biomed power was being supplied to the Command Pilot's suit.

The vendors of the torso harness materials have provided the following information:

(a) The nylon sock around the ribbon cable melts at 480 degrees Fahrenheit.

(b) The silicone, of which the ribbon is made, melts at [illegible] degrees Fahrenheit.

(c) The milene insulation around the wires cracks at 430 degrees Fahrenheit and melts at 480 degrees Fahrenheit.

ENCLOSURE 18-53

D-18-279

From the above information, it is probable that the exterior of the ribbon cable around the area of the damaged wiring was subjected to localized and supervicial heat. This would cause damage to the internal wiring insulation without damaging the silicone ribbon.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

April 1, 1967

INTEGRATION ANALYSIS SUMMARY

System Affected: Electrical Power Subsystem & ECS

Item #10
TPS CM-IV-[illegible]

Observation: DC wiring for environmental system instrumentation burned through

Discussion and Analysis:

The one suspect is wiring providing instrumentation power for some Environmental Control System instrumentation. This wiring contains both DC bus A and DC bus B power, and is located on the Command Pilot side of the Command Module in the vicinty of the Environmental Control Unit and the Lithium Hydroxide Units.

A momentary short could occur in any of four DC bus B or four DC bus A power wires in this wiring. A short would not affect the equipment being powered by these wires, and would not be reflected in any of seven measurement outputs of transducers being provided power because of diode isolation of redundant power for each equipment.

Tests have shown that a short in any of the four DC bus B wires could cause a drop in DC bus B voltage to a low enough level to cause an interruption to inverter 2. Sufficient current could be drawn through any of the eight wires to create an arc of sufficient energy which could ignite debris netting in the immediate vicinity of the wiring.

ENCLOSURE 18-54a

REVIEW OF SPACECRAFT POWER STATUS

I. POWER SOURCES

A. Internal

There are two basic sources of primary electrical power contained in the spacecraft. One is the entry batteries in the command module, and the other is the fuel cells in the service module.

The entry batteries provide power during the entry and landing period of the flight when the command module has separated from the service module. They are also used to augment the other power sources at times when heavy loads are switched on.

The fuel cells are the principal source of internal power for the spacecraft. They provide the main DC power during most of the mission. For much of the ground testing a simulator is used for the fuel cells. This simulator is composed of battery packs which are connected to the fuel cell circuits in the service module by test cables. It simulates the internal power of the fuel cells.

In addition, there are two pyro circuit batteries in the command module for providing power to the pyro devices in the spacecraft. These batteries and battery busses are isolated from the main spacecraft busses. A bus tie switch is provided to permit application of main bus power to the pyro bus in event of pyro battery loss.

B. External

In addition to the internal power system described above, the spacecraft can be powered by a ground power supply via the service module launch umbilical. This source is normally used for all pre-flight testing with a transfer from this external source to the internal source made during the final minutes of the count down.

II. SPACECRAFT DC POWER SEQUENTIAL HISTORY

The spacecraft was powered up at the beginning of the test using a ground power supply connected to the spacecraft via the launch umbilical in the normal external operating mode.

The system for transfer from the ground power supply to the spacecraft fuel cell power supply was tested and operated normally to internal and back to external power at 0938 EST (1438 GMT). Activation and operation of the fuel cells was not a part of this test. A battery pack simulating fuel cells was used in their place.

Fuel cells are not normally used in ground testing because of their limited life. From a DC power point of view, no differences in functions could be expected because of this.

Following the power transfer test, the spacecraft operations were continuted using external power. At 2331:12.4GMT and 2331:13.6GMT the command module internal power entry batteries were applied to the command module main DC busses B & A respectively. The batteries were then in parallel with the ground power input in a configuration similar to the normal flight situation where the batteries supplement the fuel cells. Refer to the attached diagram. Command module pressure and temperature instrumentation had previously indicated the presence of the fire.

At 2332:46.4GMT DC ground power was switched off. Various command module systems continued to operate on entry battery power until about 0530GMT (12:30 am EST) on Saturday, when the batteries ran down. Later detailed examination of the spacecraft interior showed the entry battery switches on the control panel in the "on" position.

III. VERIFICATION OF POWER SEQUENCE

Referring to the diagram, the basic power switching was as follows:

Switch "A"

Closed at approximately 10 sec after the crew report of fire. This is verified by an analysis of entry battery and GSE supply voltage and current measurements CC0206V, CC0207V, CC0210V, CC0211V, CC0212V, CC0222C, CC0223C, CC0224C, GC5025C, and GC5029C.

Post inspection verified the switch to be in the Closed position.

Switch "B"

Closed at approximately one hour prior to the crew report of fire (2234:32GMT). This is normal procedure.

Switch "C"

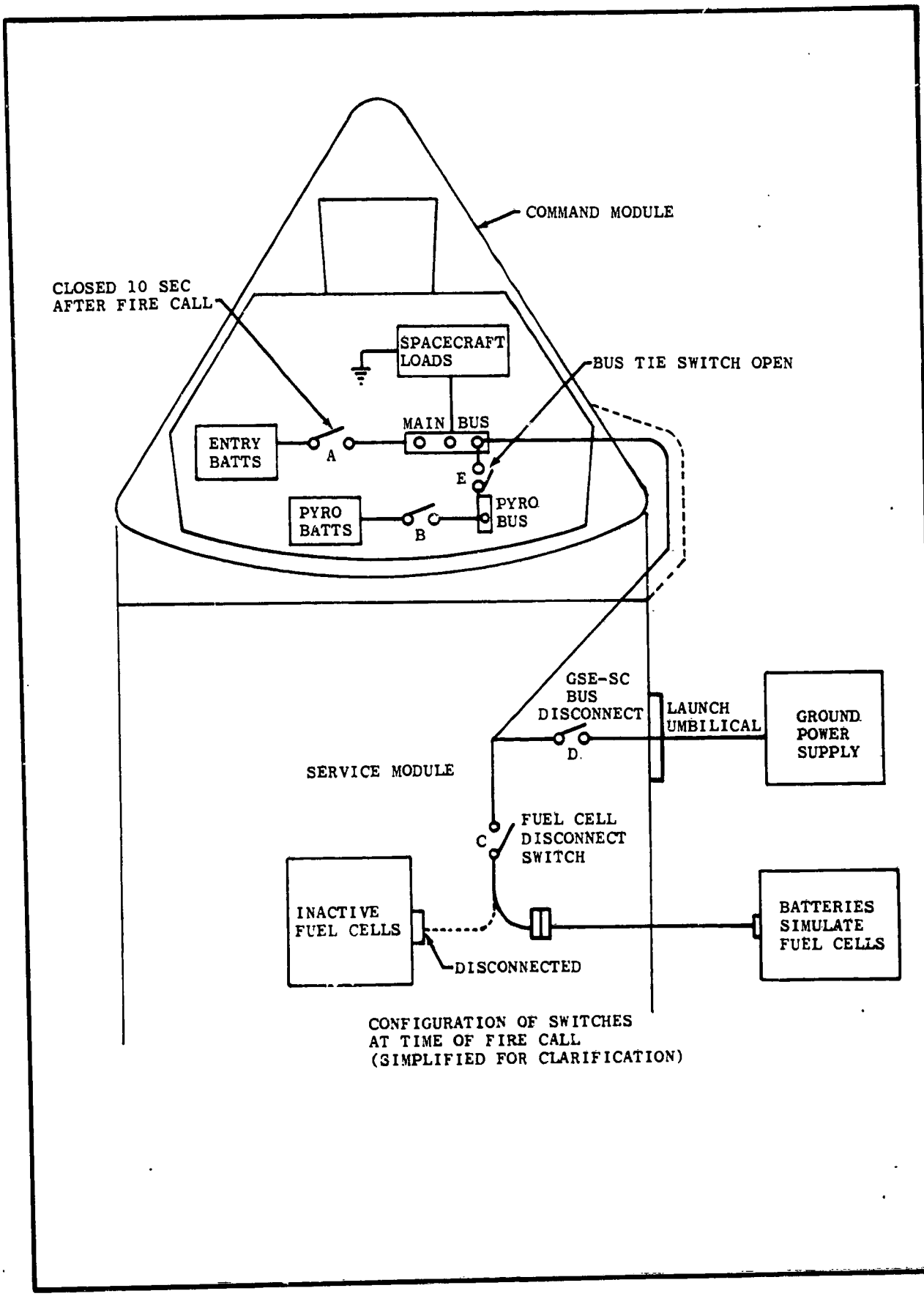
Open since the power transfer test performed about 9 hours earlier. Verified by fuel cell current measurements SC2113C, SC2114C, and SC2115C.

Switch "D"

Closed until approximately 1½ minutes after the crew report of fire (2332:46.4GMT). This was determined by verification of measurement SC2410X.

Switch "E"

Open throughout the test. This switch would only be closed in the event of a pyro battery loss. Post inspection verified the switch to be in the open position.



CONFIGURATION OF SWITCHES
AT TIME OF FIRE CALL
(SIMPLIFIED FOR CLARIFICATION)

ENCLOSURE 18-54A

D-18-285

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

February 23, 1967

TO: Panel 18

FROM: Panel 1

SUBJECT: SC 012 Electrical Configuration
(Action Item No. 43)

1. At the time of the incident, SC 012 SM jettison controller batteries were installed and electrically connected to the X00-004 circuit breaker box. The two circuit breakers (A&B) were open and consequently there was no power to the jettison controller itself.

2. The following "Q" ball power from the IU stage was turned on at T-45 minutes and remained on through the incident.

a. "Q" ball power (+28VDC) - from IU bus 6D21.

b. "Q" ball power (+28VDC) - from IU bus 6D41.

3. The following "Q" ball heater power from the IU stage was turned on at T-45 minutes and remained on through the incident.

a. "Q" ball heater power (115VAC, 60 cycle).

4. Power (28VDC) at the time of the incident was being applied to the ECS glycol shut-off valve in the SM through the Y00-085 cable from a Harrison lab power supply.

5. MESC indicates power was supplied from the GSE power supply (power supply #5) to the sequential control unit DC bus (28VDC) through the IU umbilical to the spacecraft.

6. SC 012 battery relay bus power at the time of the incident was fed from GSE power supplies #3 and #4 (bus A and bus B power supplies)

7. Other power derived from the IU stage:

   a. 6D110 (+28VDC) used to supervise EDS safe A and B in SC.

   b. 6D91 (+28VDC) used for EDS and is supplied from IU bus 6D11.

   c. 6D92 (+28VDC) used for EDS and is supplied from IU bus 6D31.

   d. 6D93 (+28VDC) used for EDS and is supplied from IU bus 6D41.

   e. Plug supervision bus (+28VDC) supplied by an isolated supply and is used to supervise the mating connectors at the SLA/IU interface (confidence loop).

   NOTE: All the above buses were turned on prior to and were on at the time of the incident.

Jesse F. Goree
Chairman, Panel 1

SUMMARY

SYSTEM	TOTAL	OPEN	CLOSED	DUPLICATE	DELETED
ECS	14	0	14		
G&N	3	0	3		
SCS	3	0	3		
SEQ	1	0	1		
RCS	1	0	1		
COMM	8	0	8		
EPS	16	0	16	8	2
CREW SYSTEMS	1	0	1		
	47	0	47		

SUMMARY OF ECS

POTENTIAL INITIATION THEORIES

ECS-1	WMS Blower as an Ignition Source	Closed
ECS-2	Water Glycol Pumps as an Ignition Source	Closed
ECS-3	Suit Compressor(s) as an Ignition Source	Closed
ECS-4	Cabin Fan(s) as an Ignition Source	Closed
ECS-5	Sponge Material in Waste Management Urine Disposal Lock	Closed
ECS-6	Odor in LEB on 1/25/67 Reported by Technician Changing Flight Qual Recorder Tapes	Closed
ECS-7	Glycol Evaporator Temp Sensor as an Ignition Source	Closed
ECS-8	Suit & Glycol Heat Exchangers' "Sponge" Material as an Ignition Source	Closed
ECS-9	LiOH Absorber Element(s) as Ignition Source	Closed
ECS-10	Plumbing Line Appears "Eaten" through	Closed
ECS-11	Heaters within ECS	Closed
ECS-12	Water Glycol Sample Analyses to Determine Contents	Closed
ECS-13	Crushed "Red Wire" at LiOH Diverter Valve Handle	Closed
ECS-14	O_2 Measurement Sensor	Closed

Total	Open	Closed
14	0	14

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-1

SUBJECT WMS Blower as an Ignition Source

SYSTEM OR COMPONENT Waste Management (ECS)

IGNITION SOURCE AND PROPAGATION AC short causing insulation burning.

SUPPORTING FACTORS Difficulty during Spacecraft 008 tests.

NEGATIVE FACTORS Blower not operated during test. Switch "OFF" per switch list and found "OFF" following accident.

CONCLUSION WMS Blower removed and visually inspected. Minor sooting noted on blower outlet. No evidence of arcing. Blower to be analyzed per TPS SC012-CM-CA-242 in MAB. Analysis complete, WMS Blower reclassified as non-initiator.

DATE: 3-22-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-2

SUBJECT Water Glycol Pumps as an Ignition Source

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION AC short, or AC overload due to friction igniting water glycol or insulation.

SUPPORTING FACTORS On last test of spacecraft 008, phases B and C of Pump #1 were shorted to ground, and the pump had a cracked cap and glycol in the motor.

NEGATIVE FACTORS Data on water glycol subsystem, CF0016, CF0018, CF0019, CF0550, CF0549, CF0481, CF0482, CF0483, CF0484, and GSE measurements do not support the subject as a source. Plastic pump caps used on 008, Inconel on 012.

CONCLUSION Inspection and disassembly show that pumps were non-initiator.

DATE 3-21-67 STATUS Non-initiator - Closed.

ENCLOSURE 18.55

D-18-291

TPS SC012-CM-CA-121 W/G pumps inspection and disassembly has been worked in sufficient depth to enable subject pumps to be reclassified as a non-initiator. Electrical insulation resistance and pin to pin resistance values all were within reasonable limits. Internally the unit was clean. Removal of the motor housing enabled verification of the existence of an inconel bearing housing on both pumps, and also enables verification of the dry condition of the external area thereto.

(This preceding constitutes an interim summary to TPS SC012-CM-CA-121)

Rev. 3-22-67

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POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-3

SUBJECT Suit Compressor(s) as an Ignition Source

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION AC short or bearing overheat due to friction, consequently electrical overload.

SUPPORTING FACTORS None

NEGATIVE FACTORS Suit measurements CF0184T and CF1053T do not support the suit compressors as an ignition source.

CONCLUSION Suit compressors have been investigated per TPS's SC012-CM-CA-096 & 098. They are both electrically sound and have been classed as non-iniators.

DATE: 3-21-67 STATUS: Non-initiator - Closed.

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-4

SUBJECT Cabin Fan(s) as an Ignition Source

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION AC Short burning insulation.

SUPPORTING FACTORS AC short in cabin air fan #1 supply wiring: (1) Cabin air fans #1 and #2 motor frozen as found during TPS SC012-CM-CA-178 and -179. (2) Motor of fans #1 and #2 frozen to stator due to melted epoxy used to coat stator.

NEGATIVE FACTORS No shorts in cabin fans. Wiring to cabin fan was found to have insulation burned off, but did not show evidence of arcing.

CONCLUSION Visual examination showed no evidence of combustion. Units are classified as non-initiators.

DATE 3-27-67 STATUS Non-initiator - Closed.

ENCLOSURE 18-55

D-18-294

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-5

SUBJECT Sponge Material in Waste Management Urine Disposal Lock

SYSTEM OR COMPONENT Waste Management Disposal

IGNITION SOURCE AND PROPAGATION Low auto ignition point of sponge material, Approx. 240° F.

SUPPORTING FACTORS None

NEGATIVE FACTORS None

CONCLUSION Removed disposal lock is discolored only and has minor sooting on top, apparently from soot settling. Visual inspection reveals no apparent burning from within. UDL has been disassembled, sponge material is undamaged and UDL has been classified as a non-initiator. Ref. TPS SC012-CM-CA-245.

DATE 3-21-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-6

SUBJECT Odor in LEB on 1/25/67 Reported by Technician Changing Flight Qual Recorder Tapes

SYSTEM OR COMPONENT Unknown (Assigned to ECS)

IGNITION SOURCE AND PROPAGATION Spark igniting volatile O_2 + odor mixture or spontaneous.

SUPPORTING FACTORS None.

NEGATIVE FACTORS The technician was interviewed and he reported that the odor similar to ether was detected two days prior to the accident. No reports of an odor similar to ether were made during the test on 1/26/67 or the day of the accident. A report of MEK (Methyl Ethyl Ketone cleaning solvent) was made on the day of the accident at the overboard vent.

CONCLUSION No substantiating evidence by physical evidence. Cleaning solvents could be an initial combustible substance; however, they would require an initiator.

DATE 3-27-67 Non-initiator - Closed.

ENCLOSURE 18-55

D-18-296

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POTENTIAL IGNITION SOURCES EVALUATION SHEET ECS-7

SUBJECT Glycol Evaporator Temp Sensor as an Ignition Source

SYSTEM OR COMPONENT ECS (Item 2.49)

IGNITION SOURCE AND PROPAGATION DC short - arc, igniting evaporator wicking.

SUPPORTING FACTORS None

NEGATIVE FACTORS Conflagration in this area should cause CF0018 to rise. CF0018 did not rise until very late - after fire crew call of fire.

CONCLUSION Sensor has been investigated per TPS SC012-CM-CA-116. Resistance check is ok and sensor has been determined a non-initiation. TPSSC012-CM-CA-115 investigated evaporator wicking and the sponge material is unburned, and damp from condensation. Pressure test of evaporator was good. Interim summaries to these TPS's are written.

DATE: 3-21-67 Non-Initiator - Closed

POTENTIAL IGNITION THEORIES EVALUATION SHEET ECS-8

SUBJECT Suit & Glycol Heat Exchangers' Sponge Material as on Ignition Source

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION Spontaneous - sponge material and glycol and/or oxygen.

SUPPORTING FACTORS None.

NEGATIVE FACTORS

CONCLUSION Glycol evaporator sponge material undamaged, damp from condensation only, classified as non-initiator. Suit heat exchanger visually ok, pressure decay performed, no decay in ten minutes. X-rays taken.

V. 3-21-67 Non-initiator - Closed.

ENCLOSURE 18-55

D-18-298

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POTENTIAL INITIATION TREORATE EVALUATION SHEET ECS-9

SUBJECT LIOH Absorber Element(s) as Ignition Source

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION Heat plus volatile gases (methane) retained by absorber elements.

SUPPORTING FACTORS

[illegible] FACTORS CF0184T, Absorber outlet temperature did not rise until very late after crew call of fire.

[illegible] Analyze remains of LIOH absorbers. Absorber elements to be investigated locally per TPS SC012-CM-CA-213 and 214. These elements are considered low probability initiators.

[illegible] 3-21-67 STATUS Non-initiators - Closed

ENCLOSURE 18-55

D-18-299

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-10

SUBJECT Plumbing Line Appears "EATEN" Through

SYSTEM OR COMPONENT Within ECU

IGNITION SOURCE AND PROPAGATION

SUPPORTING FACTORS

F FACTORS Line is "Burned" through and is in area of intense heat.
Line previously thought to be elsewhere.

SION "Line" is on aluminum W/G line not associated with electrical connection or interface. The fact that it is open in no way can be considered an initiation source. This item closed as it is an effect, not a cause.

3-21-67 I HS Non-initiator - closed.

ENCLOSURE 18-55
D-18-300

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-11

SUBJECT Heaters Within ECS

SYSTEM OR COMPONENT ECS (General)

IGNITION SOURCE AND PROPAGATION Electrical spark, material unknown.

SUPPORTING FACTORS None

NEGATIVE FACTORS Three ECS heaters (potable H_2O, steam duct, and urine dump) were all de-energized for this OCP (K-0021). Circuit Breakers for steam duct and urine dump were open per switch list, and found open after fire. Steam duct and urine dump heaters are external to pressure vessel.

CONCLUSION No visual evidence found on urine dump or steam heaters to support initiation theory. Potable H_2O assembly was investigated per TPS SC012 CM-CA-220 and revealed connector pins were corroded but no signs of arcing. thing abnormal was found upon examination of X-Rays. No evidence was found that would indicate the assembly was a potential initiator.

DATE 3-27-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-12

SUBJECT Water Glycol Analyses to Determine Contents

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION Water Glycol

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION TPS #SC012-CM-MA-004 written to perform sample analyses of Water Glycol obtained from various sources in the S/C. W/G in itself cannot be construed as an initiation source, but certainly a propagator or fuel for fire. The W/G fluid is therefore classified as non-initiator.

DATE 3-21-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-302

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POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-13

SUBJECT Crushed "Red Wire" at LiOH Diverter Valve Handle

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION.

SUPPORTING FACTORS None

NEGATIVE FACTORS Item mentioned is not a "Red Wire". It is the nylon braided cloth handle used to remove the LiOH cartridge.

CONCLUSION This item considered closed.

DATE 3-21-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET ECS-14

SUBJECT O_2 Flow Rate Sensor

SYSTEM OR COMPONENT ECS

IGNITION SOURCE AND PROPAGATION Component DC short, burning wire and propagating therefrom.

SUPPORTING FACTORS Hi O_2 flow indication.

NEGATIVE FACTORS Data analysis of CF0035, CF0036, CF0135, CF0136, and CF0137 indicate Hi demand of O_2 flow.

CONCLUSION See attached.

DATE: 3-21-67 STATUS: Non-initiator - Closed
(For associated wiring see EPS-3)

ENCLOSURE 18-55

D-18-304

ECS-14 O_2 Flow Rate Sensor:

Crew movement and apparent suit leakage has been correlated for 3 periods of Hi O_2 flow with gimbal angle and biomed data. Fire periods of Hi O_2 flow have been definitely correlated with periods of great crew activity (Cobra cable for instance).

The final Hi O_2 flow has been correlated with gimbal angles and biomed data, and the conditions analyzed lead to the conclusion that the O_2 flow transducer was giving valid data and that there was indeed a demand on the oxygen by the crew due to increased activity. The fact that a C&W signal was obtained from Hi O_2 flow 15 seconds after CF0035Q reached saturation at 23:30:59.4 GMT substantiates the conclusion that the flow transducer did not fail and was giving valid data at the time of C&W stimulation at 23:31:15 GMT.

B. High Oxygen Flow Rate

Telemetered data indicate that the high oxygen flow rate conditions for the last 30 seconds before the fire call can be attributed to the apparent high level of prime suit leakage at low suit-to-cabin differential pressure, magnified by apparent crew activity.

There has been considerable speculation as to whether the high flow could be indicative of a sensor and/or associated wiring difficulty.

The oxygen flow sensor circuit includes two separate outputs. The signal circuit going to the Pulse Code Modulation Telemetry System (PCM) is conducted to the PCM system through a twisted shielded pair of wires. A short circuit between the signal lead and either the return wire or the shield braid would cause a zero output (no flow) reading on the oxygen flow indication. It is highly improbable that any short circuit between the signal lead and a 28 volt DC supply lead could occur without a prior short circuiting to the ground lead or shield lead.

The second output from the oxygen flow sensor circuit goes to a time delay relay to indicate high flow alarm. It is on the ground circuit return side of the relay. A ground circuit completion is required to indicate high oxygen flow. This is supplied from the signal circuit going to PMC, and a ground on this line could not affect the PCM flow rate indication.

Single failures could exist within the bridge circuitry controlling the flow sensor which would indicate high flow rates on both the PCM output and the signal to the relay. These, however, will require examination of the oxygen flow sensor box to confirm or deny this possibility. A preliminary examination disclosed shorts to ground in the flow sensor; shorts to ground will produce a zero or no flow output indication. The flow sensor box is being torn down at the present time. It should also be noted that the location of the oxygen flow sensor was a high fire damage area, and that the sensor would be expected to be damaged by the fire.

Based on the above, it is concluded that the high oxygen flow data indication was valid, and that there was no malfunction of the sensor and/or associated wiring prior to the fire call.

SUMMARY OF G&N

POTENTIAL INITIATION THEORIES

G&N-1	Crew Member Motion Striking Electrical Component, Such as Panel, Connector	Closed
G&N-2	Eye Piece Stowage Unit, Heater Wire Routing G&N, LEB, Optics Stowage & Cond. Enunciator Panel	Closed
G&N-3	PSA Tray Short Circuit	Closed

Total	Open	Closed
3	0	3

POTENTIAL INITIATION THEORIES EVALUATION SHEET G&N-1

SUBJECT Crew Motion Striking Electrical Component Such as Panel, Connector, Etc.

SYSTEM OR COMPONENT Unknown

IGNITION SOURCE AND PROPAGATION Electrical short circuit - many potential fuel sources.

SUPPORTING FACTORS IMU gimbal T/M voltages CG2140 and 2170 reflect sharp vehicle motion at 23:30:54.9 coincident with AC-2 Glitch and Gas Chromatograph trace deflection.

NEGATIVE FACTORS

CONCLUSION Crew activity data are being utilized as supporting data in the evaluation of event time line. May be the cause of initiation. Physical evidence of arcing or wire damage is reported on specific items. (Reference EPS-2, EPS-3, EPS-14, EPS-22, EPS-26, COMM-1)

DATE 3-21-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET G&N-2

SUBJECT Eye Piece Stowage Unit, Heater Wire Routing

SYSTEM OR COMPONENT Optics Heaters or Heater Wires

IGNITION SOURCE AND PROPAGATION Possible failure of heater thermostat, short in heaters or wiring, initial fuel ESU Royalite cover, decal & foam or failure related to enunciator lights.

SUPPORTING FACTORS (1) Materials are combustible with a propagation rate greater than 2.5 inch/second from flammability test results. (2) SCT Eye piece cover found on C/M floor. (3) Scratches on Optics shroud. (4) Eye piece heater blanket and storage area damage. (5) G&N verb code decals were added to S/C configuration the morning of the incident. (6) Condition enunciator gimbal lock lite reads 3 ohms.

NEGATIVE FACTORS Eye piece heaters and thermostats checked ok, with no Propagation path.
Condition enunciator gimbal lock lite resistance value was verified to be nominal.
SCT eye piece cover may have been attached to Velcro by splt prior to incident. The cover dropped from Velcro after fire started.

CONCLUSION Close this item as an initiator. No source of ignition could be found in the electrical wiring or heaters and lights.

DATE 3-23-67 STATUS: Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET

G&N-3

SUBJECT PSA Tray Short Circuit

SYSTEM OR COMPONENT G&N PSA

IGNITION SOURCE AND PROPAGATION Nickel ribbon wire in module assembly of PSA, potted in urethane foam.

SUPPORTING FACTORS Previous experience of PSA tray short circuit causing ignition of foam (ambient air).

NEGATIVE FACTORS Inspection of PSA trays indicates no internal ignition of tray modules.

CONCLUSION Item closed after visual inspection of trays verified no ignition source in the modules.

DATE: 3-21-67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

SUMMARY OF SCS, SEQ, & RCS

POTENTIAL INITIATION THEORIES

SCS-1	Rotation Control Electrical Short	Closed
SCS-2	Translation Control Electrical Short	Closed
SCS-3	BMAG Power Switch Panel #24 Short	Closed

Total	Open	Closed
3	0	3

SEQ-1	Panel 10 and 11 Component Failure	Closed

Total	Open	Closed
1	0	1

RCS-1	Panel 12 RCS C/M-S/M Indicator Switch Failure	Closed

Total	Open	Closed
1	0	1

POTENTIAL INITIATION THEORIES EVALUATION SHEET SCS-1

SUBJECT Rotation Control Electrical Short

SYSTEM OR COMPONENT SCS

IGNITION SOURCE AND PROPAGATION Electrical short.

SUPPORTING FACTORS Case was warped and the cable was badly burned near the rotation control.

NEGATIVE FACTORS Data review, continuity check, visual and physical examination of the rotation control and associated wiring show no anomalies as a fire cause. Ref. TPS PIB-004, 007; CM-IV-077

CONCLUSION No evidence has been found from hardware or data examination that would indicate this component or its associated wiring was a cause or propagator of the fire.

DATE 3-21-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET SCS-2

SUBJECT Translation Control Electrical Short

SYSTEM OR COMPONENT SCS

IGNITION SOURCE AND PROPAGATION Electrical short

SUPPORTING FACTORS Problems during test with push-to-talk communications circuit. Also fracture in case.

NEGATIVE FACTORS Data review, continuity and insulation resistance check, and physical examination show no anomalies as a fire cause (ringout of associated S/C wiring showed no anomalies). Ref. TPS PIR-002, 003, 005, C/M-IV-058

CONCLUSION No evidence has been found from hardware or data examination that would indicate this component or its associated wiring was a cause or propagator of the fire.

DATE 3-21-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-314

NATIONAL AERONAUTI[illegible]ND SPACE [illegible]DMINISTRATION
APOLLO [illegible] REVIEW B[illegible]RD

IN REPLY REFER TO

March 9,. 1967

TO: A. D. Mardel, Chairman, Panel 18

FROM: C. L. Creech, Displays & Controls Subsystem Ma[illegible]ger

SUBJECT: Main Display Console Panel Number 24

Detailed investigation of the subject panel was conducte[illegible] in accordance with TPS CM-CA-030 and TPS CM-CA-031.

The Analytic Report of the above is forwarded herewith f[illegible] your information and retention.

Carlton L. Creech
Integration and Anal[illegible]sis Panel
(Panel 18)

Enclosure

ENCLOSURE 18-55

D-18-315

POTENTIAL INITIATION THEORIES EVALUATION SHEET SCS-3

SUBJECT BMAG Power Switch Short

SYSTEM OR COMPONENT SCS - Panel #24

IGNITION SOURCE AND PROPAGATION AC short, DC short, or arcing

SUPPORTING FACTORS Switch found in OFF position - S/B AC-2. Also light area on panel indicates a possible "false detent" position.

NEGATIVE FACTORS Data review and performance of TPS CM-CA-030 and -031 showed no anomalies as a fire cause. See attached report for complete analysis of BMAG Switch and Panel #24.

CONCLUSION No evidence has been found from hardware or data examination that would indicate this component was a cause or propagator of the fire.

DATE 3-21-67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

D-18-316

AS 204 ANALYTIC REPORT
MAIN DISPLAY CONSOLE PANEL #24

References:

1. TPS CM-CA-030
2. TPS CM-CA-031
3. V16-771424 - Panel Assembly Drawing
4. V16-976716 - Panel Schematic Drawing
5. Photographs - E-5C-21
   62-107C-4 through 6
   122-306C-12
   122-308C-1
   123-307C-5, 6
   123-309C-1 through 6

C. W. Fischer 3/10/67
C. W. Fischer
Systems Engineer
NAA/SID

C. L. Creech
C. L. Creech
Systems Engineer
NASA/MSC

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Abstract

Main Display Console Panel #24, Mission Sequence Control, as removed from S/C 012, presented two areas of special interest for detailed investigation. Soot shadowing on the panel gave evidence that the BMAG power switch, S-39, had been moved after the fire. Charring was present on one corner of the EDS power switch, S-1, and immediately associated wiring. Additionally, the integrity of all other switches and wiring on the panel was of interest.

Conclusions are that the BMAG switch was moved by accidental contact during the fire and again after the fire during power shut off; the EDS switch was charred by externally applied, locally concentrated, heat; the switch and associated wiring are electrically sound and functional; all other switches and wiring on the panel are electrically sound and functional.

Introduction

As removed from S/C 012, MDC Panel No. 24 was observed to have two areas requiring special investigation. The EDS Power switch, S-1, and its attached wiring were charred at one corner. The BMAG Power switch, S-39, was in OFF position as removed but the soot outline of the knob on the panel indicated that the switch had been in the AC-2 position in either the full, or "false", detent position (Ref. Photograph E-5C-21). Additionally, it was desirable to investigate the electrical and functional integrity of all of the switches and panel wiring.

Description of Tests

Tests were performed in accordance with TPS CM-CA-030 and TPS CM-CA-031 to determine the electrical integrity of all switches, panel wiring, and connectors in all positions of all switches. Special tests were performed to determine the effect of placing the rotary switches in "false" detent positions.

Detailed examination was made of the BMAG Power switch to determine the actual position of the switch during the various phases of the fire.

Record was made of a fingerprint found on the BMAG Power switch knob. (Ref. Photograph 123-309C-6.)

Test Results

The continuity tests of the panel in the as-found condition showed all normal continuity and circuit resistances.

The continuity tests in all other switch positions showed all normal continuity and circuit resistances.

The continuity tests of the rotary switches in the "false" detent positions showed that, with the exception of the BMAG Power switch, all continuities and circuit resistances were the same as in the full detent positions. In the AC-1 "false" detent position, the BMAG Power switch continuity and circuit resistances were the same as the full detent position. In the AC-2 "false" detent position, the AC circuits were closed through the switch but the DC circuit was open.

During initial examination of the soot shadow of the BMAG Power switch, a fingerprint in soot was noted on the switch knob (Ref. Photograph 123-309C-6). Prior to any manipulation of the switch, the fingerprint was photographed and "lifted" by the FBI.

The soot shadow of the BMAG Power switch knob was compared with those of other rotary switch knobs on Panel #24 (Ref. Photograph E-5C-21). It was noted that the TVC-1, Partial SCS Power, and Rate Gyro switch knobs had soot patterns that are broad in outline at the indexing point of the knob and follow the knob contour closely. The BMAG switch knob outline is pointed at the indexing point of the knob and smaller in outline than the knob. There is evidence of a double shadow of the BMAG Power switch knob. (See Photographs E-5C-21 and 123-309C-6.)

Analysis of Tests

The panel electrical continuity and resistance measurements showed that electrical continuity was present after the fire and that no damage of significant nature had been incurred by the switches, panel wiring, or connectors.

In analyzing the BMAG Power switch positions, several areas were investigated.

To establish the initial condition of the switch, Operational Checkout Procedure (OCP) K-0021 was examined. During performance of Steps 14-013 of this procedure, a Master Alarm is obtained when the BMAG switch is turned to AC-2. This was obtained thus indicating that the DC circuit was closed through the switch. Simultaneously, an indication of AC circuit switch closure appeared as Step 14-014 on the T/M record. Step 14-015 indicated satisfactory operation after warmup by confirming that the AGAF Temperature indication in the Caution & Warning Annunciator Matrix on Panel #10 did extinguish.

As noted above, the BMAG, DC heater circuit is not closed thro[illegible]e switch in the "false" detent position.

The soot shadow of the knob on the panel shows evidence of a dou[illegible]e shadow with one faint shadow in the full detent position and a denser shadow in the "false" detent position (Ref: Photograph 123-309C-6). When the switch is placed sequentially in these positions, the pointed shadow conforms closely to the overlapped outlines of the knob.

From these facts, it is deduced that the switch was in the full detent position at the initiation of the fire and was later, during fire, moved to the "false" detent position.

In considering the difference between the switch position as indicated by the panel soot shadow, and the OFF position, in which it was found when removed from the spacecraft, the fingerprint on the knob is of significance. The surface of the mylar knob was melted and bubbled indicating that the temperature at its surface had been over 500°F. The high temperature and melting and flowing of the knob surface would have destroyed any fingerprint made prior to the fire. The fingerprint on the knob was in soot and, as determined in the process of "lifting" it, entirely on the surface of the knob material.

It is deduced from this that the switch was operated after the fire to move it from the AC-2 "false" detent position to the OFF position. This action was most probably taken by the pad crew during power-down of the spacecraft.

Conclusions

It is concluded that operation and functioning of all switches on Panel #24 were normal throughout the fire. The components of the panel were not a source or a major propagator of the fire.

The charring of the EDS switch, S-1, and associated wiring, was caused by an external flame source and not by heat generated internally to the switch.

The different positions of the BMAG Power switch have been determined, or are deduced, to be:

1. Full detent AC-2 - at fire initiation.
2. "False" detent AC-2 - sometime during the fire.
   NOTE: It is postulated that during the fire the commander contacted the switch with his left foot during attempted egress. During the Mockup #2 exercises, it was noted that the commander's left foot did come very close to Panel #24 during the egress maneuver.
3. OFF - after fire during power-down.

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POTENTIAL IGNITION SOURCES EVALUATION SHEET SEQ-1

SUBJECT Panel 10 and 11 Component Failure

SYSTEM OR COMPONENT Sequencers

IGNITION SOURCE AND PROPAGATION Spontaneous - heat and glycol

SUPPORTING FACTORS Digital Event Timer (DET) on Panel 11 as experienced running hot during operations. If a glycol leak developed from the cold plate, leaking on the DET, it could cause fire.

NEGATIVE FACTORS See attached sheet

CONCLUSION The DET, or other components mounted on Panels #10 and #11 was neither an ignition source nor a propagator for the fire.

DATE: 3-21-67 STATUS Non-initiator - Closed

PANEL 10 AND 11

NEGATIVE FACTORS

Panels #10 and #11 were visually inspected. There is no evidence that the Digital Event Timer (DET) on Panel #11 was running hot. This instrument normally dissipates approximately 4 Watts and consequently has a temperature rise of only 2-3 degrees F. The backpotting if the DET was inspected and found to be sound. It is lightly sooted but still transparent enough to allow the wire connections to the header to be seen. The wire harness has no evidence of overheating and has only a light soot deposit. The panel connector is clean and the pins are straight and clean. The DET is hermetically sealed. There is no evidence that the seal is broken. The digit wheels are visible through a light soot deposit on the cover glass. There is evidence of water glycol drip on the DET case behind the panel. However, the water glycol drip has washed away some of the soot deposit and appears to have occurred late in the progress of the fire. The C&W matrices on Panels #10 and #11 were examined. The backs of these matrices were lightly sooted but had no evidence of overheating. The cable harnesses and connectors were clean and in good condition. The legend plates on the panel side of the matrices were sooted but the glass covers were all intact and the legends legible. Some deterioration of the RTV Silicone rubber potting material is evident on the matrix around the panel openings where a flue effect allowed hot gases to pass between the panel edge and the matrix edge. However, the matrix bodies are intact and are not distorted. There is no evidence of water glycol drip in the matrices.

POTENTIAL IGNITION SOURCE EVALUATION SHEET RCS-1

SUBJECT Panel #12 RCS C/M-S/M Indicator Switch

SYSTEM OR COMPONENT RCS

IGNITION SOURCE AND PROPAGATION Spark or heat plus glycol. DC short or spontaneous.

SUPPORTING FACTORS (1) Panel #12 switch (S-2) just completed potting still in cure cycle. (2) Official last switch moved per OCP prior to fire. (3) This switch is located in a heavy fire damaged path looking at the exterior of the MDF to the command pilots couch.

NEGATIVE FACTORS See attached sheet

CONCLUSION The Panel #12 S-2 switch was neither an iniator or a propagator of the fire.

DATE: 3-21-67 STATUS: Non-ignition - Closed

ENCLOSURE 18-55

D-18-323

PANEL #12 RCS C/M-S/M INDICATOR SWITCH

NEGATIVE FACTORS

Visual examination of Panel #12 S-2 back potting showed no damage other than light soot deposit. Potting material is still transparent and wire connections to switch terminals are visable through the potting material. The switch is hermetically sealed and all make and break contacts are within the sealed enclosure. The terminals are brought out through a metal-glass header to which the wiring is soldered. The solder connections are then covered with the potting material to protect the joints and terminals from exposure to the C/M atmosphere. The wire harness to S-2 and the associated connector are in good condition with only light soot deposits and no evidence of overheating. The connector interface is clean and the pins are all straight and clean. There is no evidence that the switch, or its associated wiring, were overheated. There is nothing to indicate that the switch, or associated wiring, were ignition source of a propagator of the fire.

SUMMARY OF COMM

POTENTIAL INITIATION THEORIES

COMM-1	MDAS Octopus Cable Connector Short	Closed
COMM-2	Teleflex Cable Short to TB 61-7	Closed
COMM-3	Overheating of Crewman's Electrical Assembly	Closed
COMM-4	Disconnect Spark on 0.020 Milliamp Lines	Closed
COMM-5	RF Power	Closed
COMM-6	USBE Potting Burned	Closed
COMM-7	Shorts in Biomed-Comm Suit Wiring	Closed
COMM-8	MDAS-LEM Recorder Signal Wires Short	Closed

Total	Open	Closed
8	0	8

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-1

SUBJECT MDAS Octopus Cable Connector

SYSTEM OR COMPONENT Biomed - Experiments

IGNITION SOURCE AND PROPAGATION Octopus cable 28 VDC shorting to ground caused by crewman deforming P-185 connector on scientific compartment "A" panel. Propagation via material on crewman's shoe, connector insert, sleeve, wire insulation.

SUPPORTING FACTORS 28 VDC from Bus B is available at J185 connector. CB 117 on panel 22 open and heavily sooted. This is CB feeding MDAS power.

NEGATIVE FACTORS MDAS data would have indicated a short if power had dropped below 19 VDC for 25 milliseconds or longer. Data does not indicate this occurred.

CONCLUSION Arcing was superficial, appears to be a result of the fire and not a cause.

DATE: 3-21-67 STATUS: Non-initiator - Closed

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POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-2

SUBJECT Teleflex Cable Short to TB 61-7

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Cable shorts TB 61-7 to ground causing 28 volt drop thru 825 ohms wire wound 2 watt resistor. Propagation via resistor heating up and igniting conformal coating which in turn ignites debris trap net.

MONITORING FACTORS

CORRECTIVE FACTORS (1) Continuity check TB 61-7 to ground.

(2) Visual examination of resistor R7

CONCLUSION TPS CM-IV-110 dated 3-14 references TB 61-7. Resistance checks and visual inspection concluded no shorting or grounds on terminal board. The soot was brushed away from the connector and physical inspection resulted in no indication of short.

DATE: 3-22-67 STATUS: Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-3

SUBJECT Overheating of Crewman's Electrical Assembly
(Cobra Cable, T Adapter, Noise Eliminator & PGA)

SYSTEM OR COMPONENT COMM

IGNITION SOURCE AND PROPAGATION Short inside umbilical could cause overheating of assembly. Propagation from potting compound of crewman's umbilical or portions of crewman's suits.

SUPPORTING FACTORS 1. Suits appear burned.

2. Crewman had changed umbilical to attempt to repair live mike condition.

NEGATIVE FACTORS 1. Replacing to new cable did not repair live mike condition.

2. All leads into umbilical are current limited.

CONCLUSION TPS CA-075, CM-CA-002, 005, 065, 061. These TPS's tested for shorts, grounds, material analysis, and x-rays. All Showed no anomalies that could cause incident. Physical examination did not disclose any evidence of arcing or fire initiation.

DATE 3-21-67 Non-initiator - Closed

ENCLOSURE 18-55

D-18-328

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-4

SUBJECT Disconnect Spark on .020 Millamp Lines

SYSTEM OR COMPONENT Telecommunications

SOURCE AND PROPAGATION Connector of crewman umbilical was disconnected to replace umbilical cable. Propagation from connector insert or umbilical potting compound

SUPPORTING FACTORS Crew thought they were having trouble so they replaced umbilical. The new umbilical did not clear fault symptom.

NEGATIVE FACTORS 1. Disconnect was approximately 20 minutes prior to fire call.
2. Tests ran in O_2 atmosphere showed no appreciable spark at even higher currents.

CONCLUSION As a result of above test, the conclusions are that no appreciable spark caused by disconnect can be determined as cause of incident.

3-21-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-329

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-5

SUBJECT RF Power

SYSTEM OR COMPONENT RF Systems

IGNITION SOURCE AND PROPAGATION RF radiated energy produces adequate temperature rise to ignite materials. Requires an open RF lead inside the cockpit. Propagation via any combustible near or around the S/C RF coax lines.

SUPPORTING FACTORS Very few, if any. However, adequate RF energy was available in the UHF/FM system and the C-Band system coaxs.

NEGATIVE FACTORS It would require a broken coax. It would require a combustible material in the broken coax area. It would require a unique set of conditions to produce a temperature rise in the material. PCM data indicates normal operation

CONCLUSION Visual inspection of S/C coax, Ant.'s and coax switches show no evidence of arcing or shorting. C-Bank, S-Band, and VHF/FM continued to radiate after LOS period.

DATE: 3-22-67 STATUS Non-Initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-6

SUBJECT USBE Potting Burned

SYSTEM OR COMPONENT Telecommunications

IGNITION SOURCE AND PROPAGATION ISBE (Unified S-Band Transponder) may have had internal short. Propagation via potting material inside USBE.

SUPPORTING FACTORS USBE potting is burned in blow hole fashion.

NEGATIVE FACTORS USBE transmissions continued well into general fire time. Carrier continued after voice and data terminated.

CONCLUSION Visual, resistance, and functional tests of USBE completed. No anomalies observed that could cause incident . USBE classified to "B" category.

DATE 3-21-67 STATUS: Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-7

SUBJECT Shorts in Biomed-Comm Suit Wiring

SYSTEM OR COMPONENT Biomedical - Communications

IGNITION SOURCE AND PROPAGATION DC from S/C to suit to ground

Propagation via suit and suit wiring

SUPPORTING FACTORS None - Six shorted wires in communications portion of suit wiring. Possible supporting evidence in communications anomalies. Insulation around wires was more affected by heat than cable sheathing.

NEGATIVE FACTORS Normal operation of components using these wires use only low currents of insufficient energy to create arc which would cause ignition(200° F) in suit. Type of cable used has fairly low heat resistant insulation with higher temperature (600° F) material used in the outer sheath.

CONCLUSION Shorting and damage is apparently due to external heat and burning.

DATE: 3-23-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-332

POTENTIAL INITIATION THEORIES EVALUATION SHEET COMM-8

SUBJECT MDAS-LEM Recorder Signal Wires Short

SYSTEM OR COMPONENT Experiments - MDAS

IGNITION SOURCE AND PROPAGATION Short circuit on MDAS signal wires to LEM voice recorder, propagation via debris traps.

SUPPORTING FACTORS None

NEGATIVE FACTORS These wires carry 100 PPS IRIG B timing of 5 Volts peak-to-peak.

CONCLUSION TPS CM-CA-076 duplicated suspected short on signal wires which did not draw excessive current. MDAS functioned normally.

DATE: 3-22-67 STATUS: Non-initiator - Closed

SUMMARY OF EPS

POTENTIAL INITIATION THEORIES

EPS-1	Gas Chromatograph Cable Short (Ref. EPS-2)	Duplicate
EPS-2	Gas Chromatograph Connector Short & Cable Short	Closed
EPS-3	Damaged Wire Harness Under LiOH Door	Closed (Probable Initiator)
EPS-4	Damaged Wire (1C50A16) Near J-Box C15-1A52 (Screwdriver Incident)	Closed
EPS-5	Teleflex Cable Shorting Resistor R7 at C15A7TB61-7 (Reference to COMM-2)	Duplicate
EPS-6	Electrical Short Due to Cold Flow Characteristics of Teflon Wire	Delete (General Category)
EPS-7	Q-Ball Wiring Short	Closed
EPS-8	CB64 on Panel 25 (SCS GRP 2 MNB) Rubbing Against Wire Harness	Closed
EPS-9	Tapes on Entry Batteries (White Room Tape)	Closed
EPS-10	Pyro Batteries Vented to Cabin	Closed
EPS-11	Cabin Fan Failure (Reference ECS-4)	Duplicate
EPS-12	Suit Compressor Overloaded (Reference ECS-3)	Duplicate
EPS-13	Inverter Phase Lock Box Failure	Closed
EPS-14	Panel 150 Lying Loose	Closed
EPS-15	J185 Octopus Cable Connector (Reference COMM-1)	Duplicate

EPS-16	Water Glycol Corrosion of Connector(s)	Delete (General Category)
EPS-17	Glycol Pump Overloaded. (Reference ECS-2)	Duplicate
EPS-18	AC Control Box V16-451136 Short	Closed
EPS-19	Evidence of an Arc on Tip of Pin 16 on Panel 20	Closed
EPS-20	Arc of Wire/Cover on J-Box C15-1A52 (Ref. EPS-22)	Duplicate
EPS-21	Wire Short to Junction Box Cover (Ref. EPS-22)	Duplicate
EPS-22	Damaged Wire J-Box C15-1A52 Cover Plate	Closed
EPS-23	Electrical Wires Routed in Front of Heater (Reference P 482 TPS 369 Step 17)	Closed
EPS-24	SPS PUGS Display Unit	Closed
EPS-25	Main Bus B Short to Substructure at S11, Panel 8	Closed
EPS-26	Wiring Arc Near Scientific Equipment Bay LEB Main Bus B 2	Closed Per Fire Board

Total	Open	Closed	Duplicate	Deleted
16	0	16	8	2

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-1

SUBJECT Gas Chromatograph Cable Short

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE EPS-2

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE: 3-23-67 STATUS: DUPLICATE

ENCLOSURE 18-55

D-18-336

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-2

SUBJECT GAS Chromatograph Connector Short & Cable Short

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Electrical spark or heat, propagation via plastic cover on connector.

SUPPORTING FACTORS Measurement CT0108 starts to vary at 23:30:49. CB C15A5C116 found open after fire.

NEGATIVE FACTORS

CONCLUSION Close examination of this connector shows no evidence of arcing at the connector or associated wiring attributable to an electrical short. The damaged plug and wiring has been analyzed - the cause was due to external heating.

DATE: 3-22-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-337

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-3

SUBJECT Damaged Wire Harness Under LiOH Door

SYSTEM OR COMPONENT EPS/ECS

IGNITION SOURCE AND PROPAGATION Electrical short on the DC power input wiring to the instrumentation on the O_2 panel. Propagation could have been along the nearby debris net.

SUPPORTING FACTORS Location in area determined as the probable initiation. Possible copper deposits were found on the bottom of the LiOH door. Material is being removed for analysis. Sections of the wire harness and a portion of the panel has been burnt away eliminating physical evidence of potential arcing.

NEGATIVE FACTORS

CONCLUSION This theory is still valid

DATE: 3-24-67 STATUS: Probable Initiator - Closed

ENCLOSURE 18-55

D-18-338

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POTENTIAL IGNITION SOURCE EVALUATION SHEET EPS-4

SUBJECT Screwdriver damage by technician 17 Jan. '67
Damaged Wire (1C50A16) on Panel C15-1A52

SYSTEM OR COMPONENT RCS/EPS

IGNITION SOURCE AND PROPAGATION Electrical spark from DC short propagating along the wire covering.

SUPPORTING FACTORS On DR 0917, the exposed conductor 1C50A16 was temporarily repaired with 7503 Mystic Tape and permanently repaired using heat shrink sleeving per standard repair manual.

NEGATIVE FACTORS The harness was diligently examined by a member of the Fire Panel and by EPS engineering. There is no evidence of an arc from this source. Measurement CH2087 would have indicated zero if the wire had shorted. No zero indication was noted.

CONCLUSION Based on the above data and observations, reference TPS CM IV-192, it is concluded that this item was not the ignition source.

DATE: 3-21-67 STATUS Non-initiator - Closed

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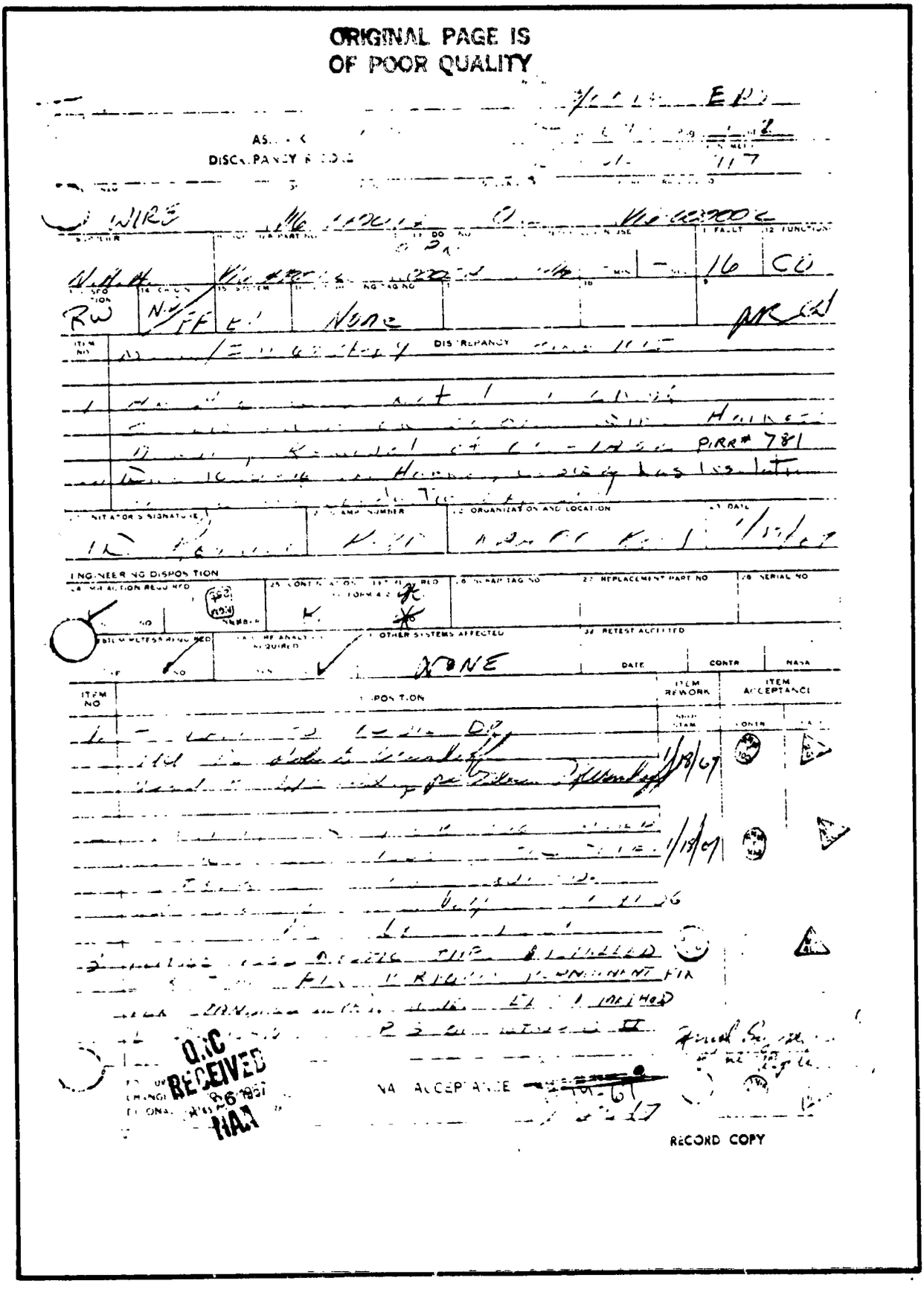

ENCLOSURE 18-55

D-16-340

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Page 1 of 2 Pages

NASA - KSC

DISCREPANCY RECORD

5/C012 S/L 111

3 PART NAME	4 CONTRACT END ITEM NO	5 SERIAL NO	6 ALL MARKING NO
WIRE	V16-440012	02	V16-000002

7 SUPPLIER	8 SUPPLIER PART NO	9 REP DOC NO	10 TIME/CYCLES IN USE HR / MIN / SEC	11 FAULT	12 FUNCTION

13 DISPOSITION	14 ORIGIN	15 SYSTEM	16 WITHHOLDING TAG NO	17	18	19

DISCREPANCY

ITEM NO	
	Cont. Dispo.

20 INITIATOR'S SIGNATURE	21 STAMP NUMBER	22 ORGANIZATION AND LOCATION	23 DATE
[signature]	4424	MMA Code 34	1/17/67

ENGINEERING DISPOSITION

24 NR ACTION REQUIRED	25 CONTINUATION SHEET REQUIRED (ASC FORM 4-21)	26 SCRAP TAG NO	27 REPLACEMENT PART NO	28 SERIAL NO
☑ YES ☐ NO	☐ YES ☐ NO			

29 SYSTEM RETEST REQUIRED	30 FAILURE ANALYSIS REQUIRED	31 OTHER SYSTEMS AFFECTED	32 RETEST ACCEPTED DATE	CONTR	NASA
☐ YES ☑ NO	☐ YES ☑ NO	NONE			

ITEM NO	DISPOSITION	ITEM REWORK SHOP STAMP	ITEM ACCEPTANCE CONTR.	ITEM ACCEPTANCE NASA
4.	CONCURRENCE WITH ENGINEERING STEP 1 & 2 OF DISCREPANCY, THE EXPOSED CONDUCTOR WILL HAVE TO BE CUT BACK TO A POINT WHERE INSULATION IS NOT DAMAGED. [illegible]			

FOR FURTHER CHANGE INFORMATION AND ADDITIONAL COORDINATION SHEETS USE NASA FORM 1018

FINAL ACCEPTANCE 1-19-67

QRC RECEIVED JAN 26 NASA

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ENCLOSURE 18-55

D-18-341

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-5.

SUBJECT Teleflex Cable Shorting Resistor R7 at C15A7TB61-7

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE COMM-2

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE: 3-23-67 STATUS: DUPLICATE

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-6

SUBJECT Electrical Short Due to Cold Flow Characteristics of Teflon Wire

SYSTEM OR COMPONENT EPS, SPS, RCS, T/C, G&N, SEQ, C&W, & Scientific Experiments

IGNITION SOURCE AND PROPAGATION Electrical spark, propagation via Velcro, debris trap.

SUPPORTING FACTORS None

NEGATIVE FACTORS Detailed examination of harnesses in suspect areas revealed no evidence of shorting or arcing due to the cold flow characteristics of teflon, Reference TPS CM-IV-192.

CONCLUSION This item is a general statement and cannot be tied to a specific location or initiation theory. It will be covered by a general discussion in the Panel 18 report. Transferred to General Discussion.

DATE 3-24-67 : Closed as a specific item.

ENCLOSURE 18-55

D-18-343

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-7

SUBJECT Q-Ball Wiring Short

SYSTEM OR COMPONENT SEQ

IGNITION SOURCE AND PROPAGATION Electrical spark, propagation via S/C harness.

SUPPORTING FACTORS None

NEGATIVE FACTORS Pin-to-pin and pin-to-ground resistance checks revealed no anomalies in these circuits. Reference TPS SC012-088 which performed resistance checks on Q-Ball wiring.

CONCLUSION Wiring was extended to CM pressure shell. The continuity checks and physical evaluation of connector at Q-Ball revealed that it was mated with the stowage connector.

DATE 3-22-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

D-18-344

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-8

SUBJECT CB64 on Panel 25 (SCS GRP 2 MNB)
Rubbing against wire harness

SYSTEM OR COMPONENT SCS

IGNITION SOURCE AND PROPAGATION Electrical spark

SUPPORTING FACTORS Indications of interference between CB64 & wire harness behind Panel 25. Indentation in Teflon insulation on wire harness matches with "white" deposit on terminal of CB 64.

NEGATIVE FACTORS No visual indication of any arc was noted.

CONCLUSION Close this item. Detailed examination of panel revealed no indications of shorts or arcs.

DATE 3-22-67 STATUS: Non-initiator - Closed

ENCLOSURE 18.55

D-18-345

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-9

SUBJECT Tapes on Entry Batteries
(White Room Tape)

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Glycol residue on tape covering battery terminals provides a conductive path which after a prolonged period gets hot and ignites.

SUPPORTING FACTORS Tape on battery terminals - flammability of material.

NEGATIVE FACTORS Location removed from Fire Panel indicated most probable ignition area. No mechanism to provide conductive path.

CONCLUSION Inspection shows no adjacent ignition source which would be a propagation path.

DATE: 3-23-67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

D-18-346

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-10

SUBJECT Pyro Batteries Vented to Cabin

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Outgassing of Batteries

SUPPORTING FACTORS None

NEGATIVE FACTORS Venting occurs only during excessive charging or discharging. Subsequent tests verify the pyro batteries had not been subject to any condition which could have resulted in venting. No indication of fire initiation in this area.

CONCLUSION Close this item based upon lack of supporting factors and result of lab tests. Physical inspection of the batteries showed no external evidence of KOH which probably indicates no venting.

DATE: 3-22-67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

D-18-347

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-11

SUBJECT Cabin Fan Failure

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE ECS-4

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-67 STATUS DUPLICATE

ENCLOSURE 18-55

D-18-348

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-12

SUBJECT Suit Compressor Overloaded

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE ECS-3

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-67 STATUS DUPLICATE

ENCLOSURE 18-55

D-18-349

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-13

SUBJECT Inverter Phase Lock Box (Panel 208) Failure

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Heat

SUPPORTING FACTORS None

NEGATIVE FACTORS The three circuit breakers CB 1, 2, and 3 on Panel 209 which supplied all power to the phase lock box (Panel 208) was open per OCP and found open subsequent to the fire.

CONCLUSION Close this item. The phase synch box was examined and shows no indication of overheating or other evidence of ignition source. The phase lock box was not energized from switch position information.

DATE: 3-22-67 STATUS: Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-14

SUBJECT Panel 150 Lying Loose

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Electrical spark or heat.

SUPPORTING FACTORS Panel 150 has circuit breakers which connect directly to the 3 entry batteries and 2 pyro batteries. This panel was not installed in place and was "resting" on a harness.

NEGATIVE FACTORS No evidence of arcing or fire initiation in this area.

CONCLUSION Close this item. Extensive examination of panel 150 revealed no evidence of arcing or shorting. Electrical checks substantiate Nominal resistance and functional circuit breakers.

DATE: 3-22-67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

D-18-351

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-15

SUBJECT J185 Octopus Cable Connector

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE COMM-1

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-67 STATUS: DUPLICATE

ENCLOSURE 18-55

D-18-352

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-16

SUBJECT Water Glycol Corrosion of Connector(s)

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION This item is very general. A discussion will be included in the Panel 18 Final Report.

DATE: 3-24-67 STATUS: Closed as a specific item

ENCLOSURE 18-55

D-18-353

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-17

SUBJECT Glycol Pump Overloaded

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE ECS-2

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-67 STATUS: DUPLICATE

ENCLOSURE 18.55

D.18.354

C-4

POTE[illegible] EVALUATION REPORT EVALUATION SHEET EPS-18

SUBJECT AC Control Box V16-451136 Short

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Electrical short and/or heat propagating via an unknown mechanism.

SUPPORTING FACTORS Burned conformal coating on terminals 13 and 23 of motor switch S5.

NEGATIVE FACTORS Visual examination showed no evidence that the teflon on the wire was damaged. Electrical tests, reference TPS CM CA-056, indicated that the circuit was still intact.

CONCLUSION Based on the above tests and visual inspection, it is concluded that this item was not the ignition source. A member of the Fire Panel concurs.

DATE 3-21-67 Non-Initiator - Closed

ENCLOSURE 18-55

D.18-355

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-19

SUBJECT Evidence of an ARC on Tip to Pin 16 on Panel 20

SYSTEM OR COMPONENT T/C

IGNITION SOURCE AND PROPAGATION Electrical spark

SUPPORTING FACTORS Visual inspection indicates that the tip of Pin 16 (VHF AM +28 VDC) has arced.

NEGATIVE FACTORS Arc is only on tip radius of pin. Tip radius is not rubbed when connector is mated. There is no evidence of overheating or arcing of pin or mating connector. The small mark on the tip radius of the pin most probably occurred during panel checkout prior to installation and was not rubbed off when the connector was mated.

CONCLUSION

There is no evidence that this item was an initiator or the fire.

DATE 3-22-67 STATUS Non-initiator Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-20

SUBJECT ARC of Wire/Cover on J-BOX C15-1A52

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE EPS-22

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-87 STATUS DUPLICATE

ENCLOSURE 18-55

D-18-357

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-21

SUBJECT Wire Short to Junction Box Cover

SYSTEM OR COMPONENT

IGNITION SOURCE AND PROPAGATION

DUPLICATE - REFERENCE EPS-22

SUPPORTING FACTORS

NEGATIVE FACTORS

CONCLUSION

DATE 3-23-67 STATUS DUPLICATE

ENCLOSURE 18-55

D-18-358

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-22

SUBJECT Damaged Wire J-Box C15-1A52 Cover Plate

SYSTEM OR COMPONENT EPS/RCS (+Yaw Normal Power MNA)

IGNITION SOURCE AND PROPAGATION Arcing of the DC power to the cover plate.

SUPPORTING FACTORS High energy source (250 amp power supply through a 20 amp circuit breaker and #16 wire).. Evidence of arcing or welding on the panel cover plate and on the adjacent power wire. Propagation could have been by the wire coating glycol residue, and/or nearby debris net, Velcro, etc. ignited either locally or at a distance by flying sparks. This area matches the Fire Panel's theory about where the fire started..

NEGATIVE FACTORS No evidence of a momentary overload on Main Bus A.

CONCLUSION This theory is not prime suspect.

DATE 3-24-67 Non-initiator - Closed

ENCLOSURE 18-55

D-18-359

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-23

SUBJECT Electrical Wires Routed in Front of Heater
(Reference P482 TPS 369 Step 17)

SYSTEM OR COMPONENT EPS/ECS

IGNITION SOURCE AND PROPAGATION Overheated wiring in vicinity of urine dump heater.

SUPPORTING FACTORS None.

NEGATIVE FACTORS Heaters not on per OCP. C/B's verify this configuration. Heater located in aft compartment. No evidence of fire having originated in this area.

CONCLUSION Since no power was applied to this circuit and physical evidence indicated fire did not originate in aft compartment, close this item.

DATE 3-28-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-24

SUBJECT SPS PUGS Display Unit

SYSTEM OR COMPONENT SPS

IGNITION SOURCE AND PROPAGATION 28 VDC and 115 V, 400 Cycle, was present within the PUGS Display Unit at the time of accident. All PUGS circuit breakers were closed.

SUPPORTING FACTORS None

NEGATIVE FACTORS TPS S/C012-CM-CA-092 was performed satisfactorily which verified the functional integrity of the PUGS Display Panel Assembly. All data obtained was within specified accuracy of applicable process spec. MA0210-0171, Sect. 61.

CONCLUSION The only visible damage to the PUGS Display Panel Assembly is a cracked glass on the face of unbalance meter. This unit should have in no way contributed to the S/C 012 accident.

DATE 3-24-67 STATUS Non-initiator - Closed

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-25

SUBJECT Main Bus B Short to Substructure at S11, Panel 8

SYSTEM OR COMPONENT Main Display Console

IGNITION SOURCE AND PROPAGATION Potential short circuit or arc through area of conformal coating on one terminal of S11 that contacted substructure behind Panel #8.

SUPPORTING FACTORS Continuity check through damaged area of conformal coating on S11 terminal shows potential short circuit to substructure. Microscopic examination of substructure disclosed minute area of sparking, or arcing, in area of terminal contact.

NEGATIVE FACTORS Area of sparking to substructure is minute. The arc pits can only be observed under at least 10 power magnification. There is no evident damage due to overheating to the conformal coating on the switch terminal.

CONCLUSION An intermittant short to the substructure existed from S11 through the conformal coating. However, the size of the observed arc pits and the lack of heat caused decomposition of the conformal coating indicate that the heating was insufficient to have been the ignition source.

ATP 3-24-67 STATUS Non-initiator - Closed

ENCLOSURE 18-55

POTENTIAL INITIATION THEORIES EVALUATION SHEET EPS-26

SUBJECT Wiring Arc near Scientific Equipment Bay 2
LEB Main Bus B

SYSTEM OR COMPONENT EPS

IGNITION SOURCE AND PROPAGATION Electrical arc igniting battery tape.

SUPPORTING FACTORS Evidence of arcing. Battery tape was burned. A short on Main Bus B could account for the AC Bus #2 voltage transient.

NEGATIVE FACTORS Inspection by the Fire Board resulted in the conclusion that the absence of a propagation path negates this theory.

CONCLUSION This theory should be closed based on the results of the Fire Board inspection.

DATE 3-27-67 Non-initiator - Closed

ENCLOSURE 18-55

POTENTIAL INITIATION THEORIES EVALUATION SHEET

SUBJECT STATIC CHARGE BUILDUP IN SUITS

SYSTEM OR COMPONENT PRESSURE GARMENT ASSEMBLY

IGNITION SOURCE AND PROPAGATION POSSIBILITY OF STATIC CHARGE BUILDUP AND DISCHARGE BETWEEN SUITED ASTRONAUT AND S/C.

SUPPORTING FACTORS SUIT AND COUCH PAD MATERIAL WAS BURNED.

NEGATIVE FACTORS TPS S/C 014 CM 038 WAS PERFORMED WITH A SUITED PERSON, VENTILATED WITH DRY AIR. READINGS OF CAPACITANCE AND VOLTAGE BETWEEN SUBJECT AND S/C WERE BELOW THE ENERGY REQUIREMENTS TO IGNITE ANY SOLID MATERIALS FOUND IN S/C.

CONCLUSION A SUITED PERSON CANNOT GENERATE SUFFICIENT ELECTROSTATIC ENERGY TO IGNITE ANY SOLID MATERIALS FOUND IN S/C

DATE: 3/27/67 STATUS: Non-initiator - Closed

ENCLOSURE 18-55

D-18-364

BRIEF SUMMARY OF SIGNIFICANT SPECIAL TEST RESULTS

1. Effect of Water-Glycol on Gas Chromatograph Cable and Connector

Tests conducted to determine the reaction of the cable and its contribution to the accident if water-glycol had contacted the gas chromatograph connector. Tests indicated that no voltages appeared at the two shielded signal leads until all connector pins were completely immersed. At that point a 400 cps, approximately 4.5 volt, signal was noted. Ignition did not occur; however, what appeared to be localized boiling was noted in the area of two 115-volt connector pins which were adjacent to each other on the connector.

2. Effects of Water-Glycol on Spacecraft Connectors

During the checkout phase of Spacecraft 012 operations, water-glycol leaks and spillages were encountered. Some of the spacecraft harnesses were wetted and subsequently cleaned with water and alcohol, and dried with nitrogen. Test conducted to determine if the cleaning procedure was adequate and to determine the effects of exposure of electrical connectors to water-glycol. Test incomplete at this time as 20-day cycle started on March 14, 1967. Tests being conducted at KSC.

3. Determine ΔP vs CDU Gimbal Angles

A test was conducted on Spacecraft 008 at MSC to obtain data on CDU gimbal angle changes at various cabin differential pressures. This data was then used for correlation with data available from Spacecraft 012. All of the data are contained in the Panel 10 Final Report.

4. Corner Ignition Test

A test was conducted at MSC in a 14.7 psia, 100% oxygen environment to determine whether ignition of a nylon chafing strip at the left-hand portion of the lower equipment bay will ignite the remaining flammable materials in the immediate vicinity. Test disclosed that all debris netting and Velcro on flight qual recorder burned completely as a result of the nylon ignition.

5. Boilerplate Mock-up Fire Tests

Boilerplate A at MSC was mocked-up as close as possible to the Spacecraft 012 internal cabin configuration with respect to flammable materials. A fire was then started to try to reproduce the Spacecraft 012 accident. Five tests have been conducted to date, under various pressure and oxygen environments. The test results are covered in detail in the Panel 8 Final Report.

6. Wet Wire Fire Ignition Test

A test was conducted at MSC to determine whether water-glycol will ultimately lead to shorting and ignition when dripped on wires with deliberate flaws. The test indicated that a conductor carrying 3 amp 28 volts DC did ignite approximately 8 hours after exposure to a water-glycol drip.

7. Summary of Spacecraft 008 DC and AC Electrical Tests

The results from each of the electrical tests conducted on Spacecraft 008 are summarized in the following paragraphs. The many tests and test conditions were primarily compared to the PCM data obtained at the time of the AC electrical transient on Spacecraft 012, to establish what condition or set of conditions would duplicate that data.

(a) Effect of Rapid Switching of Non-Essential Bus from DC bus A to DC bus B

This test condition did not produce data similar to that on Spacecraft 012.

(b) Effect of Inverter Switching to Supply AC Buses

This test condition did not produce data similar to that of Spacecraft 012. The over-shoot amplitudes on the AC bus voltages were too low and too rapid.

(c) Effect of Load Switching on the AC Buses

This test condition did not produce data similar to that of Spacecraft 012. The drop in voltage on the AC bus due to switching any of the large electrical loads was

regulated by the inverter to maintain the DC bus voltage above the minimum required to cause a dropout of the VHF/FM transmitter and C-band beacon.

(d) Effects of Shorts of Various Durations and Levels on AC bus 2 Circuits

These tests did not produce data similar to that of Spacecraft 012. The prime difference was the lack of proper amplitude for the three AC bus 2 voltages. However, dropout effects of the VHF/FM transmitter and C-band beacon, and the recovery time for the AC voltages were similar to that of Spacecraft 012.

(e) Effects of Interrupting DC Power to the Control Relays which Control Switching of AC Power to the VHF/FM Transmitter and C-band Beacon

These tests did not produce data similar to that of Spacecraft 012. The dropout of the transmitter and beacon could be reproduced; however, the effect on the AC voltages was not present.

(f) Effects of DC Shorts of Various Durations and Levels on the DC bus

DC shorts of a 5 to 20 milliseconds duration for current values of about 80 amps or greater are required to drop the voltage on the DC bus sufficiently to cause the inverter to lose regulation. These tests indicated that shorts of several milliseconds duration and of sufficient current drain can closely reproduce the Spacecraft 012 data indications at the time of the AC bus 2 transient.

(g) Effects of Momentary Interruption of DC Power to the Inverter

A DC interruption of 2.5 to 20 milliseconds duration will reproduce the Spacecraft 012 data indications at the time of the AC bus 2 transient.

(h) Determine Arcing Damage to Wires of Various Sizes Used Within the Spacecraft, With Current Limited to Values Commensurate with Circuit Characteristics of the Spacecraft

The wire damage due to arcing was found to be primarily a function of the resistance at the shorting point. A relatively high current passing through a short of very low resistance would cause little or no damage as compared to a relatively low current passing through a short of several ohms resistance.

(i) Effects of Shorting Power Leads in the Octopus Cable to the MDAS Recorder

A momentary short on the octopus cable power wires would not cause a drop of voltage on the DC bus sufficiently low enough to cause the inverter to lose regulation. Also, the effect of a momentary short appeared on the biomed monitoring channels of the MDAS recorder as transients. A short of greater than 8 milliseconds duration would cause the time reference of the MDAS to lose time.

8. TV Simulation Using Spacecraft 008

Several individuals witnessed the Spacecraft 012 accident on television monitors. A test was accomplished utilizing

Spacecraft 008 to substantiate the visual resolution that one could expect over a television monitor system. No additional conclusions or observations resulted from the conduct of this test.

9. Cobra Cable Spark Ignition Tests

The minimum ignition energies of several solvents used in the Spacecraft and the problems experienced with the communications system indicated that the connect or disconnect of a cobra cable could be suspect as a spark or ignition in a simulated Spacecraft 012 environment. Separation of the cobra cable did not produce any visible sparks or ignition.

10. Suit Electrostatic Discharge Tests

Tests were conducted to determine the energy that can be transferred from a suited person when the suit is electrostatically charged. Tests conducted in Spacecraft 014 indicate that insufficient energy is generated for ignition to occur.

11. Mock-up 2 Mobility Evaluation Test

This test was conducted to determine the capability of a crew to see certain areas of the Spacecraft and to perform certain actions with respect to time.

12. Gas Chromatograph Cable and Connector Tests

Special tests disclosed that an output from the gas chromatograph connector can be produced by:

(a) Physical movement or disturbance of the wiring and or the connector

(b) Application of external heat to the wiring and or the connector.

13. Voltage Regulation Tests at Launch Complex 34

These tests indicated that a short circuit in the range of 5 to 25 milliseconds, drawing approximately 75 amps, caused an immediate drop in DC bus voltage of 13 to 15 volts.

14. Gas Chromatograph Cable Arcing Test

A test was conducted using Spacecraft 008 to determine whether arcing would occur if the gas chromatograph connector was dropped onto a metal surface. No arcing took place.

15. Test to Reproduce Copper Flow Found on Gas Chromatograph Cable

Tests were conducted to reproduce a copper flow condition found on the AC wires of the gas chromatograph cable. All attempts to simulate the condition by either short circuits or by application of external heat did not result in a similar appearance of the wires.

16. Pyrotechnic Battery Hydrogen Outgassing Tests

Tests have been conducted on pyrotechnic batteries to determine the outgassing characteristics at ambient and elevated temperatures. Based on these tests, it was concluded that the battery relief valves did not relieve and admit hydrogen to the Command Module.

17. Flammability Propagation Rates of Debris Netting

Tests were conducted at KSC to determine the flammability propagation characteristics of the debris netting of that type located in the Command Module floor at the ECU. Tests conducted at an ambient pressure, 100% oxygen atmosphere, produced a burning rate of approximately 2 inches per second, burning in a horizontal direction. Refer to the Panel 8 Final Report for more information on other materials' flammability test results.

18. Water-Glycol Flammability Tests

A number of water-glycol flammability tests have been conducted at KSC and at MSC, and are still continuing at this time. Some of the tests indicate that the inhibitor agent in the water-glycol coolant fluid does provide a flame propagation path along electrical harnesses exposed to leakage and spillage of water-glycol.

List of References

Reference	Description
18-1	"Screening Committee Final Report", dated March 24, 1967
18-2	"Structural Assessment Report", dated February 8, 1967, prepared by NASA-MSC, Mr. P. C. Glynn
18-3	"Explanation and Discussion of ECS Water Glycol Circuit Prior to and After the Fire Report", dated February 6, 1967, prepared by NASA-MSC, Mr. F. H. Samonski
18-4	"Spillage of Ethylene Glycol Water (RS89-a) as a Possible Cause of Fire in SC204", dated February 20, 1967, prepared by NASA-MSC, Dr. W. R. Downs
18-5	"ECS Oxygen System Description and Interim Data Evaluation", dated February 9, 1967, prepared by NASA-MSC, Mr. F. H. Samonski
18-6	"Communications Analysis Report", dated February 15, 1967, prepared by NASA-MSC, Mr. O. A. Beers
18-7	"Mock-up 2 Mobility Evaluation Test Results", dated March 9, 1967, prepared by NAA-Downey, Mr J. W Montgomery
18-8	"Analysis of Tape Recorder Transmissions From Apollo Spacecraft on January 27, 1967", prepared by Bell Telephone Laboratories, Incorporated
18-9	"Analysis of Tape Recorded Transmission From Apollo Spacecraft 012", dated March 23, 1967, prepared by NASA-MSC, Instrumentation and Electronic Systems Division

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANELS 19 thru 21

REPORT OF PANEL 19
SAFETY OF INVESTIGATION OPERATIONS
APPENDIX D-19
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

RECEIVED
NASA STI FACILITY
ACCESS DEPT.

SAFETY OF INVESTIGATION OPERATIONS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Safety of Investigation Operations Panel, 19. The task assigned for accomplishment by Panel 19 was prescribed as follows:

This group is charged with the responsibility of reviewing all operations performed during the investigation to assure that all personnel safety requirements are adequately maintained.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Safety of Investigation Operations Panel:

Mr. J. R. Atkins, Chairman, Kennedy Space Center (KSC), NASA
Mr. J. McCaugh, Kennedy Space Center (KSC), NASA
Lt. Col. J. Rawers, U. S. Air Force, Air Force Eastern Test Range (AFETR)
Mr. R. Walker, Bendix Corporation, KSC
Mr. D. Karl, Pan American Airways, AFETR

2. COGNIZANT BOARD MEMBER:

Mr. E. Barton Geer, Langley Research Center (LaRC), NASA, Board Member, was assigned to monitor the Safety of Investigation Operations Panel.

C. PROCEEDINGS

1. The composition of this Panel reflected the incorporation of operations safety as identified in the Kennedy Space Center, Air Force Eastern Test Range (AFETR) Agreements (Enclosure 19-1). Launch Complex 34 is a NASA-KSC owned facility located on AFETR property at Cape Kennedy Air Force Station (CKAFS). Therefore, the Air Force exercises prime responsibility which is normal for the host Commander, NASA exercises safety responsibility for all NASA personnel, facilities and equipment located at AFETR.

2. All hazardous operations performed by NASA and their contractors at KSC and CKAFS by the requirements of Kennedy Management Instruction (KMI) 1710.1 are subject to Safety Office approval. The Uprated Saturn Ground Safety Plan delineates the safety considerations that must be satisfied during the performance of those checkout operations deemed hazardous. In consonance with the policy of KMI 1710.1, the Panel provided a technical safety review of all post-accident procedures employed in the disassembly, handling, storage and testing of Space Vehicle AS-204. In addition, selected operations and tests were monitored by a member of the safety organization. Monitoring of operations included: assuring use of required protective equipment; presence of special support, i.e., fire/medical; presence of only essential personnel; and rigorous adherence to the procedures written by the other Panels in the form of Test Preparation Sheets (TPS).

3. Safety support at Launch Complex 34 was given continuous coverage from January 31 through February 23, 1967. This safety support commenced with removal of launch vehicle ordnance at Launch Complex 34, and concluded with the arrival of the AS-204 Service Module at the Manned Spacecraft Operations Building.

4. The disassembly and removal of the Spacecraft from Launch Complex 34 was performed without incident. Ordnance, toxic materials, high-pressure vessels and structural weakness were typical problem considerations which had to be taken into account during the disassembly, transfer, storage, and clean-up of Launch Complex 34. Periodic spacecraft air samples for beryllium were taken at selected intervals at Launch Complex 34 and the Pyrotechnic Installation Building (PIB). Air samples for beryllium were taken inside the cabin as a precautionary measure due to the indicated presence of beryllium dust from swab tests taken on the exterior of the Spacecraft after the accident. All tests proved to be negative.

5. Concurrent with the activity on Launch Complex 34, the PIB and the Materials Analysis Branch laboratory were utilized in support of the investigation. Special arrangements with regard to exits were required in the PIB once it was established as the area for AS-204 storage. Special tests involving oxygen-enriched atmospheres required establishment of safety requirements and safety support during actual performance. These special tests were performed for the purpose of determining burning rates and ignition characteristics of various materials.

6. Following are items of general interest:

a. There was no indication of beryllium at toxic levels during handling and disassembly at Launch Complex 34 and the PIB.

b. The Environmental Control System (ECS) surge tank was the only pressure vessel activated during the Plugs Out Overall Test and did not present a hazard to disassembly personnel.

c. Hypergolic propellants were present only in the Ground Support Equipment and did not present a hazard over and above that established for Launch Complex operations.

d. No cryogenic propellants were present in the spacecraft. Oxygen was supplied in gaseous form from a source external to the spacecraft.

e. The Launch Escape System did not have initiators installed, thereby negating the need for special de-arming action prior to removal.

f. The ordnance in the forward section under the heat shield was removed as a precautionary measure because of possible damage to the forward bulkhead that may have been weakened by the fire. The remainder of the spacecraft ordnance was identified and did not constitute a hazard.

g. Adequate safeguards for personal protection were taken during test operations.

D. FINDINGS AND DETERMINATIONS

Not applicable.

E. SUPPORTING DATA

Enclosure

19-1 Extract, KSC/AFETR Joint Operating and Support Agreement KMI 1052.1, July 12, 1965 Pages D-8, D-9, 6 and Authority

KMI 1052.1

March 9, 1965
Effective Date

JOHN F. KENNEDY SPACE CENTER, NASA
MANAGEMENT INSTRUCTION

SUBJECT : KSC/AFETR JOINT OPERATING AND SUPPORT AGREEMENT

1. PURPOSE

This Instruction incorporates into the KSC Issuance System an agreement between the John F. Kennedy Space Center and the Air Force Eastern Test Range (Attachment A) concerning the responsibilities for performance of operating and support functions that are intrinsic to the mission assignments of both agencies.

2. AUTHORITY

NMI 1052.31, "DOD/NASA Agreement - Atlantic Missile Range and Merritt Island Launch Area."

3. SUPERSESSION

Administrative Regulation KSC 4-2, dated March 9, 1965.

Simon B. Burttschell
Chief, Administrative Branch
Administrative and Transportation Services Office

Attachment:
A. Agreement

Distribution "H"

13. Ground Safety

a. Safety policy and operation procedure on the ETR is the responsibility of the Commander, AFETR. DOD and NASA Test Activities are responsible for compliance with these policies and procedures as formulated by the pertinent AF regulations and documents, and by established practices.

b. The Director, KSC, is responsible for:

(1) Designating launch danger areas on MILA, and clearing these danger areas or accepting the risk for persons remaining therein. When deemed necessary by the Director, KSC, and subject to the possible imposition of additional launch or trajectory limitations by the Commander, AFETR, the location of impact limit lines may be jointly agreed upon by the Director, KSC, and the Commander, AFETR.

(2) Protection of life and property that could be endangered:

(a) During the transportation (on MILA), assembly, checkout, static firing, or preparation of launch of all space vehicles/missiles to be launched or intended for launch from MILA.

(b) By propellants or ordnance items during their transportation (on MILA) to and from storage or manufacture in MILA facilities.

(3) Limiting access to MILA areas which are inside designated impact limit lines.

(4) Evaluating hazards to MILA areas and the general public associated with MILA preflight operations.

(5) Providing data on toxicological and radiological materials, systems and procedures governing their use as AFETR may require to develop emergency plans or determine launch restrictions and such static instrumentation on MILA as AFETR and KSC may jointly agree is required for detecting and estimating the behavior of toxicological and radiological hazards.

c. The assignment of responsibilities in paragraphs a and b, above, is not intended to prohibit or discourage the generation of safety policies and procedures which are internal to an organization. However, internal policies and procedures will not circumvent, negate or be less stringent than those prescribed by the agency with the primary safety responsibility.

d. The area between the overlapping 0.4 psi launch danger circles of Complexes 39A (Saturn V) and 41 (Titan III) will be under operational security control of either KSC or AFETR, depending upon which complex is involved in launch operations. Should launch operations on both complexes require simultaneous placement of roadblocks, their points of intersection will be mutually agreed upon.

e. AFETR and KSC safety representatives will keep each other informed of their respective safety practices, policies and procedures. These representatives will, where applicable, prepare uniform safety criteria which are of mutual interest.

8. EFFECTIVE DATE:

This Agreement becomes effective upon the date of the latest signature shown below

V. G. HUSTON, Major General, USAF
Commander, AFETR

12 July, 1965

KURT H. DEBUS
Director, KSC

30 June, 1965

REPORT OF PANEL 20
IN-FLIGHT FIRE EMERGENCY PROVISIONS PANEL
APPENDIX D-20
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

IN-FLIGHT FIRE EMERGENCY PROVISIONS REVIEW

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the In-flight Fire Emergency Provisions Review Panel, Panel 20. The task assigned for accomplishment by Panel 20 was prescribed as follows:

> This activity involves an orderly review of planned in-flight fire emergency procedures and other provisions relative to their adequacy, as well as a review to determine that emergency procedures, in fact, exist for all appropriate activities. This review should include recommendations to the Board for changes in existing procedures and other provisions and for the creation of new emergency provisions if deemed necessary.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the In-flight Fire Emergency Provisions Review Panel:

Captain James A. Lovell, Jr., USN, Chairman, Manned Spacecraft Center (MSC), NASA
LCdr. Ronald E. Evans, USN, Manned Spacecraft Center (MSC), NASA
Mr. John L. Swigert, Jr., Manned Spacecraft Center (MSC), NASA
Mr. Richard D. Glover, Manned Spacecraft Center (MSC), NASA
Mr. Thomas R. Loe, Manned Spacecraft Center (MSC), NASA
Mr. Dickie K. Warren, Manned Spacecraft Center (MSC), NASA
Mr. Norman P. Shyken, McDonnell Company

2. COGNIZANT BOARD MEMBER:

Colonel Frank Borman, U. S. Air Force, Board Member, Manned Spacecraft Center (MSC), NASA, was assigned to monitor the In-flight Fire Emergency Provisions Review Panel.

C. PROCEEDINGS

1. In response to the direction of the Apollo 204 Review Board, the Panel derived detailed objectives. These objectives were: determine if in-flight fire procedures were available; determine the severity of and the time available to combat an in-flight fire; determine the adequacy of existing procedures established for Apollo 204 to combat an in-flight fire; recommend the development of new hardware and/or emergency procedures for the Apollo Command Module, if necessary.

2. PUBLISHED PROCEDURES. The in-flight fire emergency procedures in use by the Apollo 204 crewmen are described below.

a. APOLLO CREW ABBREVIATED CHECKLIST, MISSION AS-204, dated January 23, 1967; Fire/Smoke in C/M, page 15-1 (Enclosure 20-1). The procedure is composed of two major steps, seven total, to don the Pressure Garment Assembly (PGA), if applicable, and to vent the main cabin to ambient pressure. The emergency procedure utilizes the orbital PGA donning procedure and the normal cabin depressurization hardware. No other provisions are made for extinguishing or combating in-flight fires. This procedure is the most complete of the group and is as follows:

ASSIGNED CREWMAN	TASK
All three crewmen	Don PGA
Command Pilot	Direct 02 valve - Open
Senior Pilot	Emergency Cabin Pressure - Off
Senior Pilot	Cabin Repress valve - Closed
Pilot	Suit Fan - Off
Pilot	Cabin Fan - Off
Command Pilot	Cabin Pressure Relief - Dump

As a procedure in donning the pressure suits (Enclosure 20-4), the following Environmental Control System (ECS) controls must be activated or verified:

(1) ECS suit umbilical inlet - Uncapped

(2) Suit circuit return air valve - Closed

(3) Suit demand pressure regulator - 1 and 2

(4) Suit compressors - Compr 1 (or 2) - AC 1 (or 2)

(5) Suit flow control - Suit full flow (3 separate suit flow control levers)

b. APOLLO OPERATIONS HANDBOOK, COMMAND AND SERVICE MODULE, SPACECRAFT 012, dated November 12, 1966, with changes dated November 18 and 30, 1966; Fire/Smoke in C/M, paragraph 9.3.1, pages 9-49. (Enclosure 20-2) The procedure is essentially the same as paragraph 1.a., except that it contains no provisions for turning off the cabin vent fan and suit loop compressor fans. An additional step of closing the suit circuit return air valve as stated in the pressure suit donning procedure is included.

c. FLIGHT MISSION RULES, AS-204, dated January 10, 1967; Section 6, Environmental Control, items 6-21 and 6-22, page 6-6 (Enclosure 20-3), contain references to in-flight fires as follows:

ITEM	MALFUNCTION	RULING
6-12	Smoke or annoying odors in suit circuit	CONTINUE MISSION - Open Direct O_2 to purge suits
6-22	Smoke in cabin	CONTINUE MISSION - Turn off cabin fan. Crew may elect to abort if source of smoke cannot be located and contained. NOTE: Crew may elect to decompress cabin

d. APOLLO AS-204 FLIGHT PLAN dated December 9, 1966; pages 97 and 98. (Enclosure 20-4) The flight plan contains a PGA donning procedure planned for use at 27 hours into the mission. The exercise is scheduled after the initial PGA removal and is included as an evaluation of the suit don-doff task. It is not a complete in-flight fire emergency procedure.

3. CREW TRAINING. Records of specific Apollo crew training lectures on in-flight fire, per se, are not available. However, briefings were held with the prime Apollo crew describing the best PGA stowage configuration and donning procedures which resulted in the minimum suit donning times. These procedures were developed and are available in MSC test report CSD-A-288 (STB-A-015/29). This report also mentions that a well trained test subject accomplished the PGA donning in about 11 minutes at one g. Apollo Mission Simulator (AMS) training records indicate the prime Apollo crew donned the PGA's in the AMS at least twice; even though PGA doffing or donning is not necessarily logged. The crew specifically requested that the donning time be recorded during one PGA donning exercise. This time was about eight and a half minutes.

4. PROCEDURE EVALUATION. On February 5, 1967, two members of the Apollo 204 backup crew and a member from Panel 20 conducted a run-through of the in-flight fire procedures as published in the on board check lists (Enclosure 20-1). The purpose of the exercise was to determine the degree of difficulty and time required to perform the in-flight fire emergency procedure. The check list did not specify any variations of the procedure for the different phases of flight. Therefore, the worst case was assumed; i.e., orbital phase with crewmen in constant wear garments and pressure suits stowed.

The basic concept of the Apollo in-flight fire procedure was to depressurize the cabin to extinguish the fire. This meant that the first step was to don the PGA. The PGA and associated helmets were stowed under the couches in the orbital configuration. Donning procedures as shown in the final flight plan were followed (Enclosure 20-4). The test crew performed the emergency procedure in approximately 12 minutes. It was obvious that the degree of training and peculiar suit donning problems, such as getting zippers caught, could cause a variation in that time. However, for emergency pressure suit donning, with an actual fire condition the crew has the additional hazard of staying clear of the fire. This will add to the donning time. The process of suit donning will increase the air circulation in the cabin by feeding new oxygen to the burning material and increasing propagation of the fire. Pressure suit don-

ning as a first step toward combating an in-flight spacecraft fire requires too much time and adds to severity of the fire. For fires during boost and entry phases of flight, the crewmen are wearing PGA's and this problem does not exist.

All existing in-flight fire procedures center around extinguishing the fire by venting the cabin to remove all oxygen, allowing the fire zone to cool, and repressurizing the cabin. The systems management functions which accompany this vary with mission phase. During launch, entry, and any other time crew is suited, the only operation required is to open the cabin dump valve. (Note that below approximately 28,000 feet alittude, during earth landing sequence, this operation accomplishes nothing since atmosphere is beginning to enter through inflow valves in the cabin pressure relief assembly.) During flight phases where the crew is unsuited, the procedure calls for donning suits as soon as possible, isolating suit circuit from cabin, and venting. Several systems functions are required to assure the most rapid cabin vent after the PGA's are donned, and would normally be done prior to beginning PGA donning. Two of the functions can be done by the Command Pilot from the left-hand couch, and two by the Senior Pilot in the Left Hand Equipment Bay (LHEB). In considering these functions, several comments are in order:

a. DIRECT O_2 - CLOSED. One T-handle is normally installed in this valve and is readily accessible to the Command Pilot. This is the easiest of the four functions to perform, when the handle is installed in the valve.

b. SUIT CIRCUIT RETURN AIR VALVE - CLOSED. This function is required to assure the suit circuit is isolated from any cabin contamination caused by the fire. This valve is located in the space behind the removable attenuation panel covering LHEB panel 311. In orbit, this panel is off and stowed. The valve is closed by hand and can be reached either from the left-hand couch or from below. However, the valve assembly is recessed and difficult to reach.

c. CABIN REPRESS VALVE - CLOSED. This valve is normally closed and must be verified closed by the Senior Pilot while he is in the Lower Equipment Bay preparing to unstow the PGA's. The valve is activated by rotating a three-quarter inch diameter knurled knob on LHEB panel 314. This operation is fairly easy to accomplish in the shirtsleeve environment. However, since this small knob only extends out from the panel about three-quarters of an inch and is located under the left-hand couch, it would be difficult to operate in a fully pressurized PGA.

d. EMERGENCY CABIN PRESSURE - OFF. This valve is located on panel 314 and will normally be open for emergency pressure resulting from meteoroid cabin penetration. This valve must be closed prior to cabin vent to prevent surge tank depletion. The operation requires the Senior Pilot to remove the second T-handle from its stowed position on panel 314, insert in the emergency regulators valve and turn it to Off one-half turn. This valve cannot be moved without a T-handle and if the handle is not in its usual stowage position or if hazardous conditions exist, time could be lost in performing this mandatory function. The Senior Pilot is also responsible for the PGA unstowage.

e. CABIN FANS - OFF. Air movement in the cabin caused by the cabin fans, coupled with the location of the combustible materials, contributes to fire propagation.

5. FIRE PROPAGATION. A review of 100%, 5 pounds per square inch (psi) oxygen fire technical publications was made to determine the time available for crewmen of Apollo 204 to fight an in-flight fire. The review indicates that time available for crewmen to combat an in-flight fire is a function of fire propagation through the spacecraft, the ability to rapidly detect its presence and the span of useful consciousness. Fire propagation in the spacecraft is affected by several factors:

a. Cabin oxygen pressure

b. Presence and proximity of combustible materials

c. Location of the point of ignition energy source

d. Acceleration forces acting on the combustion process

Fire propagation roles of these factors during boost and entry phases of flight would be similar to the ground environment. The cabin oxygen pressure is the exception and will vary directly with ambient pressure changes, as long as ambient pressure is above approximately 5-6 psi. Fire propagation time is a function of the oxygen pressure. Venting the cabin to ambient pressure would reduce oxygen pressure

and fire propagation rates during the boost and orbital phase of flight. Because of the high accelerations involved and the requirement for being restrained, fire detection other than by visual means would be difficult during the boost and entry phases of flight.

The crew would be less alert to the danger of fire during these phases of flight because of attention to flight control duties and the environment of maximum dynamic pressure buffet, aerodynamic noise and attention to procedures. The pressure suit circuit would be closed to the cabin with no physiological indications. After detection, any action to combat the fire would be greatly impeded by the high acceleration loads on the crewmen.

Combustion in a zero g environment is affected by the same considerations, except that normal, buoyant, thermal convections are not present. The flame would normally assume a spherical pattern but would be affected by the actual shape of the surface that is burning and air circulation. In addition, any changes to the g field such as thruster firing would affect the pattern. The fire in zero g may propagate along the burning surface or by the omni-directional emission of burning gases generated by pyrolysis of the burning material. The distance such gas jets will extend depends on the configuration and kind of material that is burning. If combustion is confined without an additional oxygen supply, visible flame disappears. However, any disturbance of the surface before it has cooled will introduce additional oxygen causing it to flare up again. Any movements of the spacecraft or crewmen in attempting to combat the fire may be expected to make more oxygen available and thus intensify the fire. Only after sufficient thermal energy has been dissipated will the fire not be kindled by convection currents. Therefore, theoretical considerations and limited experimental evidence indicates that fire propagation may be reduced in zero g environment depending on practical aspects that are not yet fully understood. However, due to other variables, it cannot be concluded that a zero g environment will effectively reduce the spread of the fire in the cabin.

A fire test (Test No. 2-TS47-SMD 3) in an Apollo boilerplate spacecraft was conducted by the Structural and Mechanics Division of the Manned Spacecraft Center under in-flight conditions of 100% oxygen at 5 psi atmosphere and with the flammable materials scheduled to be aboard Apollo 204 for flight. The vent valve was ported to vacuum to simulate orbital flight and opened at approximately 6 psi. The fire was started near the -Y, +Z corner close to the aft bulkhead of the spacecraft with the cabin fan on.

Preliminary results indicate that a fire under 5 psi 100% oxygen is less severe than a fire at Launch Complex conditions of 16 psi. The temperature peak of the fire test at 5 psi occurred approximately 80 to 90 seconds after ignition. This was approximately 50 seconds later than on a similar test at 16 psi. The damage was confined to the left one-third of the cabin and the vent valve was able to control the rise in pressure. It appeared that vent valve operation helped exhaust the oxygen supply and limit the severity of this fire; however, a considerable amount of smoke was generated during the fire indicating a need for crew protection from smoke. The results of these investigations indicate that although an in-flight fire would be less severe than a fire under flight conditions, there was still a high probability of an uncontrolled propagation of fire for all phases of flight with the combustible materials that were on board Apollo 204.

6. CABIN PRESSURE VENTS

a. CABIN PRESSURE VENTS DURING LAUNCH. The cabin is maintained at approximately 1 psi above ambient pressure from the time of cabin oxygen purge until lift-off to prevent ambient flow into the cabin during prelaunch operations. The lift-off cabin pressure is approximately 16 psi absolute (psia), 100% oxygen. The cabin pressure remains at 16 psia until an elapsed time from lift-off of approximately 45 seconds. At this time the spacecraft is at an altitude of 10,000 feet with the ambient pressure at 10 psia. Any attempts to vent the cabin pressure prior to 45 seconds will accomplish no more than reducing the cabin pressure to ambient, somewhere between 14.7 psia and 10 psia. Opening the cabin relief valve at any time during the boost or orbit phases will in no way dilute the oxygen concentration in the cabin. It will serve only to reduce the pressure of the 100% oxygen.

Once the spacecraft has reached an altitude (approximately 10,000 feet) where the cabin pressure exceeds the ambient pressure by 6 psi, the cabin pressure relief valves will open venting cabin pressure. From this point until the ambient pressure has decreased to zero, the cabin pressure relief valves modulate to maintain 6 psi differential, finally sealing the cabin at 6 psia. It is impossible to manually vent the cabin at a rate faster than the relief valves can follow the decrease in ambient pressure. Therefore, cabin pressure vent times to 0.5 psia from lift-off to orbital insertion can vary from 3 minutes 20 seconds to 2 minutes 5 seconds.

To vent cabin atmosphere during the launch phase, the Command Pilot must release the latch on the cabin pressure relief valve and place the handle in the dump position. In the launch configuration, the crew is suited, the emergency cabin pressure selector valve is set to Off, and the suit circuit return air valve is closed.

b. CABIN PRESSURE VENT DURING ORBIT. The venting of cabin pressure was the only method available for Apollo crewmen to use in extinguishing a fire. The procedures and times for venting the cabin are covered in other areas of this report so only the time required to evacuate the cabin to 0.5 psia will be discussed. Based on reference material, it was assumed that 0.5 psi was the maximum pressure that could be utilized to effectively retard an in-flight fire. Figure 2.7-11 of the Apollo Operations Handbook (Enclosure 20-5) shows that the time required to depressurize the cabin from 5 to 0.5 psia is 1 minute and 45 seconds. It can be noted on the referenced figure that due to the relatively higher differential pressures present when the cabin venting is initiated, the initial depressurization rate is quite rapid. As an example, the time required to drop cabin pressure from 5 to 2 psia is only 45 seconds.

The Post Landing Ventilation Valves (PLV) can provide a method for decompressing the cabin more rapidly than the normal method described above. These valves allow cabin pressure to vent in less than 10 seconds; however, this method should not be used in the case of fire since the vent point is under the Apex cover where the parachutes are stowed. The introduction of fire or hot gases to this area could damage or destroy the parachutes.

c. CABIN PRESSURE VENTING DURING ENTRY. Cabin pressure may be vented during the entry with the pressure level dependent on the ambient pressure. It should be noted that venting the cabin to ambient will only serve to lower the total pressure and will not dilute the 100% oxygen concentration. The considerations that applied to orbital use of the PLV valves would also apply. Once the spacecraft has descended to approximately 26,000 feet, it will no longer be possible to lower cabin pressure by opening the dump valve. From this altitude until splashdown, the cabin pressure will be increasing and because of ambient inflow, the oxygen concentration will become diluted to a value of approximately 50%. The length of time from 26,000 feet to splashdown is approximately 6 minutes.

A cabin pressure vent during the entry phase of flight or immediately before will result in an inflated pressure suit entry, since there is insufficient time to repressurize the cabin. The inflated pressure suit limits mobility and complicates the entry portion of the flight.

7. CABIN REPRESSURIZATION. Assuming the crew has been able to perform all necessary tasks and the fire has been extinguished by venting the cabin, the problem of cabin repressurization arises. Provided no further fire hazard exists, cabin repressurization is desirable to make entry preparations and entry easier. When an extended period of time for return is required, repressurization is mandatory for biological functions. The two problem areas which exist in repressurization are: accessibility of repressurization are: accessibility of repressurization controls in inflated suit configuration, and repressurization profile.

Two modes of cabin repressurization exist: (1) a normal procedure requiring 74 minutes to reach 5.0 psia and (2) a minimum time procedure requiring 52 minutes to reach 5.0 psia. In the latter case, the 22 minutes are saved by first venting the contents of the surge tank to achieve 1.9 psia cabin pressure in slightly less than 5 minutes, then followed by the slower rise to 5.0 psia. Both of these procedures require the Senior Pilot to go to LHEB panel 314 and open the cabin repressurization valve

using a knurled knob which must be grasped with an inflated glove and turned one-half turn. If the normal repressurization profile is to be followed, no further action is required until the cabin reaches 5.0 psia in 74 minutes when the repressurization valve is closed. The gloves will probably have been removed by this time making the job somewhat easier. For emergencies, 22 minutes may be saved by venting the contents of surge tank from 900 to 150 psia. After the repressurization valve has been opened, the T-handle is removed from its stowage hole, inserted in the emergency cabin pressure regulator valve and turned one-half turn to 1 and 2 position, with inflated gloves. This immediately initiates maximum flow from the system (0.67 pounds per minute) and the surge tank contents begin venting into the cabin. The Pilot, from the right-hand couch, must monitor the surge tank pressure continuously for the remainder of the 52 minutes required to reach 5.0 psia. He must keep the Senior Pilot aware of the pressure to prevent tank pressure from falling below 150 psia, causing main regulator malfunctions. When pressure first falls to 150 psi, the emergency cabin pressure regulator must be turned Off. At this time cabin pressure is approximately 1.9 psia and the elapsed time is approximately 5 minutes. Thereafter, repressurization flow must be modulated to maintain 150 psia until the valve is again full open and surge tank pressure begins to rise slowly. When the cabin reaches 3.5 psia and the main cabin regulators cut in, an additional demand is placed on the surge tank. Surge tank pressure will again fall to 150 psia at which time the repressurization flow must be again modulated to maintain this minimum pressure. When the cabin reaches 5.0 psia, the cabin repressurization valve is closed and surge tank recharging from the Service Module cryogenic oxygen supply begins and requires approximately one-half hour to complete. The continuous attention to surge tank pressure required in this repressurization procedure is not desirable. Enclosure 20-5 shows the cabin pressure histories profiles for the two repressurization modes. The time required for repressurization is too long in either case because of two systems constraints: (1) the total available oxygen within the surge tank is only a fraction of that required for one Command Module repressurization cycle and (2) resupply flow rates from the Service Module cryogenic oxygen tanks to the surge tank are severely limited by flow restrictors (6 pounds per hour nominal). Repressurization is a lengthy process at best, and is hampered by inaccessible Environmental Control Unit management controls. In the case of the minimum time profile, a great deal of voice coordination between crewmen is required since the repressurization valve and the surge tank pressure readout are located in opposite ends of the spacecraft. In addition, possible suit damage due to the fire makes lengthy repressurization times undesirable.

D. FINDINGS AND DETERMINATIONS

1. FINDING

An in-flight fire procedure was published and available to the crew for the Apollo 204 Mission. The procedure was analyzed with reference to the Apollo 204 Command Module 012 configuration.

DETERMINATION

Based on this review, it is the judgment that the existing in-flight fire procedures are deficient in the following areas:

a. The cabin fans should be turned off as the first item of the procedural check list. This may help prevent the spread of a fire by minimizing cabin air currents.

b. The procedure should have specified the length of time to keep the cabin depressurized to insure the fire had been extinguished and that all materials had cooled to below their ignition temperature.

2. FINDING

The Apollo 204 crew had practiced the PGA donning portion of the in-flight fire procedure.

DETERMINATION

No discrepancies were noted.

3. FINDING

Coordination with Panel 8, Materials Review, and Panel 5, Origin and Propagation of Fire, indicates many materials combustible in 100% 5 psi oxygen were on board Apollo 204 Command Module 012.

DETERMINATION

It is the judgment of the Panel that these materials would yield a dangerous propagation rate in case of fire in the Command Module during the boost, orbital and entry phases of flight.

4. FINDING

Lenghty suit donning times were incompatible with fire propagation times.

DETERMINATION

The published in-flight fire procedure was impractical in view of the rapid fire propagation rate expected for an Apollo 204 in-flight fire.

5. FINDING

The Command Module depressurization time from 5 psi to 0.5 psi can vary from 1 minute and 45 seconds to 3 minutes and 20 seconds based on the flight phase ambient pressure.

DETERMINATION

The depressurization time is too slow to effectively combat a cabin fire.

6. FINDING

The emergency cabin repressurization time from a vacuum to 3.5 psi is 35 minutes.

DETERMINATION

The time required to repressurize the cabin to a minimum acceptable pressure is excessive in view of the possible fire damage to the closed loop pressure suit circuit.

7. FINDING

Actuation of the suit circuit return valve, the cabin repressurization valve, and emergency cabin repressurization valve are critical in producing an adequate cabin decompression and subsequent repressurization.

DETERMINATION

The placement of ECS controls and displays complicates the execution of the existing in-flight fire procedure.

E. SUPPORTING DATA

Enclosures

20-1	Apollo Crew Abbreviated Checklist Mossion AS-204, page 15-1, dated January 23, 1967
20-2	Apollo Operations Handbook, NAA SM2A-03-SC-012, dated November 1966, page 9-49
20-3	Flight Mission Rules, AS-204, dated January 10, 1967, page 6-6
20-4	Apollo AS-204A Flight Plan, dated December 9, 1966, pages 97 and 98
20-5	Apollo Operations Handbook, NAA SM2A-03-SC-012, dated 12 November 1966, pages 2.7-40, 2.7-42, 2.7-43
20-6	List of References
20-7	Glossary of Abbreviations

SECTION 15. EMERGENCY PROCEDURES

FIRE/SMOKE IN C/M

CSP	1	DON PGAs		
	2	SET CONTROLS		
C		DIRECT O2 - OPEN (CCW)		
S		EMERGENCY CABIN PRESSURE - OFF	Panel	314
		CABIN REPRESS - CLOSED (CCW)		
		SUIT FAN - OFF		
		CABIN FAN - OFF		
C		CABIN PRESSURE RELIEF - DUMP (Safety latch - off)	Panel	307

Extracted from: APOLLO CREW ABBREVIATED CHECKLIST
MISSION AS-204

January 23, 1967

Sta	Step	PROCEDURE	Panel	STATUS OF SYSTEM
	9.3	EMERGENCY PROCEDURES.		
		INTRODUCTION.		
		Emergency procedures provide the crew with the necessary steps to quickly alleviate situations that have (or will) become both crew hazardous and time critical. These procedures require instant reaction on the part of the crew to prevent the conditions from becoming worse. In most instances the conditions are physically sensed by the crew rather than brought to their attention by the caution and warning system, or voice communication.		
	9.3.1	FIRE/SMOKE IN C/M.		Fire in the C/M cabin is extremely hazardous because of the 100-percent oxygen atmosphere. However, the capability exists to quickly extinguish any fire originating inside the C/M by depressurizing the cabin.
CSP	1	Unsuited crewman don PGAs		
	2	Set controls:		
C		DIRECT O_2 valve - OPEN (CCW)	24	Suit circuit isolated from cabin atmosphere by differential pressure; also commences purge of suit circuit.
S		EMERGENCY CABIN PRESSURE sel - OFF	314	
		CABIN REPRESS valve - close (CCW)		
C		CABIN PRESSURE RELIEF cont (lower) - DUMP	307	Safety latch must be off.
S		Remove attenuation panel		Refer to ECS Systems Management procedures.
		SUIT CIRC RETURN VALVE - close	319	Mechanically isolates suit circuit from cabin atmosphere.
		Install attenuation panel		
C		DIRECT O_2 valve - close (CW)	24	

NASA — Manned Spacecraft Center

MISSION RULES

REV	ITEM	CONDITION MALFUNCTION	RULING	NOTES/COMMENTS SOP S
	6-19	CABIN TEMP ≥95°F.	CONTINUE MISSION - TURN OFF CABIN FANS.	AFTER INSERTION, CREW MAY OVERRIDE TEMP CONTROL VALVE AND TURN FANS BACK ON. (PHYSICALLY IMPOSSIBLE TO MANUALLY OVERRIDE CABIN TEMP CONTROL VALVE DURING BOOST.)
	6-20	GLYCOL EVAPORATOR OUT TEMP ≥55 OR <35°F.	CONTINUE MISSION - AFTER INSERTION MANUALLY OPERATE GLYCOL EVAPORATOR.	NOTE: CAN OPERATE AT LOWER TEMP BUT OPERATION SHOULD BE MONITORED FOR MALFUNCTION. NORMAL OPERATING RANGE 45 ± 5°F.
	6-21	SMOKE OR ANNOYING ODORS IN SUIT CIRCUIT.	CONTINUE MISSION - OPEN DIRECT O_2 TO PURGE SUITS.	
	6-22	SMOKE IN CABIN	CONTINUE MISSION - TURN OFF CABIN FAN. CREW MAY ELECT TO ABORT IF SOURCE OF SMOKE CANNOT BE LOCATED AND CONTAINED.	CREW MAY ELECT TO DECOMPRESS CABIN.

MISSION	REV	DATE	SECTION	GROUP	PAGE
AS-204		1/10/67	ENVIRONMENTAL CONTROL	LAUNCH INSERTION	6-6

MSC Form 364A (May 65)

PGA DONNING
GET 27:30
GET 325:00

1. Configuration:

   A. Cabin humidity taken prior to doffing PGA
   B. ECS suit umbilical inlet capped
   C. Normal ECS shirtsleeve configuration
   D. Three men in couches, wearing light coveralls, sandals, and communications carrier.
   E. Helmets stowed in bags under center couch.
   F. Commander's (C) PGA stowed in bag under LH couch.
   G. Senior Pilot's (S) PGA stowed in bag under LH couch.
   H. Pilot's (P) PGA stowed in bag under RH couch near headrest
   I. TV and seq. CAM - Setup

   J. Interior lights - All ON

2. Unstow PGAs
   A. C,S,P - Release couch restraints
   B. S - Drop center couch to 180° position, ingress LEB, fold couch to 270° position.
   C. C,S,P - Remove light coveralls, restraint sandals, bioinstrumentation, and communication connectors.
   D. C,P - Pass Light coveralls, etc, to S
   E. S - Retrieve C's PGA and pass to C
   F. P - Roll over, drop couch headrest and retrieve suit from RH bag.
   G. S - Stow light coveralls, etc, in LH suit bag
   H. S - Retrieve three helmets in bags from aft bulkhead, stow on center couch.
   I. S - Retrieve S's suit

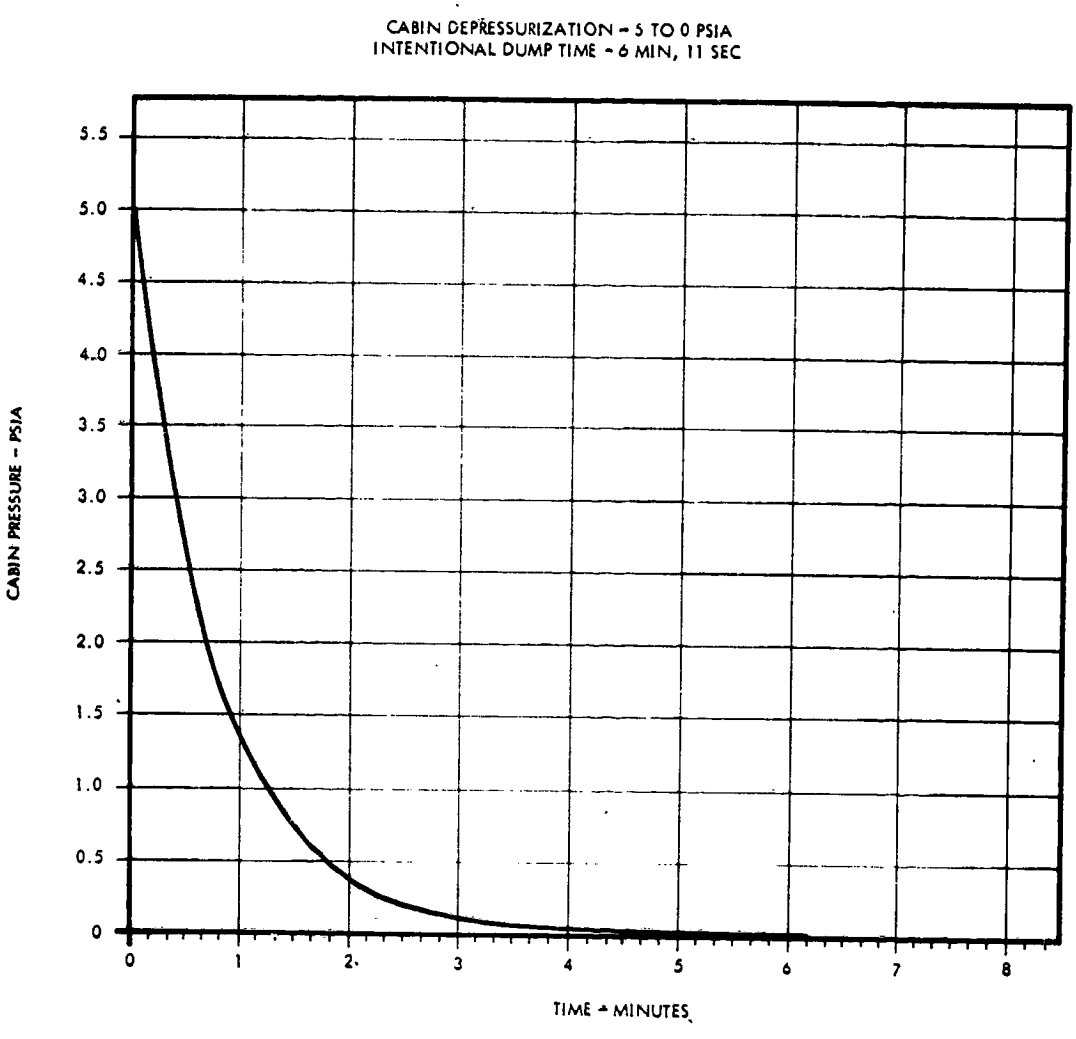
3. Prior to donning PGAs verify:
   A. ECS suit umbilical inlet - UNCAPPED
   B. SUIT CIRCUIT RETURN AIR VALVE - CLOSED
   C. SUIT DEMAND PRESSURE REGULATOR 1 & 2
   D. SUIT COMPRESSORS - COMPR 1 (or 2) - AC1 (or2)
   E. SUIT FLOW CONTROL - SUIT FULL FLOW

4. Don PGA's
   A. C - Don PGA in LH couch
      P - Don PGA in RH couch
      S - Don PGA in LEB
   B. C,P,S - Remove helmets from bags and stow bags under respective couches
   C. UCD donned
   D. Bio-med connector from underwear to suit attached.
   E. Restraint zipper closed and lanyard stowed
   F. Pressure sealing zipper closed, snap secure
   G. Don helmet; helmet comm. disconnect attached to suit disconnect and stowed
   H. Helmet attached to neckring and locked in position.
   I. Glove wrist disconnect locked
   J. Glove straps snagged down
   K. Boot zippers secure
   L. Helmet tie down - front and back - (slack takeup) and locked
   M. ECS inlet nozzle attached to suit and locked in position
   N. ECS outlet nozzle uncapped, attached to suit, and locked in position
   O. Cobra cable connected
   P. Bio-med cable attached to suit and locked
   Q. Close visor and secure double lock

5. EMERG CABIN PRESS Valve - ON

6. Perform PGA verification check (Ref. AOH)

7. Record on flight log donning times, problems encountered, comments, etc.



CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to OFF.

2. CABIN REPRESS manual valve set to close.

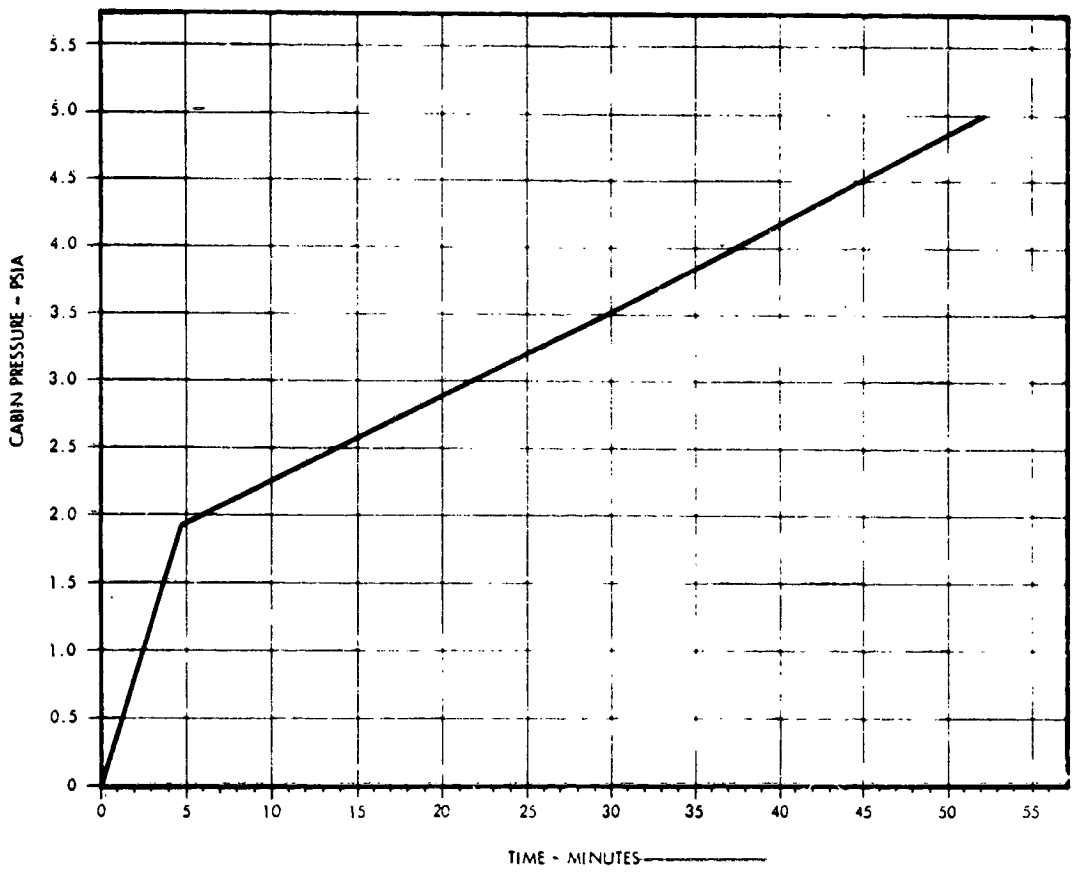
3. CABIN PRESSURE RELIEF valve set to DUMP.

4. Normal cabin pressure regulators automatically close at 3.5 psia.

SM-2A-890

Figure 2.7-11. Cabin Depressurization Rates (Sheet 1 of 2)

CABIN REPRESSURIZATION - 0 TO 5 PSIA *
MINIMUM TIME - 52 MIN, 22 SEC

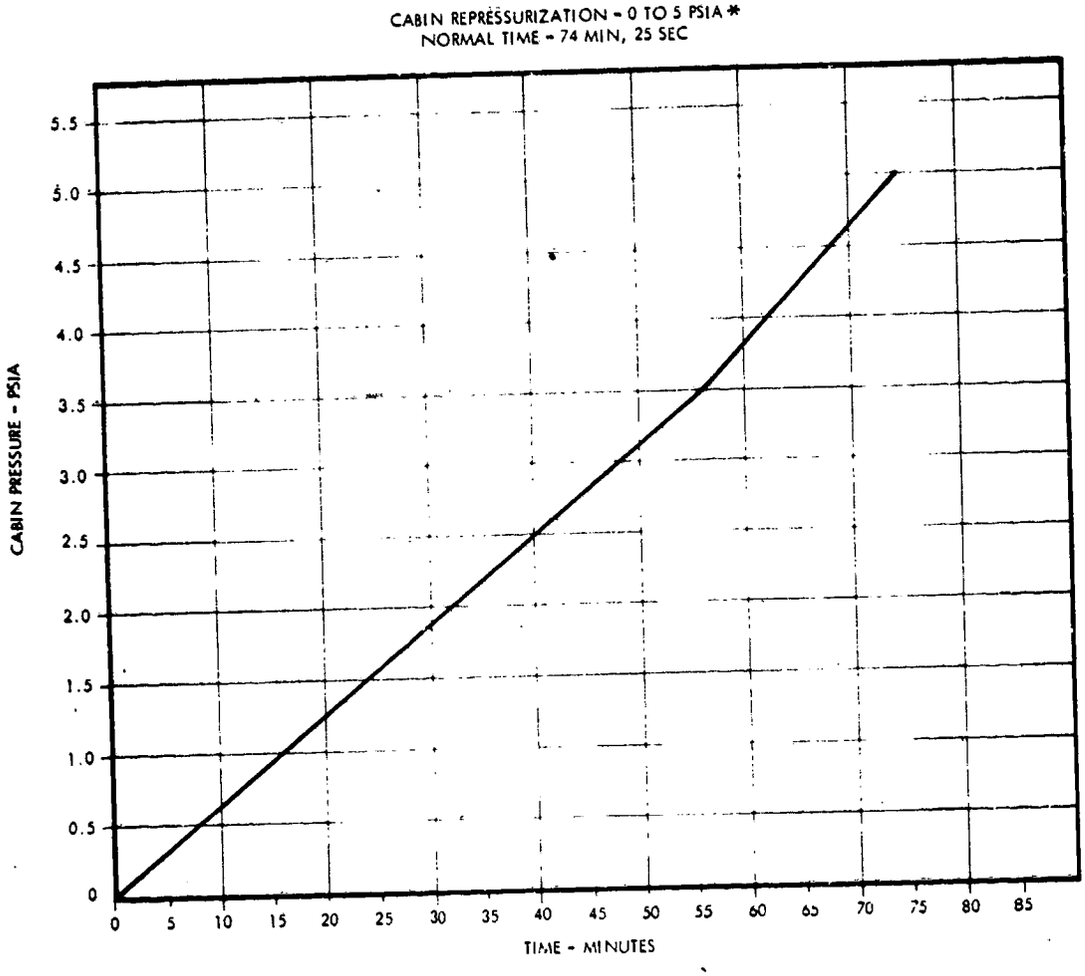


CONDITIONS
1. EMERGENCY CABIN PRESSURE selector valve set to NORMAL.
2. CABIN REPRESS manual valve set to OPEN.
3. When surge tank pressure indicator decreases to 150 psia, EMERGENCY CABIN PRESSURE selector valve set to OFF, surge tank minimum pressure (150 psia) maintained by regulating CABIN REPRESS manual valve until valve is full open and surge tank pressure starts to increase
4. Normal cabin pressure regulators automatically open at 3.5 psia
5. When surge tank pressure again decreases to 150 psia, CABIN REPRESS manual valve regulated to maintain 150 psia minimum surge tank pressure.
6. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close

* Requires 9.1 lb oxygen at 70°F cabin temperature

MA-2A-9072A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 1 of 2)



CONDITIONS- 1. EMERGENCY CABIN PRESSURE selector valve set to OFF.

2. CABIN REPRESS manual valve set to OPEN.

3. Normal cabin pressure regulators automatically open at 3.5 psia

4. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close

* Requires 2.1 lb oxygen at 70°F cabin temperature

SM-2A-88?A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 2 of 2)

LIST OF REFERENCES

20-1 Mumma, G. B. and Olson, R. E.: Report of Spacecraft Fire Hazards. Martin Company, Denver, Colorado, February 1967

20-2 Huggett, Clayton, PhD: The effects of 100% oxygen at reduced pressures on Ignitability and Combustibility of Materials. SAM-TR-65-78, USAF School of Aerospace Medicine, Brooks AFB, Texas, December 1965, pages 1, 2, 4, 7 and 8.

20-3 National Aeronautics and Space Administration, Manned Spacecraft Center, S67-71 Film of Zero-G Inflammability.

20-4 Anon: Investigation of Aerospace Vehicle Crew Station Criteria. FDL-TDR-64-86 AD452187, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, page 64.

20-5 Staklis, A.A., PhD: Fire Control for Spacecraft with 5-psia Oxygen Atmospheres. Preliminary NASA TN S-136, 1967, pages 1-5, 11, 17, 18, 27, 36, 37 and 40-42.

20-6 Henderson, Edward M., Lunde, Alfred N., and Newman, Samuel R.: Spacecraft Operational Trajectory for AS-204, S/C 012. NASA-MSC Internal Note 66-FM-113. Vol. I and II, Part B, page 33, October 17, 1966.

20-7 Anon: AS-204 CSM S/C 012 Subsystem Operating Logic Schematics. General Electric Company, ASD-MSCCO, Houston, Texas, January 1967.

20-8 Anon: MSC Test Report CSD-A-288 (STB-A-015/29) Manned Spacecraft Center, Houston, Texas, July 29, 1966, pages 6 and 7.

GLOSSARY OF ABBREVIATIONS

AC	Alternating Current
AOH	Apollo Operations Handbook
C	Command Pilot
CAM	Camera
CCW	Counterclockwise
CIRC	Circuit
C M	Command Module
COMM	Communications
COMPR	Compressor
CONT	Control
CW	Clockwise
LEB	Left Equipment Bay
LH	Left Hand
MAX Q	Maximum Dynamic Pressure
O_2	Oxygen
P	Pilot
PRESS	Pressurization
RH	Right Hand
S	Senior Pilot
SEL	Selector
SEQ	Sequence
TV	Television
UCD	Urine Collection Device

REPORT OF PANEL 21
SERVICE MODULE DISPOSITION
APPENDIX D-21
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Service Module Disposition Panel, 21. The task assigned for accomplishment by Panel 21 was prescribed as follows:

This task involves the planning and execution of necessary S/M activity beginning at the time of Board approval for Command Module (C/M) demate. This task will be performed mainly by appropriate Apollo line organizational elements in accordance with a Board approved plan which identifies the Board requirements for documentation and control of this activity.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Service Module Disposition Panel:

Mr. W. W. Petynia, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. R. D. Carothers, Kennedy Space Center (KSC), NASA
Mr. B. R. Haight, North American Aviation (NAA), KSC

2. COGNIZANT BOARD MEMBER:

Mr. John J. Williams, Kennedy Space Center (KSC), NASA, Board Member, was assigned to monitor the Service Module Disposition Panel.

C. PROCEEDINGS

1. The Panel discharged its responsibilities to the Board by planning and executing the following major S/M activities:

a. Demated the Service Module/Service Module Lunar Module Adapter (SM/SLA) from the Launch Vehicle (LV) and moved the SM/SLA to the Manned Spacecraft Operations Building (MSOB).
b. Performed a detailed inspection of both the exterior and interior areas of the S/M.
c. Performed detailed systems tests of all S/M systems mechanically or electrically connected to the C/M at the time of the accident.

Following demate of the C/M at Launch Complex 34 (LC34), the activities to demate the S/M and perform detailed systems tests were in accordance with a board approved plan (Board Action 0163). Specific tasks performed in executing this plan were conducted in the following general areas:

(1) INSPECTION AT LC 34. Following demate of the C/M, a visual inspection was made on February 17 and 18 by structural engineers to verify the structural integrity of the S/M and determine the handling method to be utilized to lower the SM/SLA from the LV and transport to MSOB.

(2) DEMATE AND MOVE TO MSOB. The SM/SLA combination was demated from the LV and moved to the MSOB on February 23, 1967. The SM/SLA was positioned in MSOB Integrated No. 1 stand in preparation for separation of S/M and SLA.

(3) DEMATE SM/SLA. Following demate of the S/M and SLA all pyrotechnic devices were removed from the SLA. Electrical continuity tests of the S/M and SLA interface wiring were made. The S/M was positioned in the H14-134 stand to remove the Service Propulsion System (SPS) nozzle extension and then moved to the H14-124 stand for access to perform the detailed inspections and systems tests. The SPS nozzle extension was reclassified to Category "C" by the 204 Review Board on March 3 (Material Release Record No. 0140) and placed in storage. The SLA was reclassified to Category "C" by the 204 Review Board on March 4 (Material Release Record No. 0142) and returned to the Apollo line organizations for storage.

(4) DETAILED INSPECTION IN MSOB. A detailed inspection was made of both the exterior and interior areas of the S/M (See Enclosure 21-2). The inspection was carried out in two phases by two different groups. The first phase was conducted with the S/M Reaction Control

System Panels (RCS QUAD) open and the top deck Mylar insulation in place. The second phase was made with the top deck Mylar removed. In order to provide access and visibility during the inspections, the following hardware was removed:

(a) Sector I access door.
(b) Sector IV access door.
(c) SPS flame shield.

The two groups inspecting the S/M were composed of both NASA and NAA personnel. The first group consisted of Quality Control Inspectors. The second group consisted of systems engineers and representatives of Apollo 204 Review Panels. Both groups included the following areas in their detailed inspection:

(a) Top deck of S/M (Mylar on).
(b) Top deck of S/M (Mylar off).
(c) Exterior areas.
(d) Sector 4 areas.
(e) Cryogenic areas.
(f) SPS engine compartment.
(g) Bottom of S/M
(h) Quad A and Quad A access area.
(i) Quad B and Quad B access area.
(j) Quad C and Quad C access area.
(k) Quad D and Quad D access area.

During the detailed inspection, appropriate photographs were taken and summary findings written. All hardware items removed for the inspection were reinstalled.

(5) SYSTEMS TESTS. Following the detailed inspection, specific detailed systems tests were made for the following systems:

(a) ELECTRICAL POWER SYSTEM

The Electrical Power System (EPS) tests consisted of the following:

(1) Selected resistance checks through the CM/SM umbilical, and the flyaway umbilical were performed prior to removal of DC Power Distribution Box (DC PDB).

(b) ENVIRONMENTAL CONTROL SYSTEM

The Environmental Control System (ECS) tests consisted of the following:

(1) The water/glycol remaining in the S/M was drained and transferred to the Pyrotechnic Installation Building (PIB) and placed in bonded storage to be included with that from the C/M.

(2) The integrity and condition of the water/glycol system was determined by leak check with dry nitrogen.

(c) PROPULSION SYSTEM

The Propulsion System tests consisted of the following:

(1) The operation and condition of the Propellant Utilization Gaging System (PUGS) controller was determined in the EPS Laboratory. The tests of the controller were made using the SPS PUGS Bench Maintenance Equipment. After completing the tests, the PUGS controller was reinstalled in the S/M.

(2) The operation and condition of the SPS Flight Combustion Stability Monitor (FCSM) amplifier and relay box were investigated.

(3) Samples of all foreign material found in the upward pointing RCS engine nozzles (-X thrust) for all four engines was collected. These samples were sent to the Material Analysis Branch laboratory for quantitative analysis.

(d) INSTRUMENTATION SYSTEM

The Instrumentation System test consisted of the following:

(1) Resistance measurements of the SM/SLA separation monitor circuits were made.

(2) The SM/SLA separation monitor was removed and sent to the PIB for component analysis.

(e) FUEL CELL/ECS OXYGEN SYSTEM

The Fuel Cell/ECS Oxygen System tests consisted of the following:

(1) The integrity of that portion of the cryogenic system used to supply breathing oxygen to the astronauts at the time of the accident was determined. The oxygen line was pressurized to 500 psi with dry helium and the pressure decay over a thirty-minute period was measured.

(2) The operation and condition of the fuel cell reactant valves was determined. The continuity between the contacts on the shut-off valves was determined. Resistance to ground through the solenoids of each of the valves was made to determine any grounding of any of the coils.

(3) The continuity through the fuel cell switch used to control the individual fuel cell heaters was determined. With the switch disconnected, the resistance through the coil of the motor switch to S/M ground point was measured.

(4) The continuity through the holding current switch contacts was determined. With the switch disconnected, the resistance through the coil of the motor switches to S/M ground point was measured.

(5) The continuity through the tank heater control switch contacts was determined. With the motor switches disconnected, the resistance through the coil of the motor switch to S/M ground was measured.

D. FINDINGS AND DETERMINATIONS

1. FINDINGS

Detailed inspections of the S/M interior and exterior areas by Quality Control Inspectors, systems engineers and 204 Panel Members (References 21-1 thru 21-4) found the S/M suffered minor damage by fire. (See Enclosures 21-3 and 21-4.)

DETERMINATION

a. There is no indication that the S/M was the origin of the fire.

b. The fire damage to the S/M resulted from a source located above the S/M.

2. FINDINGS

Test results indicate S/M motor switch S-6 in the DC PDB was transferred to the closed position resulting in fuel cell No. 2 harness being connected to Bus B (Reference 21-5). The control switches in the C/M were found in the off position.

DETERMINATION

It was determined by examination of resistance checks of the C/M wiring made at the CM/SM umbilical connector P11 J 12 that the control wiring in the C/M was shorted causing the S/M motor switch to transfer.

3. FINDINGS:

Fuel Cell No. 2 hydrogen shut-off valve was found in the open position (Reference 21-6).

DETERMINATION:

It was determined by examination of resistance checks of the C/M wiring made at the CM/SM umbilical connector P11 J 12 that the control wiring in the C/M was shorted causing the valve to open. Telemetry data up to loss of signal (LOS) from the C/M show the valve closed indicating opening was a result of the accident.

4. FINDINGS:

Test results indicated that the hydrogen tank No. 2 heater wiring circuit was open (Reference 21-7).

DETERMINATION:

It was determined that the S/M wiring was proper and that the open circuit existed in the heater circuit (containing thermal switches) inside the tank. This condition is not considered abnormal because

the thermal switches in series with the heater element open at 80°F (±10°) (Reference 21-8). Ambient temperature was well within this range of temperatures.

5. FINDINGS:

No shorts or open circuits were found in the wiring for the SM/SLA separation monitor (SS0120X) wiring, but the fuse in the S28A7 fuse box was found to be open (Reference 21-9).

DETERMINATION:

Prior to moving the S/M to LC 34 the separation monitor tape was inadvertently pulled out of its case and subsequently pushed back in. It was determined by investigation (Reference 21-10) that pushing the tape back in would cause the tape to short-to-case and thus blow the fuse.

6. FINDINGS:

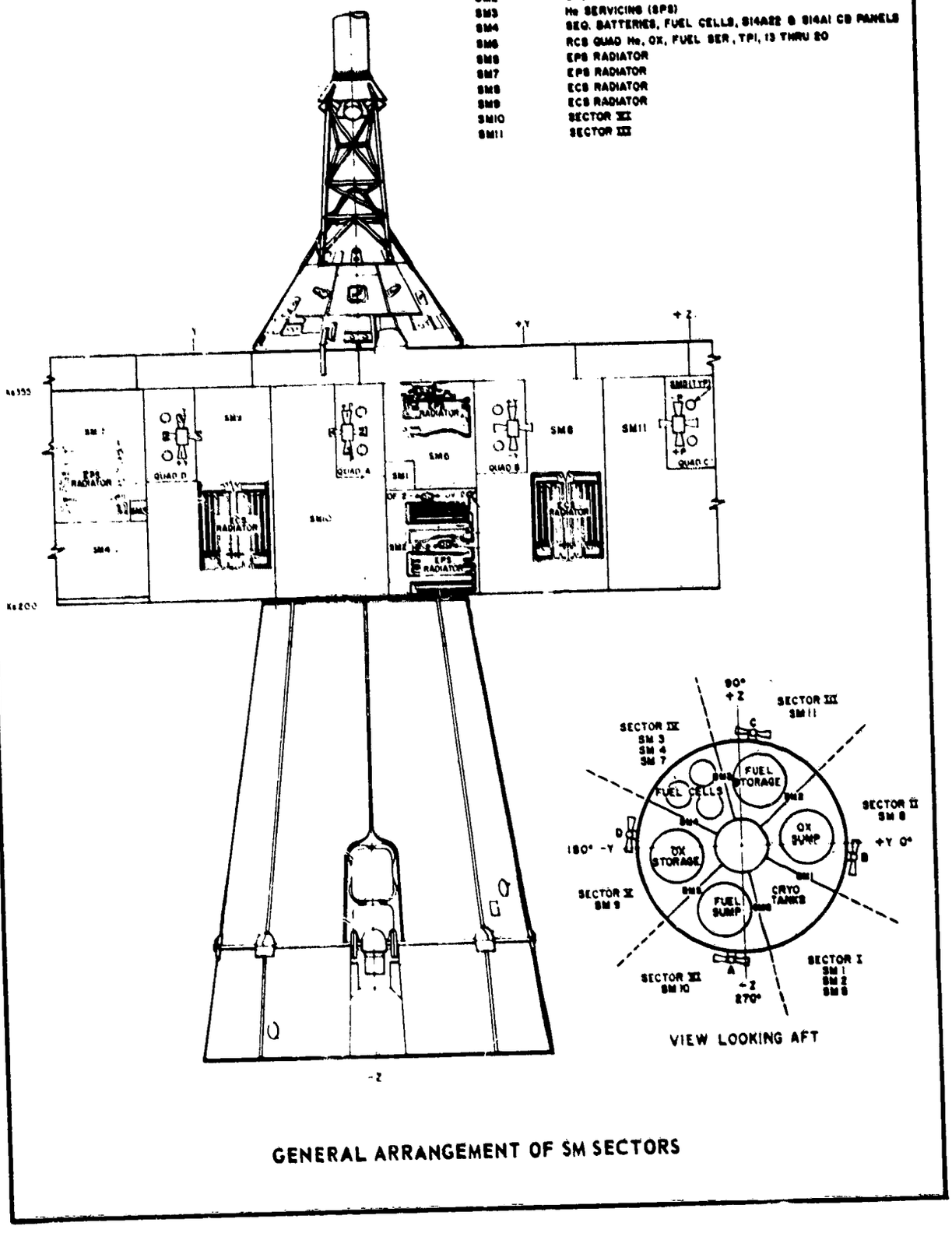
Test results failed to show any S/M anomalies due to the S/M systems (Reference 21-5 thru 21-16).

DETERMINATION:

There is no indication the S/M systems were responsible for initiating the accident.

E. SUPPORTING DATA

Enclosures	Description
21-1	Not Used.
21-2	General arrangements of S/M and sectors
21-3	Top deck of S/M with Mylar installed
21-4	Top deck of S/M with Mylar removed
21-5	List of References



GENERAL ARRANGEMENT OF SM SECTORS

ENCLOSURE 21-2

REFERENCES

REFERENCE 21-1: Inspection of S/M top deck after CM demate. TPS No. S/C 012-S/C 099, dated February 16, 1967.

REFERENCE 21-2: Quality Control Inspection of S/M. TPS No. 012-SM-IV-003 dated February 27, 1967.

REFERENCE 21-3: Engineering Inspection of S/M. TPS No. 012-SM-IV-004 dated February 27, 1967.

REFERENCE 21-4: Dry and Clean -X RCS Engines. TPS No. 012-SM-008 dated March 1, 1967.

REFERENCE 21-5: S14A1 Motor Switch Analysis. TPS No. 012-SM-CA-001 dated March 8, 1967.

REFERENCE 21-6: Fuel Cell and CGSS Investigation. TPS No. 12-SM-IV-012 dated March 2, 1967.

REFERENCE 21-7: Continuity Check - Specific S/M Circuits. TPS No. 12-SM-IV-007 dated March 1, 1967.

REFERENCE 21-8: Hydrogen Tank No. 2 Heater checkout. TPS No. S/C 012-SM-IV-016 dated March 11, 1967.

REFERENCE 21-9: Separation Monitor Investigation (SS0120X). TPS No. 012-SM-IV-002 dated February 24, 1967.

REFERENCE 21-10: Separation Monitor Investigation. TPS No. S/C 012-SM-CA-002 dated March 9, 1967.

REFERENCE 21-11: SM Water Glycol Deservicing. TPS No. 12-SM-IV-013 dated March 4, 1967.

REFERENCE 21-12: PUGS Control Unit Test. TPS No. 012 SM-IV-005 dated February 27, 1967.

REFERENCE 21-13: FCSM Checkout. TPS No. 012-SM-IV-009 dated March 2, 1967.

REFERENCE 21-14: Remove Liquid from Quad B Engine No. 3 for Analysis. TPS No. 12-SM-MA-001.

REFERENCE 21-15: Leak Check of ECS Supply Lines. TPS No. 012-SM-IV-010 dated February 15, 1967.

REFERENCE 21-16: SLA Wiring Resistance Check. TPS No. 12-SLA-IV-002 dated March 2, 1967.

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX E

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APPENDIX E

MANAGEMENT AND ORGANIZATION

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ORGANIZATION AND MANAGEMENT

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APPENDIX – E

ORGANIZATION AND MANAGEMENT == APOLLO PROGRAM

I. INTRODUCTION

It is the purpose of this Appendix to outline in brief detail the established management organization within the National Aeronautics and Space Administration for the conduct of the Apollo Program. Only the major areas of responsibility are offered here for the various levels of management. Not obvious from the organizational elements outlined in this Appendix is the necessary interplay between the various field centers and their contractors in the performance of the Apollo Program. Nor can the outline detail the myriad interfaces created by a vast and complex program which geographically spans the United States, and involves literally hundreds of contractors and subcontractors, and thousands of individual scientists, engineers and space workers.

No attempt has been made to ascertain the actual working relationships as they currently exist between the various management levels.

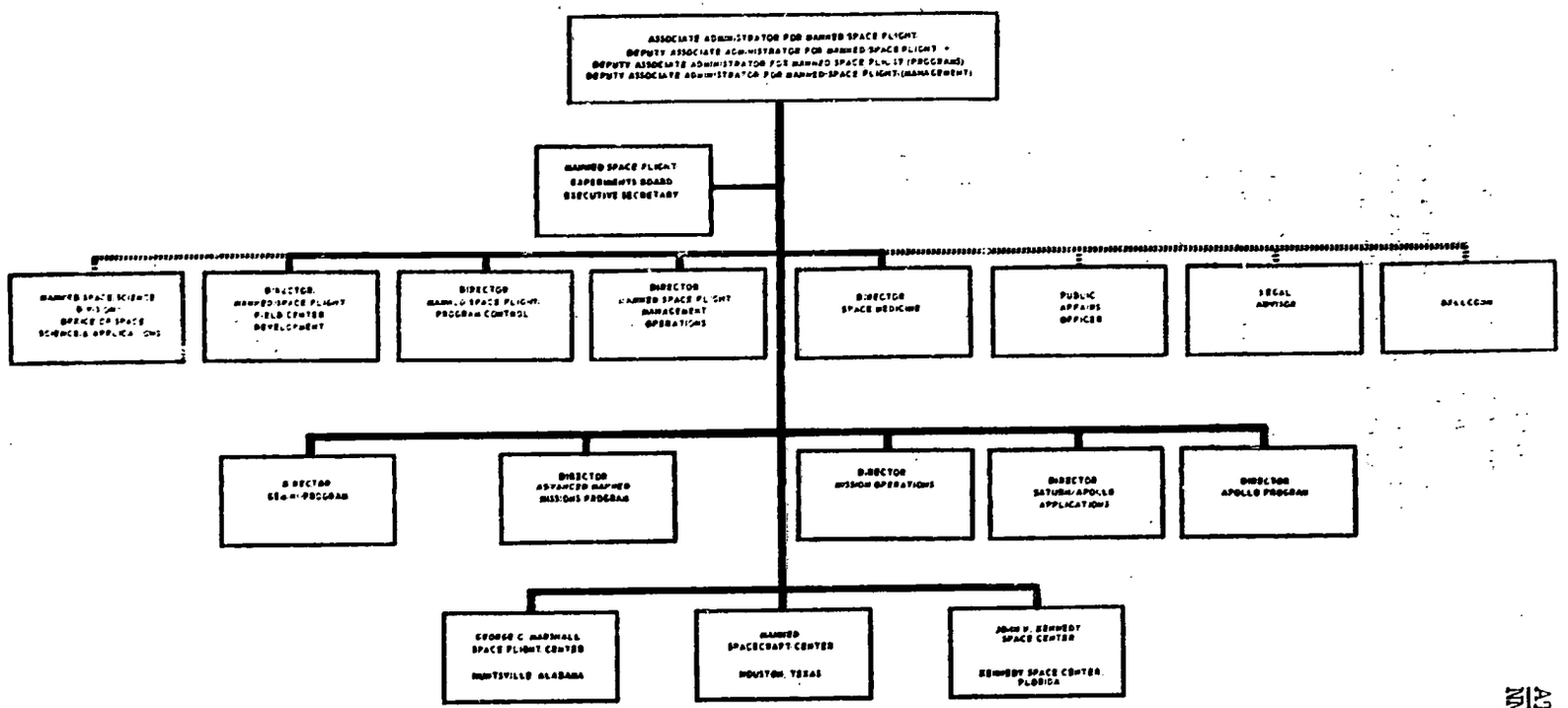
Basic information for this Appendix has been supplied by the Apollo Management Organization and a review of pertinent organizational documents.

APPENDIX E

OFFICE OF MANNED SPACE FLIGHT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OFFICE OF MANNED SPACE FLIGHT



APPROVED: James E. Webb

DATE: Aug. 6, 1965

GPO 896-621

ATTACHMENT A
NMI 1138.1

OFFICE OF MANNED SPACE FLIGHT

ASSOCIATE ADMINISTRATOR--MANNED SPACE FLIGHT

The Associate Administrator for Manned Space Flight (AA/MSF) is responsible for the overall management and direction of all Manned Space Flight programs as defined and approved by the Administrator of NASA. He is also responsible for directing launch and flight operations through completion of each mission within a program. He provides policy quidance and direction to the Directors of three Manned Space Flight Centers (MSFC, MSC and KSC), the Apollo Program Director and the OMSF Mission Operations Direcotr.

An OMSF Management Council, consisting of the AA/MSF as Chairman and the Directors of each Manned Space Flight Center, establishes policy guidelines and plans for the MSF programs. For the Apollo Program specifically, the Apollo Program Director operates within these guidelines and broad plans and advises the Council each month of his program plans and status, potential program areas, cost status and requirements for additional resources. The Council ensures that adequate resources are available for the successful conduct of the program and that policy, progress and performance goals are being met.

The Program Management Council also acts as the Design Certification Board for examining the design of the total Apollo mission complex for proof of development maturity. It assesses (1) the design of the Space Vehicle for flight worthiness and manned flight safety, and (2) the design of the Launch Complex the Mission Control Center, Manned Space Flight Network and Launch Instrumentation for manned Apollo missions. A Mission Design Certification Document, executed by the Program Management Council serves as the approval authority for proceeding with specific flight missions designated for manned flight.

APOLLO PROGRAM DIRECTOR

The AA/MSF has assigned the responsibility for all aspects of the Apollo Program to the Apollo Program Director and has delegated him the authority for planning and schedules, budgets and cost control, systems engineering, design, development, test, and performance evaluation necessary to ensure the achievement of program objectives. This authority includes the mission descriptions, technical requirements, program specification, and reliability and quality standards. The Apollo Program Director is the NASA official authority for issuing Apollo Program Directives and imposing Apollo Program requirements on Field Centers. His line of authority for direction of program affairs at each of the MSF Centers is direct to the Apollo Program Manager within the respective Center.

The Apollo Program Development Plan dated January, 1966 prepared by the Apollo Program Director in accordance with NASA General Management Instruction 4-1-1, is the basic plan for execution of the program as defined and approved by the Deputy Administrator of NASA in the Apollo Projects Approval Document. The Program Development Plan defines directly, or by reference, the program organization, responsibilities, requirements, resources and time phasing of major actions required to accomplish program objectives. Overall requirements and responsibilities in each of the functional areas of Apollo Program management are described in eighteen sections of this plan. These requirments and responsibilities are more specifically defined in additional Apollo Program Office "Key Documents". It is the responsibility of the Apollo Program Managers at each MSF Center to insure compliance with the requirements of these "Key Documents" throughout the NASA and contractor organizations which they control.

MSF CENTER DIRECTORS

DIRECTOR, MANNED SPACECRAFT CENTER (MSC)

The AA MSF has assigned the development of the Apollo Spacecraft and related ground support

equipment and support of manned space flight missions to the Director of the Manned Spacecraft Center. The Director is responsible for development, production, checkout and technical integrity of all Apollo spacecraft hardware and software. He retains this responsibility through all phases of activity, regardless of location of the hardware or software, from inception to program completion. The Director, MSC is also delegated the authority for Apollo flight operations and flight crew operations.

DIRECTOR, KENNEDY SPACE CENTER (KSC)

The AA, MSF has assigned the responsibility for Apollo Launch Operations, Facilities and Common Ground Support Equipment to the Director, Kennedy Space Center(KSC). He too, retains this assignment through all phases of activity, regardless of location of hardware or software, from inception to completion of the program.

Each Center Director assigns responsibility and delegates sufficient authority to his designated Apollo Program Manager to effectively manage his portion of the program.

CENTER PROGRAM MANAGERS, MSC AND KSC

The MSC and KSC Apollo Program Managers report organizationally to their respective Center Directors, but are responsive to program direction from the Apollo Program Director under overall direction of the Program Management Council. Each Apollo Program Manager is delegated the authority for overall coordination, planning and direction of all aspects of the Apollo Project assigned to his Center Director. This includes effective cost, schedule and technical performance management. He is required to establish project development plans, project specifications and subsidiary specifications, test and operating plans, mission descriptions and reliability and quality procedures consistent with and responsive to the direction and guidelines provided by Headquarters NASA, OMSF and the Apollo Program Director. Each Apollo Program Manager is the primary and official interface between NASA and the industrial contractors participating in his assigned project. He is responsible for supervision of the industrial contractors and other Center or NASA elements supporting his project.

INTER-CENTER RELATIONSHIPS, MSC AND KSC

TECHNICAL INTERFACES

Inter-Center Coordination Panels, acting under Co-chairmen from the two Centers involved, define and solve the technical interface problems between the spacecraft facilities and associated equipment. Basically, these panels are engineering and operational working groups responsible to a Panel Review Board (PRB) chaired by the Apollo Program Director. Eight panels and twenty-four sub-panels make available the technical competence of OMSF, MSFC, MSC, KSC and their contractors for the solution of interface problems. The panels and sub-panels function within specific assigned areas to: (1) initiate actions regarding design, analysis, study, test and operations, (2) identify and generate Interface Control Documents (ICDs) within established Program Requirements, and (3) recommend solutions to problems outside their assigned responsibility to the PRB for action by the proper panel and organization.

INTER-CENTER AGREEMENTS

The Directors of MSC and KSC have established documented agreements for inter-Center relationships concerning specific activities during the flow of hardware from manufacture and checkout through launch. Agreements also exist between the Directors of MSFC and KSC but are not deemed pertinent to the subject of this memorandum. The MSC Director retains technical design and performance responsibility for the Apollo Spacecraft at all times throughout the entire development and mission sequence.

PROGRAM REQUIREMENTS CHANGE CONTROL

Proposed changes to the established Program Requirements Baseline as defined by the Apollo Program Director. Procedures for the submittal, evaluation and approval of proposed changes are established for schedules, cost and technical performance.

Changes to the Apollo Program Development Plan are made in accordance with NMI 8020.5.

APOLLO PROGRAM DIRECTIVES

Apollo Program Directives are used to direct specific program actions and to document significant program decisions. These Program Directives, signed by the Apollo Program Director, provide a means for expediting documented direction to the Apollo Program Managers in each Center. The authority forApollo Program Directives is provided in NMI 8020.2.

APOLLO CONFIGURATION CONTROL BOARD DIRECTIVES

Additionally, Apollo Program direction is given to the Apollo Program Managers in the form of Apollo Program Office Configuration Control Board Directives. These directives, signed by the Apollo Program Director, implement the decisions of the Apollo Configuration Control Board on proposed changes to the Apollo Program Specification.

APPENDIX E

MANNED SPACECRAFT CENTER

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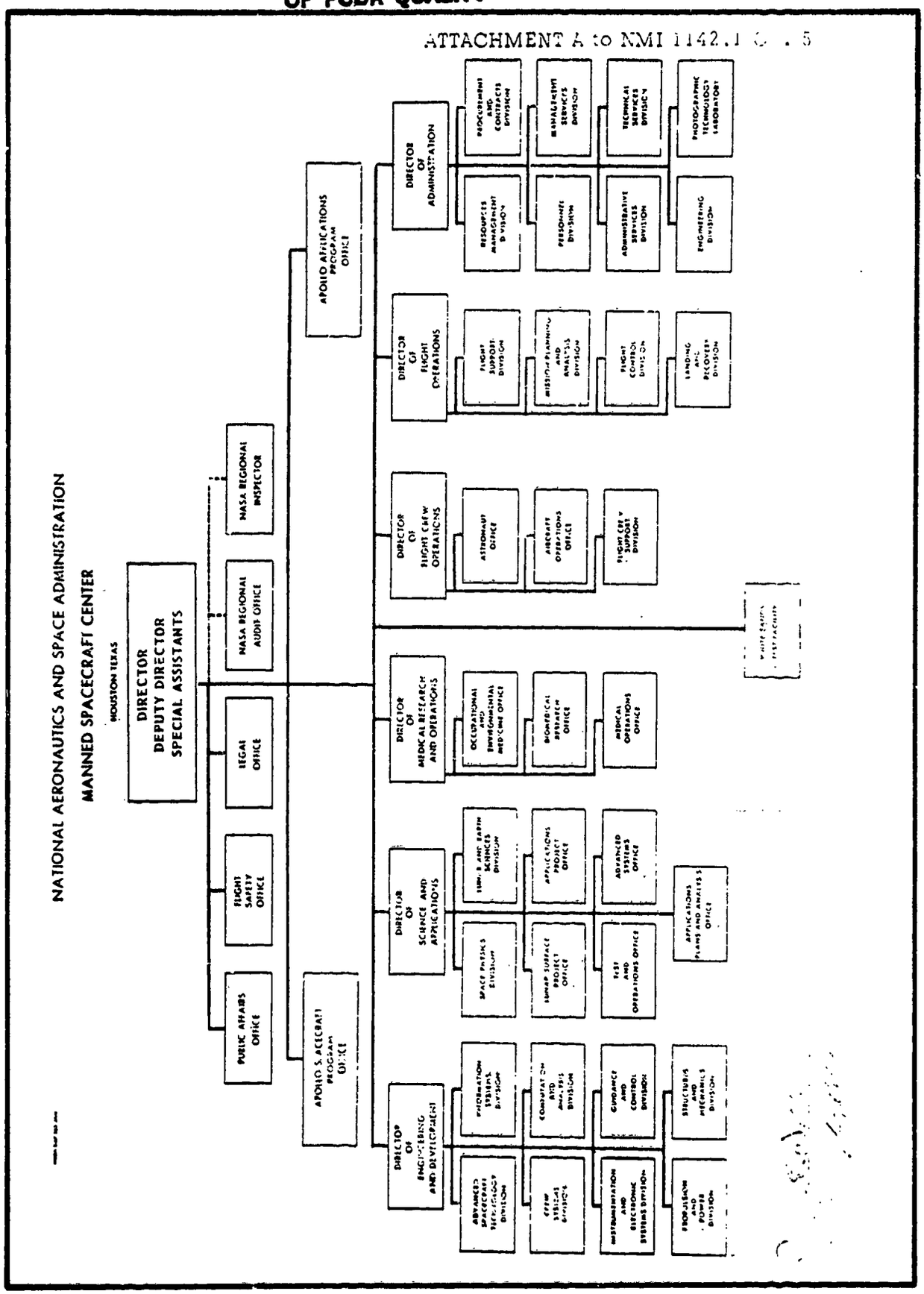


MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

The function and authority for the Manned Spacecraft Center is defined in Manned Space Flight NMI 1142.1. The management of the Apollo Spacecraft Program is assigned to the Apollo Spacecraft Program Office by the Manned Spacecraft Center Director.

DIRECTOR, MANNED SPACECRAFT CENTER (MSC)

The AA/MSF has assigned the development of the Apollo Spacecraft and related ground support equipment and support of manned space flight missions to the Director of the Manned Spacecraft Center. The Director is responsible for development, production, checkout and technical integrity of all Apollo spacecraft hardware and software. He retains this responsibility through all phases of activity, regardless of location of the hardware or software, from inception to program completion. The Director, MSC is also delegated the authority for Apollo flight operations and flight crew operations.

MSC APOLLO PROGRAM MANAGER

The MSC Apollo Program Manager reports organizationally to the MSC Center Director, but is responsive to program direction from the Apollo Program Director under overall direction of the Program Management Council. The Apollo Program Manager is delegated the authority for overall coordination, planning and direction of all aspects of the Apollo Project assigned to the Center Director. This includes effective cost, schedule and technical performance management. He is required to establish project development plans, project specifications and subsidiary specifications test and operating plans, mission descriptions and reliability and quality procedures consistent with and responsive to the direction and guidelines provided by Headquarters NASA, OMSF and the Apollo Program Director. The Apollo Program Manager is the primary and official interface between NASA and the industrial contractors participating in his assigned project. He is responsible for supervision of the industrial contractors and other Center or NASA elements supporting his project.

APOLLO SPACECRAFT PROGRAM OFFICE

The ASPO (Apollo Spacecraft Program Office), under the direction of the Apollo Program Manager, is responsible for the planning, coordination, and direction of all aspects of the Apollo Spacecraft Program. This includes the supervision of industrial contractors within the scope of the contract and the direction and coordination with other elements of MSC or NASA Headquarters which are assigned parts of the program. Specific responsibilities include:

a. Development of the Apollo Spacecraft Program resources and scheduling plans, their integration and development into an overall program development plan and the control of the implementation of this plan.

b. Serving as the primary point of coordination and control of systems design, specification, and development for the Apollo Spacecraft Program.

c. Development or approval of spacecraft subsystems design requirements, the performance of trade-off studies, the definition and control of all interfaces between spacecraft subsystems and the spacecraft, interfaces between other related program elements, and the development and maintenance of all crew safety requirements.

d. Management of the detailed planning, implementation, and reporting of results for each major flight and integrated systems ground test.

e. Coordination and development of the test program plan, the development of the mission directive documents, the determination of instrumentation and measurement lists and requirements, the determination of engineering data acquisition and reduction requirements, the establishment of detailed schedules, and the determination of the adequacy of checkout procedures for each major flight and integrated systems ground test.

f. Development and standardization of requirements for reliability and quality assurance and the reliability apportionment between various elements of the Apollo spacecraft.

g. Management of contractor and subcontractor reliability and quality control efforts and the coordination of the inspection efforts of cognizant Government inspection organizations.

h. Development of the basic design of the lunar landing mission and the development of criteria for the training of the spacecraft crew for the lunar landing mission.

RESIDENT APOLLO SPACECRAFT PROGRAM OFFICES (RASPO)

The RASPO at the contractors' sites are responsible for the conduct of all operations involving NASA personnel stationed at, or visiting the contractor in connection with the Apollo Spacecraft Program. The RASPOs also provide "on-site" monitoring of the contractor's efforts.

PROGRAM CONTROL DIVISION

The Program Control Division is responsible for the development of the Apollo Spacecraft Program resources and scheduling plans, their integration into and development of an overall program development plan, and the control of the implementation of this plan. These responsibilities include the management of spacecraft contractor efforts related to production machinery and equipment, facilities, manufacturing, configuration management, and documentation; the preparation of MSC and NASA budgets for the Apollo Spacecraft Program; the preparation of Apollo Spacecraft Program reports to meet the needs of controlling the program; and the planning and implementing of contract negotiation.

SYSTEMS ENGINEERING DIVISION

The Systems Engineering Division establishes the preliminary design, identification of subsystems and the performance of analyses and tradeoff studies when more than one subsystem is involved. Further responsibilities include the responsibility for definition, implementation and configuration control of all systems design for the Command and Service Module (C&SM) and the Lunar Module (LM) and associated Ground Support Equipment (GSE) and for providing the interface between the C&SM, LM, Launch Vehicle (LV), Launch Complex (LC) and Spacecraft LM Adapter (SLA).

MISSION OPERATIONS DIVISION

The purpose of the Mission Operations Division is to act as the focal point of all ASPO activities relating to the definition and planning of the Apollo spacecraft development and lunar missions. This Division is also responsible for defining the requirements for flight test and mission planning, determining the system and subsystem mission related design requirements, and verifying that the mission requirements are within spacecraft capabilities.

C&SM PROJECT ENGINEERING AND CHECKOUT DIVISION

The C&SM Project Engineering and Checkout Division is responsible for Program Office technical monitoring of all Command and Service Module (C&SM) and Spacecraft Lunar Module Adapter, (SLA) and checkout activities, as follows:

a. Providing Project Engineers for each C&SM SLA and ground test vehicle;
b. Assuring end item scheduling, integration and statusing to support program milestones;
c. Reviewing, monitoring and concurring on hardware and specification changes that affect C&SM and SLA;
d. Serving as primary point of contact for all close-in spacecraft;
e. Chairing the post-flight editorial board;
f. Organizing and conducting Flight Readiness Reviews for each C&SM and SLA;
g. Monitoring for the Manager, ASPO, the progress of the spacecraft from initial manufacturing to launch and from recovery to final dispostion;
h. Assuring timely recognition of unique spacecraft problems and directing their respective solutions;
i. Assuring overall flight readiness of the vehicle, associated facilities, and supporting ground test programs for each spacecraft; and
j. Managing the detail test planning and test activities associated with C&SM ground test vehicles for thermal/vacuum demonstration. Managing NASA and contractor activities associated with accomplishment of test and approving changes or workarounds as required to maintain established schedules.

LM PROJECT ENGINEERING AND CHECKOUT DIVISION

The Lunar Module Project Engineering and Checkout Division is responsible for Program Office

technical monitoring of all LMs and checkout activities as follows:

a. Managing Grumman Aircraft Engineering Corporation (GAEC) activities during the final assembly and factory checkout operations of the vehicle at GAEC.

B. Maintaining the schedule of checkout operations as designated by the spacecraft operational test procedures (OTP).

c. Controlling spacecraft configurations as defined in Apollo Configuration Management Plan dated March 3, 1965.

d. Reporting status of the spacecraft to the manager, ASPO, and all other interested parties.

e. Developing hardware and procedural solutions to problems which arise during final assembly and checkout operations at the factory.

f. Carrying out the ASPO management functions during the checkout operations of the spacecraft at KSC prior to stacking.

g. Carrying out the MSC management function of the spacecraft portion of the space vehicle after stacking and prior to final launch countdown initiation.

h. Assuring that the spacecraft systems are adquately verified prior to launch.

i. Assisting the Flight Operations Directorate and Mission Operations Division, ASPO, during the spacecraft mission as requested.

j. Arranging for the Customer Acceptance Readiness Review (CARR) and closeout action items generated by these meetings.

RELIABILITY, QUALITY AND TEST DIVISION

The Reliability, Quality and Test Division has primary responsibility for developing and monitoring of policies and procedures for assuring the reliability and quality of Apollo spacecraft systems and components; establishes the reliability apportionments between element of the spacecraft; serves as the primary point of coordination and control for all manufacturing processes and quality control problems; is responsible for the certification and qualification requirements, and their buy-off, for all spacecraft hardware items, and assures proper resolution of all spacecraft, Ground Support Equipment (GSE) and Acceptance Checkout Equipment (ACE) failures.

MISSION SUPPORT DIVISION

The Mission Support Division responsibilities include the following:

Manage the activities relating to evaluation of preflight checkout data, program office real-time mission support, test data processing, and postflight evaluation and reports for all Apollo missions.

Develop a real-time support plan for each mission, including hardware, software, and manning requirements for Houston and the contractor plants. Direct the program office real-time support activities during each mission.

Plan the data acquisition and processing requirements for real-time and postflight analysis. Manage instrumentation transducer calibration activities. Direct the activities of contractor processing of mission data.

Manage mission analysis and evaluation activity at Houston and at the contractor plants. Manage spacecraft and equipment handling after recovery until mission evaluation is completed. Expedite the identification and resolution of all anomalies observed during the mission or form postflight test activities. Issue all required reports for the mission.

Assure that a satisfactory processing and analysis of data has been performed during the final acceptance tests on each spacecraft at the contractors plants and at KSC, and for thermal-vacuum spacecraft tests conducted at MSC. Expedite the identification and resolution of all anomalies observed during thermal-vacuum spacecraft tests.

APOLLO SPACECRAFT SUBSYSTEM MANAGEMENT

The ASPO, in implementing the MSC management philosophy to attain the maximum utlization of the available resources of MSC in furtherance of the Apollo Spacecraft Program, has assigned the management of the contractors' subsystem development efforts to Subsystem Managers within specific

divisions of the Engineering and Development Directorate of MSC. The Subsystem Manager is responsible to the Manager, ASPO, for development of his subsystem to given specifications within the cost and schedule constrainsts of the program.

MSC ORGANIZATION FUNCTIONS (APOLLO)

In addition to the subsystem management responsibilities, the Engineering and Development Directorate provides special testing and test support, spacecraft R&D instrumentation, and computation support. Also, the Crew Systems Division of Engineering and Development Directorate is responsible for the development and provisiton of crew spacesuits and EMU through industrial contracts.

The Flight Crew Operations Directorate through delegated authorities from the MSC Director is responsible for providing the Apollo crew training, crew procedures and flight crew operations.

The Director of Administration is responsible for providing contract management, procurement functions, facilities and technical services requested in support of the Apollo Spacecraft Program.

MSC KSC INTERCENTER RELATIONSHIP

The Directors of MSC and KSC have established documented agreements for inter-Center relationships concerning specific activities during the flow of hardware from manufacture and checkout through launch. The MSC Director retains technical design and performance responsibility for the Apollo spacecraft at all times throughout the entire development and mission sequences.

Technical Interfaces

Inter Center Coordination Panels, acting under Co-chairmen from the two Centers involved, define and solve the technical interface problems between the spacecraft, facilities and associated equipment. Basically, these panels are engineering and operational working groups responsible to a Panel Review Board (PRB) chaired by the Apollo Program Director. Eight panels and twenty-four sub panels make available the technical competence of OMSF, MSFC, MSC, KSC and their contractors for the solution of interface problems. The panels and sub panels function within specific assigned areas to - (1) initiate actions regarding design, analysis, study, test and operations, (2) identify and generate Interface Control Documents (ICD'S) within established Program Requirements, and (3) recommend solutions of problems outside their assigned responsibility to the PRB for action by the proper panel and organization.

APOLLO SPACECRAFT CONTRACTOR SUBCONTRACTOR MANAGEMENT

The ASPO Program Manager is the primary and official interface between NASA and the industrial contractors participating in his assigned program. He is responsible for supervision of the industrial contractors

APOLLO SPACECRAFT PROGRAM CONTROL

The Apollo Spacecraft Development Plan is prepared by the ASPO and is the basic plan for the execution of the spacecraft program within the overall framework of the Apollo Program Development Plan generated by the Apollo Program Director (MSF). The execution of the spacecraft program is implemented through the appropriate contracts and contract documents with the individual spacecraft development contractors. The contract baseline consists of the contract itself, defining the contractor's tasks and responsibilities, the spacecraft specifications, test plans, checkout requirements and hardware production requirements and schedules. The control of these requirements is accomplished through the contract change procedure and the Apollo Configuration Control Procedures set forth in NPC 500-1, Supplement No. 1. Cost control is maintained through the utilization of the NASA Form 533 procedure, and the more detail control method of "work packages", which provides visibility and control of the contractor's efforts

APPENDIX E

FLIGHT CREW MISSION OPERATIONS

FLIGHT CREW MISSION OPERATIONS

The Flight Crew Director is designated by the Assistant Director for Flight Crew Operations and reports to him except during the mission period. During the mission period he reports directly to the Flight Director. During the prelaunch phase, the Flight Crew Director directs and assesses the preparations of the flight crews and their required equipment, and reports the status of these preparations and the final readiness to the Flight Director. He is responsible for scheduling the activities of the flight crew, providing the training and the training equipment, and insuring personal equipment necessary for the mission is provided. During a mission control phase, the Flight Crew Director is available to the Flight Director for assistance in flight control, if desired.

The functions reporting directly to the Flight Crew Director are the Flight crews, both primary and backup; the simulator operations section; and the flight crew activities support team. The personal flight equipment group of the Crew Systems Division and the flight surgeons of the Center Medical Office are responsive to the Flight Crew Director in order to carry out his assigned duties.

The primary and backup flight crews are assigned by the Assistant Director for Flight Crew Operations. During the prelaunch phase, both crews perform activities assigned by the Flight crew Director. During the mission control phase, the primary flight crew report to the Flight Director in accomplishing the flight plan in accordance with the mission rules and supplementary instructions from the Flight Director, or mission rules and supplementary instructions from the Flight Director, or perform such independent action as required in flight by contingency situations. The backup crew assists the Flight Crew Director during the mission control phase.

The simulator operations section is provided by the Flight Crew Support Division. This section maintains and operates the mission simulator and other necessary training devices.

The flight crew activities support team is also provided by the Flight Crew Support Division. This team is responsible for coordinating preflight crew training and briefings, providing in-flight assistance to the flight control team and flight crew as required, and conducting postflight crew debriefing. Preflight activities consist of aiding in training flight crews in spacecraft operation and scientific experiments. They are responsible for some in-flight experimental equipment and for flight crew training on all experiments. It is also their function to provide a flight plan which outlines activities to be performed by the crew during the mission. During the mission this team provides support to the Flight Director through the command communicator as specified in other documentation.

The personal equipment group is provided by the Crew Systems Division. This group is responsible for the care of flight ready equipment, suiting the crew for training sessions and flight, and aiding the crew during insertion and hookup for launch. The Crew Systems Division supplies the necessary pressure suits, hygiene equipment, rations, sensors, and other personal equipment required to support the mission.

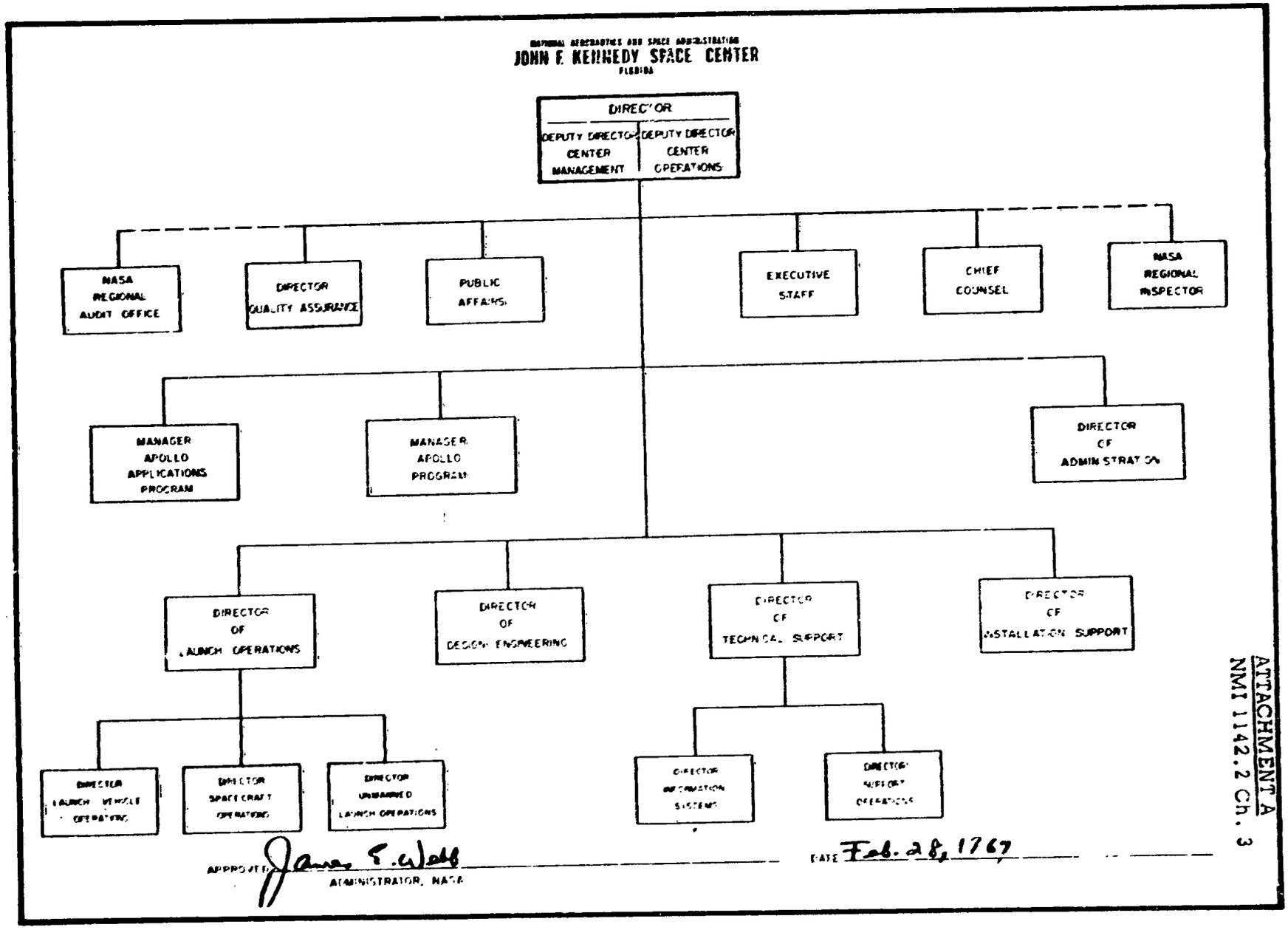
The crew flight surgeons are designated by the Chief of the Center Medical Office. During prelaunch phases, the crew flight surgeons monitor and assess the physiological status of the flight crews and report this status to the Flight Crew Director and Medical Director.

Upon recovery, the recovery flight surgeons accomplish postflight medical evaluation as directed by the Medical Director and scheduled by the Flight Crew Director.

Upon termination of flight, the flight crew technical debreifing team, appointed by the Assistant Director for Flight Crew Operations, is responsible for the planning and implementation of the technical and in-flight experiments debriefing of the flight crew. This team uses the crew debriefing document to acquire preliminary data. This document formulates a series of questions covering the areas of flight control, spacecraft systems, in-flight experiments, and recovery operations. They accomplish the required liaison with the program offices, flight operations directorate, and the in-flight experiments panel, to insure that these organizations have appropriate representation at MSC debriefing sessions. The debriefing team makes arrangements to be at the scene of the primary recovery site in order to accomplish the initial debriefing as soon as possible after recovery. They also develop plans required for debriefing the flight crews in the event of landing in a secondary or contingency site.

APPENDIX E

JOHN F. KENNEDY SPACE CENTER


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHN F. KENNEDY SPACE CENTER
FLORIDA
DIRECTOR
DEPUTY DIRECTOR CENTER MANAGEMENT
DEPUTY DIRECTOR CENTER OPERATIONS
NASA REGIONAL AUDIT OFFICE
DIRECTOR QUALITY ASSURANCE
PUBLIC AFFAIRS
EXECUTIVE STAFF
CHIEF COUNSEL
NASA REGIONAL INSPECTOR
MANAGER APOLLO APPLICATIONS PROGRAM
MANAGER APOLLO PROGRAM
DIRECTOR OF ADMINISTRATION
DIRECTOR OF LAUNCH OPERATIONS
DIRECTOR OF DESIGN ENGINEERING
DIRECTOR OF TECHNICAL SUPPORT
DIRECTOR OF INSTALLATION SUPPORT
DIRECTOR LAUNCH VEHICLE OPERATIONS
DIRECTOR SPACECRAFT OPERATIONS
DIRECTOR UNMANNED LAUNCH OPERATIONS
DIRECTOR INFORMATION SYSTEMS
DIRECTOR SUPPORT OPERATIONS
APPROVED James E. Webb
ADMINISTRATOR, NASA
DATE Feb. 28, 1967

INTRODUCTION

This report briefly summarizes the KSC Apollo organization and rsponsibilities. In each instance, the documented authority is referenced and included as enclosures.

The functioning of the office of the Center Director, Apollo Program Office, each of the four Directorates, plus additional detail in the area of Spacecraft and Launch Vehicle Operations is included.

GENERAL

The overall organizational structure of the Kennedy Space Center is shown in enclosure 1. Kennedy Space Center responsibilities are:

1. Development and construction of facilities to check out and launch space vehicles.
2. Assemble and integrate spacecraft, launch vehicles, and launch facilities.
3. Provide support services at Cape Kennedy Air Force Station and Kennedy Space Center, NASA.
5. Manage and master plan the Kennedy Space Center, NASA.

REF. AUTH. - Apollo Program Development Plan, M-DMA-500
- NMI 1142.2

DIRECTOR, KENNEDY SPACE CENTER

The Center Director is responsible to the Associate Administrator for Manned Space Flight. His responsibilities are:

1. Total responsibility for the entire KSC enterprise.
2. Establishment and or approval of all basic internal KSC policies.
3. Personal involvement at specific critical points in key managerial processes and decisions
4. Delegate authority and responsibility to the senior levels of Center management.

REF. AUTH. - NMI 1142.2
- KN 1142.2

APOLLO PROGRAM MANAGER (KSC)

The KSC Apollo Program Manager is directly responsible to the Center Director and is responsive to program direction from the Apollo Program Director under overall direction of the Program Management Council. The KSC Apollo Program Manager is responsible for:

1. Official interface with other Manned Space Flight Centers and Office of Manned Space Flight.
2. Formulation of subsidiary specification, test and operating plans, mission description, program reliability and QA procedures and operating plans.
3. Translate requirements and schedules received from the Apollo Program Director and forward to line organizations for development into detailed plans.
4. Receive, review, validate and integrate plans for individual operating Directorates into KSC Apollo Program plans.
5. At a program commitment level, coordinate, monitor and track the execution of requirements and utilization of funds against approved plans, schedules and resources.
6. Approve the scope and changes in scope in the work of stage and spacecraft contractors.
7. Assure that the scope or change in scope of support contractors are consistent with Apollo Program requirements.
8. Maintain surveillance of stage and spacecraft contractors activities to assure optimum balance in performance, schedules, and cost.
9. Review development plans for KSC designed or furnished equipment and facilities. Assure performance and design criteria is proper and acceptable with all activities involved and are consistent with Apollo Program guidelines and available resources.

REF. AUTH. - KN 1142.2
- KN 1142.21

DIRECTOR OF LAUNCH OPERATIONS

The Director of Launch Operations reports directly to the Center Director and is responsible for:
1. Management and technical direction of prelight operations and integration, checkout, and launch of all Apollo space vehicles at KSC and ETR.
2. Installation, checkout, modification, maintenance and operation of all GSE provided as used by launch vehicle and spacecraft contractors.
3. Initiates, supervises and coordinates the preparation of prelight launch operations test plans and is responsible for the execution of them.
4. Assists the Kennedy Space Center Apollo Program Manager in his negotiating with, and receiving approval of, the cognizant development Centers concerning test and operational sequences, and methods and standards.
5. In accordance with program requirements received from the KSC Apollo Program Manager, develops operational support and resource requirements needed to execute the assigned mission within approved schedules and or funding limitations
6. Oversees the management of specific contractor efforts as appropriate to their mission, insure consistency, coordination and effective management.
7. Chair the Apollo Launch Operations Committee (ALOC).

REF. AUTH. KN 1142.2
- KN 1142.22

DIRECTOR, SPACECRAFT OPERATIONS

The Director, Spacecraft Operations is responsible to the Director of Launch Operations for:
1. All operations and technical management functions relating to spacecraft contractors within the jurisdiction of KSC.
2. Management and technical integration of all KSC operations related to preparation, integ

integration modification, checkout and flight readiness of manned spacecraft.
3. Installation, checkout modification, maintenance, and operation of all GSE provided or used by the spacecraft contractors.
4. Develop operational support requirements for manned spacecraft checkout and launch at KSC.
5. Establish a uniform and consistent program within the Directorate for configuration management, reliability, QA, logistics, and systems engineering based on the prescribed guidelines.
6. Review and approve (jointly) spacecraft test requirements.
7. Review and approve detailed spacecraft operational checkout plans and procedures.
8. Accept spacecraft test results.
9. Operational direction authority of spacecraft during the conduct of tests and checkout. Assure the coordination, consistency, and effectiveness of the spacecraft contractors during the KSC operational phase.
10. Develop detailed spacecraft checkout schedules prior to electrical SC/LC mate consistent with the overall milestones developed by the Apollo Program Manager.
11. Implement MSC approved spacecraft and GSE configuration changes. Certify changes are implemented per blueprint.
12. Assure the quality of contractor work performed at KSC.

REF. AUTH. - KN 1142.2
- KN 1142.8A
- KSC MSC Agreement
- See enclosures 2 & 5.

DIRECTOR, LAUNCH VEHICLE OPERATIONS

The Director, Launch Vehicle Operations is responsible to the Director of Launch Operations for:

1. The management and technical integration of all KSC operations related to launch vehicles developed and provided by MSFC.
2. All operations and technical management of launch vehicle contractors.
3. Continuing analysis of the total Saturn systems, and assures total integration of the Saturn system, hardware and performance.
4. The development and execution of all test plans, schedules and procedures as related to the launch vehicle operations.
5. The monitoring and evaluating the quality, economy, and timeliness of launch vehicle stage contractor's performance.
6. Approving all procedures for launch vehicle tests and operations performed at KSC.
7. The development, coordination, validation of budget requirements and control of allocated resources.
8. A comprehensive Quality and Reliability Assurance Program for the receipt, preparation, prelaunch checkout, countdown and launch of the Saturn Launch Vehicle.

REF. AUTH. -KN 1142.12

DIRECTOR, TECHNICAL SUPPORT

The Director of Technical Support reports directly to the Center Director and is responsible for:

1. Provide or arrange all technical support involved in the conduct of KSC checkout and launch activities.

2. Manage and direct the maintenance and operation of test and launch complex facilities including all related equipment other than flight equipment and GSE.
3. Schedule and control all technical support services at KSC.
4. Maintain single point of NASA entry into AFETR concerning program requirements.

REF AUTH.
- KN 1142.15
- KN 1142.17A
- KN 1142.2

DIRECTOR OF INSTALLATION SUPPORT

The Director of Installation Support reports directly to the Center Director and is responsible for:

1. General operation and maintenance of the installation, including such services as maintenance and minor rehabilitation services for all KSC buildings, permanent structures, and utilities except those technically defined elements of Launch Complexes.
2. Provision of operational and industrial safety program.
3. Provision of ocupational health program.
4. Provision of photographic, reproduction, transportation, supply and small purchase services.

Responsibility for administration of pad and flight safety programs for launches from complexes located on Cape Kennedy rests completely with ETR per a Webb-McNamara Agreement. This responsibility does not include safety of operation internally to a manned spacecraft and flight safety for launches from KSC.

REF. AUTH. - KN 1142.2
- KN 1142.13A

DIRECTOR OF DESIGN ENGINEERING

The Director of Design Engineering reports directly to the Center Director and is responsible for:
1. Design, development, fabrication and refurbishment of all KSC provided equipment and facilities with exception of the electronic systems and equipment installed in the Central Instrumentation Facility.
2. Provide standards and policies for operation and maintenance of KSC facilities and launch support equipment.
3. Develop concepts and perform studies for future mission launch equipment and facilities.
4. Serve as official KSC contact and interface with the U. S. Army Corps of Engineering based on prescribed guidelines.
6. Maintain direct but informal lines of communication with the design function of other NASA Centers.

REF. AUTH. - KN 1142.2
- KN 1142.11

APPENDIX E

MANAGEMENT INTERFACE, MSC, KSC

MANAGEMENT INTERFACE
BETWEEN
MANNED SPACECRAFT CENTER
AND
KENNEDY SPACE CENTER

A chronological listing of the intercenter correspondence on this subject follows as Attachment no. 1.

CHRONOLOGICAL LISTING OF
DOCUMENTED MSC/KSC OPERATIONAL AGREEMENTS

1. Debus/Gilruth Agreement dtd 12-21-64 Debus/Gilruth Agreement.
2. Debus datafax to Shea dtd 1-23-65
   Subject: Staffing of Resident MSC Office at KSC
   Provides for Resident MSC Office at KSC to start with minimum staff of 5 personnel, to expand to no more than 15-20.

   Function of Office to remain within 12-21-64 Debus/Gilruth Agreement.

   Provision for project engineering function, one for each spacecraft. Statement that MSC Program Office would retain function responsibility for approval of all configuration changes and hardware performance waivers.
3. Shea datafax to Petrone dtd 9-23-65
   Subject: KSC Operation Management Plan
   Proposal that KSC PPR take over and perform the functions of the MSC Resident Office at KSC.
4. Petrone datafax to Shea dtd 10-7-65
   Subject: KSC Operation Management Plan
   Accepts MSC Proposal for PPR to take over and perform MSC Resident Office function at at KSC. Statement that KSC understands MSC wants CCP established at KSC with authority to approve compatibility and make-work changes.

   Requests MSC to formally delegate overall direction of S/C contractors' activity at KSC to PPR in order to properly perform Resident Office function.

   Requests that the 5 MSC personnel in KSC Resident Office be transferred to PPR.
5. Shea letter to Petrone dtd 10-12-65
   Subject: KSC Operation Management Plan
   Officially transfers MSC Resident Office functions at KSC to PPR, effective 10-12-65.
   Accepts KSC request for contractor direction, establishment of CCP at KSC, and transfer of resident personnel to PPR.

   Statement that the agreements made were within the 12-21-64 Debus/Gilruth Agreement.
6. Shea letter to Shinkle dtd 10-21-66
   Subject: Chairman of CCP at KSC
   States that Mr. W. Kapryan was appointed MSC Assistant Program Manager.

   Request that Chairmanship of the KSC CCP be changed from PPR to Mr. Kapryan effective Nov. 1, 1966.

   Statement that this, in no way would alter PPR's present relationship with MSC spacecraft contractors.

   Requests that Mr. Kapryan be authorized to sign KSC Master Schedules.

7. Shinkle letter to Shea dtd 11-1-66

Subject: Chaimanship of CCP at KSC

Agrees with MSC request that CCP Chairmanship be transferred from PPR to Mr. W. Kapryan, MSC Resident Manager. Disapproves request for Mr. Kapryan to sign KSC Master Schedules.

Statement that PPR would retain responsibilities of CCP except the authority for make-work and compatibility changes. This retained responsibility (operational scheduling of approved MSC changes) would be handled by establishing a Spacecraft Change Implementation Board (SCIB) chaired by PPR.

WORKING RELATIONSHIP BETWEEN KENNEDY SPACE CENTER AND MARSHALL SPACE FLIGHT CENTER

TEST ACTIVITIES

Test Requirements, Test Specifications and Criteria - MSFC (prime stage contractors) establishes and levies minimum TEST Requirements and field Test Specifications on KSC after coordination between originator and user.

Test Catalog - KSC (stage contractor) generates the Test Catalog which gives the testing planned at KSC. MSFC approves the Test Catalog.

Test Procedures - KSC has authority and responsibility for generation and approval of Test Procedures fulfilling Test Catalog.

Test Results - KSC has authority and responsibility for accepting test results.

FLIGHT HARDWARE CONTRACTOR MANAGEMENT AT KENNEDY SPACE CENTER

KSC has supplemental contracts with the prime stage contractors for prelaunch operations and launch. KSC establishes scope of work and has responsibility and authority for directing the contractors.

WORKING RELATIONSHIP BETWEEN KENNEDY SPACE CENTER AND MANNED SPACECRAFT CENTER

Test Requirements - Beginning on Jan. 26, 1967, KSC had joint approval and authority with MSC for Test Requirements at Kennedy Space Center.

Test Catalog - N/A

Test Procedures - KSC has authority and responsibility for generation and approval of Test Procedures.

Test Results - KSC has authority and responsibility for accepting test results.

KSC has the responsibility to insure that the Contractor performs his job adequately.... where disagreements or impasses occur between KSC and contractor, KSC authority must be discharged through MSC to Contractor's home plant. KSC has operational direction authority (during conduct of test).

	MSC has the authority for determining the level of contractor manpower requirements.
	MSC has the authority to determine the scope of the Contractor's work effort.
FLIGHT CREW ACTIVITIES	
N/A	MSC has responsibility for all Crew related training at the Kennedy Space Center.
	MSC has all responsibility with respect to GFE Flight Crew equipment and/or any stowage of same flight hardware.
SCHEDULING	
KSC has the responsibility for developing the overall space vehicle schedule.	KSC has the responsibility for developing the overall space vehicle schedule.
CONFIGURATION CONTROL	
MSFC has the responsibility for establishing and managing LV configuration and MSFC designed GSE.	MSC has the responsibility for establishing and managing the S/C and GSE (ACE included) configuration.
KSC has the responsibility to implement control of MSFC designed hardware located at KSC.	KSC has the responsibility to implement the MSC approved S/C and GSE configuration.
KSC has the responsibility for configuration control of KSC designed hardware.	
Changes to interface between KSC designed GSE and MSFC hardware (ICD) requires approval of both Centers (IRN).	Changes to interface between KSC designed hardware and MSC GSE--require approval of both Centers.
INSPECTION	
KSC is responsible for the Quality of work which is performed at Kennedy Space Center.	KSC is responsible for the quality of work which is performed at Kennedy Space Center.

KSC is responsible for certifying that approved LV or GSE configuration changes are implemented per MSFC drawings and specifications

KSC is responsible for certifying that the approved S/C or GSE configuration changes are implemented per blueprint.

MSC approves the Quality Control Plan for the activities at KSC.

SAFETY AT THE KENNEDY SPACE CENTER

KSC has the responsibility and authority for implementation of Safety Procedures and Safety Standards.

KSC has the responsibility to approve hazardous testing.

KSC has the responsibility and authority for implementation of Safety Procedures and Safety Standards.

KSC has joint responsibility with MSC with respect to approval of hazardous testing. Example – Manned Altitude Chamber Testing.

KSC DESIGN OF GSE

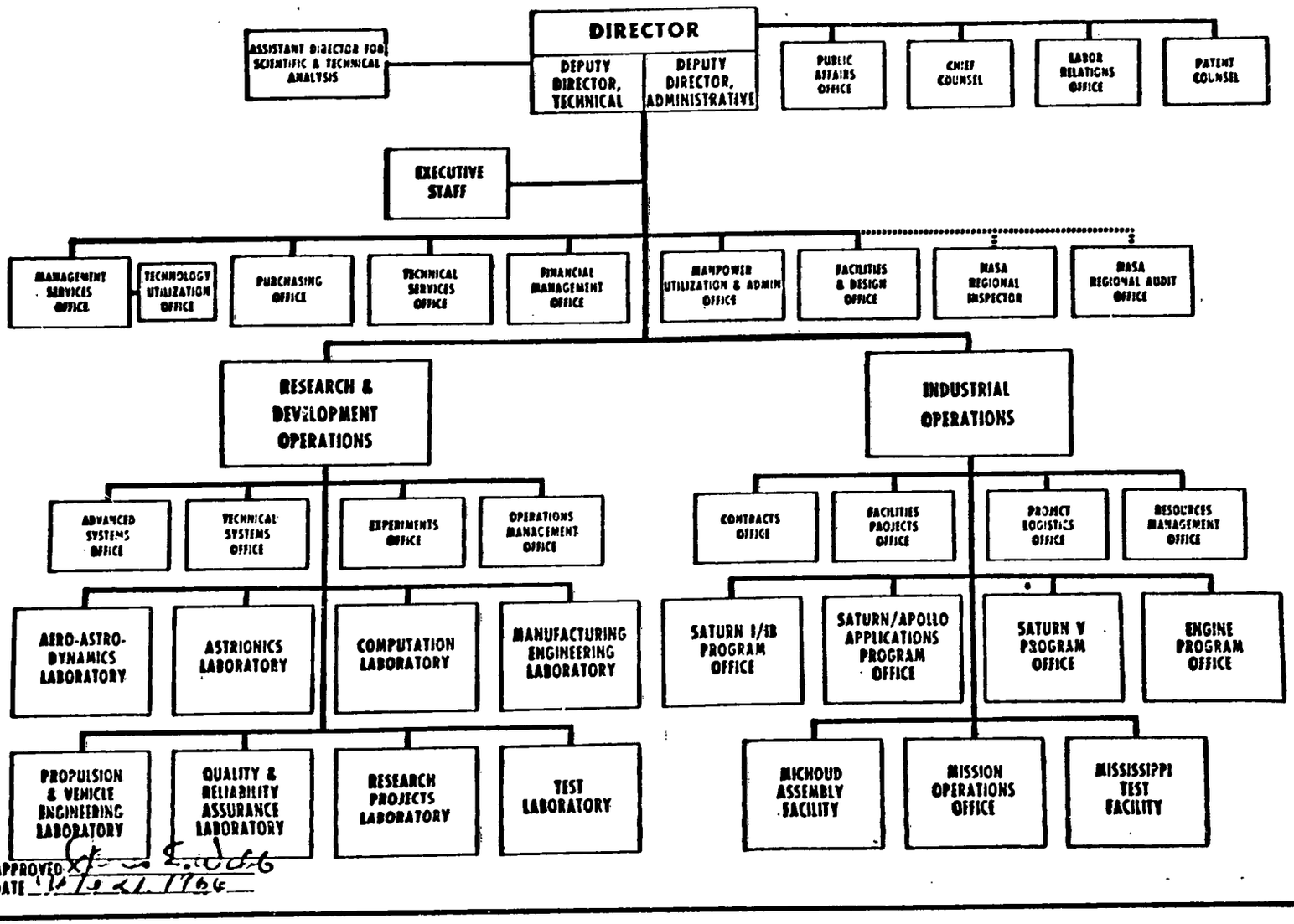
KSC has responsibility and authority for design and fabrication of GSE such as; Propellant Facilities, launch accessories, swing arms, etc. as defined by Intercenter ICDs.

KSC has responsibility and authority for design and fabrication of GSE such as; Propellant Facilities, launch accessories, swing arms, etc. as defined by Intercenter ICDs.

APPENDIX E

MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER



APPROVED
DATE 10 21 1966

MSFC MANAGEMENT SUMMARY

In mid-1960, the period during which the Marshall Center was established and, incidentally, the Apollo program was approved by the President, the basic MSFC line organization was structured functionally by technical discipline, grouped within laboratories which reported to the Center Director. These laboratories at that time already embodied a veteran technical work force with in-depth competence in all disciplines relating to rocket, ballistic missile and launch vehicle research and development. Compared to the Apollo program management structure of today, this R&D work in 1960 had a primary in-house orientation, with design, much of the development, assembly, and test actually performed within these laboratories by government personnel. Contractors were used as suppliers, for sub-system development, and to assist the laboratories in carrying out in-house assignments. The focus for management of this contractor effort was in the laboratories. Superimposed on this laboratory system were project offices, which handled conventional programmatic functions such as budgets, schedules and reporting. Center staff organizations performed administrative support. Because the in-house Saturn I booster work was of such magnitude that it pervaded all organizational elements and required the commitment of such a large part of Center resources, the over-all management of the Saturn program was in fact performed at the very top of the Marshall organization by the Center Director.

As the approved Saturn program evolved from the two-stage Saturn I into a three-vehicle family consisting of the Saturn I, IB and V, it became apparent by late 1962 that the manpower and facility requirements of the program far exceeded the capacity of the laboratories to do the entire job in-house. The Marshall Center was forced to adjust its way of doing business to meet the demands of the total vehicle program for Apollo. MSFC did this by adopting the approach which is still followed today: each stage or system is contracted out to a major aerospace firm, such as Chrysler, Boeing, Douglas, North American, and IBM.

This management change, whereby more than ninety per cent of the Saturn job is performed by contractors, necessitated a major shift in activity within the Marshall organization. The primary task for Saturn was no longer one of in-house design, development, assembly and test; the main job was now one of managing the efforts of these major prime contractors.

This shift in emphasis was reflected in the major MSFC reorganization of November 1963 and still in effect today, when Industrial Operations(IO) was created as the MSFC program management organization with the primary job of managing the major contractors. The program offices in IO are structured along the same lines as the program offices in the NASA Headquarters Office of Manned Spaceflight and at the other Manned Spaceflight Centers.

At the same time, the laboratories with practically no change in function, continue under a Director, Research and Development Operations. These laboratories have retained their direct involvement in the program through continuous, across-the-board technical support to the program manager and supervision of contractor effort through IO program management channels. Thus the technical expertise carefully nurtured through the years continues to provide a reservoir of know-how to fully support technical program decisions.

Because Saturn/Apollo continues to be the top priority job of this Center commanding the lion's share of its resources in both laboratory and program office, center management, with appropriate support from the staff offices, continues to play the major role for the general supervision of the entire Apollo Program organization.

Enclosed you will find descriptions of the duties and responsibilities of each of the major MSFC organizational elements participating in Apollo. These materials should be reviewed within the context of the background stated in this summary.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

FUNCTIONS

The George C. Marshall Space Flight Center is assigned the following functions:

a. Performing as assigned the research and development associated with large launch vehicle or space transportation systems and selected payloads, together with the related support equipment and facilities.

b. Porcuring launch vehiclx systems and subsystems, including related electrical and ground support equipment, according to assigned responsibilities; monitoring and directing contractor efforts; conducting acceptance tests; and approving all deviations and changes from contract specifications.

c. Providing or performing overall systems engineering, systems integration and production engineering for the launch vehicle or space transportation systems assigned.

d. Performing advanced studies, research, and planning in the general field of astronautics, including advanced space navigation techniques.

e. Developing and/or procuring engines for assigned support propulsion systems as well as those required to support launch vehicle and space transportation systems.

f. Porviding flight ready launch vehicle systems; insuring proper inflight functioning within the approved mission profile, and providing post-flight evaluation and analysis.

g. Providing support, according to assigned responsibilities, for the space program activities of other NASA Installations, Department of Defense elements or other Government agencies.

h. Performing in-house support research and management of research contracts with industry and universities for the advancement of the state-of-the-art in technologies associated with assigned programs.

i. Conducting operations in support of the Technology Utilization Program, including a continuing search for and reporting of new technology, including innovations in techniques, processes, materials, and devices evolved in the course of performing the functions outlined in this Instruction.

j. Providing a NASA in-hc capability for pilot manufacturing, tooling, engineering and related technical disciplines; and investigating, in considerable depth, technical problems in all the above areas when requested.

k. Reporting on the status or projects and recommending changes or modifications to meet goals and schedules.

l. Exercising management responsibility of component installations, including Michoud Assembly Facility and Mississippi Test Facility.

m. Providing administrative and management support as required for carrying out assigned functions and programs.

INDUSTRIAL OPERATIONS

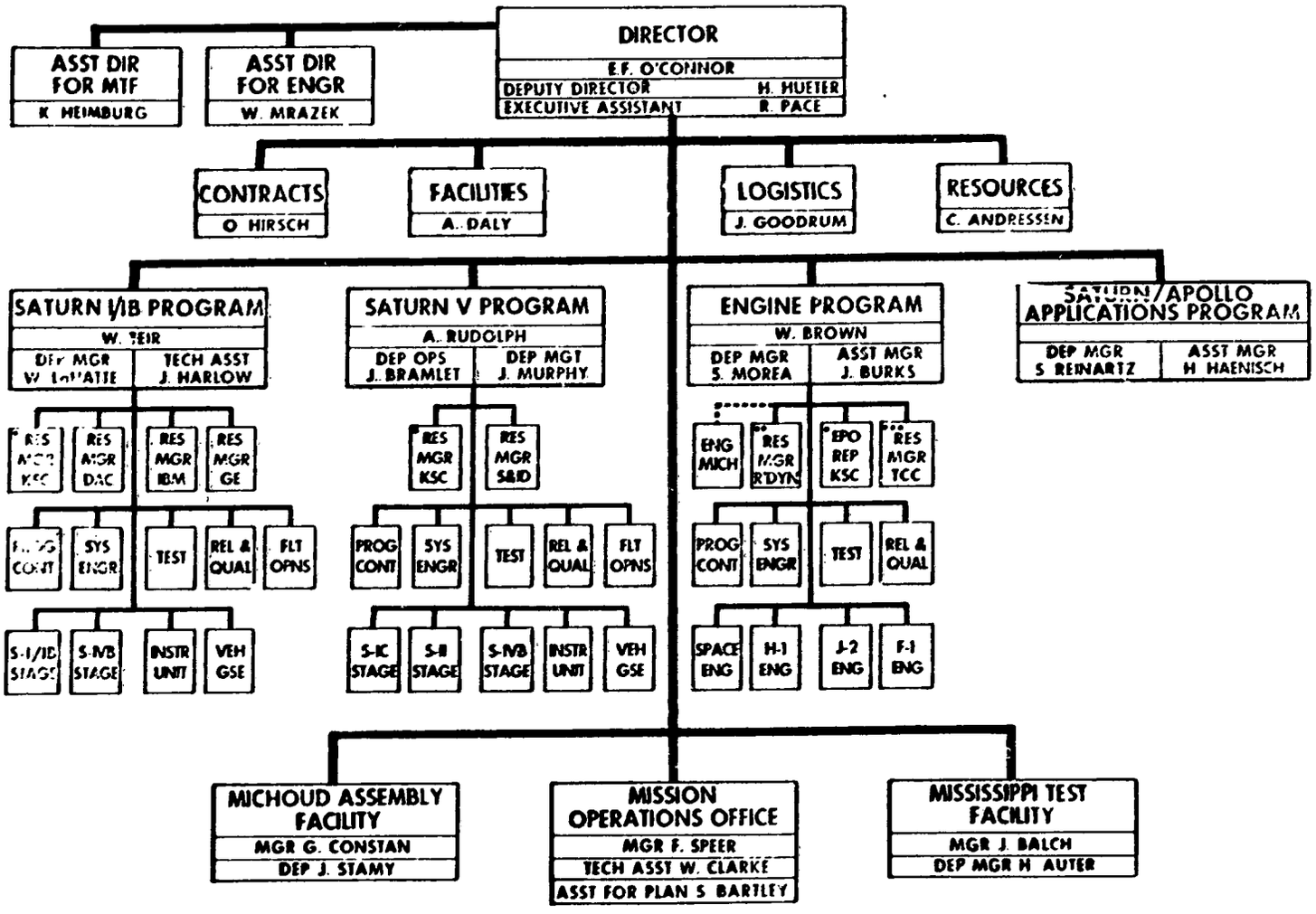
FUNCTIONS

Industrial Operations is assigned the overall responsibility for the conduct and management of the Saturn Launch Vehicle Systems Programs. In discharging these responsibilities, IO will perform the following functions:

1. Management of the Saturn Launch Vehicle Systems Programs including related GSE and MSFC assigned Saturn payloads. To take all actions necessary to ensure that the entire series of Saturn launch vehicle systems is successfully developed, produced, tested, delivered and launched to carry out the specified missions on the officially schedules dates and at the most reasonable cost to the Government within allotted funds. The term, "Saturn Launch Vehicle Systems" includes the complete launch vehicles (Saturn 1, IB and V), MSFC assigned payloads, related GSE and software and all support, handling, and logistics requirements.

2. Assure the technical adequacy of the overall launch vehicle system and the successful integration of vehicle stages, engines, GSE, associated equipment and MSFC assigned payloads.. Wherever possible, courses of action and final decision will be reached by mutual agreement between program and

GEORGE C. MARSHALL SPACE FLIGHT CENTER
INDUSTRIAL OPERATIONS



*ONE RESIDENT OFFICE; REPRESENTATION FROM SAT IB, SAT V AND ENGINE
**RESIDENT MANAGER OFFICES LOCATED AT CANOGA, NEOSHO AND EAFB
***THIOKOL CHEMICAL CORP., DENVILLE, N.J.

MSFC-67-IND E [illegible]

project managers and R&DO senior responsible personnel involved.
3. Be the final authority on all program matters assigned by the foregoing paragraphs, as well as for the launch vehicle and GSE configuration, related software, test programs, and quality and reliability programs. IO will ensure that all program participants conform to established systems specifications and program requirements.
4. Direct all Government contracting activities for launch vehicle stages, program-related facilities, program logistics and MSFC-assigned Saturn payloads, except for those sub-systems and other Saturn-related elements which are assigned to R&DO.
5. Manage the off-site field operations of MSFC, including the Mississippi Test Facility, Michoud Assembly Plant, and Resident Management Offices and attached elements.
6. Manage MSFC program logistics activities, including spare parts, propellants and pressurants, transportation, equipment and facilities, and field operations.
7. Direct a facilities program to provide and maintain facilities and equipment required for the Saturn program.

INDUSTRIAL OPERATIONS

RESPONSIBILITIES

1. Plans and manages the MSFC Industrial Operations complex, providing management skills in the areas of program and fund control, contract negotiation and administration, cost control, program logistics and facilities, utilizing these skills in the integration of the management and technical capabilities of the Government and Industry into a unified force for the accomplishment of program objectives.
2. Manages the assigned Saturn Launch Vehicle System and payload programs including: the development of plans; and the execution of programs through the successful design, development, production, ground test program, vehicle systems integration and launch site test operations of launch vehicles and payloads in the achievement of an effective balance between technical performance, schedule and cost.
3. Assures technical adequacy of the overall vehicle system and the successful integration of assigned vehicle stages, engines and associated equipment into integrated, functioning launch vehicles in readiness to meet NASA/MSFC Apollo objectives. Wherever possible, courses of action and final decision will be reached by mutual agreement between program and project managers and R&DO senior responsible personnel involved.
4. Assures that the capabilities of R&D Operations are fully utilized in systems engineering; engineering and technical support; development of systems and sub-systems, engineering studies and analysis, and supporting research for assigned programs.
5. Manages the field operations of MSFC, to include the organizing, directing, coordinating and controlling of Mississippi Test Operations, Michoud Operations, and Resident Management Offices and attached elements.
6. Manages the formulation and execution of a program for the development of systems, components, techniques and processes applicable to multi-stage launch and space vehicles as contracted by Industrial Operations with industry.
7. Directs the formulation, development and execution of Project Development Plans and associated requirements; assigning responsibility for the development of hardware relating to launch vehicle and payload programs; and reviewing such assignments to determine that planning and execution are within established program objectives and authorizations.

8. Within the Apollo Program Office and MSFC guidelines, prepares and justifies total program budgets, receives and allocates funds to contractors, to R&DO, and to other participating agencies in accordance with program requirements.
9. Established integrated program requirements and controls over assigned programs at industrial contractors and with Research and Development Operations which will provide continuously for the evaluation and review of assigned programs.

10. Ensures that project vehicles remain with MSFC approved configuration during the industrial process and that contractors conform to established and approved systems specifications and engineering requirements.
11. Ensures contractor compliance with NASA and Center policies, standards and practices in the area of quality and reliability assurance.
12. Directs activities in the solicitation, negotiation, pre-award award, execution, notification, administraton and progress assessment of MSFC Industrial Operations contracts.
13. Organizes, directs, coordinates and controls MSFC Saturn program logistics activities to include propellants and pressurants, equipment and facilities, transportation of program hardware, and field operations.
14. Directs the establishment and maintenance of an active facilities program to provide modernization and/or new facilities and equipment to support the assigned missions of Industrial Operations.
15. Interprets MSFC policy as it applies to program objectives and establishes Industrial Operations policies.

SATURN I/IB PROGRAM OFFICE
I.O., MSFC

FUNCTIONS

1. To plan and direct the execution of the Saturn I and IB Programs within established technical, schedule and resources limitations.
2. To manage the composite MSFC/industry performance through the phases of program planning, coordination, and contractor managerial and technical direction in the design, engineering, integration, development, control, production, testing, delivery and pre-launch checkout of the Saturn I and IB vehicle and associated equipment.
3. To assure the technical adequacy of the overall vehicle system and the successful integration of vehicle stages and associated equipment within the assigned mission objectives of the Saturn I and IB Programs.

SATURN I/IB PROGRAM OFFICE
I.O., MSFC

RESPONSIBILITIES

1. Directs preparation and obtains approval of Saturn I and Saturn IB Project Development Plans as a basis for operations.
2. In conjunction with the Center Director and Director, Industrial Operations, represents the Saturn I and Saturn IB Programs at the Management Council Programs at the Management Council Program Review.
3. Assures that the capabilities and resources of the Research and Development Operations are fully utilized in Systems Engineering, development of systems and sub-systems, engineering studies, and supporting research in support of the Saturn I/IB Program.
4. Directs the Saturn I and Saturn IB Programs. Establishes requirements for, and assures adequacy of the systems engineering and systems integration efforts of the Saturn I and Saturn IB Programs, including specifications and drawings, performance and weight, automation, networks ESE and MSE, RF communications and instrumentation, dynamics, controls, guidance, interfaces and configuration control.
5. Directs, through the Contracting Officer, the negotiation, administration and obtaining of required approval for Saturn I/IB Program contracts.
6. Reviews and approves design, production, qualification, and test programs; and ensures that supporting contractors meet requirements of established schedules.
7. Reviews and approves contractor plans, schedules, budgets for obtaining facilities and tooling, and contractor development plans and specifications.

8. Establishes program requirements, determines program priorities, and directs a system of program scheduling and status analysis; provides MSFC and NASA top management with periodic overall program status reports, including status of applicable MSFC schedules; ensures effective implementation of Center management control systems; and establishes information channels with counterparts in NASA Headquarters and other Centers.
9. Approves vehicle system oriented technical directives which in turn will be issued to systems prime contractors through the appropriate state manager.
10. Approves technical baselines and exercises control over the technical progress of MSFC elements in attaining vehicle system objectives. Provides the chairman for the Saturn I/IB (Level II) Configuration Control Board.

SATURN V PROGRAM OFFICE
I.O., MSFC

FUNCTIONS

1. To plan and direct the execution of the Saturn V Program within established technical, schedule and resources limitations.
2. To manage the composite MSFC/industry performance through the phases of program planning, coordination, and contractor managerial and technical direction in the design, engineering, integration, development, control, production, testing, delivery and pre-launch checkout of the Saturn V vehicle and associated equipment.
3. To assure the technical adequacy of the overall vehicle system and the successful integration of vehicle stages and associated equipment within the assigned mission objectives of the Saturn V Program.

SATURN V PROGRAM OFFICE
I.O., MSFC

RESPONSIBILITIES

1. Directs preparation and obtains Center and MSF approval of Saturn V Project Development Plans as a basis for operations.
2. In conjunction with the Center Director and Director, Industrial Operations, represents the Saturn V Program at the Management Council Program Review.
3. Assures that the capabilities and resources of the Research and Development Operations are fully utilized in Systems Engineering, development of systems and sub-systems, engineering studies, and supporting research in support of the Saturn V Program.
4. Directs the Saturn V Program. Establishes requirements for, and assures adequacy of the systems engineering and systems integration efforts of the Saturn V Program, including specifications and drawings, performance and weight, automation, networks, ESE and MSE, RF communications and instrumentation, dynamics, controls, guidance, interfaces, and configuration control.
5. Directs, through the Contracting Officer, the negotiation, administration and obtaining of required approval for Saturn V Program contracts.
6. Reviews and approves design, production, qualification, and test programs; and ensures that supporting contractors meet requirements of established schedules.
7. Reviews and approves contractor plans, schedules, budgets for obtaining facilities and tooling, and contractor development plans and specifications.
8. Establishes program requirements; determines program priorities and directs a system of program scheduling and status analysis; provides MSFC and NASA top management with periodic overall program status reports, including status of applicable MSFC schedules; ensures effective implementation of Center management control systems; and establishes information channels with counterparts in NASA Headquarters and other Centers.
9. Approves vehicle system oriented technical directives which in turn will be issued to systems prime contractors through the appropriate stage manager.

10. Approves technical baselines and exercises control over the technical progress of MSFC elements in attaining vehicle system objectives. Provides the chairman for the Saturn V (Level II) Configuration Control Board.
11. Isolates major technical problems requiring attention of MSFC top management or higher authority, and recommends solution.
12. Participates in the activities of MSFC Working Groups and Inter-Center panels, as such activities relate to the technical integrity and interface relationships of stage-to-stage, vehicle-to-spacecraft, vehicle-to-GSE and vehicle-to-launch complex.

ENGINE PROGRAM OFFICE
I.O., MSFC

FUNCTIONS

1. To plan and direct the execution of engine projects within established technical, schedule and resources limitations.
2. To manage the composite MSFC/industry performance through the phases of program planning, coordination, and contractor managerial and technical direction in the design, engineering, integration, development, control, production, checkout, testing, and delivery of assigned engine projects and associated equipment.
3. To assure the technical adequacy and the successful integration of assigned engine projects and associated equipment, within mission objectives of the Engine Program.

ENGINE PROGRAM OFFICE
I.O., MSFC

RESPONSIBILITIES

1. Directs the Engine Program; establishes requirements for, and assures adequacy of the systems engineering and systems integration efforts for Engine Projects to include specifications and drawings, performance and weight, dynamics, controls, interfaces, and configuration control.
2. In conjunction with the Center Director and Director, Industrial Operations, represents the Engine Program at the Management Council Program Review.
3. Directos preparation and obtains necessary approval of engine Project Development Plans as a basis for operations.
4. Directs the negotiation and administration, and obtains required approval of Industrial Operations contracts for the Engine Program.
5. Approves engine design, production, qualification, and test schedules, and ensures that supporting contractors meet requirements of established schedules.
6. Approves contractor plans, schedules, budgets for obtaining facilities and tooling, and contractor development plans and specifications.
7. Directs and coordinates a system of program scheduling and status analysis; provides MSFC and NASA top management with perodic overall program status reports, including status of applicable MSF schedules; and establishes information channels with counterparts in NASA Headquarters and other Centers.
8. Determines program requirements and priorities; ensures establishment of program operations requirements and effective management control systems; and governs the emphasis on contractors' work objectives.
9. Approves technical baselines and exercises control over the technical progress of MSFC elements in attaining Engine Program objectives. Appoints the chairmen for Engine Projects Level III Configuration Control Boards.
10. Isolates major technical problems requiring attention of MSFC top management or higher authority, and recommends solution.

11. Participates in the activities of Boards, Working Groups, Committees, and Panels necessary in the accomplishment of the Engine Program mission.
12. Establishes, staffs, and maintains resident management offices at the contractors' plants as approved by Industrial Operations.
13. Assures that the capabilities and resources of the Research and Development Operations are fully utilized in Systems Engineering, development of systems and sub-systems, engineering studies, and supporting research in support of the Engine Programs.

MICHOUD ASSEMBLY FACILITY
I.O., MSFC

FUNCTION

To manage the administrative and industrial activities of the government-owned, contractor-operated Michoud plant, including contracts, programs, documentation, facilities, finance, support and computation services, quality control, and on-site supervision of contractor launch vehicle development, design, manufacture, and assembly.

MISSISSIPPI TEST FACILITY
I.O., MSFC

FUNCTIONS

1. To manage the administrative, industrial, and development activities of the Government-owned, contractor-operated Mississippi Test Facility, including contracts, programs, finance, safety, quality engineering, and on-site supervision of stage and support contractor's performance of assigned developmental and acceptance testing, checkout, refurbishment, and service support programs.
2. To assure the flight worthy quality of launch vehicle stages prior to delivery for launch missions.
3. To represent NASA/MSFC in Mississippi in matters relating to state and local affairs.

MISSION OPERATIONS OFFICE
I.O., MSFC

FUNCTIONS

To plan, coordinate and direct from one single centralized point all activities involved with accomplishing MSFC's mission operations role pertaining to manned and unmanned launch vehicles during space flight missions, flight tests or similar operations.

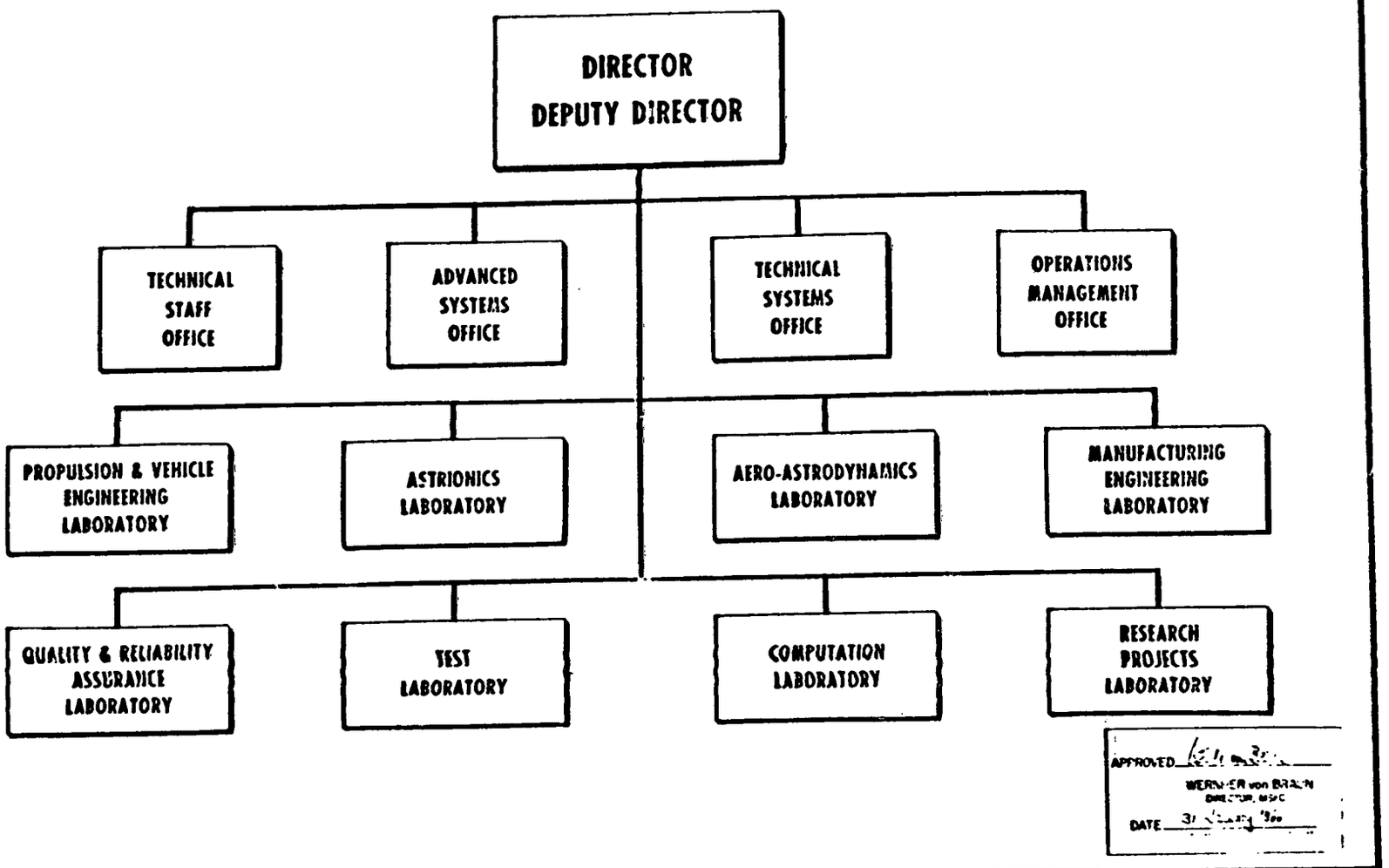
RESEARCH AND DEVELOPMENT OPERATIONS

FUNCTIONS

Responsibility for the establishment and management of the scientific and engineering capabilities of the MSFC Laboratories for the research and development of Launch Vehicle and Payload Systems, Supporting Research and Technology, and Advanced Studies rests with Research and Development Operations.

MARSHALL SPACE FLIGHT CENTER

RESEARCH AND DEVELOPMENT OPERATIONS



APPROVED _____
WERNHER von BRAUN
DIRECTOR, MSFC
DATE 31 January '64

RESEARCH AND DEVELOPMENT OPERATIONS

RESPONSIBILITIES

1. Performs research and development programs and projects within approved objectives, resources, and schedules; evaluates overall MSFC research and development objectives and recommends changes in program direction or solutions to major problem areas; develops R&D Operations requirements for inputs to overall MSFC budgets; develops annual plans for operations within authorized funds and manpower complement including supporting contractor participation.
2. Performs in support of Industrial Operations, a program of overall launch vehicle systems engineering associated with the overall integration of a system including MSFC assigned payloads, design compromise among sub-systems, definition of interfaces, analysis of sub-systems and supervision of systems testing, all to the extent required to assure that system concept and objectives are being met.
3. Manages a program which brings to bear the development capabilities of the laboratories (design; component, sub-system and whole system testing; fabrication, assembly and manufacturing engineering; quality and reliability assurance; static and dynamic analysis) to support Industrial Operations by providing the technical input with which Industrial Operations gives technical direction to its contractors.
4. Establishes a management system which will provide for a defined number of senior R&D Operations personnel and a limited number of specialists to continuously monitor their facets of the program to protect the technical adequacy of the launch vehicle system.
5. Directs and manages launch vehicle and engine projects activities for which Research and Development Operations has an assigned hardware responsibility or a developmental support commitment (quality assurance, system testing, etc.) in the Saturn I/IB, Saturn V and Engine Hardware programs.
6. Formulates and executes a program of research and development of components, systems, techniques and processes applicable to multistage launch and space vehicles. These efforts are directed toward development of back-up solutions, increases in reliability, performance and usefulness of the Saturn Launch vehicles, and in improved methods of analysis, manufacture, testing, etc.
7. Develops Center standards for quality assurance and provides technical support to the Industrial Operations to ensure contractor compliance with these standards.
8. Conducts scientific and engineering studies on Apollo follow-on programs, additional flight missions for existing Saturn Launch Vehicles, and additions and modifications to improve or extend the payload capabilities of existing Saturn Launch Vehicles.
9. Develops "Program Definition" systems specifications, engineering requirements and all technical plans for proposed projects and approved "new starts."
10. Prepares "program proposal packages" for submission to MSF Headquarters under cooperative arrangements developed with Industrial Operations.
11. Performs in-house studies and manages study contracts with industry to determine future space mission requirements and to develop launch and space vehicle concepts for fulfilling these requirements.
12. Formulates and manages a program of scientific research and advanced technology to advance the state-of-the-art in launch, space, and lunar surface vehicles and to maintain the MSFC technical proficiency in depth.
13. Establishes a system to continuously evaluate and improve the status of Research and Development Operations' manpower, technology base and facilities for fitness and compatibility with MSFC's immediate and long-range scientific/engineering objectives and goals.
14. Interprets MSFC policy as it applies to Research and Development objectives and establishes Research and Development Operations policies.
15. Ensures that the utilization of in-house support contractors is within the established MSFC policy.

APPENDIX E

NORTH AMERICAN AVIATION, INC

I. ORGANIZATION AND MANAGEMENT OF APOLLO CSM PROGRAM

A. CORPORATION

The Space and Information Systems Division (S&ID), which is responsible for the Apollo CSM and Saturn II Programs is one of seven NAA operating divisions supported by corporation adminstrative organizations. Each division is headed by a division president who is also a vice president of the corporation responsible to NAA President, J. L. Atwood. Mr. Atwood is also Chairman of the NAA's Board of Directors. The corporation establishes and administers the broad policies which constitute the framework within which each operating division functions. Chart "X" shows the NAA corporate organization.

B. S&ID

S&ID is headed by Division President, H. A. Storms. This division is responsible for the Apollo CSM and Saturn II Programs which are being carried out under separate program managers. The Apollo CSM Program is directed by Apollo CSM Program Manager and S&ID Vice President, H. A. Storms. Advanced Programs Development, and Research, Engineering and Test furnish special technical support as needed. Other S&ID functions provide administrative support.

The Apollo CSM Program Manager, D. D. Myers, is assisted by Deputy Program Manager, C. H. Feltz and four Assistant Program Managers. Directors of four functional areas report directly to the Program Manager. The Director of Quality and Reliability Assurance is responsible to thePro-Manager in technical matters although reporting administratively to the S&ID Director of Quality and Reliability Assurance. The Director of Apollo CSM Operations, Florida, J. L. Pearce, is responsible to the NAA General Manager of the Florida Facility, W. S. Ford. This organizational plan gives the Apollo CSM Program Manager direct control and responsibility over all phases of the Program including all subcontracting.

D. FLORIDA FACILITY

The Apollo CSM Florida Director, J. L. Pearce is supported by three managers, the Chief Project Engineer, R. W. Pyle, and the Technical Support Chief, R. E. Franzen. The three managers have separate areas of responsibility: Test Operations, J. M. Moore; Test Sites, R. E. Barton; and Quality and Reliabilty Assurance, J. L. Hansel. Very close liaison and control between Downey and Florida Apollo CSM operations is maintained.

II. PROGRAM HARDWARE RESPONSIBILITY

S&ID is responsible, with NASA concurrence, for the overall development, design, manufacture, and test of Apollo CSM hardware.

A. SPACECRAFT CONFIGURATION

S&ID is responsible for the command and service modules, the launch escape system, the spacecraft lunar module adapter, and most subsystems pertaining to these modules. S&ID is responsible for coordinating the physical and operating interfaces of these modules and systems with Associate Contractors and NASA.

B. GROUND SUPPORT EQUIPMENT (GSE)

NAA supplies GSE as directed by NASA to support Apollo CSM test and checkout operations at all test sites. This GSE consists of checkout equipment, auxiliary equipment, servicing, and handling equipment. NAA is responsible for the design, manufacture, and checkout of this GSE.

C. SUBSYSTEMS

The following Apollo CSM subsystems and modules are being produced inhouse at NAA:

SUBSYSTEM OR MODULE	DIVISION
Command and Service Modules (Complete)	S&ID
SLA (Complete)	S&ID
Launch Escape System Structure	Los Angeles Division
Sequencer System	Autonetics
Command Module Reaction Control System	Rocketdyne

Units that are made at other NAA divisions are designed, manufactured, and tested under S%ID supervision and control.

D. SUBCONTRACTORS

Major and minor subcontractors are selected with NASA concurrence by S%ID, and are under S%ID surveillance. The subsystems they fabricate are designed, manufactured, and tested under S%ID supervision and control.

E. SUPPLIERS

S%ID buys hardware for the Apollo CSM Program directly from over 12,000 first tier suppliers of which 9,600 represent small business; and the remainder, large business. All such hardware must be bought from S%ID approved sources and the hardware must be certified and tested as required to meet applicable specifications. Suppliers of these first tier suppliers represent many thousands of additional firms.

III. PROGRAM CONTROL PROCEDURES

A. The baseline for NASA and NAA management of the program is contained in the contract. The particular control baselines are the technical, master end item and specific end item specifications, the contract plans, and contract change notices which become incorporated into the baselines by specification and supplemental agreements. The controlling plans are the Manufacturing Plan, the Quality Control Plan, the Configuration Management Plan, the Ground Operations Requirement Plan and the Reliability Plan.

B. Control Tools-Cost, Schedule and Quality. Program control procedures are implemented only after formal Joint NASA/NAA interface agreements. These interfaces consist of contractual, technical and schedule meetings and documentation. Contractual direction is given by NASA to NAA through (bilateral) Supplemental Agreements and Contract Specification Change Notices and through (unilateral, by NASA) Contract Change Authorizations, Technical direction is given by NASA through Program Management Meetings, letters and wires to the NAA contracting officer and in formal reviews and Interface Control Documents. Formal joint reviews are Preliminary and Critical Design Reviews (PDR's and CDR's), First Article Configuration Inspection (FACI), Customer Acceptance Readiness Reviews (CARR) and Flight Readiness Reviews (FRR).

Through the S%ID Apollo CSM Program Manager's Office, control is exercised over CSM program costs, schedule and quality. The control media include the following.

1. COST CONTROL is provided primarily through Joint NASA/NAA negotiated and approved "work packages" with individula work package managers assigned to control costs, schedule achievements and quality. The choice of work package breakdown structure has enabled individual cost control of functional elements within S%ID as well as major subcontractors which supply CSM subsystems. NASA, NAA division and corporate policies assure proper make or buy decisions, subcontractor bid selection and the like.

2. SCHEDULE CONTROL is provided by use of a "Master Development Schedule," a formal schedule change system, a PERT reporting system of scheduled milestones and formal critical problem reports. Major schedule changes receive concurrence of the NASA Program Manager prior to NAA implementation. The selection of schedule milestones, monitored by PERT are also identified in the cost control work packages, yielding an integrated cost/schedule measuring device.

3. CONTROL OF QUALITY is provided by (a) jointly approved hardware qualification test-selection, criteria, test surveillance and test report approval, (b) Joint NASA/NAA mandatory inspection point assignments and surveillance, and (c) step/by/step inspections (NASA/NAA) through manufacture, checkout and pre-launch operations. A failure reporting system assures follow-up on potentially discrepant hardware. Control of subcontractor quality is provided in a similar fashion.

C. MANAGEMENT CONTROL DOCUMENTS-Management control documents for Apollo CSM hardware exist at both the program level and at the first-line level of NAA S%ID management. The

top documents serve to record design and product certification and flight readiness. These are the jointly approved minutes of PDR, CDR, FACI, CARR, Design Certification Review (DCR) and FRR.

The first-line level management control documents are:

1. DESIGN - Master Change Records (MCR), drawings, process specification interface control documents and measurement lists.
2. MANUFACTURING - Fabrication and inspection record tickets, planning tickets, tool orders and parts replacement requests.
3. MATERIAL (PURCHASING) - Purchase order, purchase order change notice and specification control documents.
4. TEST AND OPERATIONS - Operational test plan, operational checkout procedure, not satisfactory report, test preparation sheet, development test procedure.
5. QUALITY AND RELIABILITY ASSURANCE- Inspection test instructions, material review disposition and quality control specifications.

D. CONFIGURATION MANAGEMENT - Configuration Management is practiced through compliance with the NASA Apollo ConfigurationManagement Manual and NAA Division Policies as implemented by the Apollo CSM Change Control Board, chaired by the Assistant Program Manager. Configuration changes with major program impact are resolved at Joint Change Control Board meetings between the NASA and S%ID Program Managers.

Changes imposed on program baseline originate from both NASA and NAA. NASA directed changes are processed by Contracts through the Change Control Board for preparation of proposals. In-house changes are processed by the Apollo CSM chief project engineer also through the Board for evaluation and direction. Change control documentation is in the form of a Master Change Record (MCR) which defines the change and is the basis of an order to the functional departments to provide cost and schedule information for necessary evaluation, prior to final implementation. The MCR can be used, as above, to determine details of a change prior to implementation; however for urgent changes the purpose of the MCR is to initiate action, which is accomplished upon MCR approval by Program Management for "Release to Production".

Configuration records are maintained in records of released engineering drawings and specifications. These records provide indentured drawing lists, parts lists and alpha-numeric parts or drawing lists. The manufacturing planning system assures drawings and engineering order (E.O.) compliance utilizing Fabrication and Inspection Records (FAIR) and a Change Verification Record (CVR) for each end item. The FAIR provides both fabrication instructions and inspection verification; the CVR provides E.O. records and verification of compliance.

During Downey, Houston and Florida Testing, a Test and Inspection Record (TAIR) system provides identical configuration and inspection information.

E. Subcontractor control baseline consist of (a) approved design specifications, drawings, components, qualification test plans and reports, acceptance test plans, critical process specifications, and component failure histories. A FACI is conducted for complex (major) procurements by S%ID with a NASA audit. Other procurements are subjected to FACI at NAA, utilizing subcontractor data. All baselines are re-verified to NASA at the SC 101 (Block II lunar capable vehicle) FACI.

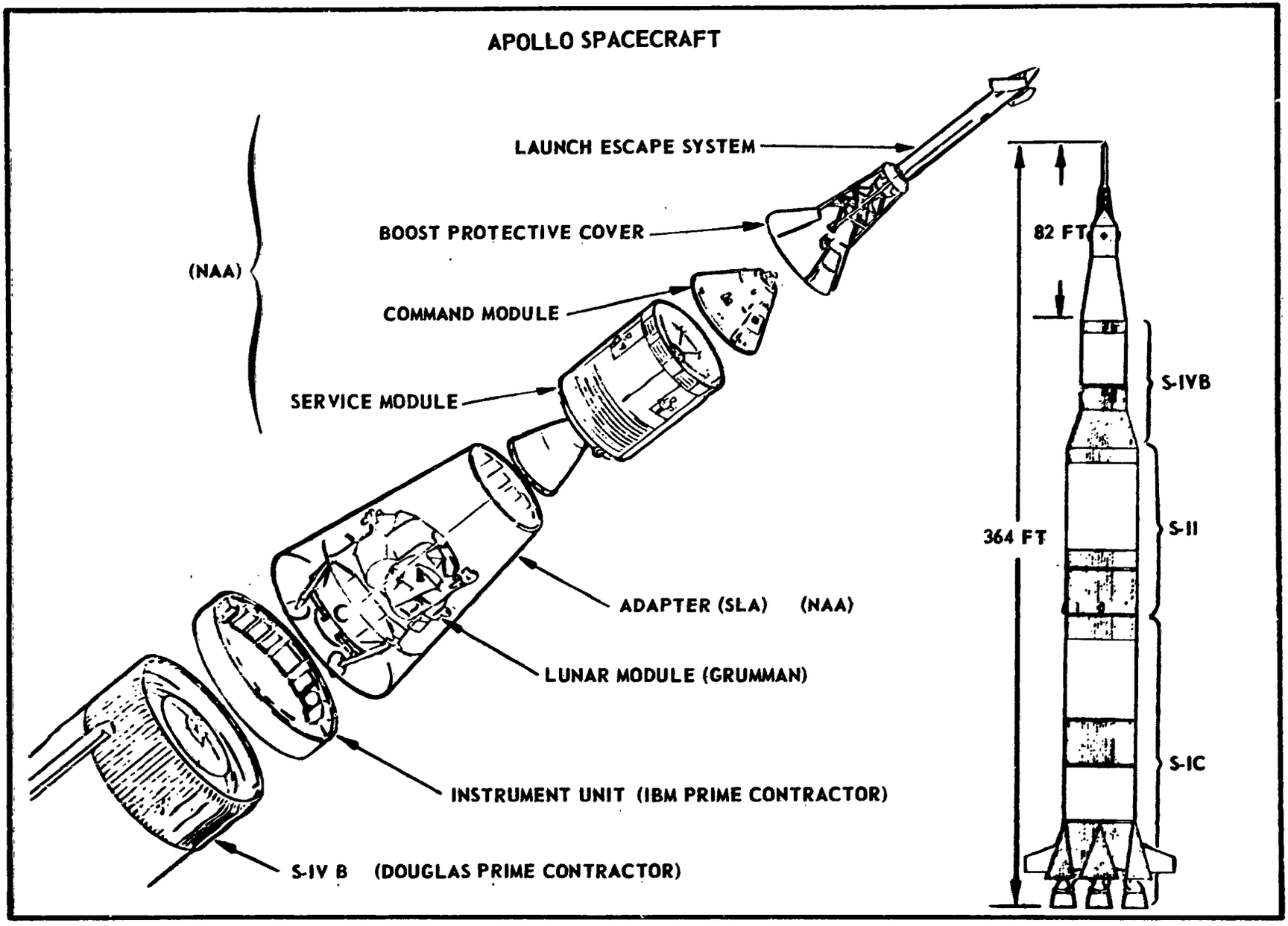
Conformance of the subcontractors is controlled by "freezing" component changes at FACI, strict part number control, identification and reidentification, source or receiving inspection to formally approved drawings and baselines and component reapir or overhaul, controlled to the configuration specified in the approved baseline.

Changes are justifiable only for NASA or NAA requirements modiciations; failure in qualification, during production or in operational tests; or for significant cost reduction. Change controls parallel the NASA-S%ID change control procedures. This method of subcontractor control is in effect at such major subcontractors as Honeywell, AiResearch, Beech and Pratt % Whitney.

F. Field Site Control - Apollo CSM Program Field Site efforts with activities at Florida, MSC-Houston, White Sands, New Mexico and El Centro, California, are managed as are similar efforts in Downey. The management differences are caused by the fact that hardware at field sites has usually been transferred to NASA-owned, and also is governed by NASA field site management procedures, rather than NAA or NASA-MSC.

Hardware flow through the field site is controlled by the Ground Operations Requirement Plan (GORP) contractual document, as modified by operational changes and deviations approved by the NASA-KSC or other field site change board.

Hardware changes evolving from NASA and NAA sources, identified previously, are processed through the Downey system for incorporation in a similar manner to other changes.


APOLLO SPACECRAFT
LAUNCH ESCAPE SYSTEM
BOOST PROTECTIVE COVER
(NAA)
COMMAND MODULE
SERVICE MODULE
ADAPTER (SLA) (NAA)
LUNAR MODULE (GRUMMAN)
INSTRUMENT UNIT (IBM PRIME CONTRACTOR)
S-IV B (DOUGLAS PRIME CONTRACTOR)
82 FT
364 FT
S-IVB
S-II
S-IC

APPENDIX E

MSC-KSC INTERFACE DOCUMENTATION

MSC-KSC RELATIONSHIPS

The following series of documents establishes the working relationships between the MSC Apollo organization, and its counterpart at the Kennedy Space Center. Indluded in the documents are the delegations of authority from the Apollo Spacecraft Program Office to the KSC Director of Plans, Programs & Resources. Due to subsequent reorganizations, the names of the organizational elements have been changed during the formulation of the MSC-KSC interface, though it is believed that the same individuals are essentially involved in the intra-center working relationships.

APOLLO SPACECRAFT MANAGEMENT GUIDE

CHAPTER: 35

EFFECTIVE DATE: April 1, 1966

SUBJECT:
KSC-MSC Relationships at the Cape

A. The overall policy and relationships which exist between MSC and KSC for those spacecraft activities occuring at the Cape are defined in the agreement on KSC-MSC Cape Relationships, signed by the Director, Manned Spacecraft Center, and the Director, John F. Kennedy Space Center, dated December 12, 1964.

B. Additional definitization of relationships between ASPO and KSC is contained in the following documents, which are incorporated in this chapter.

1. MSC datafax to KSC, dated September 23, 1965, subject: Proposed Apollo Spacecraft Program Office KSC Operations Management Plan.
2. Message from KSC, dated October 5, 1965, subject as above.
3. TWX to KSC from Manager, ASPO, dated October 12, 1965.
4. Memorandum from Manager, ASPO, subject: Apollo Spacecraft Program Office Operation Plan at KSC, dated October 18, 1965.
5. Memorandum from ASPO, Program Control Division to PPR1, Mr. G. McCoy, subject: "Change of Management Interface", dated March 15, 1966.
6. Memorandum from KSC/PPR, subject: "Apollo Program Directive No. 14", dated February 4, 1966.
7. Memorandum from Program Manager, subject: "Apollo Spacecraft Program Office and Kennedy Space Center Management Interface", dated March 23, 1966.

C. An on-site engineering evaluation group from NAA has been physically relocated to KSC to provide a closer cognizance of the spacecraft subsystems performance during checkout tests. Specific duties of this team and of the ATO data support personnel, and the detailed KSC operational information are included in the memorandum from PM/Chief, Checkout and Test Division, dtd. Feb. 3, 1966, which is included in this chapter.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

KSC-MSC CAPE RELATIONSHIPS

This paper establishes the overall policy and relationship which shall exist between MSC and KSC for those spacecraft activities occurring at the Cape. The following relationship shall exist:

1. MSC shall be responsible for the determination and control of the configuration of the spacecraft and all spacecraft contractor-supplied GSE, including ACE. MSC shall be responsible for approval of all changes in configuration.

2. MSC shall establish overall checkout standards and plans. These standards and plans shall set the broad parameters for checkout and inspection for all spacecraft checkout and inspection for all spacecraft checkout form the factory through Cape checkout. MSC shall establish detailed factory checkout procedures; KSC shall review and advise MSC on these procedures. KSC shall develop Cape checkout plans for review and approval by MSC as a part of the overall spacecraft checkout plan; KSC shall develop detailed checkout procedures shall be adopted which are not concurred in by MSC.

3. MSC shall conduct technical reviews, inspection, and checkout acceptance activities at the spacecraft contractors' plants; KSC shall provide checkout personnel to serve as observers and advisors; KSC shall conduct detailed Cape checkout of spacecraft, securing MSC approval of necessary performance and checkout procedure waivers or inspection deviations; KSC shall conduct the actual countdown and launch activities. This includes direction of those MSC spacecraft contractor personnel engaged in preflight checkout activities at the Cape.

4. MSC shall provide to KSC performance data, systems or subsystems specifications, or test results which are needed or requested by KSC.

5. MSC shall provide data requirements for format and or reduction requirements for pre-mission, real-time mission, real-time mission support, or post-mission evaluation.

6. MSC shall determine the disposition and place of failure analysis of all failed components after removal from the spacecraft; KSC shall conduct failure analyses as requested by MSC and make recommendations for corrective action as applicable.

These aranagements relate to all KSC-MSC relationships for activities conducted at MILAand the ETR.

7. MSC shall retain responsibility for all astronout activities; KSC shall provide necessary housing and logistical support as required.

8. MSC shall prepare all on-board experiments which are intimately associated with the astronaut; KSC shall prepare those experiments intimately associated with the spacecraft.

9. KSC shall participate as a Board Member of the Acceptance Review Board in conducting formal pre-delivery reviews of spacecraft at the contractors' plants and on the MSC Spacecraft Readiness Review Board; MSC shall participate as a Board Member in launch readiness reviews and shall participate in preflight and post-launch debriefings of launch crews conducted by KSC. MSC shall conduct necessary post-mission tests of spacecraft.

10. MSC shall establish minimum readiness specifications or lift-off rules for spacecraft systems; KSC shall conduct necessary integrated space vehicle checkouts.

11. KSC shall provide MSC such administrative and housekeeping support for personnel assigned to the MSC Resident Offices as may be necessary.

12. KSC shall serve as the agent of MSC in conducting Gemini spacecraft checkout, inspection, and testing at the Cape. This function shall be delegated to the Deputy Director for Launch Operations, KSC, who shall be directly responsible to MSC for these activities. The Directors, KSC and MSC, shall periodically discuss any problems which may arise relating to staffing levels assigned to the Gemini Program. (This arrangement shall be reviewed prior to GT-6).

13. KSC shall make the KSC Deputy Director for Launch Operations available to function as the agent for MSC in providing local direction (at the Cape) to the Air Force 6555th Test Wing in its preparation, checkout, and launch of the Gemini launch vehicle and the Atlas-Agena target vehicle.

(ORIGINAL SIGNED BY ROBERT R. GILRUTH)
Robert R. Gilruth, Director
Manned Spacecraft Center
December 21, 1964
Date

(ORIGINAL SIGNED BY KURT H. DEBUS)
Kurt H. Debus, Director
John F. Kennedy Space Center
December 21, 1964
Date

PROPOSED
APOLLO SPACECRAFT PROGRAM OFFICE
KSC OPERATIONS MANAGEMENT PLAN

1. General:

The KSC-MSC relationship signed by Dr. K. Debus and Dr. R. Gilruth on December 21, 1964, assigns certain responsibilities to MSC for the Apollo Spacecraft operations at KSC. It is the purpose of this plan to delegate a limited number of these responsibilities to KSC for execution and to delineate other of these responsibilities that KSC shall refer to MSC-ASPO for action.

2. Responsibilities delecated to KSC, plans, programs and resources office:

A. Provide the interface with the MSC Apollo spacecraft program office manager for activities at KSC involving support of the Apollo spacecraft program.

B. Accomplish technical management of ASPO contractor(s) at KSC within the scope of defined con-contractor tasks and coordinate with the app Apollo spacecraft tasks.

C. Provide appropriate ASPO contractor performance reviews to MSC.

C. Provide appropriate ASPO contractor performance reviews to MSC.

D. Be responsible for the configuration management of the Apollo Spacecraft, GSE, and ACE AT KSC in accordance with the specifications furnished with the delivery of the equipment and MSC Apollo CCP or CCB Directives. Changes in this established configuration initiated at KSC, including compatibility or make work, shall be referred to this chairman of the cognizant MSC MSC Spacecraft Configuration Control Panel for approval action. Action on these configuration changes shall be handled in the most expeditious manner, TWX or telephone. The cognizant contractor shall be responsible for documenting all changes in accordance with the Apollo Spacecraft Program Office "Apollo Configuration Management Manual, MSC Suppliment no. 1 (to NPC-500-1), Exhibit IX".

E. Provide to MSC-ASPO daily status reports on Apollo Spacecraft work, including overall schedule performance compliance, EO's worked and other pertinent program information.

F. KSC shall provide facilities and general service for the MSC personnel such as project and systems engineers, GSE, site activation, quality, checkout, and subsystem managers assigned by ASPO

S

E. Provide to MSC-ASPO daily status reports on Apollo Spacecraft work, including overall schedule performance compliance, EO's worked, and other pertinent program information.

F. KSC shall provide facilities and general service for the MSC personnel, such as project and Systems Engineers, GSE, site activation, quality, checkout, and subsystem managers assigned by ASPO th specific hardware or functions that are being handled by KSC for MSC. KSC shall provide internal working interface arrangements for these individuals in support of the accomplishment of the tasks.

3. A more detailed level or assigned responsibility is contained in the following list. The notation "KSC" indicates those activities in which responsibility for primary accomplishment is delegated to KSC, plans, programs, and resources; the notation "MSC" indicates that primary responsibility is to remain with MSC (ASPO); and the notation KSC, KSC refers to those accomplishments in which reciprocal activities are required.)

DETAILED MSC-KSC INTERFACE ACTIVITIES FOR APOLLO SPACECRAFT ACTIVITIES AT KSC

KSC	1. Change coordination A. SC configuration B. GSE configuration C. ACE configuration
MSC	2. GORP
MSC	3. Failure analysis designation (SC, GSE, and ACE) - PE
KSC/MSC	4. OCP Review (field to factory and reverse)
KSC/MSC	5. Checkout results documentation
MSC	6. Supporting test results to KSC
KSC/MSC	7. Calibration coordination (MSC requirements)
KSC	8. Launch support requirement generation
KSC	9. ACE program material elaborate ref.
KSC	10. Site Activation - Board Chairman (Dir. contractor) ORD's SAND's
MSC	11. Subsystem manager coordination - PE
MSC	12. ALOC representation for countdown - PE
KSC	13. ICD and IRN review for adequacy and coordination with co-chairman
MSC	14. Approve deviations to subsystem performance requirements and resolution of anamolies granted by KSC
KSC	15. ASPO Contractor and NASA Visitor Control
KSC	16. Logistic, travel, meeting arrangements with KSC for MSC (Apollo)
KSC	17. Provide SC, GSE, and ACE failure and anomoly data that is timely and compatible with ASPO system

UNITED STATES GOVERNMENT

Memorandum

TO: MANNED SPACECRAFT CENTER
MANAGER, APOLLO SPACECRAFT PROGRAM OFFICE, PA

DATE:

FROM: DIRECTOR, PLANS, PROGRAMS & RESOURCES, PPR
MANNED SPACECRAFT OFFICE, PPR-1

MSC NO. 19
RECEIVED: OCT 5 – 4:59 PM 1965
NASA COMMUNICATIONS CENTER

SUBJECT:

1. YOUR PROPOSAL THAT KSC, PLANS, PROGRAMS, & RESOURCES PERFORM THE FUNCTIONS OUTLINED IN YOUR DATAFAX DATED SEPTEMBER 23, 1965, IS ACCEPTED.

2. OUR BASIC COMMENTS ON THE DATAFAX ARE AS FOLLOWS:

   (a) IT IS ASSUMED THAT THE ACTIVITIES, ENUMERATED IN PARAGRAPH "F" WILL BE CARRIED OUT IN KEEPING WITH THE INTENT OF PARAGRAPH A AND B.

   (b) IT IS UNDERSTOOD FROM MY RECENT TELEPHONE CONVERSATION WITH YOU THAT A KSC CCP WILL BE ESTABLISHED IN ACCORDANCE WITH THE APOLLO SPACECRAFT PROGRAM CONFIGURATION MANAGEMENT PLAN. IT IS UNDERSTOOD THAT THE SCOPE OF KSC DELEGATED CHANGE AUTHORITY WILL BE LIMITED TO COMPATIBILITY OR MAKE IT WORK CHANGES.

   (c) PARAGRAPH 3 OF THE PROPOSAL IS A GENERAL GUIDELINE WHICH WILL REQUIRE AMPLIFICATION AND SOME DETAILED MODIFICATION AS THIS PLAN DEVELOPS.

3. IN ORDER TO CARRY OUT THE ABOVE, IT IS REQUESTED THAT ASPO TAKE ACTION TO:

   (a) FORMALLY DELEGATE OVERALL DIRECTION OF SPACECRAFT CONTRACTORS ACTIVITIES (NAA, GAEC, GE/ACE, AND MIT) AT KSC TO THE KSC, PLANS, PROGRAMS, AND RESOURCES OFFICE.

   (b) TRANSFER THE PERSONNEL AND POSITIONS PRESENTLY ASSIGNED TO THE LOCAL MSC OFFICE TO KSC.

s/t ROCCO A. PETRONE

cc:
W. BLAND, PH

In accordance with Configuration Management Plan

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : DIRECTOR, PLANS, PROGRAMS & RESOURCES, PPR
MANNED SPACECRAFT OFFICE, KSC

DATE:

FROM : MANAGER, APOLLO SPACECRAFT PROGRAM OFFICE, PA
MANNED SPACEGRAFT CENTER

SUBJECT:

THE APOLLO SPACECRAFT PROGRAM OFFICE – KSC OPERATION MANAGEMENT PLAN PROPOSED BY THIS OFFICE ON SEPTEMBER 23, 1965, AND ACCEPTED BY YOU ON OCTOBER 5, 1965, IS THEREFORE CONSIDERED IMPLEMENTED AS OF OCTOBER 12, 1965. I AM NOW TAKING ACTION TO PRONOUNCIATE THIS PLAN BY:.

(1) ANNOUNCING TO THE ASPO CONTRACTORS A DELEGATION OF AUTHORITY TO YOU TO DIRECT CONTRACTOR WORK AT KSC.

(2) TRANSFER THE PERSONNEL ASSIGNED TO THE FIELD TEST OFFICE TO KSC.

(3) ESTABLISH AN ASPO CONFIGURATION CONTROL PANEL AT KSC WITH YOU APPOINTED AS CHAIRMAN WITH POWER OF DELEGATION.

THE FOLLOWING IS IN REFERENCE TO YOUR COMMENTS ON THE AGREEMENT:

(a) THE ACTIVITY IN PARAGRAPH "f" WILL BE IN KEEPING WITH THE INTENT OF PARAGRAPHS "a" AND "b".

(b) THE AUTHORITY OF THE SPACECRAFT CCP AT KSC WILL BE LIMITED TO COMPATIBILITY AND MAKE WORK CHANGES. THE SCOPE WILL BE AS SHOWN IN THE ENCLOSURES.

(c) I AGREE, THE GENERAL GUIDELINES OF PARAGRAPH 3 WILL REQUIRE FURTHER DEVELOPMENT. IT IS FELT THAT THIS WILL BE DONE AS NECESSARY DURING THE ACCOMPLISHMENT OF THE INTERFACE TASKS LISTED. AS WE PROGRESS, MODIFICATION AND ADDITIONS WILL BE MADE TO THIS LIST.

SINCE THIS AGREEMENT IS WITHIN THE SCOPE OF THE KSC-MSC RELATIONSHIP SIGNED BY DR. K. DEBUS AND DR. R. GILRUTH OF DECEMBER 21, 1965, ITEMS NOT SPECIFICALLY COVERED SHALL BE IN ACCORDANCE WITH THE BASIC DOCUMENT.

FURTHER ADJUSTMENTS NOT PREVIOUSLY MENTIONED WILL BE WITHDRAWING OF MSC PROJECT ENGINEERING SUPPORT FOR THE FACILITY VERIFICATION VEHICLE AT KSC AND THE ASSUMPTION OF THE GSE-GE SUPPORT AT KSC BY KSC, BEFORE OCTOBER 15, AND NOVEMBER 1, 1965, RESPECTIVELY, UNLESS YOU ASK FOR FURTHER CONSIDERATION.

ENCLOSURES

/s JOSEPH F. SHEA

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10/12/65

APOLLO SPACECRAFT CONFIGURATION CONTROL PANEL AT KSC

The configuration control procedure outlined in the "Apollo Spacecraft Program Office Configuration Management Plan," March 1965, has been adopted by ASPO and is being followed to process all engineering changes to Apollo Spacecraft hardware. As stated in this plan, the Configuration Control Board consists of the "Board" (CCB), and several panels (CCP's). These panels (CCP's) are an integral part of the CCB and function under the jurisdiction of, and with delegated authorities from, the Chairman of the CCB.

Director Plans Program and Resources, KSC, will establish and chair an Apollo Spacecraft CCP at KSC to consider and process engineering changes to Apollo Spacecraft and associated hardware undergoing checkout and test at KSC. The ASPO Configuration Management Plan is being revised to reflect this action. The authority of this CCP shall be restricted to the review of end item hardware (including GSE) and software configuration changes to determine if the change is mandatory in conduct of tests at KSC, and the approval of the contractor's plan for making the mandatory change to specific Apollo hardware end items at KSC. Where the spacecraft cannot be restored to its original configuration once a change has been incorporated, approval of the change shall be concurred in by the KSC assigned Project Engineer. Changes that cannot be removed without major schedule purturbation (24 hours) shall also be referenced to the MSC-PE. All mandatory changes are by definition either "compatibility" or "make work" changes. Compatibility changes are those required to correct a design deficiency that is directly attributable to the con-

tractor. Make work changes are those required to correct deficiencies for which the contractor did not have design responsibility. Concurrent with the implementation of mandatory changes to the spacecraft or associated hardware, the appropriate contractor will prepare an Engineering Change Proposal (ECP) covering the change and submit it to ASPO-MSC for processing in accordance with the procedure outlined in the ASPO Configuration Management Plan. Review and approval of the ECP by the ASPO CCB will cover the requirement for the inclusion of the change in other end items and will insure documentation of the test site change.

The operating procedures for processing changes through the Apollo Spacecraft CCP at KSC should be coordinated with the Secretary of the ASPO CCB, Mr. A.L. Brady. These procedures should show how Type A TPS's, EO's, etc., are generated, signed off and processed.

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: Oct 18, 1965
In reply refer to;
PH12:JJS:ibr

FROM : PA/Manager, Apollo Spacecraft Program Office

SUBJECT: Apollo Spacecraft Program Office
Operation Plan at KSC

An operation management plan has been developed within the scope of the KSC-MSC Relationships agreement of December, 1964, whereby the Director of Plans, Programs, and Resources Office at Kennedy Space Center is delegated the authority to fulfill limited MSC ASPO responsibilities at the KSC. The present ASPO test office at KSC has been transferred to KSC to assist in the accomplishment of these tasks.

A general summary of the functions that will be performed for ASPO are:

(a) Provide the interface with KSC for the MSC ASPO
(b) Accomplish technical management of ASPO Contractors at KSC
(c) Establish an ASPO Configuration Control Panel at KSC

Operational details of the plan are being developed as necessary. Information concerning your area of assigned responsibility may be obtained from the Staff Office of the Checkout and Test Division, extension 5221.

/s/ Joseph F. Shea

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO:

PP

TO: PPRL/Mr. E. McCoy
Chief, Manned Spacecraft Office

FROM: PP/Chief, Program Control Division
Apollo Spacecraft Program Office

SUBJECT: Change of Management Interface

You are no doubt aware of the recent re-orientation of the MSC Apollo Spacecraft Program Office, but perhaps not fully aware of the minor change this creates in the existing working interfaces.

Effective March 10, 1966, the ASPO Program Control Division, specifically Gordon J. Stoops, was named as the individual responsible for the management interface with your office. The interface for the solution of technical problems is the LEM and CSM Project Engineering and Checkout Division; Owen Morris and R. Lanzkron Division Chiefs, respectively.

We are looking forward to continuing our relationship with the same success as enjoyed prior to the re-orientation of our organization.

J. Thomas Markley

cc:
PA/W. L e
PA/J. Kotanchik
PD/Chief
PE/Chief
PF/Chief
PM/Chief
PR/Chief

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO:

PPR-36

Feb 4, 1966

TO: Manned Spacecraft Center
Apollo - Office of Program Manager
Attention: Dr. Joseph Shea, PA

FROM: Director, Plans, Programs and Resources, PPR

SUBJECT: Apollo Program Directive No. 14

To facilitate compliance with the subject Directive and in accordance with the MSC ASPO-KSC Operation Management Plan implemented October 12, 1965, Mr. H.E. McCoy, Chief, Manned Spacecraft Office, PPR-1, is designated as the prime KSC contact. All requests for delivery of MSC equipments to KSC with "open" work will be concurred in by Mr. McCoy or his designated representative prior to shipment to KSC.

To avoid unnecessary delays in coordination, it is suggested that the KSC Manned Spacecraft Office, PPR-1, be advised of possible problems two (2) weeks prior to scheduled shipment. It is also recommended that representatives of the KSC Manned Spacecraft Office, PPR-1, attend MSC/Contractor Configuration reviews when it is known or expected that equipment will not be in the design configuration when shipped to KSC. Upon determination that equipment will require "open" work to be accomplished at KSC, MSC/Contractors shall immediately provide KSC with a detailed "open" work status. The status shall define the work required and the scheduled MSC/Contractor dates for providing KSC with the equipment/engineering necessary to close the work. This information shall be documented on the "Material Inspection and Receiving Report", Form DD-250 (or MSC equivalent).

s/ Rocco A. Petrone

OPTIONAL FORM NO. 1
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : See Distribution DATE:

FROM : PA/Manager, Apollo Spacecraft Program Office

SUBJECT: Apollo Spacecraft Program Office and Kennedy Space Center Management Interface

Effective immediately the following management interfaces are established to minimize Apollo direction channels to KSC:

R.W. Lanzkron - Chief, CSM Project Engineering and Checkout Division
O.G. Morris - Chief, LEM Project Engineering and Checkout Division
J.T. Markley - Chief, Program Control Division
A. Cohen - Chief, Systems Integration Branch, Systems Engineering Division

All correspondence of non-policy nature directed to KSC shall be submitted to one of the above for signature. Dr. Lanzkron will sign all technical correspondence specifically pertaining to the CSM, CSM site activation, and CSM checkout. Mr. Morris has the same signature authority for LEM. Mr. Cohen is responsible for establishing and approving all changes to all Interface Control Documents (ICD's) with KSC and will sign all correspondence relating to ICD's. All other correspondence whose subject is not specifically CSM, LEM, or ICD oriented will be submitted to the Program Control Division for signature.

The establishment of this interface and the attendant signature authority does not alter the existing functions and authorities of the Launch Operations Panel.

/s/ Joseph F. Shea

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Distribution

Feb 3, 1966
In reply refer to:
PN/N-98-66

PN/Chief, Checkout and Test Division

Apollo Spacecraft Checkout at KSC

During the Flight Readiness Review for S/C 009, it became apparent that a closer cognizance of the spacecraft subsystems performance during the check-out tests was needed. To implement this need the North American Aviation Apollo Test Operations have instituted an onsite engineering evaluation group. This group consisting of eight engineers from Downey who have been physically relocated to KSC to participate in the checkout with the operational personnel of both NAA F/F and KSC.

Provisions have been made for MSC subsystem managers or their representatives to participate at KSC with the NAA engineering evaluation group. Contact should be made with A.E. Morse, PPR-12, KSC, who will establish the operational interface with NAA through Stan Taylor, NAA-F/F. An orientation will describe the facilities, procedures, and information available for the visiting personnel.

Following the briefing, personnel will participate in a pre OCP Review (including Post Test Data Requirements), the OCP itself, and the OCP Results Review.

To provide the necessary visibility for effective interfacing with the current NAA/KSC analysis effort, detailed KSC operational information is presented. (Attachment 1.)

Specific duties of the NAA analysis team as well as those of ATO data support personnel have been defined by NAA F/F. (See attachment 2.)

/s/William N. Bland, Sr.

Enclosures

PH6:REMcKann:sml

Attachment I

The post-test pre-flight data generated by the ACE station at KSC is in the format of strip charts and ACE tapes. Additional data is available from the Communications Ground Station which records data from the FM links on an open or closed loop basis. The ACE tapes are presently stored by General Electric in the computer room area. The strip charts are stored in a Data Evaluation Room under the cognizance of the Information Systems Directorate (INS) of KSC. INS has no authority to edit, annotate, or otherwise ammend these records other than to provide a storage, record, and check-out function. INS has a further, separate function to reduce data on an "off-line" basis, as required, based on a previously negotiated and validated requirement and for which a program has been prepared.

The spacecraft system engineers of NASA, KSC, Spacecraft Operations Directorate (SCO) usually submit their requests for data processing through their spacecraft contractor representatives (NAA for S/C 009). NAA has a central point of contact for all their NAA F/F or NAA-Downey representatives' request for data. A direct interface has been established between NAA and INS, however this interface is subject to SCO review and approval if required. Additional, separate requests for data processing may be imposed on INS directly by SCO.

SCO does not at this time have data group directly responsible for data control (i.e., cross referencing, editing, reduction of redundent data, compilation of data reports for systems review) although they have been asked to establish such a group by the KSC Program Office. For their own purposes SCO had not previously established such a group because their systems people were intimately familiar with the test details by personal review of the real time events and past test data review as required.

It is the requirement for data to be made available for other than KSC-SCO and NAA F/F personnel that makes the requirement for a data control group mandatory. NAA-Downey, integrating their requirements and review with their NAA F/F counterpart, requires an NAA effort of this type but due to their "on the spot" efforts they may not provide a formal report and records sufficient to satisfy other requests. NAA F/F cannot integrate the requirements of MSC and NAA-Downey although this effort would be beneficial to consolidate analysis of the problem and the specific data requirement.

The KSC Manned Spacecraft Program Office is the official interface through which the MSC requests for data are processed. At the moment, until a data evaluation team or office is established at KSC, this office has no operational control of the original data without specific coordination with the SCO engineers on a per request basis. This effort is being pursued by the KSC Program Office with the support of General Electric personnel. Because of the time required to pursue these individuals requests, a quick "turn-around-time" cannot be presently supported.

Prior planning and submission of specific types of data for the pre-launch checkout has been accomplished to some degree through the PSRD. This information relates primarily to the flight PCM data recorded by KSC-INS. Data records are available at KSC but no known pre-flight post-test MSC requests are presently programmed in the PSRD. All data reduced from these tests would be voluminous. Like other data generated by ACE, copies of data for specific time intervals should be requested.

The underlying problem throughout the quest for data for engineers external to KSC is the volume of data available and the difficulty in anyone not familiar with the records and their annotation in obtaining that specific piece of data required. Also requests for all data pertaining to a certain event or function requires a detailed analysis of the the total data to determine the complete cross referencing of data on ACE tapes, or strip charts, or ground telemetry station records. Only a system engineer, versed in the OCP preparation, format, and operation can coordinate, readily, requests of this type.

Due to the limited time remaining in the pre-flight checkout of S/C 009, it is strongly recommended that the most expeditious method of obtaining the required system data is for personal visits to be made to KSC. The advantages of this intermediate solution to the problem of being versed on the proper operation of the spacecraft systems are that the interfaces established by the NAA-Downey system evaluation team can be readily assimilated and that coordinated review of the problems and data required can be made with the NASA and NAA engineers. The KSC Program Office and the NAA test team have promised their full cooperation in providing whatever information and support they can in making this endeavor successful.

Attachment 2

EXPECTED DUTIES OF ANALYSIS TEAM

1. Review OCP in advance of its performance.
2. Define in advance those sequences of specific interest.
3. Specify what data is desired and what format it should be in.
4. Review data pertinent to your system.
5. Prepare a summary report giving analysis of your system's performance during a given OCP.
6. Review data from tests already performed and write summary report.
7. On special tests of a troubleshooting nature, participate directly by being in the ACE Control Room, or wherever the work is being accomplished.
8. During performance of OCP's specify times when access to control room is desired to monitor testing first hand.
9. Close coordination with your ATO Systems counterpart is expected (at least initially) to interpret what is actually going on during specific sequences of an OCP.

NOTES a) Where data (other than hand written values) is required as permanent documentation, special requests for additional playbacks or reproduction of existing data must be made. All raw data at this facility generated by ACE or NASA support facilities belongs to KSC.

b) For personnel who are not familiar with the area, a tour of the facilities is recommended so they may better appreciate working conditions under which tests are performed.

APPENDIX E

SYNOPSIS OF APOLLO CONTRACT WITH NORTH AMERICAN

SYNOPSIS OF APOLLO CONTRACT WITH NORTH AMERICAN INCORPORATED

TOTAL PROGRAM:

The portion of the Apollo Program contracted with North American Aviation Incorporated started on December 21, 1961, and will extend through completion of the Program in 1969.

Major Contractual Phases are:

Time Period	Contract Type
21Dec 61 - 13 Aug 63	Letter
21Dec 61 - 1 Oct 65	CPFF
3 Oct 65 - 3 Dec 66	CPIF
4 Dec 66 - Onward	Letter

Prime Document
Letter Contract NAS 9-150
Contract NAS 9-150
S/A 115 to NAS 9-150
S/A 220 to NAS 9-150

DEC 61 TO OCT 65 CPFF:

During the CPFF period 21 December 1961, through 4 October 1965, North American furnished design, development, manufacturing and field services including 19 mockups, 19 boilerplates, 4 spacecraft (001, 004, 007 and 009), GSE valued at 156.6M and spare parts valued at 32.6M. The North American plants were at Downey, California, and Tulsa, Oklahoma, with the bulk of the effort at Downey. The field services were furnished at WSTF, MSC, and KSC and involved site activation, vehicle checkout and test operation. The total estimated cost of the CPFF effort through October 2, 1965, was settled as $1.47 billion with a fee of $78 million.

OCT 65 to DEC 66 CPIF - S/A 115:

Supplemental Agreement 115, for the conversion to CPIF, was written in the form of a total contract that summarized the contractual agreements under the CPFF portion and presented in effect a complete new contract for the CPIF portion. It covers the period from 5 October 1965, through 3 December 1966 and includes Development, Manufacturing, and Test under an "Interdependency" incentive; GSE Manufacturing under a "Cost" incentive; Spare Parts Manufacturing under a "Cost" incentive; and a very limited amount of provisioned overhaul, repair, and facility activation under a cost plus fixed fee arrangement.

DEC 66 ONWARD:

Letter Amendment designated Supplemental Agreement No. 220 extend the contract through December 30, 1966. Subsequent amendments to S/A 220 have extended coverage through 1 April 1967. The contract presently under negotiation, has essentially the same features and incentive conditions as S/A 115. There are moderate differences in the method of applying incentives on checkout and flight, the management incentive is dropped, a FY 67 cost incentive is added and there are differences in the sharelines and weightings given the various incentive measurements.

S/A 115 CONTRACT ROAD MAP

The index to Part 1 Schedule is on page II of the schedule. The index to the entire S/A 115 is on page 91 of the schedule. The contract is:

Part I Schedule

In addition to special provisions such as Government Furnished Tooling, Make or Buy, Security, Overtime, Contractor Pricing Data, etc. Part I includes extensive provisions for the operation of the incentives under Article V, "Consideration and Payment" and Article XXIX, "Special Incentive Provisions."

Part II Statement of Work

The Statement of Work covers the task to be performed throughout the scope of the entire program. It covers the full range of goods and services from initial design trhou

It covers the full range of goods and services from initial design through post flight analysis of the last spacecraft.

Part III NASA Tasks

This covers NASA responsibilities for supplying data, interfaces, equipment, facilities, etc.

Part IV Hardware and Delivery Requirements

This specifies the hardware to be delivered with appropriate specification references and with the delivery schedule. Since the S/A 115 includes all previous effort, this part specifies the program totals from the beginning of the CPFF phase through the total contracted mockups, boilerplate, and spacecrft. To determine the items to be delivered in the October 65-December 66 CPIF period, one should deduct the items delivered prior to October 1965 and those scheduled for delivery past December 1966.

S/A 115 called for the delivery of 1 boilerplate and 14 spacecraft during the Oct 65-Dec 66 period. The boilerplate was cancelled; two spacecraft were cancelled; 10 spacecraft were delivered; and 2 remained undelivered.

Exhibit E-GSE

This is a reference list of S/A's that are priced GSE lists.

Exhibit F-Spare Parts

This is a reference list of S/A's that are priced Spare Parts lists.

Exhibit G-GFP/GFE

This is the list of GFP/GFE to be furnished by the Government. Its index is on Figure III of exhibit G and it is broken down into GFP at the manufacturers' plants, GFE for incorporation in hardware and base support to be furnished the contractor in his operations at MSC, KSC, WSTF and El Centro.

Exhibit H-Make or Buy List

Exhibit I-Documentation

This exhibit lists all documentation to be furnished by NAA, including CSM data packages, test reports, checkout plans, training materials, security plans, etc., specifying the frequency and the approval level for changes. (Type I documents require NASA approval before implementating. Type II documents are issued with information copies furnished for NASA surveillance. Type III documents are all others.)

Exhibit L-PERT.

This defines Pert and cost procedures used on this program.

Exhibit M-Off Site Test Programs Work Statement

This is the statement of work for NAA activity at KSC, WSTF, and MSC.

Exhibit N-Facility/GSE Site Activation Subcontracting

This exhibit is a reference of S/A's that list subcontracted site activation at WSTF, MSC and Downey.

Exhibit O-Common Usage Requirements

This exhibit specifies requirements for implementing common usage of equipment within the Apollo Program.

Exhibit P-Deviations to Contracted Language

Exhibit Q-Miscellaneous Hardware List

This list covers items authorized by the Contracting Officer for contractor procurement in the lieu of Base Support.

Exhibit R-Incentive Exhibit

This exhibit contains the measurement criteria by which incentive performance points are earned and a table of rates for computing earned fee.

Exhibit S- Flight Operations Support Program

This exhibit lists additional personnel to be furnished at KSC and MSC in direct support of flight operations.

Exhibit T-Work Packages

This exhibit is in support of a unique arrangement occasioned by the cutoff date of December 3. The NAS 9-150 Statement of Work covers all effort through the end of the program. This effort is limited to work through December 3rd by S/A 115. In order to ascertain that the work negotiated was performed in the contract period (5 October through 3 December) and thus assure that the recorded costs were for the work negotiated, a more detailed definition of the work to be accomplished in this specific period was spelled out in Exhibit T, "Work Packages".

A recommended order for reading the contract would be:

Page 91 of the schedule-index Part I
Page 11 of the schedule-index contract
Page II Statement of Work
Part II Statement of Work
Part IV Hardware Delivery Requirements
Part III NASA Tasks
Exhibit M Off Site Test Programs
Exhibit S Flight Operations Support
WExhibit T Work Packages
Exhibit R Incentive Provisions
Part I, Article XXIX Special Incentive Provisions
Part I, Article V Consideration and Payment
Charts A, B and C - Following Part I
Other portions of Part I of interest
Other exhibits of interest

S/A 115 CPFF AND CPIF:

The portions of work in S/A 115 that are under CPFF, Cost Incentive, and Interdependent Incentive are:

THE OVERHAUL, REPAIR AND FACILITY ACTIVATION portion has an estimated cost of $3.9M *and a fixed fee of $0.2M.

The SPARE PARTS target cost is $12,000,000* , and is on a CPIF cost sharing basis which is specified on page 16 of S/A 115's schedule (Article V7(i)(z)). Exhibit F of S/A 115 lists the supplemental agreements that price the spare parts. Approximately 70% of the spare parts have been delivered as of December 3, 1966, cutoff data does not apply to the separately provisioned and priced spare parts.

The GSE TARGET COST is $43,427,668 *and is on a CPIF cost sharing basis which is specified on page 15 of S/A 115's schedule (Article V7(i)(1)). Exhibit E of S/A 115 lists the supplemental agreements that price the GSE. Approximately 90% of the GSE has been delivered. As in the case of the spare parts, the December 3, 1966, cutoff date does not apply to these separately provisioned and priced items.

The DEVELOPMENT, MANUFACTURING AND TEST EFFORT has a target cost of $561, 649,000* and is under interdependent incentives on cost and performance.

*These target values are the latest value reflecting the most current supplemental agreemental *These target values are the latest value reflecting the most current supplemental agreements and are therefore different from the values originally specified in DS/A 115.

S/A 115 INTERDEPENDENCY INCENTIVE:

The interdependency can be described as a family of fee-cost sharlines. The highest fee-cost shareline is assigned to a performance rating of 1000 points. Progressively lower fee-cost sharelines are established for lower performance ratings down to a minimum performance of 500 points. The fee earned by the contractor is thus subject to two parameters, cost and performance. For illustration purposes, Charts A, B and C following page 93 of the S/A 115 schedule depict fees at representative levels of performance points and cost. Maximum fee for best cost and best performance is approximately 15%. There is a base fee of 4½% of target. Fee at target cost and maximum performance is approximately 12%.

Performance points in S/A 115 are measured in the areas of Pre-dilivery Mission Sequence Runs, Deliveries, Qualification, Ground Test, Pre-Flight Checkout and Launch, Flight Test, Block II Space-

Performance points in S/A 115 are measured in the areas of Pre-delivery Mission Sequence Runs, Deliveries, Qualification, Ground Test, Pre-Flight Checkout and Launch, Flight Test, BLlock II Spacecraft Manufacturing and Management. The cost-fee-performance arrangement is specified in Article V7 (i) (3) on page 16 of S/A 115 schedule. This in turn references a table in Exhibit R OF S/A 115 that specifies rates of fee decrease for each performance point from 1000 to 500 points. Exhibit, specifies the measurement criteria by which performance points are earned in each of the above areas as well as the table of rates for computing earned fee decreases.

In addition, the administration and scoring of the performance incentives are subject to a number of provisions relating to availability of government furnished items, methods of notation of points scored, pretest conditions, etc., which are specified in Article XXIX of the schedule. Also the scoring of the cost portion is subject to a work package adjustment. The work packages are defined in Exhibit T and the mechanism by which the final cost for fee purposes is adjusted for differences in work accomplished versus the work defined in the work packages is specified in Article XXIX (r) on page 84 of S/A 115 schedule.

In summary, Exhibit R and Article V, Part 1, specify the measurement criteria for performance and cost. However, both measurements are further refined by adjustments made according to provisions in Article XXIX of the schedule and Exhibit T.

HARDWARE SCHEDULES:

The hardware delivery schedules are specified in Part IV. To assist the overview of the contract, attached are summary delivery charts that show the effort plotted against time:

Attachment 11-2-26 shows boilerplates delivered during the CPFF portion of the contract.

Attachment 11-2-27 shows spacecraft (Block I) delivered as of September 64, the end of the CPFF portion of the contract.

Attachment 11-2-46 shows Block I spacecraft delivered as of December 66, the end of the S/A 115 portion of the contract.

Attachment 11-2-49 shows Block II spacecraft and mockups delivered as of December 66.

Attachment 11-2-55 shows the deliveries of Spacecraft LM Adapters through SC 109 as of December 66.

Attachment 11-2-56 shows the delivery schedule for Spacecraft LM Adapters for SC 110 through 115.

It should be noted that the Block II program extends through Spacecraft 115. The contract at present covers the program through Spacecraft 112. The addition of Spacecraft 113, 114, and 115 is currently under negotiation. Relative to effort beyond December 3, 1966, negotiations have been underway since October 66 for the definitization of the program from 4 December 66 through Spacecraft 112's launch and postflight analysis which is expected in mid-1969. The addition of effort related to SC 113, 114, and 115 will extend the expected completion to late 1969.

SCHEDULE RESPONSIBILITY S THOMAS MARKLEY

STATUS RESPONSIBILITY S C. L. TAYLOR

MANNED SPACE FLIGHT SCHEDULE
APOLLO MANUFACTURING & DELIVERY SCHEDULE
BOILERPLATES

3 LEVEL

CONTRACTOR:

PROJECT: Apollo

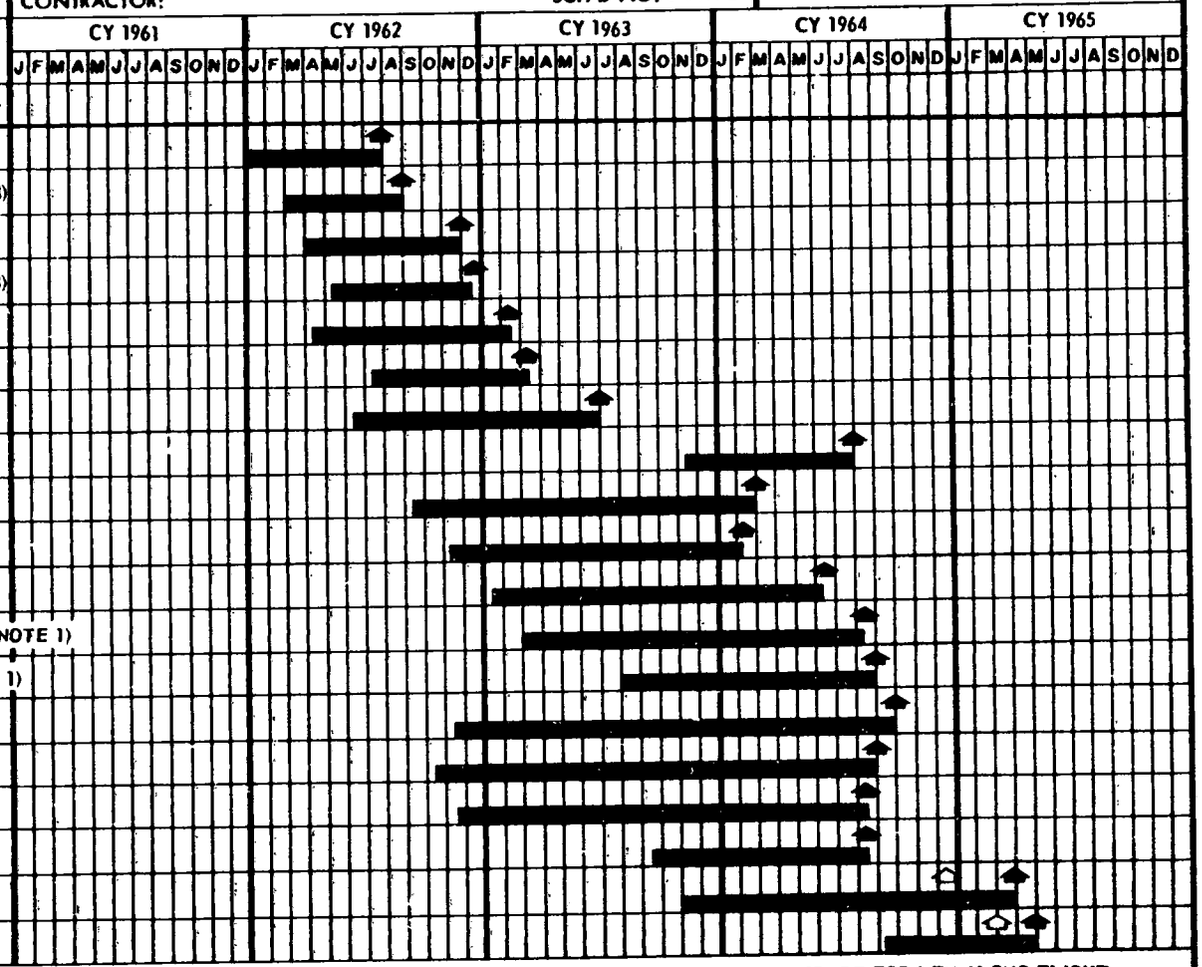
SCH'D NO: 3-1411-2a

ORIGINAL SCHEDULE APPROVAL 2 8 63 (Date)

LAST SCHEDULE CHANGE JAN 65 (2) (Date)(No.) (Initials)

STATUS AS OF SEPT. 30, 1965 (Date) (Initials)

	MILESTONES
1	
2	BP-25CM FLOATATION & HANDLING (MSC)
3	BP-1CM LAND & WATER IMPACT (NAA) (NOTE 3)
4	BP-3CM PARACHUTE DROP TEST (N-V)
5	BP-2CM LAND & WATER IMPACT (NAA) (NOTE 3)
6	BP-19CM PARACHUTE DROP TESTS (N-V)
7	BP-9CSM DYNAMIC TESTS (MSFC)
8	BP-6CM PAD ABORT #1 (WSMR)
9	BP-6A PARACHUTE RECOVERY TEST (N-V)
10	BP-12CSM TRANSONIC LES DEV (WSMR)
11	BP-13CSM APOLLO DEVELOPMENT (KSC)
12	BP-15CSM APOLLO DEVELOPMENT (KSC)
13	BP-16CSM MICROMET EXP APOLLO DEV (KSC)(NOTE 1)
14	BP-26CSM MICROMETEOROID EXP (KSC) (NOTE 1)
15	BP-23CSM HI Q ABORT (WSMR)
16	BP-14CSM HOUSE SC #1 (NAA) (NOTE 3)
17	BP-28CM EARTH IMPACT TEST (NAA)
18	BP-27CSM DYNAMIC TEST (MSC) (NOTE 2)
19	BP-22CSM HI ALT ABORT DEV (WSMR)
20	BP-29CM FLOATATION TEST (MSC)



NOTES
1. SN AND ADAPTER DELIVERED TO MSFC FOR MODIFICATION.
2. BP-27 DELIVERED TO MSFC ON 2-1-65, AFTER MODAL TESTS AT KSC.
3. DELIVERY NOTED IS TRANSFER FROM MFG TO ENGR.

CSM STRUCTURE FOR LEN ALONG FLIGHT IS IDENTIFIED AS BP-30.
MFG & DELIVERY SCHED FOR BP-30 IS SHOWN ON PAGE 30.

NASA FORM 796 REV. SEP. 63

11-2-26

S J THOMAS MARKLEY
SCHEDULE RESPONSIBILITY

S C L. TAYLOR
STATUS RESPONSIBILITY

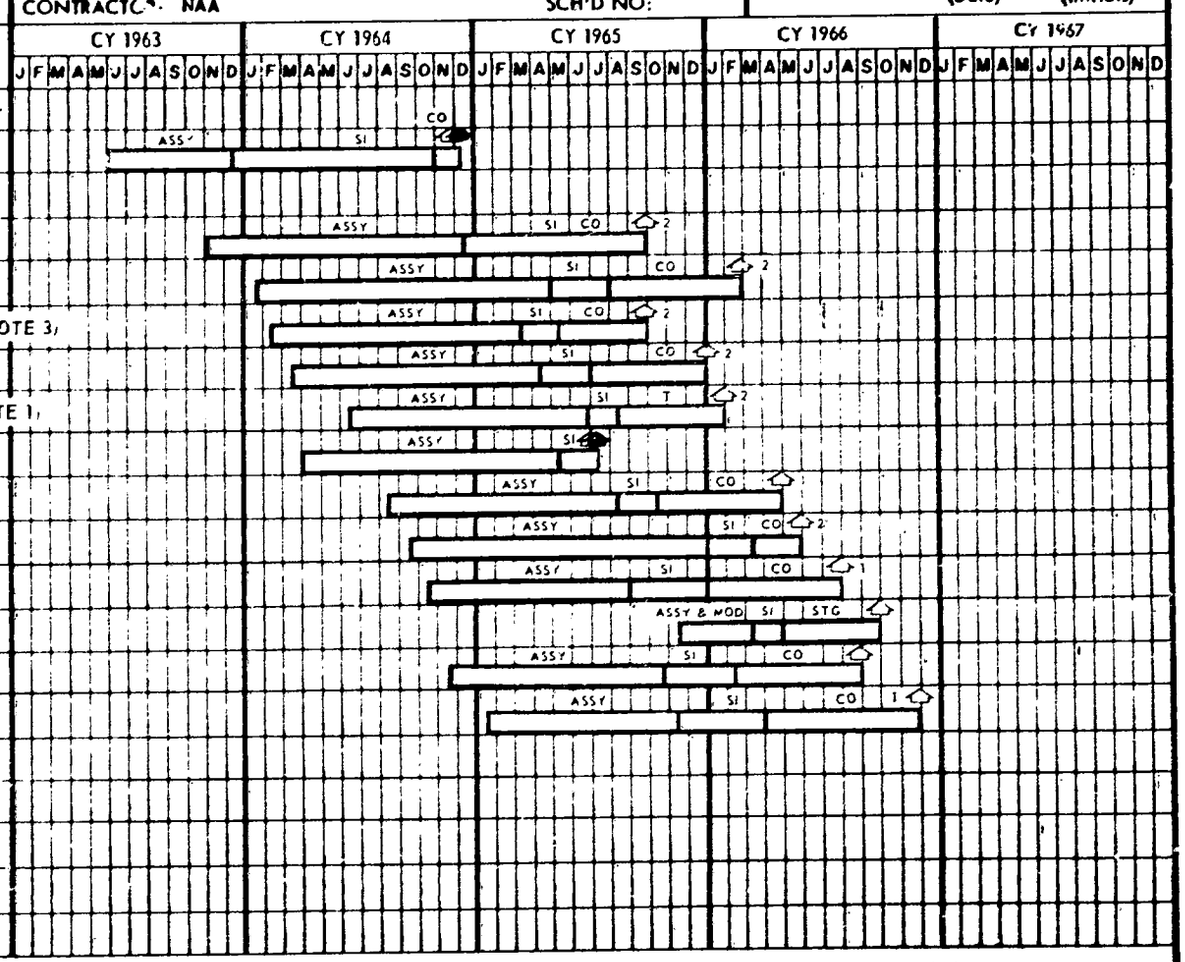
MANNED SPACE FLIGHT SCHEDULE
SPECIAL SUMMARY
APOLLO MANUFACTURING & DEL SCHED
CSM–BLOCK I

3 LEVEL

PROJECT: Apollo
SCH'D NO:
CONTRACTOR: NAA

FEB 8, 1963
ORIGINAL SCHEDULE APPROVAL (Date)
LAST SCHEDULE CHANGE JAN 65 (2)
STATUS AS OF SEPT. 30, 1965 (No) (Initials)
(Date) (Initials)

	MILESTONES
1	
2	SM 001 PROPULSION TEST (WSTF)
3	
4	CSM 009 SUPERCIRCULAR REENTRY (KSC)
5	CSM 008 T V TESTS (MSC)
6	CSM 002 INTERMEDIATE ALT ABORT (WSTF) (NOTE 3)
7	CSM 011 SUPERCIRCULAR REENTRY (KSC)
8	CSM 007 ACOUSTIC & FLOATATION TESTS (NOTE 1)
9	CSM 004 STRUCTURAL TESTS (NAA)
10	CSM 012 MANNED FLIGHT (KSC)
11	CSM 010 BACKUP FOR 002 (WSTF)
12	CSM 014 MANNED FLIGHT (KSC)
13	BP-30 LEM DEVELOPMENT (KSC)
14	CSM 017 SUPERCIRCULAR REENTRY (KSC)
15	CSM 020 SUPERCIRCULAR REENTRY (KSC)
16	
17	
18	
19	
20	



NOTES
ASSY–ASSEMBLY
SI –SUBSYSTEMS INSTALLATION
CO –FACTORY CHECKOUT
STG –STORAGE

◇ SCHEDULED SHIP
T TEST
◆ SHIPPED

1. END DATE IS DEL TO MSC FOLLOWING ACOUSTIC TESTS AT NAA
3. CHANGED TO AGREE WITH PAGE 29.

NASA FORM 796 REV SEP 63

11-2-27

E-98

SCHEDULE RESPONSIBILITY S J MC CLINTOCK

STATUS RESPONSIBILITY S R. C. HOOD

MANNED SPACE FLIGHT SCHEDULE
SPECIAL SUMMARY
APOLLO MANUFACTURING & DEL SCHED
CSM–BLOCK I

3 LEVEL

PROJECT: Apollo

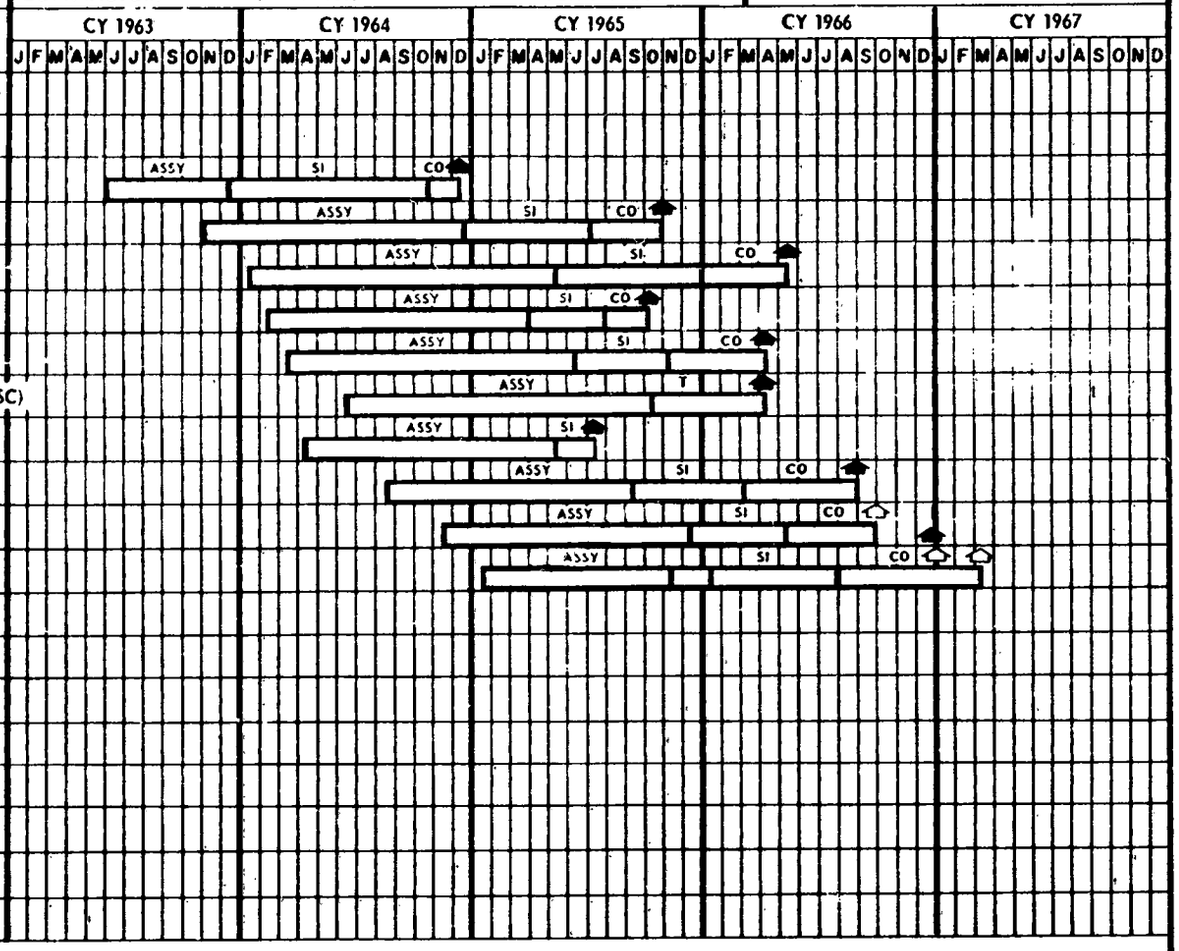
CONTRACTOR: NAA (NAS 9–150) SCH'D NO:

ORIGINAL SCHEDULE APPROVAL _____ (Date)

LAST SCHEDULE CHANGE 12-9-65(1) RRG

STATUS AS OF DEC. 31, 1966 (No) (Initials)
(Date) (Initials)

	MILESTONES
1	
2	
3	SM 001 PROPULSION TEST (WSTF)
4	CSM 009 SUPERCIRCULAR REENTRY (KSC)
5	CSM 008 T V. TESTS (MSC)
6	CSM 002 INTERMEDIATE ALT ABORT (WSTF)
7	CSM 011 SUPERCIRCULAR REENTRY (KSC)
8	CSM 007 ACOUSTIC & WATER IMPACT TESTS (MSC)
9	CSM 004 STRUCTURAL TESTS (NAA)
10	CSM 012 SPACECRAFT MISSION
11	CSM 017 SUPERCIRCULAR REENTRY (KSC)
12	CSM 020 SUPERCIRCULAR REENTRY (KSC)
13	
14	
15	
16	
17	
18	
19	
20	



NOTES
ASSY–ASSEMBLY
SI –SUBSYS INSTAL
CO –FACTORY C O
STG –STORAGE

SCHED SHIP
T TEST
SHIPPED

THE COMPLETION OF ASSEMBLY BAR IS NOW DEFINED AS TRANSFER TO SYSTEMS INSTALLATION AREA. COMPLETION OF SYSTEM INSTALLATION IS NOW DEFINED AS TRANSFER TO SYSTEM TEST.

NASA FORM 796 REV SEP 63

11-2-46

5 YEAR

SCHEDULE RESPONSIBILITY S J MC CLINTOCK

STATUS RESPONSIBILITY S R. C. HOOD

MANNED SPACE FLIGHT SCHEDULE
SPECIAL SUMMARY
APOLLO MFG. & DEL. SCHED.
CSM BLOCK II

3 LEVEL

PROJECT: Apollo

CONTRACTOR: NAA (NAS9-150)

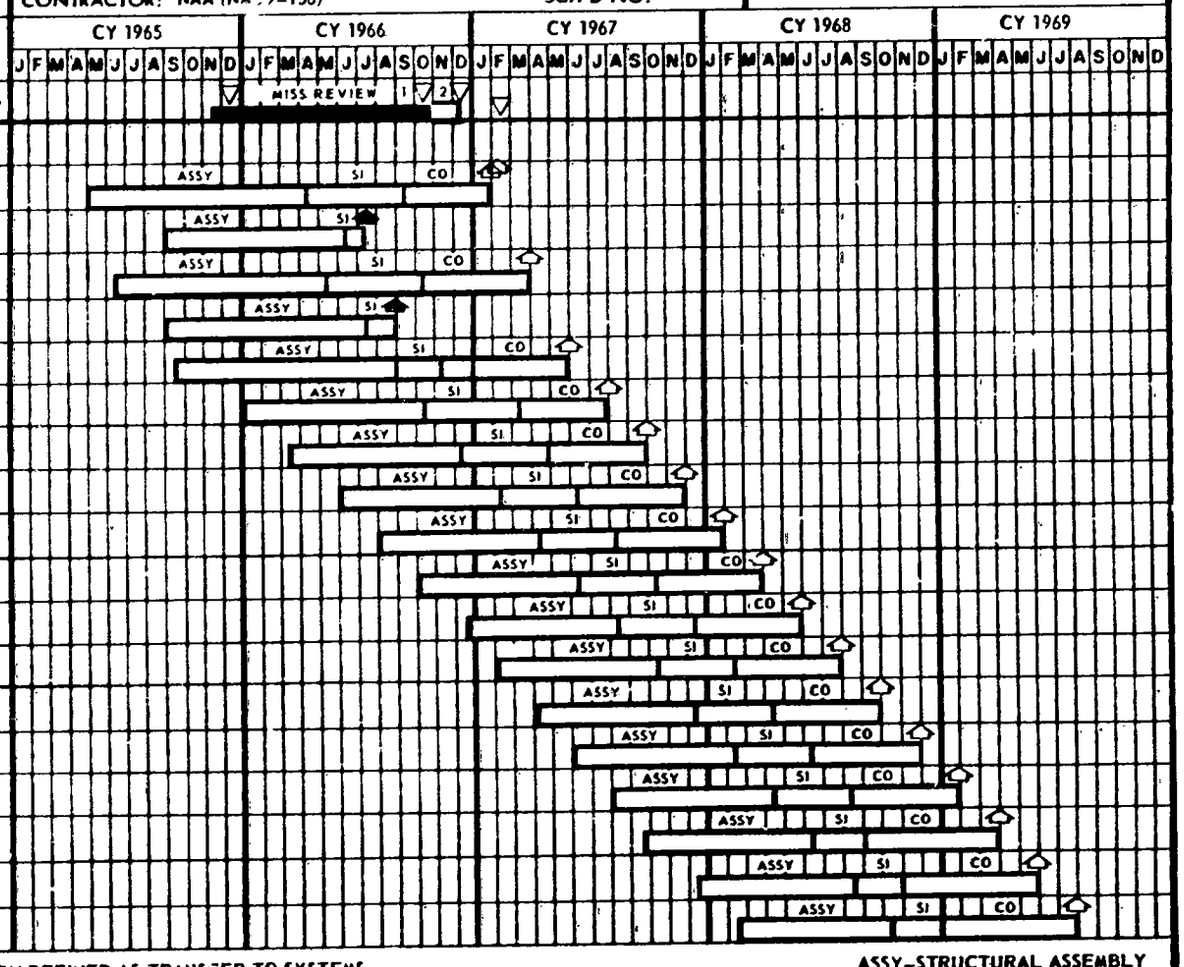
SCH'D NO:

ORIGINAL SCHEDULE APPROVAL FEB. 8, 1963 (Date)

LAST SCHEDULE CHANGE 12-9-65(1) RRG (No) (Initials)

STATUS AS OF DEC. 31, 1966 (Date) (Initials)

	MILESTONES
1	BLOCK II HARDWARE INSPEC & REV
2	
3	2TV 1 T V TESTS (MSC)
4	2S-1 CM IMPACT TESTS
5	CSM 101, SPACECRAFT MISSION (KSC) (NOTE 1)
6	2S-2 STATIC STRUCTURAL TESTS
7	CSM-102, SPACECRAFT MISSION (KSC)
8	CSM-103, SPACECRAFT MISSION (KSC)
9	CSM-104, SPACECRAFT MISSION (KSC)
10	CSM-105, SPACECRAFT MISSION (KSC)
11	CSM-106, SPACECRAFT MISSION (KSC)
12	CSM-107, SPACECRAFT MISSION (KSC)
13	CSM-108, SPACECRAFT MISSION (KSC)
14	CSM-109, SPACECRAFT MISSION (KSC)
15	CSM-110, SPACECRAFT MISSION (KSC)
16	CSM-111, SPACECRAFT MISSION (KSC)
17	CSM-112, SPACECRAFT MISSION (KSC)
18	CSM-113, SPACECRAFT MISSION (KSC)
19	CSM-114, SPACECRAFT MISSION (KSC)
20	CSM-115, SPACECRAFT MISSION (KSC)



NOTES
THE COMPLETION OF ASSEMBLY BAR IS NOW DEFINED AS TRANSFER TO SYSTEMS INSTALLATION AREA. COMPLETION OF SYSTEM INSTALLATION IS NOW DEFINED AS TRANSFER TO SYSTEM TEST
1 RESCHEDULED DELIVERY DATE APPROVED BY APD-CCB #68,8-16-66

ASSY–STRUCTURAL ASSEMBLY
SI –SYSTEMS INSTALLATION
CO –FACTORY CO
⬠ –DELIVERY SCHEDULED

NASA FORM 796 REV SEP 63

11-2-49

E-90

5 YEAR

SCHEDULE RESPONSIBILITY S J MC CLINTOCK

STATUS RESPONSIBILITY S R. C. HOOD

MANNED SPACE FLIGHT SCHEDULE
APOLLO MFG & DEL. SCHEDULE
ADAPTER

3 LEVEL

PROJECT: Apollo

CONTRACTOR: NAA (NAS 9-150) SCH'D NO:

ORIGINAL SCHEDULE APPROVAL FEB. 8, 1963 (Date)

LAST SCHEDULE CHANGE 2-28-66(2) RRG (No) (Initials)

STATUS AS OF DEC. 31, 1966 (Date) (Initials)

	MILESTONES
1	CSM DELIVERIES
2	ADAPTER 19 (SC110) (KSC)
3	ADAPTER 20 (SC111) (KSC)
4	ADAPTER 21 (SC112) (KSC)
5	ADAPTER 22 (SC113) (KSC)
6	ADAPTER 23 (SC114) (KSC)
7	ADAPTER 24 (SC115) (KSC)
8	
9	
10	
11	
12	
13	
14	
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16	
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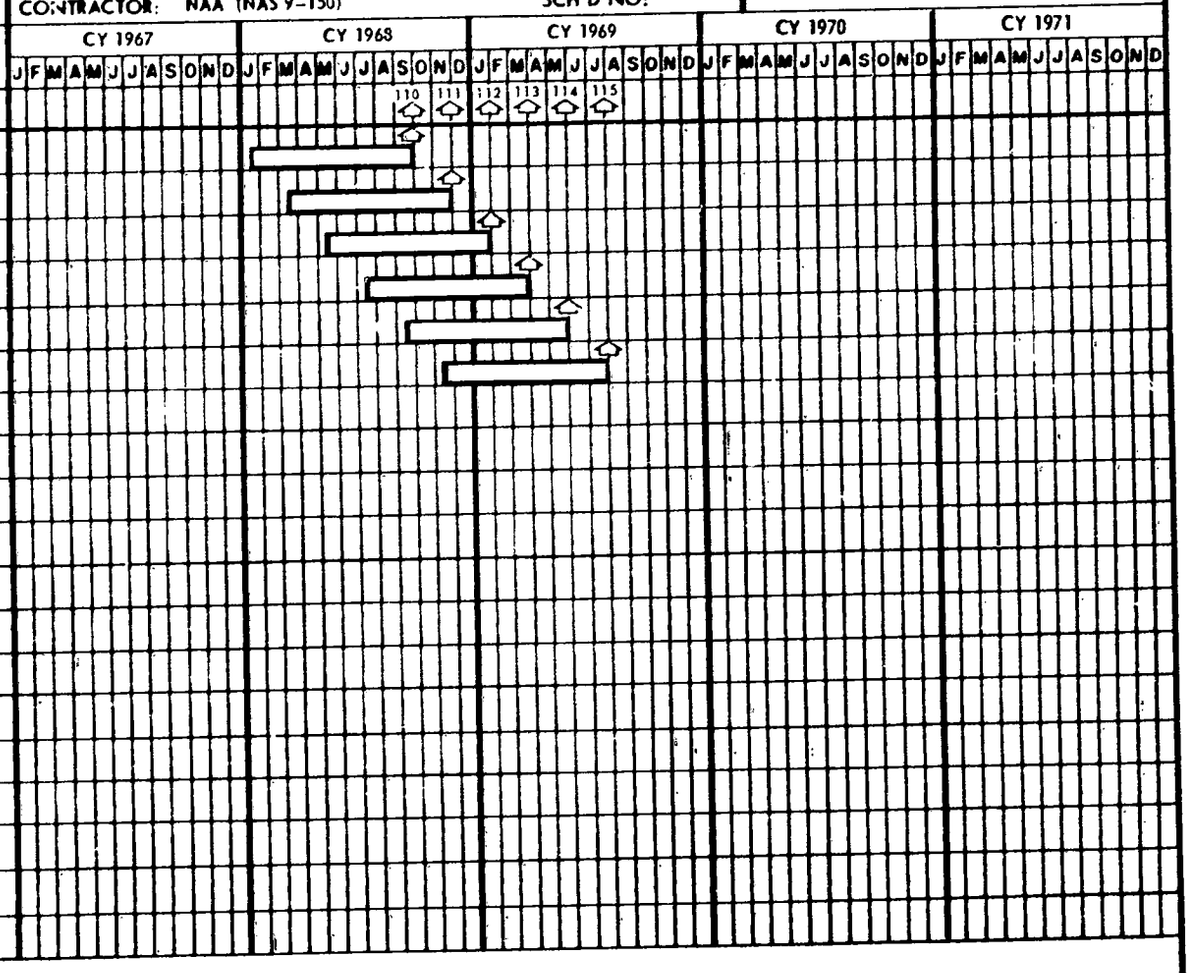
19	
20	



NOTES

11-2-56

NASA FORM 796 REV SEP 63

E-91

SCHEDULE RESPONSIBILITY S J MC CLINTOCK

STATUS RESPONSIBILITY S R C. HOOD

MANNED SPACE FLIGHT SCHEDULE
APOLLO MFG. & DEL. SCHEDULE
ADAPTER

3 LEVEL

PROJECT: Apollo

CONTRACTOR: NAA (NAS-9-150)

SCH'D NO:

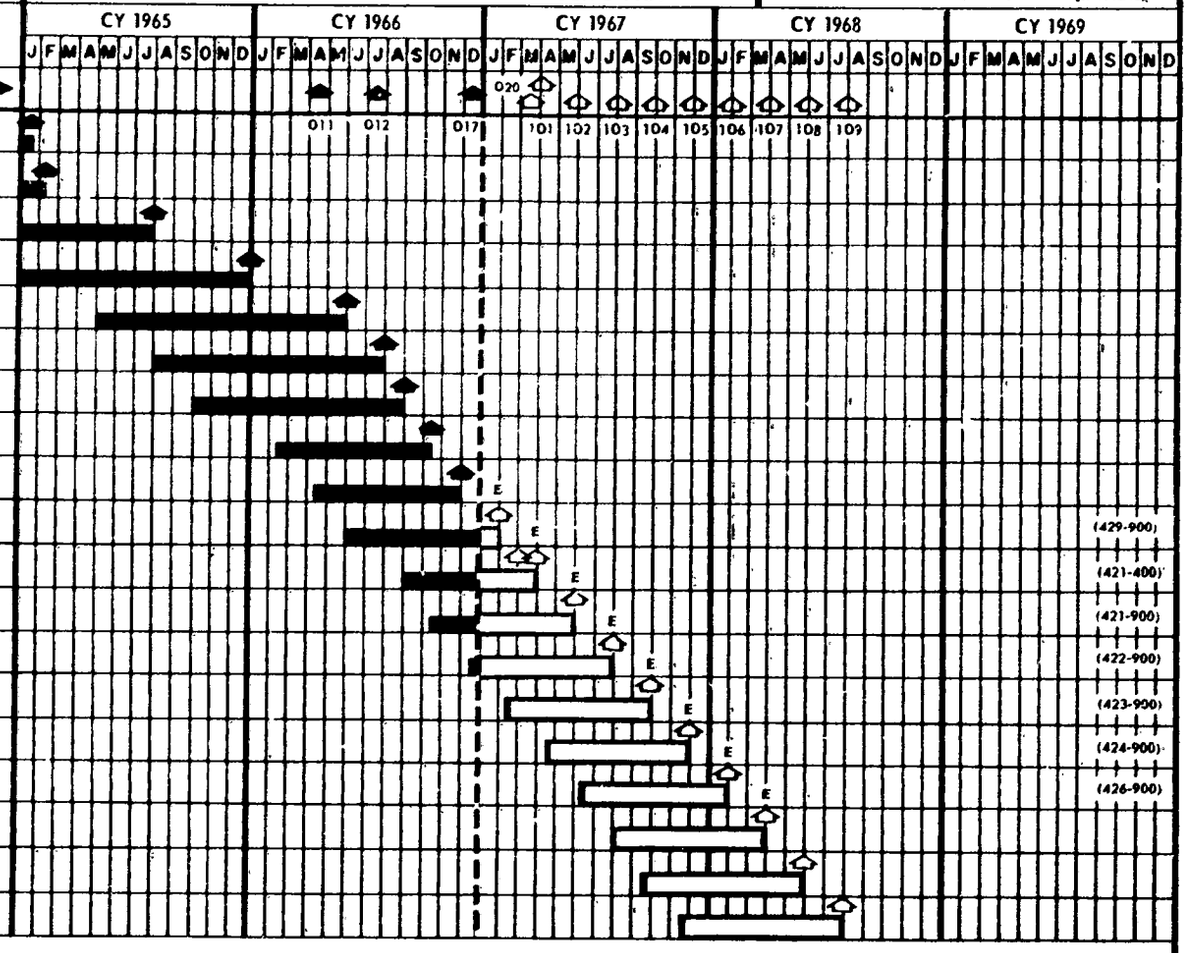
FEB. 8, 1963

ORIGINAL SCHEDULE APPROVAL _____ (Date)

LAST SCHEDULE CHANGE 2-28-66(2) RRG (No) (Initials)

STATUS AS OF DEC. 31, 1966 (Date) _____ (Initials)

	MILESTONES
1	CSM DELIVERIES
2	ADAPTER 1 (BP-27) (MSFC)
3	ADAPTER 1 (STRUCT TEST) (TULSA)
4	ADAPTER 3 (CSM009) (KSC)
5	ADAPTER 4 (CSM011) (KSC)
6	ADAPTER 5 (CSM012) (KSC)
7	ADAPTER 6 (CSM014) (KSC)
8	ADAPTER 8 (CSM017) (KSC)
9	ADAPTER 7 (LM ENCL =1) (KSC)
10	ADAPTER 9 (CSM020) (KSC) (NOTE 1)
11	ADAPTER 7A (LM ENCL =2) (KSC)
12	ADAPTER 10 (SC101) (KSC)
13	ADAPTER 11 (SC102) (KSC)
14	ADAPTER 12 (SC103) (KSC)
15	ADAPTER 13 (SC104) (KSC)
16	ADAPTER 14 (SC105) (KSC)
17	ADAPTER 15 (SC106) (KSC)
18	ADAPTER 16 (SC107) (KSC)
19	ADAPTER 17 (SC108) (KSC)
20	ADAPTER 18 (SC109) (KSC)



NOTES

1. DO 250 SIGNED. SLA PLACED IN STORAGE AT TULSA. TO BE SHIPPED AT LATER DATE.

NASA FORM 796 REV SEP. 63

11-2-55

(NASA-TM-84103) REPORT OF APOLLO 204 REVIEW BOARD. APPENDIX F: SCHEDULE OF PHYSICAL EVIDENCE (NASA) 58 p

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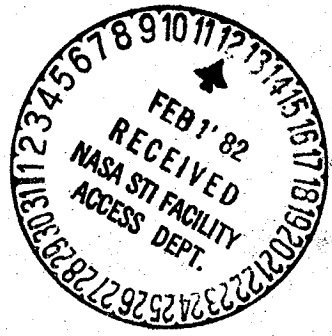

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX F

(NASA-TM-X-69479) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX F (NASA) 58 p
LIMIT NASA+NASA CONTR.

X73-81554

Unclas
00/99 15865

12.4 All laboratory reports connected with Task XII will be submitted to and impounded by D/816.

12.5 After the impound of above noted quantities destined for laboratory analysis, all balances may be released for use.

XIII. TASK.

All new equipment whose equivalent has not been used on Spacecraft 012 but is now in areas which are controlled by the Board will be released for use.

LOGIC.

13.1 D/810 will formulate a list of all new equipment whose equivalent has not been used on Spacecraft 012.

13.2 All equipment indicated on said list noted in Paragraph 13.1 above will be immediately released.

XIV. TASK.

IMCC Houston not utilized but for monitoring shall be released.

LOGIC.

This item does not apply to the Florida Facility.

XV. TASK.

OCP's, Checklists, Schematics, etc., both flight and non-flight, being used by the crew at the time of the incident, shall be removed and stored in sealed boxes. Removal must be made under precise conditions, photographs taken to establish the condition of the books. Provide photographs where technically possible, showing the location and condition of these items as found. The only books to be removed are those over the couches.

LOGIC.

D/816 will verify in writing the accomplishment of all effort specified in Task XV above.

S. T. Beddingfield
Chief, Mechanical and Ordnance Branch
NASA-KSC

J. M. Moore, Manager
Apollo Test Operations
Florida Facility, NAA/S&ID

ENCLOSURE F-1

10.2 Upon receipt of this list, D/816 will authorize the release of all such hardware except for communication equipment.

10.3 All communication equipment noted in list per Paragraph 10.1 above will have affixed to same an M59-B by D/816. This category of equipment will then be impounded until released by the Board in writing.

XI. TASK.

All non-flight hardware (non-GSE) utilized during chamber run shall be baselined in terms of configuration, copy of records impounded in Room 3344, and released for use (except the communication equipment which will be controlled by the Board).

LOGIC.

11.1 D/818, together with D/810, will prepare a list of all non-flight hardware (non-GSE) utilized during chamber run.

11.2 Configuration of such hardware shall be accomplished, per paragraph 2.2 above, by D/818 and recorded on applicable documents.

11.3 D/816 will provide inspection surveillance according to existing procedures.

11.4 D/818, together with D/810, will prepare a list of all communication equipment in this category.

11.5 D/816 will affix an M59-B tag to equipment noted in Paragraph 11.4 above and such equipment will be impounded under the control of D/816 pending official release by the Prime Investigation Board.

XII. TASK.

All laboratory supplies used on Spacecraft 012 shall be handled as follows:

LOGIC.

12.1 D/818 will prepare a list of all laboratory supplies used on Spacecraft 012 and shall indicate on said list adequate quantities necessary for laboratory analysis. If no remaining quantities exist, said list shall so indicate.

12.2 D/816 shall label and impound quantities noted above indicated for laboratory analysis.

12.3 D/818 will issue Support Requests as required to accomplish laboratory analyses on such quantities.

APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

TEST IN PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.

APPENDIX F
SCHEDULE OF PHYSICAL EVIDENCE

APPENDIX F

PREFACE

Immediately following the Apollo 204 accident of January 27, 1967, all associated equipment and material were impounded. Release of this equipment and material for normal use was under the close control of the Apollo 204 Review Board. Apollo Review Board Administrative Procedure No. 11, February 11, 1967, established the Apollo 204 Review Board Material Release Record (MRR). This MRR was the official form used to release material from full impoundment and was valid only after being approved by the Board and signed by a Member. The form was used as the authority to place any impounded item into one of the three Categories defined in Administrative Procedure No. 11. This appendix contains all of the authorized MRR's. Each item submitted on an MRR was given a control number; a description, including the part number and serial number; the relevance and location to the accident; any constraints before release; and the control category. The categories placed on the equipment were as follows:

Category A - Items which may have a significant influence or bearing on the results or findings of the Apollo 204 Review Board.

Category B - All material other than Category A which is considered relevant to the Apollo 204 Review Board investigation.

Category C - Material released from Board jurisdiction.

Several classes of equipment were released by special Board action prior to the establishment of the MRR system. The operating procedure for release of these classes is Enclosure F-1 to this appendix.

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0001	White Room Door	None Loc: White Room	None	A	C	Approved 2/15/67
0002	Flow sensor set (RCS) P/N G-16-858170-201 S/N 7 Log #135 PIRR #252 (kit for RCS plugs) to measure gas flow	None Loc: A8 +Z+Y	None	A	C	Approved 2/15/67
0003	LC antenna coupler set ME481-0050-0001 Log #132 PIRR #257 (empty box) (equip out at Pad)	None Loc: A8 +Z+Y	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0004	SCS Breakout Box X00-002 S/N FF-001 Log #133 PIRR #254 (was not used on this test)	None A-8 –Z –Y	None	A	C	Approved 2/15/67)
0005	Flow Adapter Set (RCS) P/N G16-824499 S/N 3 Log #134 PIRR #253 (Empty) Plugs in S/C	None Loc: Level A8 +Z+Y	None	A	C	Approved 2/15/67
0006	Module Leak Test Unit S14-079 Log #255 PIRR #384 (and attached hoses)	None Loc: White Room	Hold TPS GSO 79-3-018 generated to run analysis pending results - then release	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0007	Box of A.C. Extension Cords Log #105 PIRR #235 Cannot be plugged into S/C	None Loc: Level A8 +Z+Y	None	A	C	Approved 2/15/67
0008	Differential Voltmeter J. Fluke Model 803B S/N 1365 Log #221 PIRR #344	None Loc: Level 8–Z–Y under Q.C. Desk OCP 0005	None	A	C	Approved 2/15/67
0009	Decade Resistor (Biddle-Gray) S/N 31837 used with scope	None Loc: Level A8 Inside Cabinet at +Z OCP 0005	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0010	Power Supply (Hewlett Packard) P/N NASA LOC-AMR #39602 S/N 310-18470 Used with scope for trouble shooting	None Loc: Level A8 in cabinet at +Z	None	A	C	Approved 2/15/67
0011	Oscilloscope P/N Tektronix - 321 S/N 002906	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67
0012	PIB (Area 15) Brush recorder P/N RD2522-20 (No S/N)	None Loc: Level A8 In cabinet at +Z Used in OCP 0005	None	A	C	Approved 2/15/67
0013	Audio Oscillator LOC-AMR-43855 S/N 331-03345	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0014	CD Milliammeter (HP Clip-on) NASA LOC #AMR 43018 S/N 131-01808	None Loc: Cabinet A8-1 Used in OCP 0005	None	A	C	Approved 2/15/67
0015	Test Set (?) (Shallcross) #6100 S/N 32956	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67
0016	VTVM Model 410C NASA Property S/N F329730	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67
0017	Simpson Meter Model Z69 S/N Z13869	None Loc: Cabinet -A8-1	Perform functional & release	A	C	Approved 2/15/67
0018	L&N Test Set P/N 5300 S/N 1644965	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67
0019	Bag of test leads Log No:	None Loc: Cabinet -A8-1	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0020	Bag of connector covers	None Loc: Cabinet -A8-1	None	A	C	Approved 2/15/67
0021	Bracket antenna Coupling Set P/N ME481-0050-0001	None Loc: Cabinet -A8-1	None	A	C	Approved 2/15/67
0022	Heat Gun Model #751-CD S/N 725277	None Loc: Cabinet -A8-1	None	A	C	Approved 2/15/67
0023	Weber Temp Check P/N 38611 S/N Z00446 (PIB Area Cab #7)	None Loc: Cabinet -A8-1	None	A	C	Approved 2/15/67
0024	Hard Hat 2 ea. Log #217 PIRR 334	None Loc: 1 ea. Bottom left corner of cabinet A8-1 1 ea. bottom left corner of NASA QC Desk	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0025	Bolts NAS 1153-C9 (PIB Area Cab. #7)	None Loc: Cabinet A8-1	None	A	C	Approved 2/15/67
0026	Head Set Log #154 PIRR 287 S/N 170A	None Loc: Cabinet A-8+Z	None	A	C	Approved 2/15/67
0027	Blower 1 ea. Log #112 PIRR #242 S/N 100330 Brought up after fire to exhaust smoke	None Loc: Level 8A+Y+Z	None	A	C	Approved 2/15/67
0028	Water Cooler 1 ea. Log #148 PIRR #259	None Loc: Level 8+Z+Y	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0029	Lock out box (2 ea.) Z00-065 TE 459 S/N FF002 FF003 (PIB Area Cab. #7)	None Loc: In Cabinet on A8 (Cabinet #A8-1	None	A	C	Approved 2/15/67
0030	Tool box, personal Mr. J.A. Walters Log #222 PIRR #347 Locked time unknown	None Loc: Removed from swing arm	Inventory and release to owner	A	C	Approved 2/15/67
0031	Cardboard box - clean room clothing Log #129 PIRR #243	None Loc: Front of A8-1 cabinet +Y+Z Axis	Used - hold Clean -- release	A	C	Approved 2/15/67
0032	Headsets (2 ea.) Log #81 PIRR #123 S/N A6039 & A6044	None Loc: Removed from White Room	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0033	Monkey Bar, GSE Ingress egress assist Log #82 PIRR #128	None Loc: White Room	Visual inspection & release	A	C	Approved 2/15/67
0034	Tool pouch Log #98 PIRR #198	None	Record the contents Release to Owner	A	C	Approved 2/15/67
0035	Kit, Optical Align S/N 233913 Log: #127 PIRR #248 (empty)	None Loc: Level A8 -Z-Y Axis	Visual Inspection	A	C	Approved 2/15/67
0036	Gas Mask Log #89 PIRR #133	None Loc: White Room	Insp. for functional use, examine canister contents from used gas masks, check for functional use and analyze. This work to be accomplished under cognizance of Norris Gray. Release upon approval of Panel 11 & 13.	A	C	Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0037	3 ea. cardboard Boxes containing used gas masks. Log #107 108 109 PIRR #230 229 231	None Loc: Level A8 - +2+Z+Y	Same as previous 0036.	A	C	Approved 2/16/67
0038	Gas Mask 4 ea. Log #117 118 (2 each) 119 PIRR #236 238 234 S/N 7-1321 7-1326 7-139 7-1069	None Loc: 2 ea. under NAA Q.C. Desk -Y Axis 1 ea level A-8 +Y 1 ea under swing arm Step +Y-Z Axis	Same as previous 0036			Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0039	Face Portion Gas Mask 2 ea. Log #115 116 PIRR #237 239	None Loc: Swing arm entrance to White Room and under -Y corner of White Room	Same as previous 0036			Approved 2/16/67
0040	Spares for water glycol and oxygen servicing Ground Support Equipment. A14-033 S14-019 S14-053 S14-119* S14-121** S14-125 S14-140 *Not used to service water/glycol, only potable water. **Water/glycol primary loop, does not interface with spacecraft.	None Loc: Impounded to support the investigation of the Apollo 204 accident. These components were in storage at the time of, or procured since, the accident and are required as replacements for failed items on GSE being used to continue operations in support of AS 501, 502 & 206.	None	A	C	Approved 2/15/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0041	GSE Cable P/N SCH-105026 S/N-1	None Loc: Bonded Locker 2440 MSOB	None	B	C	Approved 2/16/67
	GSE Cable P/N SCA-105027 S/N-1	None Loc: Bonded Locker 2440 MSOB	None	B	C	Approved 2/16/67
	Chamber-to-Power Supply Adapter P/N SCA-105028 S/N-1	None Loc: Bonded Locker 2440 MSOB	None	B	C	Approved 2/16/67
	Torso Harness P/N 103120E S/N 61	Same type as Astronauts were wearing. Bonded Locker 2440 MSOB	None	B	C	Approved 2/16/67
	Physio-Simulator P/N SOB 105007 S/N 004	Used in past S/C testing prior to OCP-K-0021-1 Loc: Bonded Locker 2440 MSOB	None	B	C	Approved 2/16/67
	CWG Adapter P/N SCA 105020 S/N 1	None Loc: Bonded Locker 2440 MSOB	None	B	C	Approved 2/15/67
	Lightweight headset P/N A2013-000 S/N 102 or 103	Used in past S/C testing Loc: NAA GFE Crib MSOB	Unkown	B	C	Approved 2/16/67
0042	Li OH Canisters P/N ME 901-0218-0001 (2 each)	These canisters are of the same type that were installed in S/C 012 during OCP-K-0021.	Approved TPS for analysis and approval of Panel 5 and 18.	A	C	Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0043	Fire Hood 1 ea. Log #114 PIRR #241 Left by Firemen	None Loc: Level A8- +Y+Z	Return to Norris Gray upon approval of Panel 13.	A	C	Approved 2/16/67
0044	Mobile Press Unit Assy. (Nitrogen "K" bottle and cart). Log #277 PIRR #415 S/N 2	None Loc: Level A-7	Sample analysis and release upon approval of Panel 18.	A	C	Approved 2/16/67
0045	Fire extinguishers (16 ea.) 15 lb. CO^2 (1 ea.) Dry Chem (20 ea.) 50 lb. CO^2 (Cart mounted) 16 ea. 15 lb. CO^2 Log # PIRR # 95 214 96 218 96 219 94 213 94 209 93 202 93 204 (Cont.). 94 208	None Loc: Levels A7 and A8, LC 34 S/N # G-129200 H-513994 H-656271 K-382116 None K-699689 K-700304 K-381892	Fire Dept. to report status of each extinguisher and run functional, and release upon approval of Panel 11 & 13.	A	C	Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0045 (Cont.)	Log # PIRR #	S/N #				
	93 205	K-380859				
	93 203	K-380976				
	93 206	None				
	93 207	None				
	95 216	H-657852				
	95 212	None				
	227 346	J-853959				
	228 345	K-381100				
	1 ea. Dry Chem.					
	94 211	None				
	2 ea. 50 lb. CO^2					
	95 215	None				
	94 210	None				
	Condition: All Fire Ext. used.					
0046	0_2 Analyzer P/N 52E180113-3 2 ea. S/N 3 & 4	None (1) Outside w/r A-8 S/N 4	TPS S/C 012-007 and release by Panel 18.	A	C	Approved 2/16/67
	Log # 289,290	(2) 0^2 panel inside w/r S/N 3				
	PIRR #109, 108					
	(2 not used)					
	K bottle was used					
	Hold for more inf.					

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0047	Trash Cans 7 ea. Log #91 and 239 PIRR #197, 195, 199, 196, 220, 200, 372	None Removed from levels 5,6,7 and 8	Examine contents in presence of fire panel. Store residue. Ship container to pad.	A	C	Approved 2/16/67
0048	Box - Gask Mask Log #104 PIRR 238	None Loc: Level A-8 +Y	Same as previous 0036	A	C	Approved 2/16/67
0049	Foot lockers 2 ea. - normal purpose of these lockers is for pad storage of crew systems equip. Log #130 & 128 PIRR #249 & 246 GFE Equipment carriers. Not used in test.	None Loc: -Z	Visual inspection inventory contents, release upon approval of Panel 18.	A	C	Approved 2/15/67
0050	Trash Cans 3 ea. Log #75, 79, 74 PIRR #186, 201, 185	None Loc: 1 ea. -Y 1 ea. level 7 +Z+Y	Examine contents in presence of fire panel and other interested personnel, store residue and return container to pad.	A	C	

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0051	Gas Mask Box #16 Log #111 PIRR #228	None Loc: Level A-8+Y+Z	Same as previous 0036	A	C	Approved 2/16/67
0052	Gas Mask Box #18 Log #110 PIRR #232	None Loc: Level A-8-Y+Z	Same as previous 0036	A	C	Approved 2/16/67
0053	S14-091 S/N 3 Battery Conditioner S14-111 S/N 4 S14-111 S/N 5 Battery Charger Constant Voltage SK818-0019 FQ 0502 (Battery Test Unit) SK818-2012 FQ 0503 (Load Box) TAIR Book #FF0731 & All TAIR Books for above units	Located in Battery Room Bldg. M505. These units were used to charge S/C 012 batteries for OCP 0006 & OCP 0021 and are needed to support the continued operations in support of AS 501, 502 & 206. Insp. book for battery shop maintenance.				Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0054	Gas Mask Box (seal broken) Log #223 PIRR #347 S/N 13A	None Loc: - Removed from Swing Arm	Same as previous 0036			Approved 2/16/67
0055	Boots, Protective Log #84 PIRR #136 (Booties)	None Loc: White Room	Inventory: Approval required by Panel 13.	A	C	Approved 2/16/67
0056	ECU O_2 Flow-rate Transducer (1 each) (AiResearch P/N 836112-2-2-1)	Same type of units were installed in ECU on S/C 012. (Located in bonded storage in MSOB)	This Transducer will be utilized to determine different failure mode characteristics.	A	C	Approved 2/17/67
0057	ACE Carry-on Uplink C14-264-3 C14-265-3 DTCS C14-266-3	1. Used in "Plugs In" Test 2. Disconnected but in the area for "Plugs Out" Test. 3. Location A8 Level	1. No Constraints 2. Necessary to support S/C 017 Testing. 3. Needed One Week Prior to re-stacking S/C 017 at VAB	A	C	Approved 2/16/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0058	ACE Carry-on Downlink C14-203-10, C14-204-10 Racks C14-210-4 PCM Unit C14-211-12, C14-212-12, C14-213-11 Signal Conditioners C14-574-10 Cable Set WO215 PCM Cable	1. Used in "Plugs In" Test 2. Disconnected but in the area for "Plugs Out" Test 3. Location A8 Level	1. No Constraints 2. The uncontrolled environment at LC34 - A8 Level is detrimental to the equipment. This equipment is necessary for use on future S/C.	A	C	Approved 2/16/67
0059	Tee Adapter P/N V16-601396	Not in Spacecraft 012 at time of accident. Similar configuration.	None	A	C	Approved 2/18/67
0060	Cobra Cable P/N V16-601263-41	Not in Spacecraft 012 at time of accident. Similar configuration.	None	A	C	Approved 2/18/67
0061	Noise Limiter P/N V16-601549	Not in Spacecraft 012 at time of accident. Similar configuration.	None	A	C	Approved 2/18/67
0062	PGA Adapter P/N V16-601357-31	Not in Spacecraft 012 at time of accident. Similar configuration.	None	A	C	Approved 2/18/67
0063	Torso Harness P/N 103120E, S/N 69	Not in Spacecraft 012 at time of accident. Similar configuration	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67
0064	Communications GSE Adapter P/N SCA-105029,S/N 1	Not attached to Spacecraft 012 at time of accident. Similar configuration.	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0065	GSE Power and Distribution Cable P/N SCC-105024, S/N 1	Not attached to Spacecraft 012 at time of accident. Similar configuration.	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67
0066	Mobile Test Rack P/N SCC-100137, S/N 2	Not attached to Spacecraft 012 at time of accident. Similar configuration.	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67
0067	Interconnect Box P/N 688541-1F, S/N HS-GSE-003, and Headset.	Not attached to Spacecraft 012 at time of accident. Similar configuration.	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67
0068	Light Weight Headset P/N A2013-000, S/N 102 or 103.	Not attached to Spacecraft 012 at time of accident. Similar configuration.	Special test to be performed in accordance with RST 3A.	A	C	Approved 2/18/67
0069	A14-037 S/N-7 Adapter and Duct Set	Used on S/C 012 to supply C/M circulating air and was physically connected prior to hatch closeout. Needed urgently to support S/C 017 operations.				Approved 2/21/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0070	C14-209-4 Spacecraft External Mounting Rack	1. Used during "Plugs In" test. 2. Disconnect but in the area for "Plugs Out" test 3. Location A8 Level	1. No constraints. 2. Necessary to support S/C 017 testing. 3. The uncontrolled environment at LC 34 A8 Level is detrimental to the equipment stored in this rack. The equipment has been reassigned to Category "C".	A	C	Approved 2/21/67
0071	C14-206-1 Spacecraft External Mounting Rack	1. Used during "Plugs In" test. 2. Disconnect but in the area for "Plugs Out" test. 3. Location A8 Level.	1. No constraints. 2. Necessary to support S/C 017 testing. 3. The uncontrolled environment at LC 34 A8 Level is detrimental to the equipment stored in this rack. The equipment has been reassigned to Category "C".	A	C	Approved 2/21/67
0072	Log Books from Unified S-Band Station: 1. M & O Log 2. Apollo Displays Log 3. Recorders Log 4. GCC Log 5. Tel Track Log 6. Launch Support Log	Used at time of accident and located at station.	None – Obtain copies of pages in use for OCP 0021 then release.	A	C	Approved 2/21/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0073	Mechanic's Tool Box (SEHORN)	None known. Located on South side of Level A-7, Pad 34	Inspect and record contents	A	C	Approved 2/22/67
0074	Seven hard hats	None Located on East side of Level A-7, Pad 34	None	A	C	Approved 2/22/67
0075	50 Volt DC Power Supply	Was to have been used during 0021 test to hold ECS coolant valves open after flyaway umbilical release. Located on East side of Level A-7, Pad 34.	Perform functional check. Have electrical systems engineers determine that power supply could not have caused the problem.	A	C	Approved 2/22/67
0076	Mechanic's Tool Bag	None known. Located on East side of Level A-7, Pad 34.	Inspect and record contents.	A	C	Approved 2/22/67
0077	Three Gas Masks	On hand for emergency use. Located on Northeast side of Level A-7, Pad 34.	Inspect and evaluate functionally by Norris Gray, KSC – Return to stock	A	C	Approved 2/22/67
0078	SSMT OCP Book	In use by technician on Northeast side of Level A-7, Pad 34.	Turn whole book to Panel 6.	A	A	Approved 2/22/67
0079	Mechanic's Tool Box (Williams)	None known. Located on Southwest side of Level A-6, Pad 34.	Inspect and record contents	A	C	Approved 2/22/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0080	Two Hard Hats	No relation Located on South side of Level A-6, Pad 34.	None	A	C	Approved 2/22/67
0081	Mechanic's Tool Box (Fairman)	None known. Located on West side of Level A-6, Pad 34.	Inspect and record contents.	A	C	Approved 2/22/67
0082	Volt ohm-milliammeter	None – not connected. Located on West side of Level A-6, Pad 34.	None	A	C	Approved 2/22/67
0083	Vacuum Pump and Bell Jar	No relation – used to mix potting compounds. Located on North side of Level A-6, Pad 34.	None	A	C	Approved 2/22/67
0084	SSMT OCP Book	In use by technician on Southwest side of Level A-6, Pad 34	Turn whole book to Panel 6	A	C	Approved 2/22/67
0085	Special Clothing for entering the White Room	No relation. Located on Southwest side of Level A-6, Pad 34. Probably not in use at time of accident.	Inspect, document any unexpected conditions – release if none found.	A	C	Approved 2/22/67
0086	Five battery-operated lanterns.	No relation. Used after fire started.	None - units functioned properly.	A	C	Approved 2/22/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0087	Land Line 1TV185 1TV176 1TV186 1TV177 1TV187 1TV178 1TV184 1TV077 1TV190 1TV188 1TV191 1TV189 2DAC-004 thru 2DAC-015 2DAC-229 2DAC-230	From LC34 to MSOB ACE S/C Rm. 3436	Lines required to support other testing.	A	C	Approved 2/22/67
0088	Z-00692 J Fluke Diff. VM. 803B S/N L57873	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0089	Z-00697 HP Audio Osc. 201C S/N L41167	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0090	Z-01173 HP Audio Osc. 201C S/N L43852	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0091	Z-01346 HP Pwr. Sup. 4301A S/N L63518	On standby in S.E. trailers	None	A	C	Approved 2/22/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0092	Z-00341 Tektronic Sq. Wave Gen. 105	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0093	Z-00932 Brush Recorder RD2522 S/N L41025	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0094	Z-00364 Tek. Plug In H S/N L54895	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0095	Z-00980 Tek. Plug In 1A1 S/N L45419	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0096	Z-00765 Simpson VOM 270	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0097	Z-00762 Simpson VOM 270	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0098	Z-00350 Simpson VOM 270 S/N L41120	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0099	Z-00759 Simpson VOM 270	On standby in S.E. trailers	None	A	C	Approved 2/22/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0100	Z-00758 Simpson VOM 270	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0101	Z-00728 Simpson VOM 270	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0102	Z-00178 Simpson VOM 270 S/N L41118	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0103	Z-00175 Simpson VOM 270 S/N L41114	On standby in S.E. trailers	None	A	C	Approved 2/22/67
0104	All spacecraft spare bulk items located in D/810, Material and Supply Support, Warehouse.	Impounded to support the investigation. These components were in storage at the time of, or procured since the accident and will be used to support S/C 017 operations, as required.				Approved 2/23/67
0105	S14-121-9 Water/Glycol Refrigeration Unit G14-845000	Utilized on S/C 012 during OCP 0006 & 0021. Located at Base of Tower Task #3 Item.	Required for LC-39 Site Activation. Required 2/24/67.	A	C	Approved 2/23/67
0106	S14-019R-8 Water/Glycol Service Set ME901-0092-0002	Utilized on S/C 012 during OCP 0006 & 0021. Located at Base of Tower Task #3 Item.	Required for LC-39 Site Activation. Required 2/24/67.	A	C	Approved 2/23/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0107	Pyrotechnics initiator substitute unit. G16-820402 A14-139-65 A14-139-66 A14-139-67 A14-139-68 A14-139-69 A14-139-70 A14-139-71 A14-139-72 A14-139-73 A14-139-74 A14-139-75 A14-139-76 A14-139-77 A14-139-78	Used during "Plugs In". Disconnected, but remained in area during "Plugs Out" Level A7 & A8.	1. Necessary to support S/C 017 testing. 2. Required by 3/1/67.	A	C	Approved 2/23/67
0108	A14-275-1 RCS Quad Simulator	Used during "Plugs In." Disconnected, but remained in area A7 during "Plugs Out".	Necessary to support S/C 017 testing. Required by 3/7/67	A	C	Approved 2/23/67
0109	C14-480-5 Initiators Stimuli Unit G16-850650	Used during "Plugs In." Disconnected, but remained in area A8 during "Plugs Out."	Necessary to support S/C 017 testing. Required by 3/1/67.	A	C	Approved 2/23/67
0110	C14-451-5 Earth Landing System Sequence Controller Pressure Stimuli Generator. G14-854726	Was powered up during "Plugs In" & "Plugs Out," but not utilized. Located at Level A8.	Necessary to support S/C 017 testing. Required by 3/7/67.	A	C	Approved 2/23/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0111	3 ea. GSE Physio Simulators – P/N SCB 105007 PIRR – 244	Not used during 0021 Located in suitcase on Southeast side of Level 8A, Pad 34.	None 1 ea. has been sent to MSOB per TPS S/C 012 MA 014. 2 ea. presently located in PIB.	A	C	Approved 2/23/67
0112	3 ea. GSE Physio Simulator Adapter Cables – P/N 105018-A PIRR – 244	Not used during 0021. Located in suitcase on Southeast side of 8A Level, Pad 34.	None	A	C	Approved 2/23/67
0113	Empty. 2 ea. Suitcases (Color Charcoal) PIRR – 244	Used only to transport equipment to Pad. One located on Southeast side of 8A Level, Pad 34.	None	A	C	Approved 2/23/67
0114	1 ea. DSEA Recorder GSE Check Out Fixture with Storage Box S/N 104 PIRR – 249	Used to transport DSEA Recorder to Pad. Located on Southwest side of Level 8A, Pad 34.	None	A	C	Approved 2/23/67
0115	T. V. Camera Box Log #178 PIRR #322 (Empty)	LOC: Cabinet A8-1 Camera Onboard S/C	None	A	C	Approved 2/23/67
0116	Support Bracket P/N DTT 101161-13 Log #185 PIRR #329	LOC: Cabinet A8-1 GSE – Not Installed	None	A	C	Approved 2/23/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0117	S/C Window Cover (2 each) P/N MK394-10061-021 Log #191 PIRR #331	LOC: Cabinet A8-1 GSE – Not Installed	None	A	C	Approved 2/23/67
0118	Window Cover GSE 3 each MK 394-1001-032 MK 394-10061-31 MK 394-10061-017 Log #246, 247, 248 PIRR #380,381,382	A-8 in Cabinet Not Installed During Test	None	A	C	Approved 2/23/67
0119	Oscilloscope TechTronic 555 S/N 008004 with Scope Camera C-13 SN 006452, and Type L Plug-In Unit S/N 016499 Log #122 PIRR #255	LOC: Level A8 +Z –Y Used OCP 0005	None	A	C	Approved 2/23/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0120	Power Supply S/N 4020 Log #125 PIRR #255	LOC: LEVEL A-8 +Z+Y AXIS Was a stand by unit	None	A	C	Approved 2/23/67
0121	Box of Body Shrouds Log #226 PIRR #343 (Plastic Bags) Not used by medical people	LOC: Removed from Level A-8 in front of C-14-451	None	A	C	Approved 2/23/67
0122	Box – RCS Nozzle Plugs w/flow sensor Log #218 PIRR #323	LOC: Cabinet A8-1 GSE Not Installed	None	A	C	Approved 2/23/67
0123	Launch Complex 34 – All areas below adjustable Level 5, not to include spacecraft GSE.	As Noted	Walk down of all levels involved.	A	C	Approved 2/24/67
0124	Tool Bag (Mechanics)	N.W. corner of tower Level A-7 (Relevance to Accident – NONE)	Inspect contents, record each item in inventory form, and release to owner.	A	C	Approved 2/24/67
0125	C14-385-3 Test Set ACE	Used to check out C14-231 per IDR-026 during OCP-K-0006	Unit has been released for use at VAB per Investigation TPS GC 385-3-004	A	C	Approved 2/24/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0126	One (1) Belt Type Tool Kit with the following tools: (Personal – Givens) A. Screw Driver – 8 in. Common B. Screw Driver – 14 in. Common (2 each) C. Pair of Side Cutters D. Pair of Water Pump Plyers E. 8 in. Crescent Wrench F. Screw Driver – 6 in. Reed & Fringe G. Open End-Box wrench H. Small roll of black plastic tape	LOC: On 220' Level during the accident, now in the PIB.	None	A	C	Approved 2/28/67
0127	Pressure Test Stand Z00-025-401 FF001 FF0803	Utilized during 0021 in LC 34 White Room (Used to reduce the pressure between the K bottle and S/M entrance) not located in white room – located in S.E. corner of 8A level of service structure.)	None Has been sampled per TPS-013. TPS complete and no unusual amount of contaminants were found. Analysis has been in the hands of Panel 16 for several days.	A	C	Approved 3/1/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0128	The entire voice Operational Intercomm System (OIS) used for the AS-204 Plugs Out Test, except the following items not to be released. 1. Launch Complex 34 OIS 2. Launch Complex "CAST" Panel 3. Umbilical Communications Link	The Operational Intercomm System (OIS) has been thoroughly documented by the Voice Communications Group of Panel 9 as to configuration (submitted to Panel 1), performance, and tests simulating the "plugs-out" configuration. These circuits are urgently needed to support other areas and to proceed with modifications to Launch Complex 39 communications.	None	A	C	Approved 3/1/67
0129	S14-099-3 Protective Pressure Unit G14-848540	Utilized to Maintain Pressure on SPS Tanks. S/M Required for S/M 012 Investigation Effort.	None	A	C	Approved 3/1/67
0130	(1) ea. mirror personal (L. D. Reece)	Log Card 225 LC-34 White Room	None	A	C	Approved 3-1-67
0131	(1) length of 12 gage (approx.) 18 ft.	Log Card 225 LC-34 White Room	None	A	C	Approved 3-1-67
0132	(1) length of single strand wire (no ID) white approx. 100 ft.	Log Card 225 LC-34 White Room	None	A	C	Approved 3-1-67
0133	Transfer Van	Used to transport astronauts from MSOB to LC-34	None	A	C	Approved 3-1-67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0134	ACE - S/C Computer Room (MSOB, 4452)	Ground Station used to conduct OCP-0021, but specific configuration documented and submitted to 204 Review Board.	Required to provide latitude in present testing schedules.	A	C	Approved 3-1-67
0135	ACE - S/C Control Room (MSOB, 3446)	Ground Station used to conduct OCP-0021, but specific configuration documented and submitted to 204 Review Board.	Required to provide latitude in present testing schedules.	A	C	Approved 3-1-67
0136	ACE S/C Signal Distribution Room (MSOB, 3436)	Ground Station used to conduct OCP-0021, but specific configuration documented and submitted to 204 Review Board.	Required to provide latitude in present testing schedules.	A	C	Approved 3-1-67
0137	Spares for Ground Support Equipment A14-011 S14-120 S14-088 S14-041 A14-019	None Location: These components were in storage at the time of, or procured since, the accident and are required as replacements for failed items on GSE used to continue operations in support AS 501, 502, & 206.	None	A	C	Approved 3-1-67
0138	ME435-0013-0035 V16-714385-11 S/N 0014 Data Storage Eqpt. Tape Recorder – DSE	None Item utilized as spare. Did not see S/C 012. Required to support S/C 017.		A	C	Approved 3-2-67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0139	ME435-0026-0002 V16-714394 Flt. #8 S/N Flight Qual. Tape Recorder FQ T/R	None Item utilized as spare. Did not see S/C 012. Required to support S/C 017		A	C	Approved 3/2/67
0140	SPS Nozzle Extension	The constraints listed have been satisfied and no discrepancies were noted.	(1) Inspection (2) Nozzle removed (3) Cover Nozzle	A	C	Approved 3/2/67
0141	1 Tube DuPont PR-240 AC Lube	In Storage Cabinet on Level A-6	Identify Sample and Release upon Approval of Panel #18.	A	C	Approved 3/2/67
0142	Spacecraft LEM Adapter (SLA)	No discrepancies were noted in satisfying any of the constraints listed.	1. SM/SLA demate 2. Electrical Ringout 3. Inspection	A	C	Approved 3/4/67
	PYROS	None	None	A	C	Approved 3/4/67
0143	Gemini Suit Check-out Console P/N SE-AE-000504 S/N S-15638	None Location: Suiting White Rooms	1. Communication Checkout 2. Calibration Checkout	A	C	Approved 3/4/67
0144	Gemini Suit Check-out Console P/N SE-AE-000504 S/N S-15639	None Location: Suit White Rooms	1. Communication Checkout 2. Calibration Checkout	A	C	Approved 3/4/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0145	Spacecraft Parts Trailer containing parts for open TPS's & DR's on S/C 012	Located at LC-34-Parts in trailer were not installed on S/C 012		A	C	Approved 3/6/67
0146	Tool Box (Wingfield)	None. Located lev. A-6 LC-34	Inventory and record contents	A	C	Approved 3/4/67
0147	C14-599-1 Radio Frequency Switching Console G16-850130 Connects one of three identical transmission lines from the S/C to the radio frequency system c/o unit.	This unit currently assigned Cat. 3. Utilized during 0021. Located MSOB Seq. Lab. Room 3412. Required to support S/C 017 operations.	None	A	C	Approved 3/6/67
0148	Release LC 34 to Operational Status		TPS LC 34-577 (Investigation) removes remaining items of concern from LC 34 to PIB. Upon completion of this removal, release LC 34 to operational status.	A	C	Approved 3/6/67
	X00-040-1 FF 0710 SK818-0608 TM Breadboard Assy.	Utilized on S/C 012 during OCP 0006 or OCP 0021. Cat. III LC 34 Required to Support S/C 017.		A	C	

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
	C14-472-1 G16-85305 Provides the necessary cabling to interconnect the S/C under test, the associated GSE and the facility services at Launch Complex 34.	Utilized during OCP 0006 & OCP 0021 Located at LC 34 Required by Quality Control personnel to document existing discrepancies at Launch Complex 34.		A	C	
0149	Q-Ball Part #50M12580 Serial #7	None Loc: Top of Launch Escape System	None	A	C	Approved 3/7/67
0150	A14-056-5 ME127-0007-0002 S/M Propulsion Eng. Gimbal Locking Links	None Install per OCP 0006 Installed on Service Module MSOB Required to Support S/C 012 Operation		A	C	Approved 3/7/67
0151	Spacecraft Spares Pitch Electronic Control Assy. ME901-0166-0324 S/N 10028 DAE 1020	None Units were in warehouse stock during accident. These units to be returned to vendor for mod, to be used on S/C 017		A	C	Approved 3/9/67
0152	Roll Electronic Control Assy. ME901-0167-0334 S/N 10028 EAG 1014	None Units were in warehouse stock during accident. These units to be returned to vendor for mod. To be used on S/C 017.		A	C	Approved 3/9/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0153	S/C Tool Box (Gray)	Located on Lev. A-8 Contained special tools for working on the S/C. Now in PIB	Inventory & record contents.	A	C	Approved 3/9/67
0154	S/C Tool Box (Red)	Located on Lev. A-8 Contained special tools for working on the S/C. Now in PIB	Inventory & record contents.	A	C	Approved 3/9/67
0155	Tool Kit NASA Suit Tech. A. Rochford	In the transfer van and not used.	Inventory	A	C	Approved 3/10/67
0156	Tool Kit NASA Suit Tech. W. Salyer	In the transfer van and not used.	Inventory	A	C	Approved 3/10/67
	Batteries from Spacecraft 011 (4)	These batteries were in the deep freeze in the battery shop at the time of the incident.				
0157	4090-11A S/N 0886A		None	A	C	Approved 3/13/67
0158	4090-11A S/N 0887A		None	A	C	Approved 3/13/67
0159	4095-3A S/N 0906A		None	A	C	Approved 3/13/67
0160	4095-3A S/N 0910A		None	A	C	Approved 3/13/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
	YOO-057-1 FF 1459 DTT-101137 Cable hook-up for X99-025	Utilized on S/C 012 during OCP 0006 or OCP 0021. Cat. III LC 34 Required to Support S/C 017		A	C	
	YOO-057-2 FF 1461 DTT-101137 Cable hook-up for XOO-025	Utilized on S/C 012 during OCP 0006 or OCP 0021. Cat. III LC 34 Required to Support S/C 017		A	C	
	YOO-057-3 FF 1462 DTT-101137 Cable hook-up for XOO-025	Utilized on S/C 012 during OCP 0006 or OCP 0021. Cat. III LC 34 Required to Support S/C 017		A	C	
	XOO-004-1 FF 0770 TE 270 EPS Battery Control Box	Utilized on S/C 012 during OCP 0006 or 0021. Cat. III LC 34 Required to Support S/C 017		A	C	
	XOO-025-1 FF 0707 DTT-101133 TE 396 Battery Substitute Unit	Utilized on S/C 012 during OCP 0006 or 0021. Cat. III LC 34 Required to Support S/C 017		A	C	
	YOO-085 FF 001 TE 490 EPS Cable Assy.	Cat. III was utilized during OCP 0006 or 0021 LC 34 Required to Support S/C 017 Operations.		A	C	

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0161	Service Module Gen Assy V17-000002-131	No discrepancies were noted in satisfying any of the constraints listed.	1) Board approval of Panel 21 Final Report of 204 Review Board. 2) No additional testing in support of CM investigation	A	C	Approved 3/14/67
0162	Rate Gyro Assembly P/N ME-493-0005-0314 S/N 10028EAB1015	These items were stored in the warehouse or procured since. Were not installed on S/C 012. Required to support S/C 017 operation.	None	A	C	Approved 3/17/67
0163	Attitude Gyro/Accelerometer Assembly P/N ME-493-0006-0314 S/N 10028EAC1018					Approved 3/17/67
0164	Auxiliary Electronic Control Assembly P/N ME-901-0169-0314 S/N 01128EAH1017					Approved 3/17/67
0165	Displays Electronic Control Assembly P/N MF-901-0170-0334 S/N 10028DAD1019					Approved 3/17/67
0166	Gimbal Position/ Attitude Set Indicator P/N ME-432-0056-0304 S/N 10028EAJ1021					Approved 3/17/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0167	A14-019 Umb. Disconnect	Connected to S/C	None	A	C	Approved 3/20/67
0168	S14-112 Scupper Set	Connected to S/C	None	A	C	Approved 3/20/67
0169	G17-828107-41 S/N 8 S/M Radiator Protective Cover Log 695	None. Sent to PIB	None	A	C	Approved 3/20/67
0170	2 ea. LCQ-2 Lights Log 369	Used to Work in C/M after the Accident.	None	A	C	Approved 3/20/67
0171	Nylon Sling S/N 002 LEM Handling Log 404	Borrowed to Transport C/M to PIB	None	A	C	Approved 3/20/67
0172	Hatch Closeout Tool Kit. Log 86	In White Rm. Used to Close Hatches	None	A	C	Approved 3/20/67
0173	Fiber Glass Container. (Contains V16-601356-21 Cable S/N AAG014 and CWG Helmet S/N 103) Log 92	On Tower Level	None	A	C	Approved 3/20/67
0174	Z-00924 H/P Counter	Standby Log 216	None	A	C	Approved 3/20/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0175	Z-00368 NJE Pwr. Sup.	Standby Log 215	None	A	C	Approved 3/20/67
0176	Z-00878 Webber Temp. Meter	Thermocoupler Connected to S/M Isolation Valve During Test. Log 381	None	A	C	Approved 3/20/67
0177	Z-00439 Triplet VOM	Standby Log 992	None	A	C	Approved 3/20/67
0178	Z-00683 Simpson VOM	Standby Log 992	None	A	C	Approved 3/20/67
0179	Z-01175 Simpson VOM	Standby Log 992	None	A	C	Approved 3/20/67
0180	Mod. 594 Thermograph Log 87	None. Records temp. & Humidity of C/M During Normal Work. Remove Prior to Hatch Closeout.	Remove any data and turn in to Room 3344 and release item	A	C	Approved 3/20/67
0181	BB8BB144-60G Flex Hose Log 417	None	None	A	C	Approved 3/20/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0182	Adapter Duct Part of A14-037 Log 380	Used to Furnish Air to C/M Prior to Closeout.	None	A	C	Approved 3/20/67
0183	5 ea. 800328-1-1 Suit Ventilators Log 260-262-263 264-265	Not Used	Previously sampled	A	C	Approved 3/20/67
0184	3 ea. Head Rest Pads Log 152	None. On Tower Level.	None	A	C	Approved 3/20/67
0185	G16-824415 Hatch Prot. Seal. S/N LAY0116 Log 416	None. Used to Protect Hatch Edges During Normal Work	None	A	C	Approved 3/20/67
0186	Velostat Covered Pads Log 146	Used as Protective Pads in C/M During Normal Work	None	A	C	Approved 3/20/67
0187	G02 K-Bottle S/N AF8837 Log 725	On Level 8	Sample and turn in results to Panel 4	A	C	Approved 3/20/67
0188	G02 K-Bottle S/N TH1833 Log 231	On Level 8 Sampled per TPS S/C 012-S/C 013	Sample and turn in results to Panel 4	A	C	Approved 3/20/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0189	G02 K-Bottle S/N 199699 & Reg. S/N 661. Log 412	On Lev. 8	Sample and turn in results to Panel 4	A	C	Approved 3/20/67
0190	G02 K-Bottle S/N EL 17652 Log 415	On Lev. 8	Sample and turn in results to Panel 4	A	C	Approved 3/20/67
0191	2 ea. GN2 K-Bottles 1 with Reg. Log 137 and 253	On Lev. 8	Sample and turn in results to Panel 4	A	C	Approved 3/20/67
0192	2 ea. GHE K-Bottles Log 138 and 271	On Lev. 8	Sample and turn in results to Panel 4	A	C	Approved 3/20/67
0193	Engine Pneumatic Actuation Package S/N XX0057, P/N 1119600-149	None. In Apollo Warehouse. Required per TPS S/S 320.		A	C	Approved 3/20/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0194	Velostat Covered Board Log 140	None. Level 8 of Tower		A	C	Approved 3/22/67
0195	Scott Air Pack Log 106	None. Used after accident.		A	C	Approved 3/22/67
0196	Sample Bottle Log 832	None. On Tower at Time of accident.		A	C	Approved 3/22/67
0197	Box Asst'd. Items Log 992	Collected off Tower. Inventoried per TPS PI-047		A	C	Approved 3/22/67
0198	1902431-031 PSAAM Log 207	Removed from C/M Prior to Hatch Close Out.		A	C	Approved 3/22/67
0199	Trash Can Log 672	On Umb. Tower. Contents Checked by Dr. Carhart.		A	C	Approved 3/22/67

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0200	Crew Couches from S/C 014 (3 ea.)	None	None	A	C	

Following is a listing of part numbers and quantities of equipment requested for release and subsequent shipment to: Link Group, GPI
1740A NASA Blvd.
Houston, Texas, 77058
Attn: Mr. Wayne Shotwell

	P/N	Quantity	Description			
1.	V16-531501	1	Crew couch installation complete (Perspective)	A	C	
2.	V16-601472-11	2	Pads, Back	A	C	
3.	V16-601472-81	1	Pad, back	A	C	
4.	V16-601472-92	1	RH Pad, hip and thigh	A	C	
5.	V16-601472-71	1	Center pad, hip and thigh	A	C	
6.	V16-601472-111	1	Center pad, hip and thigh	A	C	
7.	V16-601472-101	2	Pad, hip and thigh	A	C	
8.	V16-601472-91	1	LH Pad, hip and thigh	A	C	
9.	V16-601472-41	4	Pads, control arm	A	C	
10.	V16-601472-61	3	Pads, control arm	A	C	

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
	P/N	Quantity	Description			
0200	11. V16-601472-131	12	Pads, head rests	A	C	
	12. V16-601472-121	3	Pads, head rests	A	C	
	13. V16-601495	2	Cover	A	C	
	14. V16-601494	1	Cover, upper protective	A	C	
	15. V16-601496-1	1	LH cover, side protective	A	C	
	16. V16-601496-2	1	RH cover, side protective	A	C	
	17. V16-571314-31	2	Struts, Z-Z axis	A	C	
	18. V16-571412-41	1	RH Struts, X-X axis (head)	A	C	
	19. V16-571412-51	1	LH Struts, X-X axis (head)	A	C	
	20. V16-571411-41	2	Struts, X-X axis (foot)	A	C	
	21. ME 901-0257-0002			A	C	
	22. ME 901-0257-0004		Harness assembly restraint, Crewman (Spec. control part)	A	C	
	23. ME 901-0257-0006					

APOLLO 204 REVIEW BOARD MATERIAL RELEASE RECORD

ITEM NO.	DESCRIPTION	RELEVANCE TO ACCIDENT (INCLUDE LOCATION)	CONSTRAINT PRIOR TO RELEASE	CURR. CATEGORY	DESIR. CATEGORY	BOARD ACTION
0201	Trash, being held per MRR 0047 and 0050.	Fire panel and interested parties have checked thru the residue and find nothing relevant to the accident.		A	C	Approved 3/28/67
0202	Clean RM clothing Ref. MRR 0031	All items are dirty from normal use.		A	C	Approved 3/28/67
0203	P/N ME478-0027-0003 S/N 013100050016 "C" Band Transponder	Spacecraft Spare - was in warehouse at time of accident. Part to be returned to vendor and modified Ref. MCR A1943 Req. to support S/C 017.	None	A	C	

Revised: February 10, 1967

February 7, 1967

TO: Those Concerned

FROM: S. Beddingfield, KSC
J. M. Moore, NAA/FF

SUBJECT: Removal of Equipment and Facilities from Impounded Status

In accordance with the Accident Investigation Board's direction, the equipment and facilities noted herein may be released from Impounded Status in accordance with the procedures defined in this letter.

When the specified procedures for release from impoundment have been executed, a copy of the configuration records, where applicable, will be forwarded to Data Records for impoundment.

Each NAA and NASA-KSC supervisor of applicable equipment or areas involved will maintain the status of equipment or facilities released from impoundment and will be accountable to the Board for the proper and accurate execution for this plan.

This direction applies:

PLAN OF ACTION

PURPOSE: To delineate and delegate specific tasks to departments of NAA to accomplish compliance with, and completion of, certain conditions set forth in a letter from Prime Investigation Board governing the release from impound of selected groups of material and GSE/STE connected with Spacecraft 012.

LOGIC: Sequentially numbered, 1 through 15, under the heading "TASK", is a verbatim statement of the task as spelled out by the Prime Investigation Board.

Directly following the statement of task, under the heading "LOGIC", and numbered in steps, 1.1, etc., will be found specific instructions to individual departments within NAA.

Text follows:

I. TASK.

All GSE/STE and facility equipment on Launch Complex 34 which was not utilized for checkout or servicing of Spacecraft 012 will be released immediately.

LOGIC.

D/818 will provide to D/816 a list of above equipment signed by J. M. Moore. No TPS will be required.

II. TASK.

All GSE/STE and facility equipment on Launch Complex 34 utilized prior to Plugs In and removed prior to Plugs In, but which is still in the Complex area, shall be statused in terms of configuration, copies made and retained in Room 3344, and then released for further use.

LOGIC.

2.1 D/818 will provide a list of all GSE/STE and facility equipment utilized on Launch Complex 34 prior to Plugs In and removed prior to Plugs In.

2.2 Configuration of the end item will be referenced to the exact configuration at the time of the incident. Copies of TPS's, DR's, and DRS's in the TAIR Book will be reproduced and stapled together with a cover sheet. The cover sheet will specify open work items at time of S/C 012 incident. This package will be placed in a special folder in the Acceptance Data Package.

2.3 Any deviations will require the initiation of a DR indicating discrepancies in detail.

2.4 D/816 will provide inspection coverage as required to verify all efforts involved in the above noted tasks.

III. TASK.

All GSE/STE and facility equipment on Launch Complex 34 utilized during Plugs In or later will require Board approval for release.

LOGIC.

3.1 All GSE/STE and facility equipment on Launch Complex 34 utilized during Plugs In or later will require an official letter from the Prime Investigation Board approving the release of all, or any part of, subject equipment. No TPS will be required.

3.2 Configuration will be established in accordance with the provisions outlined in paragraph 2.2 above.

IV. TASK.

All GSE/STE and facility equipment on Launch Complex 34 utilized in build-up prior to arrival at Launch Complex 34 of Spacecraft 012 shall be released immediately.

LOGIC.

4.1 D/818 shall submit a list to D/816, with copies to those concerned, indicating all GSE/STE and facility equipment indicated in Task IV above.

4.2 Upon receipt and approval by D/816 of items called out in said list, such items will immediately be released for use.

V. TASK.

All GSE/STE and facility equipment outside of Launch Complex 34 utilized prior to arrival at Launch Complex 34 of Spacecraft 012 shall be checked for configuration status, per paragraph 2.2 above, and the fluids sampled for future records. These records will be impounded in Room 3344. Equipment may then be released.

LOGIC.

5.1 Task V. above requires the establishment of a configuration status, per paragraph 2.2 above.

5.2 D/819, under the surveillance of NAA and NASA QC, will take three fluid samples from each of the above noted items of GSE/STE and facility equipment which contain fluids. A Support Request will be initiated to obtain laboratory reports and such reports will be filed in the pertinent TAIR Book with a copy of said report impounded in Room 3344, MSOB. The following statement will be on the Support Request: "NAA and NASA Inspection Coverage Mandatory." Equipment may then be released.

VI. TASK.

All BME Equipment outside of Launch Complex 34 utilized on Spacecraft 012 hardware prior to completion of chamber run will be released for use. (Suit BME will remain under Board cognizance.)

LOGIC.

6.1 D/818 will prepare and submit a list to D/816 of all BME Equipment outside of Launch Complex 34 utilized on Spacecraft 012 hardware prior to the completion of the chamber run.

6.2 All Suit BME will be separately identified.

6.3 Upon verification of the list by D/816, all BME Equipment except that listed in paragraph 6.2 above will be immediately released.

6.4 All Suit BME (listed in paragraph 6.2 above) will not be released without written Board approval.

6.5 Above lists will identify equipment by model and serial number.

VII. TASK.

Spacecraft spares which were utilized in Spacecraft 012 shall stay impounded.

LOGIC.

7.1 D/816 will affix M59-B Withholding Tags to all spacecraft spares which were utilized in Spacecraft 012 and such spares will be impounded under the cognizance of D/816, and will not be released without written Board approval.

VIII. TASK.

Spacecraft spares which did not see Spacecraft 012 shall be dispositioned as follows:

8.1 Items of large quantity production (more than 50) - impound three of each lot and release the balance.

8.2 Small production items (less than 50) - impound one of each lot and release the balance.

LOGIC.

8.1 Release of all impounded items will be accomplished by written approval of the Board.

IX. TASK.

All GSE spares shall be released, except those utilized to service oxygen and water glycol.

LOGIC.

9.1 D/818 and D/810 will identify all GSE spares utilized to service oxygen and water glycol and will present a list of such items to D/816.

9.2 D/816 will affix an M59-B tag to such items and such items will be impounded in the NAA Warehouse, Building M7-505/KSC.

9.3 All GSE spares not included on list noted in paragraph 9.1 above will be released immediately.

X. TASK.

All non-flight hardware (non-GSE) not utilized after chamber test, will be released except for the communication equipment which will be controlled by the Board.

LOGIC.

10.1 D/818, together with D/810, will submit a list to D/816 identifying all non-flight hardware (non-GSE) not utilized after chamber test.

(NASA-TM-84138) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX G, PART 1 (National Aeronautics and Space Administration) 60 p

N82-72458

Unclas
00/12 13934

REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-TM-X-72183) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX G, PART 1 (NASA) 60 p

X75-70639

Unclas
00/98 05659

APPENDIX G

PART 1

RECEIVED
NASA STI FACILITY
ACCESS DEPT.

APOLLO SPACECRAFT

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. [illegible] of the consumables used in the mission are stored in the S/M. [illegible] is a truncated cone which connects the S/M to the launch [illegible] also provides the space wherein the lunar module (L/M) is [illegible] missions.

TEST [illegible] PROGRESS AT TIME OF ACCIDENT

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

TESTS AND ANALYSES

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

CONVERSION OF TIME

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 G[illegible] converted is 6:31 p.m. EST.

For sale by the Sup[illegible] of Documents, U.S. Government Printing Office
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E R R A T A S H E E T

Report of
Apollo 204
Review Board
Sheet 1 of 2
Summary

1. Page 1-12, third line, Bureau of Mines.

2. Page 3-9, 9th paragraph, read "numerous" for "numorous."

3. Page 3-10, second paragraph, period at end of final sentence.

4. Page 3-14, January 31, 1967, paragraph 3, line 5, read "made of these potential."

5. Page 3-20, February 10, 1967, paragraph (3), line should read, "The Chairman emphasized to the Board Members who are Panel Monitors that copies of all Panel reports should be forwarded to the Integration Analysis Panel (#18) for coordination and integration."

6. Page 3-26, second paragraph, final line, read "Panel Coordination Committee."

7. Page 3-26, sixth paragraph 7., read "Following the General Session..."

8. Page 3-27, March 8, 1967, second paragraph, third sentence, read "for oral review..."

9. Page 3-28, March 10, 1967, third paragraph, read "...Fire Propagation Test #3..."

10. Page 3-28, March 10, 1967, fourth paragraph, read "...Barnett of Panel #13..."

11. Page 3-30, third paragraph, 5., read "... Item 0180, which was ..."

12. Page 4-1, 9th line, flush right.

13. Page 4-1, fourth paragraph, seventh line, first word, delete "made."

14. Page 4-2, sixth line, delete word "After."

15. Page 4-4, sixth line, read "by 23:20 GMT (6:20 p.m. EST) all final ..."

16. Page 4-5, 4. EVENTS FROM THE REPORT OF FIRE, etc., fifth paragraph, read "All transmissions of voice and data ..."

17. Page 5-1, second paragraph, third line, read "(2) removal or safetying of all pyrotechnics..."

18. Page 5-1, fourth paragraph, requires indentation.

19. Page 5-2, second line, flush right.

20. Page 5-4, 3. DATA ANALYSES, second paragraph, indent and space the line which reads, "A summary of these results follows."

21. Page 5-5, paragraph (a), third line, flush right.

22. Page 5-5, second to the last line, check left margin, right margin.

23. Page 5-6, first line, check left margin.

24. Page 5-9, paragraph d. MEDICAL ANALYSES, second line, read "environmental concentrations..."

25. Page 5-9, paragraph d. MEDICAL ANALYSES, third line, read "... and pulmonary irritants..."

26. Page 5-10, paragraph c. ELECTRIC ARCS, line 22, read " ... the lithium hydroxide access..."

27. Page 5-11, paragraph d. EFFECT OF COOLANT, etc., fifth line, should read "... mixture is not highly..."

28. Page 5-11, paragraph d. EFFECT OF COOLANT, etc., sixth line, read "hazard" instead of "hazards."

29. Page 5-12, sixth line, should read "... in the use of such a system ..."

30. Page 5-13, V-1, read "... Bay Above Environmental ..."

E R R A T A S H E E T

1. Page A-7, Line 4, delete comma after "concerned"
2. Page A-7, Line 11, "this assembly" should be "disassembly"
3. Page A-7, Line 15, change "alright" to "alright"
4. Page A-7, Line 22, "prefocused" for "pre-focused" and "flourescent" should be "fluorescent"
5. Page A-7, Line 23, "spot" should be "spotlight"
6. Page A-7, Line 28, "find" should be "finding"
7. Page A-7, Line 35, insert "have" after "and"
8. Page A-7, Line 41, second "this" should be "this debris"
9. Page A-8, Line 4, delete "in a building" put period after "floor"
10. Page A-8, Line 12, right, bulkhead should be "bulkhead right"
11. Page A-8, Line 18, "Mr." should be "Dr."
12. Page A-8, Line 21, "24-foot" for "24 foot" also "office" should be "building"
13. Page A-8, Line 22, "24-foot" for "24 foot"
14. Page A-8, Line 23, "300 feet by 100 feet" for "300 ft. by 100 ft."
15. Page A-8, Line 34, delete comma after "parts"
16. Page A-8, Line 37, semicolon after "ourselves"
17. Page A-8, Line 43, where should be "and"
18. Page A-8, Line 44, "two" should be "2"
19. Page A-9, Line 6, "if" should be "is"
20. Page A-9, Line 10, should be "1-1/2 inches"
21. Page A-9, Line 11, "a" should be "the"
22. Page A-9, Line 22, "TPS" should be "Test Preparation Sheet (TPS)"
23. Page A-9, Line 33, "legs, supports" should be "leg supports"
24. Page A-9, Line 34, delete comma after supports
25. Page A-9, Line 40, "criticized" should be "critiqued"
26. Page A-10, Line 7, delete second "Mr. Geer"
27. Page A-10, Line 22, "board" should be "Board"

28. Page A-10, Line 27, "panels" should be "Panels"
29. Page A-10, Line 30, "board" should be "Board"
30. Page A-10, Line 31, "verbal" should be "oral"
31. Page A-10, Line 31, "member" should be "Member"
32. Page A-10, Line 32, "board" should be "Board"
33. Page A-10, Line 35, "board" should be "Board"
34. Page A-11, Line 12, "board" should be "Board"
35. Page A-11, Line 14, "panels" should be "Panels"
36. Page A-11, Line 22, delete comma after "Mr. Williams"
37. Page A-11, Line 24, "panels" should be "Panels"
38. Page A-12, Line 6, "board" should be "Board"
39. Page A-12, Line 10, "board" should be "Board"
40. Page A-12, Line 12, "panel chairman" should be "Panel Chairman"
41. Page A-12, Line 12, "board" should be "Board"
42. Page A-12, Line 13, insert "of" after "statement"
43. Page A-12, Line 14, "panel" should be "Panel"
44. Page A-12, Line 15, "board" should be "Board"
45. Page A-12, Line 24, "board members should be "Board Members"
46. Page A-12, Line 24, "board members" should be "Board Members"
47. Page A-12, Line 26, "board member" should be "Board Member"
48. Page A-12, Line 27, "board members" should be "Board Members"
49. Page A-12, Line 27, "board members" should be "Board Members"
50. Page A-12, Line 29, "board" should be "Board"
51. Page A-12, Line 34, "panel chairmen" should be "Panel Chairmen"
52. Page A-12, Line 36, "board" should be "Panel"
53. Page A-12, Line 36, "panel chairmen" should be "Panel Chairmen"
54. Page A-13, Line 2, "panel members" should be "Panel Members"
55. Page A-13, Line 7, insert comma after "action" and after "privately"

56. Page A-13, Line 8, "board" should be "Board"

57. Page A-13, Line 11, "panel" should be "Panel"

58. Page A-13, Line 13, "#20" should be "#19"

59. Page A-13, Line 17, "board monitor" should be "Panel Monitor"

60. Page A-13, Line 18, "board" should be "Board"

61. Page A-13, Line 18, "panel" should be "Panel"

62. Page A-13, Line 18, "board" should be "Board"

63. Page A-13, Line 19, "members" should be "Members"

64. Page A-13, Second Session, 5th paragraph spoken by Mr. Long.

65. Page A-14, Line 3, "chairman" should be "Chairman"

66. Page A-14, Line 8, delete "we are in the process. We got a lot of material typed. It . . ." add "The material has been typed and . . ."

67. Page A-14, Line 11, delete this line completely.

68. Page A-14, Line 16, "panels" should be "Panels"

69. Page A-14, Line 24, "board" should be "Board"

70. Page A-14, Line 24, change the "to" after board to "if I"

71. Page A-14, Line 28, "board" should be "Board"

72. Page A-14, Line 34, "them" should be "to"

73. Page A-14, Line 35, "board" should be "Board"

74. Page A-15, Line 1, "command" should be "Command"

75. Page A-15, Line 1, insert "and" after Command

76. Page A-15, Line 1, "module should be "Module"

77. Page A-15, Line 4, "interaction" instead of "inter-action"

78. Page A-15, Line 7, "second Quarter of" instead of "2nd quarter of"

79. Page A-15, Line 14, "second Quarter of" instead of "2nd Quarter of"

80. Page A-15, Line 17, "command" should be "Command"

81. Page A-15, Line 17, insert "and" after Command

82. Page A-15, Line 17, modules should be "Modules"

83.

84.

86. Page A-15, Line 23, second "that" should be "the"

87. Page A-15, Line 26, insert comma after spacecraft

88. Page A-15, Line 26, insert comma after 101

89. Page A-15, Line 26, insert comma after Downey

90. Page A-15, Line 27, insert comma after March, delete "and" and make "we" capital

91. Page A-15, Line 28, insert "it" after "that"

92. Page A-15, Line 33, insert comma after "not" and comma after "course"

93. Page A-15, Line 34, delete "and that's to get" and add "to be"

94. Page A-15, Line 34, delete "out of" and add "from"

95. Page A-15, Line 35, insert comma after 502

96. Page A-15, Line 38, "ten" should be "10"

97.

98. Page A-15, Line 44, "command" should be "Command"

99. Page A-15, Line 44, insert "and" after Command

100. Page A-15, Line 44, "service module" should be "Service Module"

101. Page A-15, Line 45, "Houston" should be "MSC"

102.

103. Page A-15, Line 46, "Houston" should be "MSC"

104. Page A-15, Line 47, "chamber" instead of "Chamber" also delete "in the" and insert "for"

105. Page A-15, Line 49, insert comma after "Center" and after "LEM's", take out hyphen and also remove hyphen after "doing" and put period.

106. Page A-15, Line 49, delete "all" and add "for"

107. Page A-15, Line 49, "block" should be "Block"

108.

109. Page A-15, Line 52, "We" instead of "we"

110. Page A-16, Line 2, delete "and"

111. Page A-16, Line 2, delete "in" and add "at"

112. Page A-16, Line 3, delete "Houston" and add "MSC"

113. Page A-16, Line 4, delete 'compensate for' and add "concentrate on"

114. Page A-16, Line 7, delete Houston and add MSC

115. Page A-16, Line 10, delete "on" and add "in"

116. Page A-16, Line 12, "boards" should be "Boards"

117. Page A-16, Line 12, delete staff and add "things"

118. Page A-16, Line 13, "14" should be "014"

119. Page A-16, Line 14, "12" should be "012"

120. Page A-16, Line 14, delete comma after "here" and comma after "program"

121. Page A-16, Line 15, "block one" should be "Block I"

122. Page A-16, Line 17, delete comma after delivered and add a hyphen also make capital "T" in three a small "t"

123. Page A-16, Line 18, "we" should be "We"

124. Page A-16, Line 28, delete comma after "use" and put in "and"

125. Page A-16, Line 18, command module should be "Command Module"

126. Page A-16, Line 19, "command module" should be "Command Module"

127. Page A-16, Line 21, insert 'such' after "in" and make "involving" read "involved"

128. Page A-16, Line 22, "14" should be "014" and "12" should be "012"

129. Page A-16, Line 26, "12" should be "012"

130. Page A-16, Line 27, "14" should be "014" (twice)

131. Page A-16, Line 29, insert comma before "have" also "they" should be "then"

132. Page A-16, Line 30, "14" should be "014"

133. Page A-17, Line 10, "thermo-vacuum" instead of "thermo vacuum"

134. Page A-17, Line 11, "thermo-vacuum" instead of "thermo vacuum" also "14" should be "014" and "in Houston" should be at "MSC"

135. Page A-17, Line 16, "12" should be "012" also "Environmental Control System" should be upper case

136. Page A-17, Line 17, "environmental control system" should be "Environmental Control System"

137. Page A-17, Line 18, "environmental control system" should be "Environmental Control System"

138. Page A-17, Line 18, "Houston" should be "MSC"

139. Page A-17, Line 19, "8" should be "008"

140. Page A-17, Line 24, "8 spacecraft" should be "Spacecraft 008"

141. Page A-17, Line 26, "board" should be "Board"

142. Page A-17, Line 26, "This" should be "There"

143. Page A-17, Line 27, "environmental control system" should be "Environmental Control System"

144. Page A-17, Line 27, delete "which is at Houston" also delete commas

145. Page A-17, Line 28, "nonelectrical" instead of "non-electrical"

146. Page A-17, Line 29, "environmental control system" should be "Environmental Control System"

147. Page A-17, Line 31, "possible" should be "possibly"

148. Page A-17, Line 31, "non-electrical" should be "nonelectrical"

149. Page A-17, Line 32, "Kotawchick" should be "Kotanchik"

150. Page A-17, Line 33, "structures and mechanics division" should be "Structures and Mechanics Division

151. Page A-17, Line 33, Houston should be "MSC"

152. Page A-17, Line 34, "board" should be "Board"

153. Page A-17, Line 35, insert "and" after "combustion"

154. Page A-17, Line 36, delete "G" and add "g"

155. Page A-17, Line 37, delete "G" and add "g"

156. Page A-17, Line 43, delete "G" and add "g"

157. Page A-17, Line 44, delete "G" and add "g"

158. Page A-17, Line 44, delete "G" and add "g"

159. Page A-17, Line 44, should be "16 psi"

160. Page A-17, Line 46, delete "G" and add "g"

161. Page A-18, Line 2, "board" should be "Board"

162. Page A-18, Line 3, "nonflight" instead of "non-flight"; delete "or be sure it is up to date with"; "board" should be "Board"

163. Page A-18, Line 6, delete comma after "temperature" insert "and" next line delete comma after "rates"

164. Page A-18, Line 7, delete comma after "people" insert "and"

165. Page A-18, Line 8, delete comma after "board" also "board" should be "Board"

166. Page A-18, Line 13, "in Houston" should be "at MSC"

167. Page A-18, Line 25, "mult" should be "multi"

168. Page A-18, Line 26, "command module and service module" should be "Command Module and Service Module"

169. Page A-18, Line 26, insert period after Module and capitalize "y" in you.

170. Page A-18, Line 28, "mockup" should be "scale model mockup"

171. Page A-18, Line 29, delete "is"

172. Page A-18, Line 29, insert period after "disassembled"

173. Page A-18, Line 29, capitalize "it's"

174. Page A-18, Line 30, insert comma after spacecraft.

175. Page A-18, Line 30, "But" should be "but"

176. Page A-18, Line 31, "inter" should be "inner"

177. Page A-18, Line 31, insert comma after "is" and comma after "on"

178. Page A-18, Line 32, "service module" should be "Service Module"

179. Page A-18, Line 32, insert comma after module

180. Page A-18, Line 34, "mock-up" instead of "mockup"

181. Page A-18, Line 35, "is" should be "will be"

182. Page A-18, Line 35, delete "sort of"

183. Page A-18, Line 35, last "we" should be "you"

184. Page A-18, Line 36, "using" should be "needing"

185. Page A-18, Line 36, "Houston" should be "MSC" also delete "just - a sort of - it's the big kid's"

186. Page A-18, Line 37, "interstructure" instead of "inter-structure"; delete "except it's valuable"; "earlier" should be "other"

187. Page A-18, Line 38, "in" should be "of"

188. Page A-18, Line 42, "Houston" should be "MSC" also "boiler plate" should be "boilerplate"

261-115 O - 67 - 2

189. Page A-18, Line 48, delete comma after problem.

190. Page A-19, Line 1, "Houston" should be "MSC" also insert "use to" after "finally"

191. Page A-19, Line 3, "Houston" should be "MSC"; delete "now"; delete "let's say the"

192. Page A-19, Line 5, "there is a" should be "to the"

193. Page A-19, Line 8, "rereview" instead of "re-review" also "six and seven" should be "6 or 7"

194. Page A-19, Line 11, insert "and" before "emergency"

195. Page A-19, Line 12, "of when you go into" should be "is needed to explain"

196. Page A-19, Line 14, "PASC" should be "PSAC" also "doing" should be "including"

197. Page A-19, Line 15, delete "'s" on "anybody's"

198. Page A-19, Line 16, delete "that" also "we'll then" should be "then we'll"

199. Page A-19, Line 19, insert "and" after "Engineering" also "Houston" should be "MSC"

200. Page A-19, Line 22, "relook" instead of "re-look"

201. Page A-19, Line 23, delete comma after "that" ; "it's" should be "it"; insert "stems from" after "primarily"

202. Page A-19, Line 24, "denitrogenated" instead of "de-nitrongenated"

203. Page A-19, Line 25, delete comma and insert hyphen after "bends"

204. Page A-19, Line 26, delete comma and insert hyphen after "blood"

205. Page A-19, Line 27, delete comma and insert hyphen after "flight" also insert period after "purged" and capital "T" in "the"

206. Page A-19, Line 34, "psi" for "PSI"

207. Page A-19, Line 37, "this" should be "these"

208. Page A-19, Line 38, delete comma and insert period after "trades" made "w" in "we've" a capital

209. Page A-19, Line 42, "six or seven, eight or ten" should be "6 or 7, 8 or 10"

210. Page A-19, Line 47, "six or eight" should be "6 or 8"

211. Page A-19, Line 47, "rereview" instead of "re-review"

212. Page A-19, Line 51, "redesigning" instead of "re-designing" also "re-examining" should be "reexamining"

213. Page A-19, Line 50, "reexamining" instead of "re-examining"

214. Page A-19, Line 52, "re-designing" should be "redesigning"

215. Page A-19, Line 52, "that" should be "the"

216. Page A-19, Line 53, introducted should be "introduced"

217. Page A-20, Line 1, "of Houston" should be "at MSC"

218. Page A-20, Line 2, delete "in, but the communications actually all during that day, and you've heard some of the tapes and so on, and communications left a fair amount to be desired. We've set up a committee . . ."

219. Page A-20, Line 9, "cleanup" instead of "clean-up"

220. Page A-20, Line 10, "partially" should be "surely"

221. Page A-20, Line 11, insert comma after "were"

222. Page A-20, Line 13, delete comma after "had"

223. Page A-20, Line 28, "- over -" should be "Board" also insert period after "Board"

224. Page A-20, Line 28, capitalize "a" in "at"

225. Page A-20, Line 33, insert period after "here" and delete "I've asked"

226. Page A-20, Line 33, capitalize "t" in "the"

227. Page A-20, Line 33, Houston should be "MSC"

228. Page A-20, Line 40, delete from "Lastly" in Line 40 down to "Board as well." at bottom of page.

229. Page A-21, Line 8, insert comma after decisions

230. Page A-21, Line 9, "Houston" should be "MSC"

231. Page A-21, Line 10, "something" instead of "some thing"

232. Page A-21, Line 19, insert "were" after "you" also insert "and" after "files"

233. Page A-21, Line 20, insert comma after supplied and after files

234. Page A-21, Line 29, "Mr." should be "Dr."

235. Page A-21, Line 34, "that" should be "the"

236. Page A-21, Line 43, delete "we have done this"

237. Page A-22, Line 21, insert period after "LES" and delete "which we do not have"

238. Page A-22, Line 22, delete "the same time of"; insert "order" after "equipment"

239. Page A-22, Line 23, "thing" should be "structure floor"; "it" should be "the LES"

240. Page A-22, Line 27, delete comma after "plan" and insert "and"

241. Page A-22, Line 29, delete comma after "damage"

242. Page A-22, Line 30, insert period after "on" and delete "and we plan two hours for photography"

243. Page A-22, Line 33, "Launch Escape System" instead of "launch escape system"

244. Page A-22, Line 43, delete "I'll ask. I think you want to say something about the work"; make "D" in "did" a small letter; delete "some" and insert "a"

245. Page A-23, Line 10, "subsystem" for "sub-system"

246. Page A-23, Line 11, insert comma after "etc." and make "R" in "Relative" a small letter

247. Page A-23, Line 12, insert comma after GSE and delete comma after data

248. Page A-23, Line 28, under task 15 should be "by Panel 15"

249. Page A-23, Line 33, insert "after" before "further"

250. Page A-23, Line 38, delete "That meeting will be at 12:00"

251. Page A-24, Line 20, "twenty-four" should be "24"

252. Page A-24, Line 34, "two" should be "2"

253. Page A-24, Line 44, "takeoff" for "take off"

254. Page A-24, Line 47, "of" should be "the"

255. Page A-25, Line 12, "two" should be "2"

256. Page A-26, Line 7, insert "to perform gas analysis." after analyzer. Then capital "This gas analyzer ..."

257. Page A-26, Line 24, "setup" for "set-up"

258. Page A-26, Line 24, "setup" instead of "set-up"

259. Page A-26, Line 37, "pad" for "Pad"

260. Page A-27, Line 2, Question mark should be inserted after questions.

261. Page A-28, Line 34, "overview" for "over-view"

262. Page A-29, Line 7, "System" instead of "system"

263. Page A-30, Line 14, insert "can" after "American."

264. Page A-30, Line 26, "checklist" for "check list"

265. Page A-30, Line 35, "checklist" for "check list"

266. Page A-31, Line 7, "set-up" should be "setup"

267. Page A-31, Line 10, "close out" should be "closeout"

268. Page A-31, Line 23, "two or three" should be "2 or 3"

269. Page A-35, Line 4, launch escape system should be "Launch Escape System"

270. Page A-35, Line 5, "three or four" should be "3 or 4"

271. Page A-35, Line 10, some-time should be "sometime"

272. Page A-35, Line 14, "two" should be "2"

273. Page A-35, Line 16, "any way" should be "anyway"

274. Page A-35, Line 20, "non-attached, non-connected" should be "nonattached" "nonconnected"

275. Page A-36, Line 5, "non-flight" should be "nonflight"

276. Page A-36, Line 17, "non-flight" should be "nonflight"

277. Page A-36, Line 22, "item" should be "Item"

278. Page A-39, Line 23, delete periods between F.B.I.

279. Page A-40, Line 12, "close-out" should be "closeout"

280. Page A-40, Line 13, "close-out" should be "closeout"

281. Page A-41, Line 1, change one and one-half to "1-1/2"

282. Page A-41, Line 17, delete apostrophe after "TPS'"

283. Page A-42, Line 5, "follow up" should be "followup"

284. Page A-43, Line 35, "eight hour" should be "8-hour"

285. Page A-43, Line 37, "all right" should be "alright"

286. Page A043, Line 43, "four hours" should be "4-hours"

287. Page A-43, Line 45, "eight hours" should be "8-hours"

288. Page A-46, Line 8, "two" should be "2"

289. Page A-46, Line 1, first sentence should be changed to read "The meeting was called to order by Col. Strang, Acting Chairman, at 11:50 a.m."

290. Page A-46, Line 4, "2000 hours" should be "8:00 p.m."

291. Page A-46, Line 5, "1800 hours" should be "6:00 p.m." Capitalize "panel"

292. Page A-46, Line 6, "1700 hours" should be "5:00 p.m."

293. Page A-46, Line 7, Capitalize "panel"

294. Page A-46, Line 14, Capitalize "panel"

295. Page A-46, Line 26, first sentence should be corrected to read "Mr. Carl Jackson of AiResearch, ..."

296. Page A-46, Line 28, Delete "spacecraft" and insert "C/M" in its place

297. Page A-46, Line 31, insert "Analysis" after "integration"

298. Page A-46, Line 35, Delete "If you" and insert "I" also delete "#"

299. Page A-46, Line 36, Capitalize "medical data acquisition"

300. Page A-46, Line 36, "medical data acquisition system" should be "Medical Data Acquisition System"

301. Page A-46, Line 37, insert comma after system. Delete "removal; we would like to remove it." and insert "be removed from the C/M."

302. Page A-47, Line 3, "pre-removal" and "pre-opening" should be "preremoval" and "preopening"

303. Page A-47, Line 4, Substitute "C/M" for "spacecraft"

304. Page A-47, Line 5, Insert period after equipment. Start new sentence with "There"

305. Page A-47, Line 6, Insert "we" after "and"

306. Page A-47, Line 7, Insert comma after "compartment"

307. Page A047, Line 8, Delete comma after "them"

308. Page A047, Line 9, Capitalize "items"

309. Page A047, Line 11, Delete "available and in the presence of the work: and insert "present during the work" in its place.

310. Page A-47, Line 22, Substitute "C/M" for "spacecraft"

311. Page A-47, Line 24, Substitute "C/M 014" for Spacecraft 14"

312. Page A-47, Line 25, Substitute "C/M 012" for Spacecraft 12. Change "14" to "014"

313. Page A-47, Line 35, Substitute "C/M" for "spacecraft"

314. Page A-47, Line 37, Substitute "C/M" for "spacecraft"

315. Page A-48, Line 1, Substitute "C/M" for "spacecraft"

316. Page A048, Line 4, "quarter to a half" should be "1/4 to 1/2"

317. Page A-48, Line 36, Substitute "C/M 008" for "spacecraft" and "MSC" for "Houston"

318. Page A-48, Line 40, "studies" should be "studied"

319. Page A-48, Line 48, Substitute "MSC" for "Houston"

320. Page A-48, Line 51, Substitute "MSC" for "Houston"

321. Page A-49, Line 1, Substitute "MSC" for "Houston"

322. Page A-49, Line 12, Period should be replaced with question mark

323. Page A-49, Line 21, Capitalize "panel chairman"

324. Page A-49, Line 23, Capitalize "chairman" and "executive session"

325. Page A-49, Line 24, "ten thirty a.m." should be "10:30 a.m."

326. Page A-49, Line 25, Change "6 February 1967" to "February 6, 1967"

327. Page A-49, Line 37 (last line) Change sentence to read "The meeting was adjourned at 12:03 p.m."

328. Page A-50, Line 20, close-out should be "closeout"

329. Page A-51, Line 14, "H2o" should be "H_2O"

330. Page A051, Line 15, "Xray" should be "X-ray"

331. Page A-51, Line 16, "Xray" should be "X-ray"

332. Page A-52, Line 26, "contractors" should be followed by "and subcontractors"

333. Page A-52, Line 29, Capitalize "panel" and delete "#"

334. Page A-52, Line 33, Delete "#"

335. Page A-53, Line 30, Insert comma after "insulation"

336. Page A-53, Line 31, Insert "and" after "rubber" and insert comma after "system"

337. Page A-53, Line 48, "bio-medics" should be "biomedics"

338. Page A-54, Line 26, leave space after "you'll"

339. Page A-54, Line 33, Insert comma after "couch"

340. Page A-54, Line 34, Insert comma after "moved"

341. Page A-54, Line 44, Insert comma after "way"

342. Page A-55, Line 3, "not" should be "now"

343. Page A-53, Line 5, delete comma after "is"

344. Page A-55, Line 13, "area" should be "areas"

345. Page A-55, Line 17, delete ", so" and delete "and"

346. Page A-55, Line 18, Insert period after "couch", begin new sentence with "A"

347. Page A-55, Line 19, delete "so"

348. Page A-55, Line 21, insert comma after "First"

349. Page A-55, Line 30, Substitute "clear" for "to appear"; insert hyphen after "propa"

350. Page A-55, Line 45, Insert "at" after "again"

351. Page A-56, Line 2, insert comma after "suspect"

352. Page A-56, Line 3, insert "a" before "clockwise"

353. Page A-56, Line 6, substitute "one" for "the"

354. Page A-56, Line 12, insert period after "o'clock", start new sentence with "These", substitute "are" for "being"

355. Page A-56, Line 13, Insert period after "say", start new sentence with "We"

356. Page A-56, Line 27, Substitute "break" for "hatch"

357. Page A-56, Line 34, Insert period after "important", start new sentence with "The"

358. Page A-56, Line 42, delete one comma after "fires"

359. Page A-57, Line 4, "thru" should be "through"

360. Page A-57, Line 43, substitute "also" for "another"

361. Page A058, Line 2, insert "and we are" before "just"

362. Page A-58, Line 10, delete "glycol"

363. Page A-58, Line 15, insert "we have" before "aluminum"

364. Page A-58, Line 16, delete "itself"

365. Page A-60, Line 13, capitalize spacecraft

366. Page A-60, Line 15, insert comma after "indicator"

367. Page A-60, Line 19, delete concerning

368. Page A-60, Line 22, insert period after "different", begin new sentence with "We", add word "now" after "We"

369. Page A-60, Line 23, delete "on now"

370. Page A-60, Line 28, insert "unit" after "this"

371. Page A-60, Line 29, Capitalize "spacecraft"

372. Page A-60, Line 30, Capitalize "panel" and insert comma after reference

373. Page A-60, Line 38, Launch vehicle-spacecraft should be changed as

374. Page A-60, Line 40, Capitalize "launch vehicle" and "spacecraft"

375. Page A-61, Line 5, Capitalize "spacecraft"

376. Page A-61, Line 8, Capitalize "service module"

377. Page A-61, Line 16, insert "it" after transport

378. Page A-61, Line 20, Capitalize "command module"

379. Page A-61, Line 24, "rotational" should be rotation. Delete word "hand"

380. Page A-61, Line 25, Delete word "hand"

381. Page A-62, Line 4, Insert comma after "appropriate"

382. Page A-62, Line 13, Put period in place of colon

383. Page A-62, Line 15, insert "he is" after 'which'

384. Page A-62, Line 38, Insert GMT in place of "zebra"

385. Page A-63, Line 5, insert comma after word "call"

386. Page A-63, Line 7, Delete "Zebra (Zebra-Zulu Mean Greenwich Mean Time)" and insert "GMT" in its place.

387. Page A-63, Line 8, Delete "Zebra" and insert "GMT"

388. Page A-63, Line 12, Delete "Zebra" and insert "GMT"

389. Page A-63, Line 21, "fro" should be "for"

390. Page A-63, Line 26, Capitalize "spacecraft"

391. Page A-63, Line 27, Delete "#"

392. Page A-63, Line 39, "people" should be the last word of the sentence.

393. Page A-63, Line 40, Substitute "last" for "other"

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394. Page A-64-1, Line 21, Substitute "committee" for "panel"

395. Page A-64-2, Line 7, Capitalize "spacecraft"

396. Page A-64-2, Line 14, Delete "hand" after rotation and translation

397. Page A-64-2, Line 21, Capitalize "command module" and "service module"

398. Page A-64-2, Line 22, Insert period after "guillotine" delete "and" and start new sentence with "What"

399. Page A-64-2, Line 26, Insert "in" after none

400. Page A-64-2, Line 27, Insert dash after "time"

401. Page A-64-2, Line 29, Capitalize "spacecraft"

402. Page A-64-2, Line 31, Delete "ring" and insert "get" in its place. Capitalize "spacecraft"

403. Page A-64-2, Line 32, Capitalize "spacecraft"

404. Page A-64-2, Line 33, Capitalize "spacecraft"

405. Page A-64-3, Line 1, Capitalize "service module"

406. Page A-64-3, Line 5, Delete "ringing" and insert "testing wiring" in its place. Capitalize "spacecraft"

407. Page A-64-3, Line 10, Capitalize "command-module/service-module"

408. Page A-64-3, Line 14, Capitalize "spacecraft"

409. Page A-64-3, Line 19, Delete "ring out" and insert "test" in its place

410. Page A-64-3, Line 32, Capitalize "spacecraft"

411. Page A-64-3, Line 35, Capitalize "command module"

412. Page A-64-3, Line 36, Capitalize "command module"

413. Page A-64-4, Line 19, Insert "information" after damage

414. Page A-64-4, Line 36, Delete comma and hyphen after "2" and insert semicolon in its place.

415. Page A-64-5, Line 11, Insert period after "time" and start new sentence with "They"

416. Page A-64-5, Line 26, Delete comma and hyphen after it and put semicolon in its place

417. Page A-65, Line 28, delete "on the" and insert "under"

418. Page A-66, Line 12, delete "hand"

419. Page A-66, Line 13, Substitute "was" for "were"

420. Page A-66, Line 17, insert "the" after "of" and delete "hand"

421. Page A-66, Line 21, insert "is" after "0085" and insert hyphens after "pin", "to", and "vehicle"

422. Page A-66, Line 41, Delete "which" and insert period after "Items"

423. Page A-66, Line 42, Delete "and" and put "It" in its place.

424. Page A-66, Line 45, Leave space after "believe"

425. Page A-67, Line 9, "233054" should be "23:30:54 GMT"

426. Page A-67, Line 12, Insert "than" for "that"

427. Page A-68, Line 2, Delete "a photographic"

428. Page A-68, Line 3, Delete "study"

429. Page A-68, Line 9, Insert "On" before "The" and lower case "The"

430. Page A-68, Line 10, "the understanding" is duplicated. Delete one of these.

431. Page A-68, Line 13, Capitalize "yes", insert "we" after "and"

432. Page A-68, Line 17, insert "and" before "a" at the end of the line.

433. Page A-68, Line 18, Capitalize "panels"

434. Page A-68, Line 27, Insert "with" before "Panel", delete "#"

435. Page A-68, Line 28, Delete "#" twice, insert "with" before "Panel"

436. Page A-68, Line 29, Delete "#"

437. Page A-68, Line 30, Substitute "is" for "we". Delete "him", Delete "#", insert period after "9", delete "and"

438. Page A-68, Line 31, insert "with" before "Panel". Delete "#" twice

439. Page A-68, Line 32, Delete "#"

440. Page A-68, Line 38, Delete "#"

441. Page A-69, Line 1, Delete "#"

442. Page A-79, Line 4, delete "the" before "Procedure", delete "#", delete comma after distributed

443. Page A-69, Line 6, delete "the" before three. Insert colon after "categories"

444. Page A-69, Line 7, delete "this" before material. Insert "that" after "material"

445. Page A-69, Line 11, Delete "#"

446. Page A-69, Line 12, Capitalize "spacecraft"

447. Page A-69, Line 36, "hasnt't" should be "hasn't"

448. Page A-69, Line 40, Insert "used" before "during", insert "the" before "reported"

449. Page A-69, Line 12, Capitalize "spacecraft", insert comma after "GSE"

450. Page A-69, Line 42, insert "the" before "total"

451. Page A-70, Line 2, Insert comma after "have"

452. Line 3, Substitute "of" for "a", delete word "an"

453. Page A-70, Line 5, insert "to review" after "afternoon"

454. Page A-71, Line 1, capitalize "panel"

455. Page A-71, Line 2, insert comma after "reports"

456. Page A-71, Line 4, insert comma after "findings"

457. Page A-71, Line 5, Insert "nd" after "22"

458. Page A-71, Line 10, delete parenthesis around 22 and insert "nd" after "22"

459. Page A-71, Line 24, Capitalize "spacecraft"

460. Page A-71, Line 30, Substitute "tests" for "ring-out", capitalize "command", delete one "and" after command, change "service modules umbilicals" to read "Service Module umbilicals"

461. Page A-71, Line 32, Capitalize "spacecraft"

462. Page A-71, Line 37, Insert "at" after "possibly"

463. Page A-72, Line 8, delete "item 113 of", delete "to inspect" after "today" and insert "regarding inspection of" after "today", Capitalize "spacecraft", Capitalize "service"

464. Page A-72, Line 9, Capitalize "module"

465. Page A-72, Line 10, Delete "WILLIAMS", insert "Item 113:" at beginning of sentence. Capitalize "Service Module"

466. Page A-72, Line 12, Insert colon after "Item 114", insert "to" before inspect, delete comma and insert "and" before "will"

467. Page A-72, Line 14, insert colon after "reason", capitalize "spacecraft"

468. Page A-72, Line 17, Insert colon after "Item 116", insert "the" before "spacecraft" and capitalize "spacecraft"

469. Page A-72, Line 18, Insert colon after "reason" and delete "is"

470. Page A-72, Line 21, insert colon after "Item 117"

471. Page A-72, Line 22, insert colon after "reason" and delete "for, insert "that" after "cannister"

472. Page A-72, Line 24, Delete comma and "of" after "out", insert "concerning a" after "out"

473. Page A-72, Line 26, "than" should be "that"

474. Page A-72, Line 27, Capitalize "board"

475. Page A-73, Line 5, Delete "just", insert "I"

476. Page A-73, Line 6, Capitalize "board"

477. Page A-73, Line 7, Capitalize "panels"

478. Page A-73, Line 8, insert comma after "requirements"

479. Page A-73, Line 9, insert comma after "days"

480. Page A-73, Line 10, Insert "the" after "of"

481. Page A-74, Line 5, "PM" should be lower case.

482. Page A-74, Line 10, delete "00"

483. Page A-74, Line 11, delete first word of line, "items"

484. Page A-74, Line 17, Capitalize "spacecraft", insert period after "slowly", begin new sentence with "We"

485. Page A-74, Line 18, delete "to"

486. Page A-74, Line 22, "check" should be "checks", "and" should be "on"

487. Page A-74, Line 23, Capitalize "spacecraft" and "service module"

488. Page A-74, Line 24, Begin line with "Regarding", lower case "The", Insert semicolon after system, sybstitute "it" for "that"

489. Page A-74, Line 25, Capitalize "spacecraft"

490. Page A-74, Line 27, Delete "due to the" after "be" and insert "because"

491. Page A-74, Line 28, Insert semicolon after "servoir" and a comma after "but"

492. Page A-74, Line 29, Delete "there" before "on" and "the" after "on"

493. Page A-74, Line 34, Capitalize "board"

494. Page A-74, Line 37, Capitalize "board"

495. Page A-75, Line 12, Insert semicolon after "catagories"

496. Page A-75, Line 20, Delete last "o" in "alsoo"

497. Page A-75, Line 21, Capitalize "board"

498. Page A-76, Line 8, Insert comma after "items" and then insert "items 118 to 138". "were" should be "was"

499. Page A-76, Line 9, A period should come after "Williams", delete "Items 118 to 138"

500. Page A-76, Line 10, Insert "and" before "that"

501. Page A-76, Line 22, "thru" should be "through"

502. Page A-76, Line 24, Insert semicolon instead of comma after "time"

503. Page A-76, Line 25, Insert comma before "I" and after "think"

504. Page A-76, Line 29, insert "action" before "items", insert period after "previously", delete "to action items, and" Begin new sentence with "The"

505. Page A-76, Line 39, Capitalize "spacecraft"

506. Page A-76, Line 40, Capitalize "spacecraft"

507. Page A-77, Line 7, Delete the first word of the line, "in"

508. Page A-77, Line 12, Insert period after "system" and begin new sentence with"it"

509. Page A-77, Line 14, "ruptures" should be "rupture". Insert "of the" after "rupture"

510. Page A-78, Line 11, read "Spacecraft" for "spacecraft"

511. Page A-78, Line 14, insert semicolon after "panel 24"

512. Page A-78, Line 18, read "is to demate" for "is demate"

513. Page A-78, Line 18, read "Launch Vehicle" for "launch vehicle"

514. Page A-78, Line 119, insert colon after "Required"

515. Page A-78, Line 20, read "MSO Building" for "MSOB Building"

516. Page A-78, Line 21, read "is to analyze" for "is analyze"

517. Page A-78, Line 22, read "Spacecraft" for "spacecraft"

518. Page A-78, Line 39, insert comma after "committee"

519. Page A-79, Line 1, delete comma after "be" and capitalize "g" in "government"

520. Page A-79, Line 5, delete hyphen after "paper"

521. Page A-79, Line 9, read "taken" for "yaken"

522. Page A-79, line 10, insert comma after "fails"

523. Page A-79, Line 11, read "disassembly. A report . . ." for "disassembly, a report . . ."

524. Page A-79, Line 15, read "be" for "by"

525. Page A-79, Line 17, substitute a semicolon for the comma after "week"

526. Page A-79, Line 28, read "Spacecraft" for "spacecraft:

527. Page A-79, Line 28, insert comma after "TVI"

528. Page A-79, Line 29, insert comma after "spacecraft"

529. Page A-79, Line 30, substitute "MSC" for "Houston"

530. Page A-79, Line 36, read "oxygen" for "02"

531. Page A-79, Line 38, read "data" for "date"

532. Page A-79, Lines 40 and 41, read "Spacecraft 008 at MSC" for "spacecraft 008 in Houston"

533. Page A-79, Line 42, read "Spacecraft" for "spacecraft"

534. Page A-79, Line 43, first word, read "is" for "in"

535. Page A-79, Line 47, read "activities of people external to the Spacecraft" for "activities people external to the spacecraft."

536. Page A-80, Line 5, delete "capsule or Service Module."

537. Page A-80, Lines 6 and 7, delete "we were following up this morning,"

538. Page A-80, Line 7, read "N_2O_4" for "N204"

539. Page A-80, Line 8, read "Service Module; we..." for "Service Module, and we..."

540. Page A-80, Lines 15 and 16, read "Spacecraft" for "spacecraft"

541. Page A-80, lines 24 and 25, omit dash after "20" and insert a comma after "20" and after "data"

542. Page A-80, Line 31, after "TPS's" insert comma and then read "and 47 are in work. Most of those Board actions requiring TPS's will be completed after ..."

543. Page A-80, Line 37, read "oxygen" for "osyben"

544. Page A-80, Line 39, substitute semicolon for comma after "Board" and omit "that"

545. Page A-80, Line 40, insert comma after "Center"

546. Page A-80, Line 40 and 41, read "responsibility" for "responsibilith"

547. Page A-81, Line 1, read "O_2" for "02"

548. Page A-81, Line 2, read "preparation" for "preaparation"

549. Page A-81, Line 4, read "Chairmen" for "Chairman"

550. Page A-82, Line 7, read "Panels" instead of "panels"

551. Page A-82, Line 8, read "Panel" instead of "panel"

552. Page A-82, Lines 19, 20, and 25 read "C/M" instead of "CM"

553. Page A-82, Line 20, delete comma and insert "the" after "is"

554. Page A-82, Line 20, read "to" for "at"

555. Page A-82, Line 21, read "not" for "noting"

556. Page A-82, Line 28, read "TPS's" for "TPS'"

557. Page A-82, last line, delete "CHAIRMAN:"

558. Page A-83, Line 5, read "a.m." for "A.M."

559. Page A-83, Lines 5 and 8, read "p.m." for "P.M."

560. Page A-83, Line 5, after "Saturday" insert comma and read "February 18, 1967; another meeting, a general meeting, at 10:30 a.m. Saturday; another Executive . . ."

561. Page A-83, Line 14, read "Spacecraft" for "spacecraft"

562. Page A-83, Line 17, insert comma after "cabling" and after "Board"

563. Page A-83, Line 19, read "Service Module for "service module"

564. Page A-83, Lines 25, 26, and 29, read "Spacecraft" for "spacecraft"

565. Page A-84, Line 8, read "Item 151" for "151"

566. Page A-84, Line 9, read "test" for "ring" (omit quotation marks) and read "and" for "out with"

567. Page A-84, Line 10, substitute period for comma after "movement" and read "It's in the way . . ."

568. Page A-84, last line, read "11:03 a.m." for "11:03."

569. Page A-85, Line 4, read "C/M" for "c/m"

570. Page A-85, Line 11, read "needing" for "need"

571. Page A-85, Line 23, delete "CHAIRMAN:"

572. Page A-85, Line 33, read "Spacecraft" for "spacecraft"

573. Page A-85, Line 36, insert comma after "you"

574. Page A-85, Line 41, read "are" for "is"

575. Page A-86, Line 1, read "underway" for "under way"

576. Page A-86, Line 4, insert comma after "Dr. Faget"

E R R A T A S H E E T

Appendix D Panel 10
204 Review Board Report
Sheet No. 1 of 1

1. Page D-10-3, Line 39, Insert a hyphen between "direct" and "wire"

2. Page D-10-4, Line 20, read "induced" for "indiced"

3. Page D-10-4, Line 30, Delete period and add "at 23:31:18 GMT, 23:31:20 GMT, and 23:31:22 GMT."

4. Page D-10-6, Line 27, Read "soldered joints at unions"

5. Page D-10-8, Line 13, Read "soldered joints at unions"

6. Page D-10-8, Line 16, Read "soldered aluminum joints at unions"

1. Page D-11-5, Line 12, read "phonocardiogram" instead of all caps.

2. Page D-11-6, Line 18, read "gross" instead of "gorss"

3. Page D-11-8, 16. Finding, should read "Suit damage decreased progressively from the Command Pilot's side of the spacecraft to the Pilot's side."

4. Page D-11-27, Paragraph 3, second line, should read "Burns involving this percentage . . ."

5. Page D-11-37, Line 31, delete the line.

6. Page D-11-37, Line 32, should read ". . . for metallographic analysis."

7. Page D-11-43, Line 9, delete "AS" and insert "Apollo"

E R R A T A S H E E T

Appendix D Panel 12
204 Review Board Report
Sheet No. 1 of 5

1. Page D-12-3, first line, delete "WITNESS STATEMENTS"
2. Page D-12-3, sixth line, read "whom" for "who"
3. Page D-12-3, eighth line, delete "formal"
4. Page D-12-3, eighth line, read "task" for "tasks"
5. Page D-12-3, Paragraph B.1, nineteenth line, read "McNamara" for "McNanara"
6. Page D-12-3, Paragraph C.1.b, thirty-sixth line, delete "Review"
7. Page D-12-3, Paragraph C.1.c., thirty-eighth line, read "5. OBJECTIVE B" for "5. Objective (b)"
8. Page D-12-3, Paragraph C.1.d, thirty-ninth line, delete "Review"
9. Page D-12-4, Line 1, delete quotation marks.
10. Page D-12-4, Line 7, read "pedestal" for Pedestal"
11. Page D-12-4, Line 10, read "accident" for "incident"
12. Page D-12-4, Line 13, read "exiting" for "existing"
13. Page D-12-4, Line 13, read "accident" for "incident"
14. Page D-12-4, Paragraph C.3., Line 17, read "Statements" for "Statement"
15. Page D-12-4, Paragraph C.3., Line 18, delete quotation marks.
16. Page D-12-4, Paragraph C.3., Line 20, read "accident" for "incident"
17. Page D-12-4, Paragraph C.3., Line 20, read "Airways" for "Airwasy"
18. Page D-12-4, Paragraph C.3., Line 25, delete quotation marks.
19. Page D-12-4, Paragraph C.4, Line 26, read "accident" for "incident"
20. Page D-12-4, Paragraph C.4., Line 27, read "from" for "for"
21. Page D-12-4, Paragraph C.4., Line 27, read "persons" for "people"
22. Page D-12-4, Paragraph C.4., read "forty" for "forth"
23. Page D-12-4, Paragraph C.4., Line 29, delete "a total of"
24. Page D-12-4, Paragraph C.4., Line 29, read "were" for "was"

25. Page D-12-4, Paragraph C.5., Line 31, delete "Review"

26. Page D-12-4, Paragraph C.5., Line 36, delete "time"

27. Page D-12-4, Paragraph C.5., Line 38, delete "The"

28. Page D-12-4, Paragraph C.5., Line 40, read "from" for "fron"

29. Page D-12-4, Paragraph C.5., Line 42, insert period at end of line.

30. Page D-12-5, Paragraph C.5., Line 9, delete "time"

31. Page D-12-5, Paragraph C.5., Line 10, read "6:33:00" for "6:33"

32. Page D-12-5, Paragraph C.5., Line 17, delete "time"

33. Page D-12-5, Paragraph C.5., Line 17, read "6:33:00" for "6:33"

34. Page D-12-5, Paragraph C.5., Line 18, read "6:37:00" for "6:37"

35. Page D-12-5, Paragraph C.5., Line 22, read "Outer" for "outer"

36. Page D-12-5, Paragraph C.5., Line 29, delete "time"

37. Page D-12-5, Paragraph C.5., Line 29, read "6"37:00" for "6:37"

38. Page D-12-5, Paragraph C.5., Line 30, read "6:45:00" for "6:45"

39. Page D-12-5, Paragraph C.5., Line 35, delete "time"

40. Page D-12-5, Paragraph C.5., Line 35, read "6:45:00" for "6:45"

41. Page D-12-5, Paragraph C.6., Line 45, read "Spacecraft" for "spacecraft"

42. Page D-12-5, Paragraph C.6., Line 45, read "two-and-one-half"

43. Page D-12-6, Paragraph C.6., Line 1, read "Spacecraft" for "spacecraft"

44. Page D-12-6, Paragraph C.6., Line 6, read "accident" for "incident"

45. Page D-12-6, Paragraph C.6., Line 6, insert comma after "screens"

46. Page D-12-6, Paragraph C.6., Line 7, read "momentary" for "monetary"

47. Page D-12-7, Paragraph C.7.a., Line 22, read "panel" for "paned"

48. Page D-12-7, Paragraph C.7.a., Line 35, read "Bruce W. Davis" for "Bruce, W. David"

49. Page D-12-7, Paragraph C.7.a., Line 37, read "Umbilical" for "umbilical"

50. Page D-12-8, Paragraph C.7.a., Line 12, read "Heard" for "Hears"

51. Page D-12-8, Paragraph C.7.a., Lines 16, 19, 23, and 41, read "QC" FOR "Q. C."

52. Page D-12-8, Paragraph C.7.a., Line 18, read "Heard" for "Hears"

53. Page D-12-8, Paragraph C.7.a., Line 18 and 19, read "Module" for "Mod-"

54. Page D-12-8, Paragraph C.7.a., Line 36, read "diminish" for "dimish"

55. Page D-12-8, Paragraph C.7.a., Line 41, insert period after "Fire in Cockpit"

56. Page D-12-9, Paragraph C.7.a., Line 1, read "Heard" for "Hears"

57. Page D-12-9, Paragraph C.7.a., Line 2, insert "Umbilical Tower," after "Technician;"

58. Page D-12-9, Paragraph C.7.a., Line 43, insert period after "A-8"

59. Page D-12-10, Paragraph C.7.a., Line 40, read "base of hatch" for "base hatch"

60. Page D-12-11, Paragraph C.8., Line 22, delete "and releaser for the statements"

61. Page D-12-11, Paragraph C.8., Line 30, read "testimony directly relevant" for "testimony relevant"

62. Page D-12-11, Paragraph C.8., Line 33, read "provide directly relevant" for "provide relevant"

63. Page D-12-11, Paragraph C.9., Line 42 and 43, read "statements, tape recordings, and releases of all witnesses" for "statements and/or tape recordings of all witnesses"

64. Page D-12-11, delete last sentence on page: "The requirements came....."

65. Page D-12-12, Paragraph C.11., Line 10, delete "Review Board"

66. Page D-12-12, Paragraph D., Line 15, read "persons" for "people"

67. Page D-12-23, delete information shown and indicate "this page left blank intentionally."

E R R A T A S H E E T

Appendix D Panel 6-7
204 Review Board Report
Sheet No. 1

1. Page D-6-3, second line, change "accomplished" to "accomplishment"

2. Page D-6-3, fifth line in paragraph 1.a., change "operational" to "operations"

3. Page D-6-3, seventh line in paragraph 2.a., add "records" after "quality"

4. Page D-6-4, first line in paragraph 4.b., change "Panel 7" to "Panel 6"

5. Page D-6-4, second line in paragraph 4.b., add "by" after "requested"

6. Page D-6-20, second line in paragraph e., change "(Reference 61-8)" to "(Reference 6-18)"

7. Page D-6-23, second line from top of page, change "publicwtion" to "publication"

8. Page D-6-28, seventeenth line under paragraph e., change "other" to "of the" after "objective"

9. Page D-7-4, first line in paragraph h., change "indlude" to "include"

10. Page D-7-5, second line in third paragraph under parabraph b, add "a" after "not"

11. Page D-7-7, third line in paragraph 6., change "7-18" to "7-8"

12. Page D-7-9, fourth line in paragraph (2), change "makeing" to "making"

68. Page D-12-24, Line 19, delete comma after "for launch"

69. Page D-12-24, Line 22, read "Environmental Control Assembly" for "environmental control assembly"

70. Page D-12-24, Lines 22, 23, 25, 27, 28, 36, 37, 38, 40, 42, 43, and 44, "white room", delete quotation marks and capilatize "w" and "r".

71. Page D-12-24, Line 30, read "fueled" for "fueld"

72. Page D-12-24, Line 34, read "widespread" for "wide spread"

73. Page D-12-24, Line 41, read "its" for "it's"

74. Page D-12-25, Line 11, read "the" for "thr"

75. Page D-12-25, Lines 13, 17, 25, 26, 33, 36, 39, and 44, "white room", delete quotation marks and capitalize "w" and "r".

76. Page D-12-25, Line 30, read "the" for "te"

77. Page D-12-25, Line 30, read "reported" for "report"

78. Page D-12-26, Lines 1, 2, 5, 6, 7, 9, 10, 30, 39, and 42, "white room", delete quotation marks and capitalize "w" and "r".

79. Page D-12-26, Line 9, read "other persons" for "all others"

80. Page D-12-26, Line 16, read "floor" for "door"

81. Page D-12-26, Line 22, read "and" for "ans"

82. Page D-12-26, Line 34, delete comma after "shortly"

83. Page D-12-27, Lines 5, 7, 9, 10, 12, 19, 25, and 26, "white room", delete quotation marks and capitalize "w" and "r"

84. Page D-12-27, Line 4, read "Plugs Out Test" for "plugs out test"

85. Page D-12-27, Lines 10 and 12, read "mask" for "maks"

86. Page D-12-27, Line 19, read "at the White Room" for "at white room"

87. Page D-12-27, Line 31, read "This activity was stopped based upon the certain knowledge that the astronauts were dead, which was confirmed by physicians who had arrived at the Command Module, and that an....."

88. Page D-12-27, Line 27, read "bring" for "being"

89. Page D-12-27, Line [illegible] read "closest position to the Command Module" for "closes[illegible] the "white room" in the Command Module"

90. Page D-12-28, Line 1, read "umbilical tower" for "Umbilical Tower"

91. Page D-12-28, Lines 5, 7, 10, 13, 14, 22, 25, 26, and 28, "white room", delete quotation marks and capitalize "w" and "r"

92. Page D-12-28, [illegible] 2, Line 15, read "its" for "it's"

93. Page D-12-28, Line 30, delete comma after "detail"

94. Page D-12-2[illegible] 30, read "psia" for "pounds per square inch"

95. Page D-12-28, Line 36, insert "atmosphere" after "oxygen"

96. Page D-12-29, Line 1, read "accident" for "incident"

97. Page D-12-29, Line 14, read "He nevertheless" for "He, nevertheless,"

98. Page D-12-29, Line 15, "white room", delete quotation marks and capitalize "w" and "r"

99. Page D-12-31, Line [illegible] read "preceding" for "preceeding"

100. Page D-12-31, [illegible] read "accident" for "incident"

101. Page D-12-31, Lines 11, 13, and 15, delete "Board"

102. Page D-12-31, Line 20, read "accident" for "incident"

103. Page D-12-32, Line 2, read "accident" for "incident"

104. Page D-12-32, Line 4, read "sniff" for "s niff"

105. Page D-12-32, Line 10, read "accident" for "incident"

106. Page D-12-32, Lines 19 and 20, read "Thomas R. Baron, Donald O. Babbitt..." for "Thomas R. Baron (self-employed), Donald O. Babbitt..."

E R R A T A S H E E T

Appendix D Panel 15
204 Review Board Report
Sheet No. 1 of 2

1. Page D-15-3, Paragraph B.2., Line 1, delete colon.

2. Page D-15-4, Paragraph (5) (c), read "CO_2" for "CO2."

3. Page D-15-5, Paragraph (10), Line 1, read "indicates" for "indicated."

4. Page D-15-7, No. 5C, read "Testing" and "Support."
No. 7A, read "Jurisdiction."

5. Page D-15-8, No. 25, read "Recess."

6. Page D-15-9, Paragraph: POLICY 2. for "full time" read "full-time."

7. Page D-15-10, Paragraph: POLICY - read "service structure, umbilical tower, AGCS room."

8. Page D-15-10, Under PROCEDURES AND RESPONSIBILITIES, begin second paragraph with 2. Make third paragraph read 3. instead of 1. Line up margin properly.

   In new paragraph 3. delete information following colon: "Authorize, in writing, access to the spacecraft areas of the service structure for purposes of photographing the spacecraft, or performing any work on the spacecraft."

9. Page D-15-10, New Paragraph 3 e. read "Maintain" for "Maintains."

10. Page D-15-10, New Paragraph 3 f. read "Brief" for "Briefs."

11. Page D-15-11, Paragraph 5.a., Line 1, for "provide" read "provided."

12. Page D-15-11 - Paragraph 5.b., read "patrolmen."

13. Page D-15-14, Paragraph POLICY 2., read "full-time."
Page D-15-14, Paragraph POLICY 5., read "full-time."

14. D-15-17, Paragraph POLICY, Line 3, read "one-shift."

15. Page D-15-19, Paragraph 6, Capitalize initial letter in listing a., c., and d.

16. Page D-15-19, Paragraph 8, Line 3, read "off-site" for "off site."
Page D-15-19, Paragraph 8, Line 5, read "on-site" for "on site."

17. Page D-15-20, Paragraph 9, Line 1/2, Change "concurrency by" to "the concurrence of."

18. Page D-15-21, Line 11, delete commas before and after "status."

19. Page D-15-22, Line 26, read "Quality" instead of "qualify."

20. Page D-15-37, Line 7, read "Propagation."

21. Page D-15-40, Line 12, change final comma to a period.

22. Page D-15-40, Line 29, read "(1)" instead of "3a."

23. Page D-15-40, Last line, read "Negatives."

24. Page D-15-60, Lines 16-17, insert parentheses beginning "who ... signature."

25. Page D-15-63, Line 13, delete "(IV)."

26. Page D-15-7, No. 4a, correct to read "Secretarial."
No. 18c, correct to read "Test Preparation Sheets."

E R R A T A S H E E T

Appendix D Panel 18
204 Review Board Report
Sheet No. 1 of 1

1. Page D-18-3, Line 14, insert "(MSC)"
2. Page D-18-3, Line 15, insert "(NAA)"
3. Page D-18-3, Line 16, insert "(KSC) NASA"
4. Page D-18-3, Lines 25 through 27, Panels (plural)...panels... panels ... (both lower case)
5. Page D-18-3, Line 30, insert "Apollo 204 Review" before Board
6. Page D-18-4, Lines 3 and 6, "provision" should be "presentation"
7. Page D-18-4, Line 12, remove comma after parenthesis
8. Page D-18-4, Line 17, change "activity" to "phase"
9. Page D-18-4, Line 18, change "fed" to "given"
10. Page D-18-4, Line 19, should be "Test Preparation Sheet (TPS)" (Enclosure 18-2) ..."
11. Page D-18-5, Line 18, insert "two" after "in"
12. Enclosure 18-42, Octopus.
13. Page D-18-20, Line 43, The "21" of 21:31:20 GMT should be "23".
14. Page D-18-21, Line 22, after "09.72" insert "GMT".
15. Page D-18-24, Line 30, change "was" to "were"
16. Page D-18-25, Line 3, add "and" after "interface"
17. Page D-18-25, Line 6, remove "equipment"
18. Page D-18-34, Line 22, after the word "considered," insert "as a source. An"
19. Page D-18-41, Line 18, read "Enclosure 18-34" instead of "Enclosure 18-35:

E R R A T A S H E E T

Appendix D Panel 19-20
204 Review Board Report
Sheet No. 1 of 1

1. Page D-19-3, Line 24, Delete comma following "Commander" and insert a period.

2. Page D-20-3, Line 40, Read "Direct O_2 valve."

3. Page D-20-5, Line 8, Read "altitude" instead of "alittude."

4. Page D-20-6, Line 26, Read "and with the combustible materials."

5. Page D-20-6, Line 27, Read "valve was open to vacuum to simulate orbital flight and functioned at approximately."

6. Page D-20-6, Line 28, delete hyphen before "Y", insert a minus sign instead.

7. Page D-20-6, Line 37, Read "a fire under test conditions."

E R R A T A S H E E T

1. Page E-18, Line 47, last word, utilization.

2. Page E-23, Line [illegible], Flight Crew Director.

3. Page E-28, Line 2, delete "and included as enclosures."

4. Page E-28, Line 5, reference should be to Page E-27, not enclosure 1.

5. Page E-29, last line, delete "integ".

6. Page E-30, dele[illegible]ference to enclosure.

7. Page E-31, Director of Design Engineering, reference in paragraph 4. should be to U.S. Army Corps of Engineers. Add the following paragraph 5.

   "5. Establish within the Directorate a uniform and consistent program for configuration management, reliability, QA, logistics, and system engineering based on prescribed guidelines."

8. Page E-45, Paragraph b. Read, "Procuring launch vehicles . . ."

9. Page E-45, Para[illegible] f. Read, "Providing flight ready . . ."

10. Page E-45, Paragraph k. Read, "of" for "or".

11. Page E-47, Paragraph 9. Read, "Establishes" for Established."

12. Page E-48, Paragraph 12. Read ". . . negotiation, pre-award, award . . ."

13. Page E-50, Engine Program Office, Responsibility, Paragraph 3, read "Directs."

14. Page E-57, Paragraph 1, delete reference to Chart "X".

15. Page E-57, Paragraph IB, subparagraph 2, third sentence should read, "The Dire[illegible] of Quality and Reliability Assurance is responsible to the Program Manager in technical matters although reporting administratively to the S&ID Director of Quality and Reliability Assurance." Same subparagraph, line 6, insert comma after words Florida Facility.

16. Page E-58, reference throughout should be to S&ID instead of as printed.

17. Page E-58, fourth line, read "fabricate."

18. Page E-58, Paragraph III B., subparagraph 1., second line, read "individual."

E R R A T A S H E E T

Appendix F
204 Review Board Report
Sheet No. 1 of 1

1. Preface, Line 4, should be "Review Board."

2. Preface, Line 2, change "were" to "was" to agree with collective subject "all."

3. PF-21, Item 0057, Col. 4

   a. "No Constraints;" should be "constraints."

   b. ... "S/C 017 Testing;" should be "testing."

   c. "Needed One Week Prior;" should be "Needed one week prior."

4. PF-24, Item 0070, Col. 3, No. 2, "Disconnect but...;" should be "Disconnected."

5. PF-24, Item 0071, Col. 3, No. 2, "Disconnect" should be "Disconnected."

6. PF-25, Item 0078, Col. 4, should be "Turn whole book over to Panel 6."

7. PF-26, Item 0082, Col. 2; should be "millimeter."

8. PF-26, Item 0084, Col. 4; should be "Turn whole book over to Panel 6."

9. PF-33, Item 0120, Col. 3; should be Loc: Level A-8 +Z+Y Axis."

10. PF-33, Item 0124, Col. 3; should be "(Relevance to accident - None)."

11. PF-34, Item 0127, Col. 3, Line 5; should be "entrance.) Not located in white."

    Line 7; should be "8A level of service structure."

12. PF-35, Item 0128, Col. 2, Line 5; should be "Following items, is not to be."

19. Page E-59, reference throughout should be to S&ID instead of as printed.

20. Page E-59, Paragraph E. subparagraph 3, last line, read "Pratt & Whitney."

21. Page E-63, second line, read "Included" at beginning of second sentence.

22. Page E-62, last line, read "inter-center working relationships."

23. Pages E-64 and E-66, delete in their entirety, substituting Attachment 1 of this Errata Sheet.

24. Page E-83, delete material following first paragraph, and substitute the following table:

Major Contractual Phases are:

Time Period	Contract Type	Prime Document
21 Dec 61 - 13 Aug 63	Letter	Letter Contract NAS 9-150
21 Dec 61 - 2 Oct 65	CPFF	Contract NAS 9-150
3 Oct 65 - 3 Dec 66	CPIF	S/A 115 to NAS 9-150
4 Dec 66 - Onward	Letter	S/A 220 to NAS 9-150

25. Page E-83, read $ for % wherever it appears.

26. Page E-84, delete line 7.

27. Page E-85, line 19, read Exhibit.

28. Page E-85, delete line 43.

29. Page E-86, delete lines three and four.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

KSC-MSC CAPE RELATIONSHIPS[1]

(Chapter 35 of Apollo Spacecraft Management Guide, effective April 1, 1966)

This paper establishes the overall policy and relationships which shall exist between MSC and KSC for those spacecraft activities occurring at the Cape. The following relationship shall exist:

1. MSC shall be responsible for the determination and control of the configuration of the spacecraft and all spacecraft contractor-supplied CSE, including ACE. MSC shall be responsible for approval of all changes in configuration.

2. MSC shall establish overall checkout standards and plans. These standards and plans shall set the broad parameters for checkout and inspection for all spacecraft checkout from the factory through Cape checkout. MSC shall establish detailed factory checkout procedures; KSC shall review and advise MSC on these procedures. KSC shall develop Cape checkout plans for review and approval by MSC as a part of the overall spacecraft checkout plan; KSC shall develop detailed checkout procedures for MSC review and concurrence. No checkout procedures shall be adopted which are not concurred in by MSC.

3. MSC shall conduct technical reviews, inspections, and checkout acceptamce activities at the spacecraft contractors' plants; KSC shall provide checkout personnel to serve as observers and advisors; KSC shall conduct detailed Cape checkout of spacecraft, securing MSC approval of necessary performance and checkout procedure waivers or inspection deviations; KSC shall conduct the actual countdown and launch activities. This includes direction of those MSC spacecraft contractor personnel engaged in preflight checkout activities at the Cape.

4. MSC shall provide to KSC performance data, systems or sub-systems specifications, or test results which are needed or requested by KSC.

5. MSC shall provide data requirements for format and/or reduction requirements for pre-mission, real-time mission support, or post-mission evaluation.

6. MSC shall determine the disposition and place of failure analysis of all failed components after removal from the spacecraft; KSC shall conduct failure analyses as requested by MSC and make recommendations for corrective action as applicable.

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[1] These arrangements relate to all KSC-MSC relationships for activities conducted at MILA and the ETR.

7. MSC shall retain responsibility for all astronaut activities; KSC shall provide necessary housing and logistical support as required.

8. MSC shall prepare all on-board experiments which are intimately associated with the astronaut; KSC shall prepare those experiments intimately associated with the spacecraft.

9. KSC shall participate as a Board Member of the Acceptance Review Board in conducting formal pre-delivery reviews of spacecraft at the contractors' plants and on the MSC Spacecraft Readiness Review Board; MSC shall participate as a Board Member in launch readiness reviews and shall participate in preflight and post-launch debriefings of launch crews conducted by KSC. MSC shall conduct necessary post-mission tests of spacecraft.

10. MSC shall establish minimum readiness specifications or lift-off rules for spacecraft systems; KSC shall conduct necessary integrated space vehicle checkouts.

11. KSC shall provide MSC such administrative and housekeeping support for personnel assigned to the MSC Resident Offices as may be necessary.

12. KSC shall serve as the agent of MSC in conducting Gemini spacecraft checkout, inspection, and testing at the Cape. This function shall be delegated to the Deputy Director for Launch Operations, KSC, who shall be directly responsible to MSC for these activities. The Directors, KSC and MSC, shall periodically discuss any problems which may arise relating to staffing levels assigned to the Gemini Program. (This arrangement shall be reviewed prior to GT-6.)

13. KSC shall make the KSC Deputy Director for Launch Operations available to function as the agent for MSC in providing local direction (at the Cape) to the Air Force 6555th Test Wing in its preparation, checkout, and launch of the Gemini launch vehicle and the Atlas-Agena target vehicle.

APPROVED:

(Original Signed by Robert R. Gilruth)
Robert R. Gilruth, Director
Manned Spacecraft Center

December 21, 1964
Date

(Original Signed by Kurt H. Debus)
Kurt H. Debus, Director
John F. Kennedy Space Center

December 21, 1964
Date

MOST EXPEDITIOUS MANNER, TWX, OR TELEPHONE. THE COGNIZANT CONTRACTOR SHALL BE RESPONSIBLE FOR DOCUMENTING ALL CHANGES IN ACCORDANCE WITH THE APOLLO SPACECRAFT PROGRAM OFFICE "APOLLO CONFIGURATION MANAGEMENT MANUAL, MSC SUPPLEMENT NO. 1 (TO NPC-500-1), EXHIBIT IX".

E. PROVIDE TO MSC-ASPO DAILY STATUS REPORTS ON APOLLO SPACECRAFT WORK, INCLUDING OVERALL SCHEDULE PERFORMANCE COMPLIANCE, EO'S WORKED, AND OTHER PERTINENT PROGRAM INFORMATION.

F. KSC SHALL PROVIDE FACILITIES AND GENERAL SERVICE FOR THE MSC PERSONNEL, SUCH AS PROJECT AND SYSTEMS ENGINEERS, GSE, SITE ACTIVATION, QUALITY, CHECKOUT, AND SUBSYSTEM MANAGERS ASSIGNED BY ASPO TO SPECIFIC HARDWARE OR FUNCTIONS THAT ARE BEING HANDLED BY KSC FOR MSC. KSC SHALL PROVIDE INTERNAL WORKING INTERFACE ARRANGEMENTS FOR THESE INDIVIDUALS IN SUPPORT OF THE ACCOMPLISHMENT OF THE TASKS.

3. A MORE DETAILED LEVEL OR ASSIGNED RESPONSIBILITY IS CONTAINED IN THE FOLLOWING LIST. THE NOTATION "KSC" INDICATES THOSE ACTIVITIES IN WHICH RESPONSIBILITY FOR PRIMARY ACCOMPLISHMENT IS DELEGATED TO KSC, PLANS, PROGRAMS, AND RESOURCES; THE NOTATION "MSC" INDICATES THAT PRIMARY RESPONSIBILITY IS TO REMAIN WITH MSC (ASPO): AND THE NOTATION KSC/MSC REFERS TO THOSE ACCOMPLISHMENTS IN WHICH RECIPROCAL ACTIVITIES ARE REQUIRED.

U. S. GOVERNMENT PRINTING OFFICE : 1967 O - 261-115

PROPOSED
APOLLO SPACECRAFT PROGRAM OFFICE
KSC OPERATIONS MANAGEMENT PLAN

1. GENERAL:

THE KSC-MSC RELATIONSHIP SIGNED BY DR. K. DEBUS AND DR. R. GILRUTH ON DECEMBER 21, 1964, ASSIGNS CERTAIN RESPONSIBILITIES TO MSC FOR THE APOLLO SPACECRAFT OPERATION AT KSC. IT IS THE PURPOSE OF THIS PLAN TO DELEGATE A LIMITED NUMBER OF THESE RESPONSIBILITIES TO KSC FOR EXECUTION AND TO DELINEATE OTHER OF THESE RESPONSIBILITIES THAT KSC SHALL REFER TO MSC-ASPO FOR ACTION.

2. RESPONSIBILITIES DELEGATED TO KSC, PLANS, PROGRAMS, AND RESOURCES OFFICE:

A. PROVIDE THE INTERFACE WITH THE MSC APOLLO SPACECRAFT PROGRAM OFFICE MANAGER FOR ACTIVITIES AT KSC INVOLVING SUPPORT OF THE APOLLO SPACECRAFT PROGRAM.

B. ACCOMPLISH TECHNICAL MANAGEMENT OF ASPO CONTRACTOR(S) AT MSC WITHIN THE SCOPE OF DEFINED CONTRACTOR TASKS AND COORDINATE WITH THE APPROPRIATE ASPO PROJECT OFFICER IN THE ACCOMPLISHMENT OF THE CONTRACT WORK STATEMENT AMENDMENTS AND/OR RESOURCE CHANGES REQUESTED BY MSC TO ACCOMPLISH APOLLO SPACECRAFT TASKS.

C. PROVIDE APPROPRIATE ASPO CONTRACTOR PERFORMANCE REVIEWS TO MSC.

D. BE RESPONSIBLE FOR THE CONFIGURATION MANAGEMENT OF THE APOLLO SPACECRAFT, GSE, AND ACE AT KSC IN ACCORDANCE WITH THE SPECIFICATIONS FURNISHED WITH THE DELIVERY OF THE EQUIPMENT AND MSC APOLLO CCP OR CCB DIRECTIVES. CHANGES IN THIS ESTABLISHED CONFIGURATION INITIATED AT KSC, INCLUDING COMPATIBILITY OR MAKE WORK, SHALL BE REFERRED TO THE CHAIRMAN OF THE COGNIZANT MSC SPACECRAFT CONFIGURATION CONTROL PANEL FOR APPROVAL ACTION. ACTION ON THESE CONFIGURATION CHANGES SHALL BE HANDLED IN THE

MOST EXPEDITIOUS MANNER, TWX, OR TELEPHONE. THE COGNIZANT CONTRACTOR SHALL BE RESPONSIBLE FOR DOCUMENTING ALL CHANGES IN ACCORDANCE WITH THE APOLLO SPACECRAFT PROGRAM OFFICE "APOLLO CONFIGURATION MANAGEMENT MANUAL, MSC SUPPLEMENT NO. 1 (TO NPC-500-1), EXHIBIT IX".

E. PROVIDE TO MSC-ASPO DAILY STATUS REPORTS ON APOLLO SPACECRAFT WORK, INCLUDING OVERALL SCHEDULE PERFORMANCE COMPLIANCE, EO'S WORKED, AND OTHER PERTINENT PROGRAM INFORMATION.

F. KSC SHALL PROVIDE FACILITIES AND GENERAL SERVICE FOR THE MSC PERSONNEL, SUCH AS PROJECT AND SYSTEMS ENGINEERS, GSE, SITE ACTIVATION, QUALITY, CHECKOUT, AND SUBSYSTEM MANAGERS ASSIGNED BY ASPO TO SPECIFIC HARDWARE OR FUNCTIONS THAT ARE BEING HANDLED BY KSC FOR MSC. KSC SHALL PROVIDE INTERNAL WORKING INTERFACE ARRANGEMENTS FOR THESE INDIVIDUALS IN SUPPORT OF THE ACCOMPLISHMENT OF THE TASKS.

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E R R A T A S H E E T

Appendix B
204 Review Board Report
Sheet No. 1 of 1

1. Page B-5, entry 8, fourth column, Line 1, change "200" to "220."

2. Page B-7, entry 36, fourth column, Line 2, change "LCC" to "LC."

3. Page B-7, entry 39, fourth column, change "LCC" to "LC."

4. Page B-10, fifth entry, third column, Line 2, change "LCC" to "LC."

5. Page B-15, first entry, fourth column, add "34" after "LC."

6. Page B-15, twelfth entry, fourth column, delete apostrophe after "70" and add " - foot" after "60."

7. Page B-25, fifteenth entry, fourth column, delete apostrophe after "27" and add " - foot" after "27."

8. Page B-28, thirteenth entry, fourth column, Line 2, delete apostrophe after "152" and add " - foot" after "152."

PANEL 1

Page D-1-5, line 11, pertinent spelled wrong

PANEL 2

Page D-2-4; under 3, Vehicle Test Comarison; 3rd line, should read: "30 minutes of testing"

Page D-2-8; under 2. Finding - correct water ethylene to "water/ethylene"

Page D-2-25; line 9, correct spelling to untreated

PANEL 3

Page D-3-4; line 5 from bottom; time should read "22:38 GMT"

Page D-3-38; paragraph (a) 4. - second line, 41.2 kilo-bit should be "51.2"

Page D-3-42; C A5484 - under Low, should read 0; under Data Range High, should read +150

Page D-3-45; C G2140, under Units delete PSA

Page D-3-45; C H0047, under Units - MANP should be "MAMP"

Page D-3-46; C H0100, under Low - should be "OFF"; under High - should be "ON"; under Units - should be "EVENT"

Page D-3-46; C H0101, under High - change "ONN" to "ON"

Page D-3-46; C H3186, under High - should be "+13K"

Page D-3-46; C H4100, under High - should be +12; under Units - should be VAC

Page Page D-3-48; B S0040, under Low - should read "OFF"; under High - should read "ON"; under Units - should read "EVENT"

Page D-3-46; C H1074, under High - should read +25

Page D-3-48; C T0128, under Low - should read "0"

Page D-3-48; C T0191, unable to read High and Unit column - should read - "-110 and DBM"

Page D-3-49; b.(1)(a) sentence deleted - The sequential system was in launch configuration with the following exceptions:

Page D-3-49; Under (2), third paragraph - "02" should read "0_2"

Page D-3-49; Under (2), fourth paragraph - second sentence deleted - At 23:31:26.716 GMT EDS "unsafe B: came on.

PANEL 3 (cont'd)

Page D-3-50; Under (2), third paragraph, last sentence not complete - should read, "The switches used to accomplish this (panel 22 - main bus tie Bat A&C and main bus tie Bat B&C) were found during post-incident inspection to be in the positions that would connect these batteries to the main buses."

Page D-3-53; (2) (a), Sentence should read "At 23:30:54.85 GMT"

Page D-3-53; (2) (a), Second paragraph, last two sentences should read, "At the same time, small transients were noted on the pitch and yaw rotation control output (see Figure 4.5-1). The rotation control output measurements are proportional to the amount and direction of controller position."

Page D-3-56; f.(1)(d), last sentence - change "02" to "0_2", two places.

Page D-3-56; f.(2), first sentence - change 02 to "0_2"

Page D-3-60; g.(1)(c), flight space should read "flight spare"

Page D-3-65; paragraph heading H. should be "h."

Page D-3-65; i(1), GN2 should read "GN_2", two places

Page D-3-66; (4)(a) first sentence should read 23:31:22.432 instead of 23:31:22:432

Page D-3-66; j(2) fourth sentence should read - "These noise spikes are believed to be caused by RFI, which has been duplicated during post-incident bench test by imposing transients on the input power."

E R R A T A S H E E T

Appendix D Panel 5
204 Review Board Report
Sheet 1 of 1

1. Page D-5-3, Line 3, Comma after "chemical analyses"
2. Page D-5-3, Line 26, Remove comma after "fire"
3. Page D-5-5, Line 28, Word "defeated" should be "defected"
4. Page D-5-6, Line 14, Delete comma and word "photograph" after "hatch"
5. Page D-5-7, Line 27, Remove comma after "structure"
6. Page D-5-7, Line 40, Period at end of sentence
7. Page D-5-8, Line 27, aluminum
8. Page D-5-9, Line 23, Read "5-29" instead of "5-20"
9. Page D-5-13, Line 44, conditions
10. Page D-5-15, Line 51, Delete comma after "had"

E R R A T A S H E E T

Appendix D Panel 8
204 Review Board Report
Sheet No. 1 of 2

1. Page D-8-7, Line 1, "Table C-4," should be "Table 4."

2. Page D-8-7, Line 5, (Function Column), "Insulation" should be "insulation."

3. Page D-8-7, Line 10, (Function Column), "Net" should be "net."

4. Page D-8-7, Line 16, (Function Column), "Compartments" should be "compartments."

5. Page D-8-7, Line 11, (Material Column), "oxford cloth" should be "Oxford Cloth."

6. Page D-8-7, Line 17, (Function Column), "Window" should be "window."

7. Page D-8-7, Line 13, (Material Column), "Nylon cord" should be "Nylon Cord."

8. Page D-8-7, Line 14, (Material Column), "Nylon tape" should be "Nylon Tape."

9. Page D-8-7, Line 24, (Function Column), "OCP Note paper" should be "OCP note paper."

10. Page D-8-7, Line 29, (Function Column), "ECS Line insulation" should be "ECS line insulation."

11. Page D-8-7, Line 19, (Material Column), "Silicone foam" should be "Silicone Foam."

12. Page D-8-7, Line 20, (Material Column), "Cotton cloth" should be "Cotton Cloth."

13. Page D-8-7, Line 22, (Material Column), "Nomex fabric" should be "Nomex Fabric."

14. Page D-8-8, Line 3, "Nonmetallic Materials Status" should be upper case.

15. Page D-8-8, Last Line, "(ref. 8-33 and 8-91)" should be "(Ref. 8-33 and 8-91)."

16. Page D-8-9, Line 31, "10^{-5} lb in^2" should be 10^{-5} lb/in^2."

17. Page D-8-11, Line 33, "or organic" should be "of organic."

18. Page D-8-13, Line 34, "case. Namely," should be "case; namely,"

19. Page D-8-15, Line 26, "even samples" should be "even on samples."

20. Page D-8-27, Items 1 and 3 in the TYPE Column:

    "n-CF2-CFCl" should be "n-CF_2-CFCl"

    "n-CF2-CF2Cl-n" should be "n-CF_2-CF_2Cl-n"

21. Page D-8-29, Line 4, "tion," 6.5.)" should read "tion," 6.b.)"

22. Page D-8-35, Line 40, "8-6 C/M 012 p Pressure" should be "8-6 C/M 012 Pressure."

23. Page D-8-35, Line 45, "on Aft Bulkhead % Hatch" should be "on Aft Bulkhead & Hatch."

24. Page D-8-35, Line 50, "(Neg, No. 216-467C-6)" should be "(Neg. No. 216-467C-6)."

25. Page D-8-85, Item 8-7, Line 2, "December 28, 1967" should be "December 28, 1966."

26. Page D-8-85, Items "8-19 & 8-18" are reversed.

27. Page D-8-86, Item 8-44, Line 2, "February 18, 1967" should be "February 28, 1967."

28. Page D-8-87, Item 8-84, Line 3, "No. 99-0058" should be "No. 999-0058."

E R R A T A S H E E T

Appendix D Panel 9
204 Review Board Report
Sheet 1 of 1

1. Page D-9-10, Line 37, Delete semicolon following "system", insert comma instead

2. Page D-9-10, Line 42, Delete semicolons following "encountered" and "network", insert commas instead

3. Page D-9-10, Line 45, delete "incident", insert "accident" instead

4. Page D-9-29, Line 6, delete "ect", insert "etc." instead

5. Page D-9-29, Line 7, read "5.6×10^{-6}"

6. Page D-9-29, Line 17, read "0.035 inch"

7. Page D-9-29, Line 36, Delete "twenty" insert "20" instead

8. Page D-9-29, Lines 39 through 46, delete exclamation marks and insert closed brackets (⊐) instead

9. Page D-9-29, Line 39, read "N_2O4"

10. Page D-9-29, Line 41, read "Optimum"

11. Page D-9-29, Line 47, read "N_2O4"

12. Page D-9-30, Lines 5, 13, 20, 24, 28, 34, 40, Delete exclamation marks and insert closed brackets (⊐) instead

13. Page D-9-31, Line 2 read $(OH)_3$

14. Page D-9-31, Lines 7, 10, 11, 19, Delete exclamation marks and insert closed brackets (⊐) instead

15. Page D-9-31, Line 10, insert a period following "pounds"

16. Page D-9-31, Line 20, read "10^{-6}"

17. Page D-9-31, Line 24, read "3.54×10^{-7} and 1.27×10^{-7}"

18. Page D-9-31, Line 25, read "10^{-6}"

577. Page A-86, Last line, read "11:30 a.m." for "11:30"

578. Page A-87, Line 20, read "Spacecraft" for "spacecraft"

579. Page A-87, Line 26, read "action" for "aOtion"

580. Page A-87, Line 29, read "Item 155 is to" for "155 is"

581. Page A-87, Line 30, read "harness, suit" for "harness, suits"

582. Page A-87, Line 31, insert comma after "harness" and before "and"

583. Page A-87, Line 33, read "Item 156 - following 155 - " for "Item 156 - Following 155,"

584. Page A-87, Line 35, read "is to perform" for"is perform"

585. Page A-87, last line, insert "the" before "Manned"

586. Page A-88, Line 8, read "Government" for "government"

587. Page A-88, last line, read "11:31 a.m." for "11:31."

588. Page A-89, Line 8, "of the panels. This" should be "of the Panels. This"

589. Page A-90, Line 13, "today is 163," should be "today are 163,"

590. Page A-90, Line 18, "service module" should be "Service Module"

591. Page A-90, Line 20, "the reasis to" should be "the reason is to"

592. Page A-90, Line 23, "if installed" should be "if the installed"

593. Page A-90, Line 27, "presented Mr." should be "presented by Mr."

594. Page A-90, Line 30, "DEPUTY" should be "Deputy"

595. Page A-90, Line 32, "meeting I" should be "meeting, I"

596. Page A-91, Line 8, "Yes, we" should be "We"

597. Page A-91, Line 22, "Item 128, I'd" should be "Item 128. I'd"

598. Page A-91, last line, "test and" should be "tests and"

599. Page A-93, Line 11, "spacecraft" should be "Spacecraft"

600. Page A-93, Line 13, "reason to investigate" should be "the reason is to investigate"

601. Page A-93, Line 17, "The reason, to" should be "The reason; to"

602. Page A-93, Line 20, "action - the interior" should be "action regarding the interior"

603. Page A-93, Line 24, "Disassembly Plan as to when" should be "Disassembly Plan and when"

604. Page A-93, Line 35, "Panels orerating" should be "Panels are operating"

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605. Page A-95, Line 5, "Thin we found over the weekend, Friday evening in ..." should be "Thing, we found over the weekend, on Friday evening. In..."

606. Page A-95, Line 33, "menagage..." should be "manage"

607. Page A-96, Line 4, "The discussion ha brought" should be "This discussion brought"

608. Page A-96, Line 7, "possible, the" should be "possible. The"

609. Page A-97, Line 3, "there approved" should be "therefore approved."

610. Page A-99, Line 15, "qualibying" should be "qualifying"

611. Page A-99, Line 30 "command module" should be "Command Module"

612. Page A-100, Line 2, "power supposedly," should be "power,..."

613. Page A-100, Line 3, "conditions, circuit breaker" should be "conditions. The Circuit breaker"

614. Page A-100, Line 4, "physically in, and was found" should be "was found"

615. Page A-100, Line 13, "spacecraft" should be "Spacecraft"

616. Page A-100, Line 24, "submitted. Only" should be "submittal. There is only..."

617. Page A-100, Line 25, "and this is discussed" should be "and this was discussed."

618. Page A-100, Line 36, "summarize, first on" should be "summarize; the first is on"

619. Page A-102, Line 10, "packages, we" should be "packages; we"

620. Page A-102, Line 20, "We reviewed 8" should be "We have reviewed only 8"

621. Page A-102, Line 27, "people we" should be" people were"

622. Page A-102, Line 31, "Category A, ECS stuff, there" should be "Category A, there"

623. Page A-102, Line 34, "stay there, the" should be "stay there, also, the..."

624. Page A-103, Line 22, "on 7 March; No. 150" should be "on 7 March 150"

625. Page A-103, Line 24, "spacecraft" should be "Spacecraft"

626. Page A-103, Line 25, "craft 17" should be "craft 017"

627. Page A-103, Line 35, "electrical ring-out;" should be "electrical check"

628. Page A-104, Line 1, "wire ring out" should be "wire checking"

629. Page A-104, Line 2, "spacecraft" should be "Spacecraft"

630. Page A-104, Line 9, "rema ining" should be "remaining"

631. Page A-104, 4th line from bottom, "propogation combustion" should be "propogation and combustion"

632. Page A-106, 2nd line from bottom, "items, toe plate" should be items: toe plate"

633. Page A-107, Line 9, "I woule" should be "I would"

634. Page A-107, 5 lines from the bottom, "statements by re -" should be "statements be re -"

635. Page A-108, line 3, "except hose" should be "except those"

636. Page A-108, Line 16, "spacecraft" should be "Spacecraft"

637. Page A-108, Line 22, "the ring-out of the cables taken place" should read "the testing of the cables takes place"

638. Page A-107, Line 27, "so far, a total of 179." should be "so far is 179."

639. Page A-110, Lines 13 and 14, "I would say, and we are about at the stage of, I would say, more" should be "I would say, more"

640. Page A-110, Line 21, "TPS's (work orders) to" should be "TPS's to"

641. Page A-111, Line 10 and 11, "these items are describing the condition." should be "these items."

642. Page A-111, Line 16, "Item 180," should be "Item 180:"

643. Page A-111, Line 18, "Item 179," should be "Item 179:"

644. Page A-111, Line 20, "This technique utilized on Action Item 178 which was," should be 'This technique was utilized on Action Item 178 which was:"

645. Page A-111, Line 23, "distributions" should be "distributed"

646. Page A-112, Line 22, "Item 181," should be "Item 181:"

647. Page A-112, Line 25, "Item "The reason is" should be "The reason is:"

648. Page A-112, Line 26, "Item 182," should be "Item 182:"

649. Page A-112, Line 27, "The reason," should be "The reason:"

650. Page A-114, Line 7, "panel" should be "Panel"

651. Page A-114, Line 12, " and 11" should be "and 11"

652. Page A-116, Line 14, "these pacts," should be "these parts,"

653. Page A-117, Line 23, "Board Review" should be "Review Board.

654. Page A-117, Line 35, "States Inverter" should be "Static Inverter"

655. Page A-118, Line 14, "900 pis" should be "900 psi"

656. Page A-120, Line 38, "Spacecraft 12" should be "Spacecraft 012"

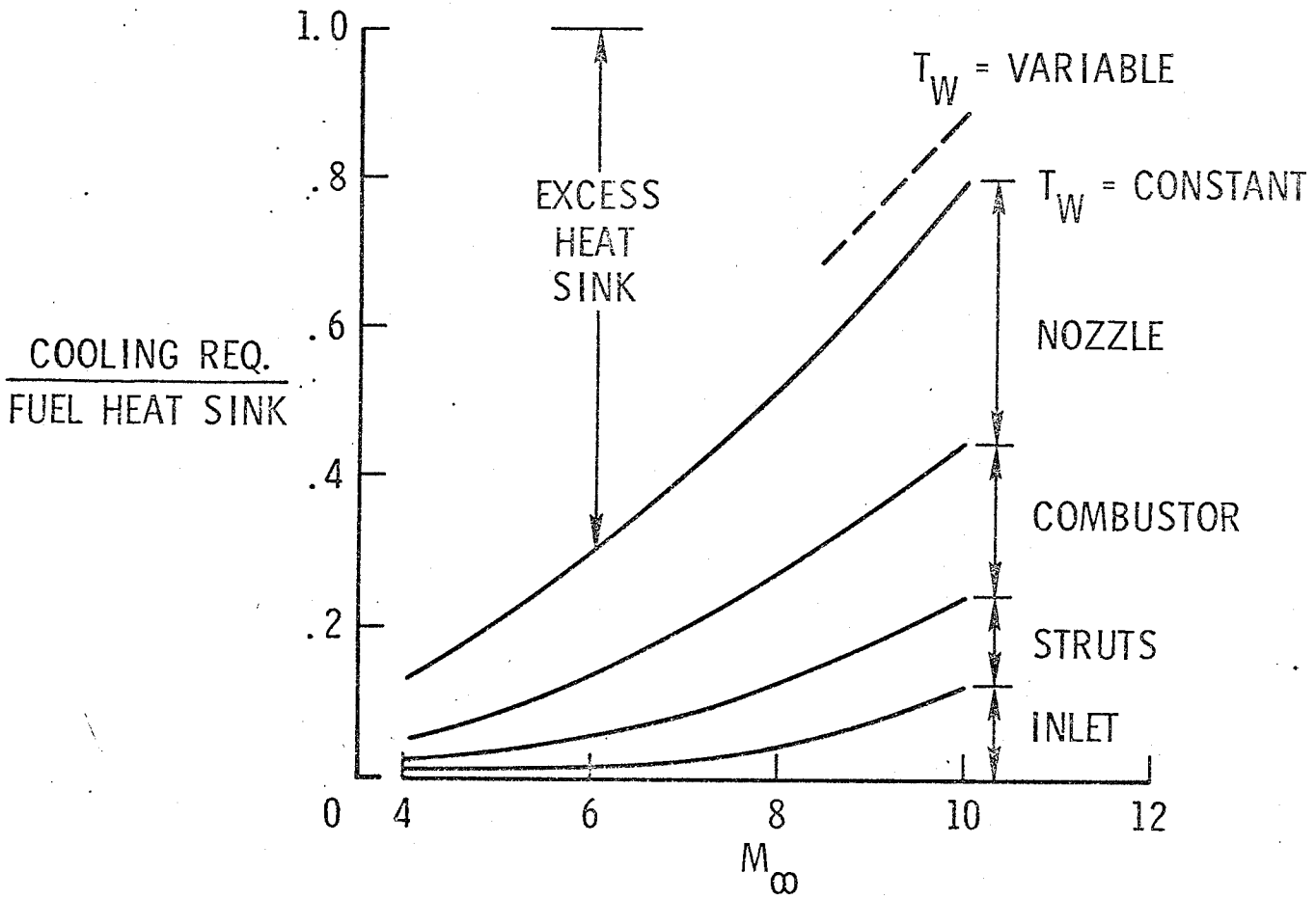

Figure 23.- Langley Scramjet cooling required. q_∞ = 47.9 kN/m^2 (1000 psf), ϕ = 1.0.

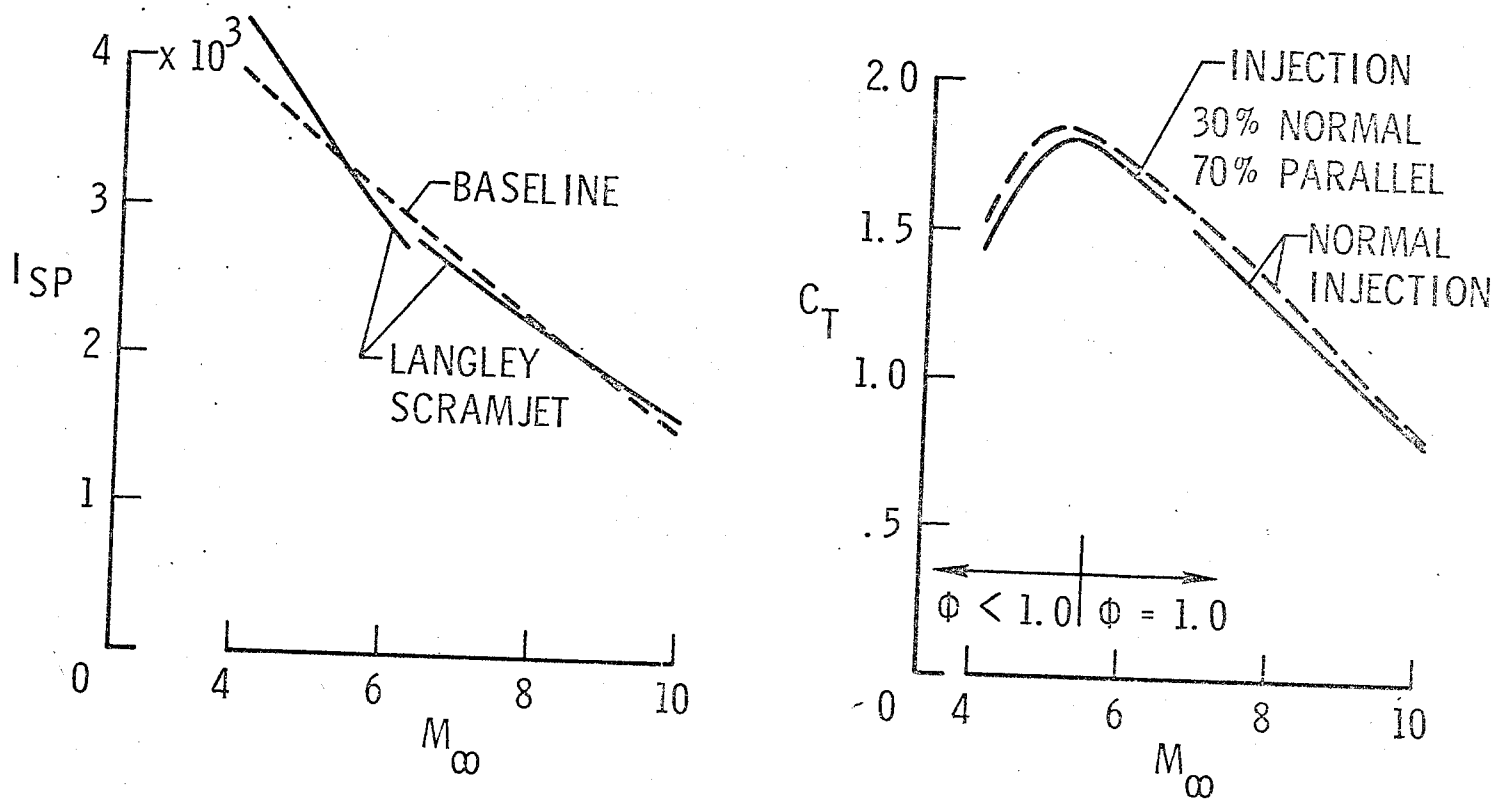

Figure 24.- Performance prediction.

NASA-Langley, 1972

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