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

TABLE OF CONTENTS

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 13M20408."

(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 instances, 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 40M37508A, 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.

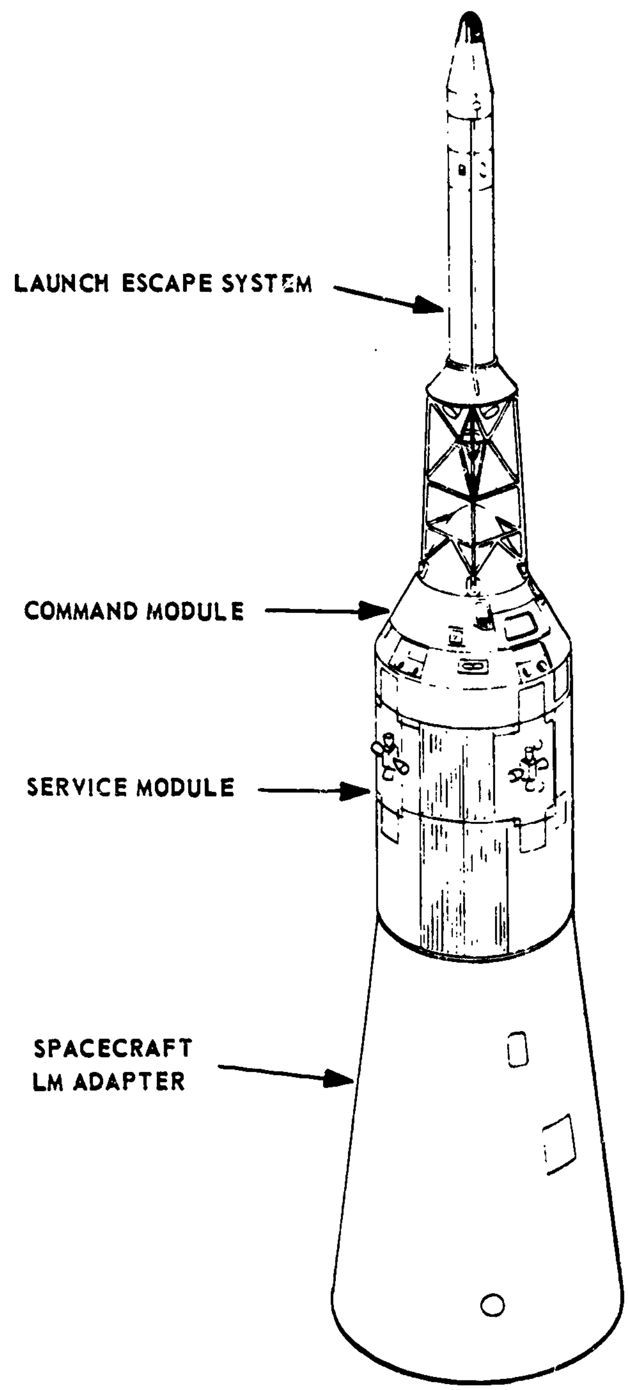
4. FINDING

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

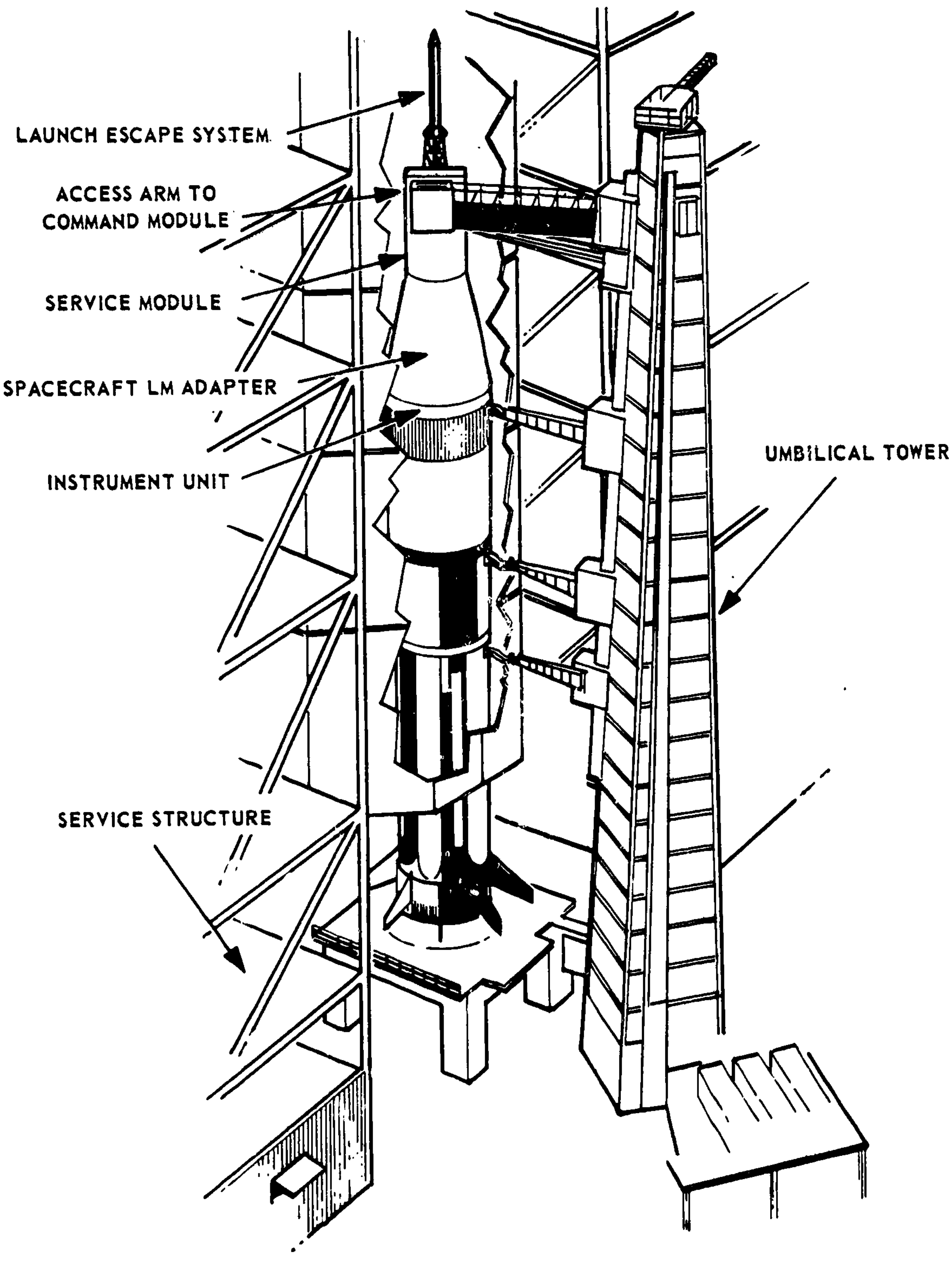
Procedures for controlling entry of items into the Spacecraft were not strictly enforced.

SPACECRAFT CONFIGURATION

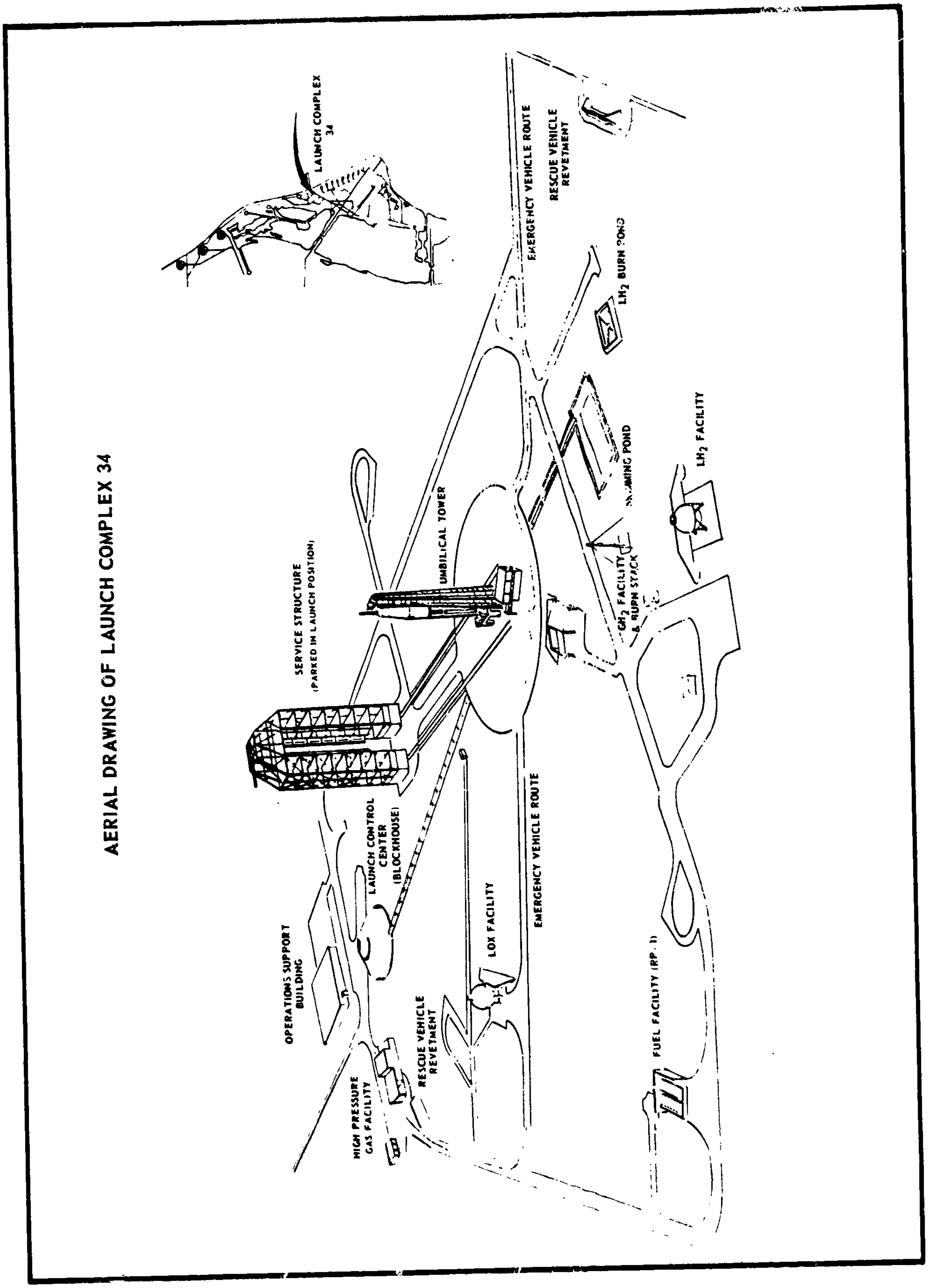


ENCLOSURE 1-1

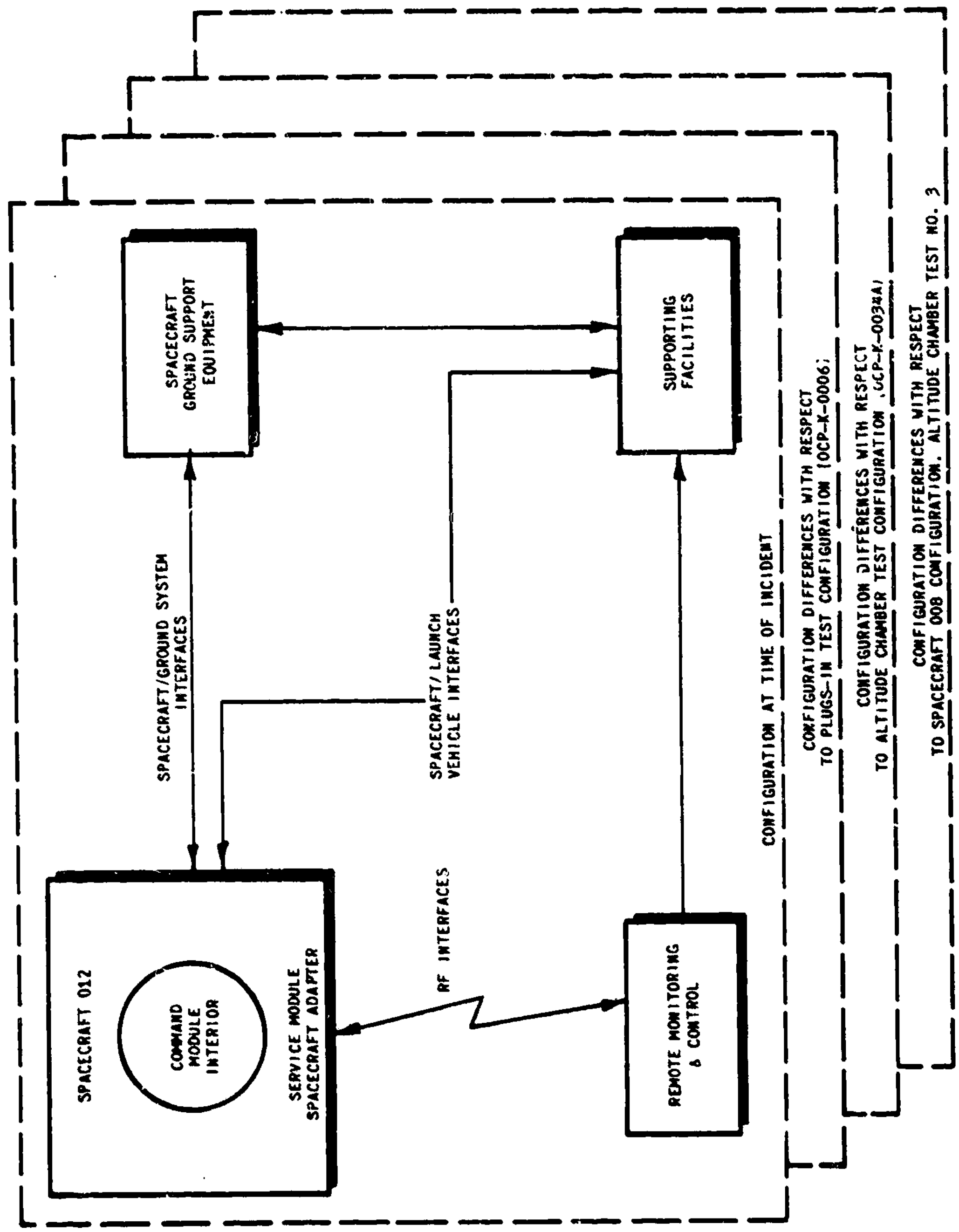
VIEW OF SPACECRAFT LAUNCH VEHICLE IN SERVICE STRUCTURE
WITH ACCESS ARMS EXTENDED



ENCLOSURE 1-2

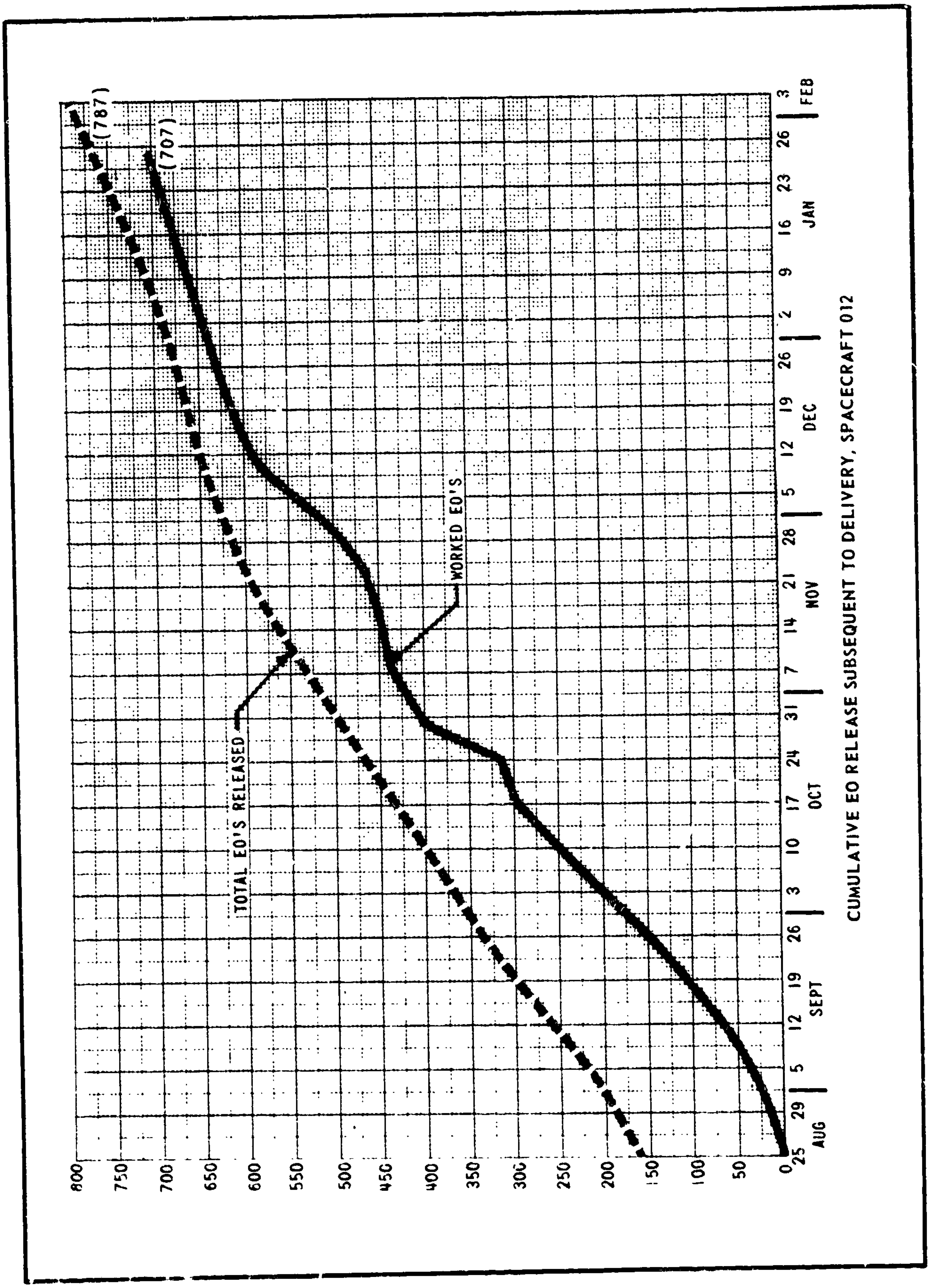


ENCLOSURE 1-3



SCOPE OF INVESTIGATION, PANEL 1

ENCLOSURE 1-4



ENCLOSURE 1-5

SPACECRAFT 012 CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

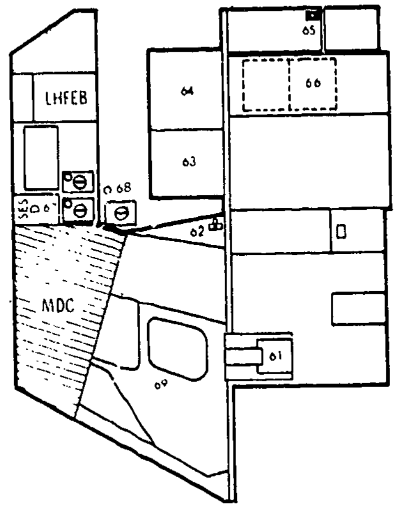
The attached table lists by area the configuration of stowage items and other loose equipment for the Spacecraft 012 Crew Compartment. This information is given for the planned launch, Operational Checkout Procedure (OCP) K-0034A-1-Manned Altitude Chamber Test, and OCP K-0021-1-Plugs-Out Test.

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 compartment, 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



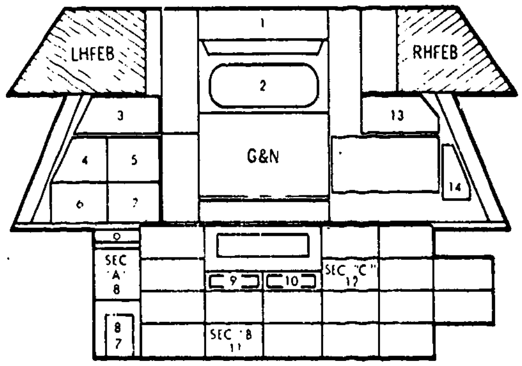
CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible]

STOWAGE AREA	QUANTITY PLANNED LAUNCH	OCP K-0034A-1	OCP K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
67	[illegible]	1	-	V16-[illegible]	Scientific Container "D"	[illegible]	
67	[illegible]	1	1	EC[illegible]	Dew Pt Hygrometer Sensor	[illegible]	- Stowed on floor of area 67 in LEB for [illegible]
67	[illegible]	1	1	EC3[illegible]004	Sensor Cable	039	- (same as above)
67	[illegible]	1	1	EC[illegible]	Control Unit	040	- (same as above)
67	[illegible]	1	1	SEB1110001[illegible]	Control Pwr Cable	041	- (same as above)
67	[illegible]	1	1	SDC18300001	Octopus Cable	[illegible]13	- Installed across LEB
6[illegible]	[illegible]	1	1	V16-601140-11	Tee Handle	805C	
[illegible]	[illegible]	-	-	TA44-[illegible]	Roll Tape	0[illegible]7	
[illegible]	[illegible]	-	-	V16-601[illegible]	Container (Food Strg Supp)	81[illegible]	
[illegible]	[illegible]	-	-	14-01[illegible]	Food Set	[illegible]	- [illegible] food stowed in special container on 0034A-1
6[illegible]	[illegible]			SEB[illegible]10007[illegible]	Plastic Bag	[illegible]	
[illegible]	[illegible]	[illegible]	-	A[illegible]-000	[illegible]G	[illegible]	
6[illegible]	[illegible]	[illegible]	-	A[illegible]007-000	In Flt Coveralls (Jacket)	0[illegible]1	
6[illegible]	[illegible]	[illegible]	-	A[illegible]006-000	In Flt Coveralls (pants)	0[illegible]1	
6[illegible]	-	-		ME901-0[illegible]	Sandals ([illegible] pr)	80[illegible]	
[illegible]	[illegible]	[illegible]	-	ME901-03[illegible]5-00[illegible]	Sandals ([illegible] pr)	80[illegible]	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-03[illegible]-00[illegible]	Sandals ([illegible] pr)	80[illegible]	
6[illegible]		[illegible]	[illegible]	ME901-0[illegible]-00[illegible]	Sandals ([illegible] pr)	80[illegible]	
[illegible]	[illegible]	1	1	ME901-0[illegible]-00[illegible]	Sandals	80[illegible]	
[illegible]	[illegible]	-	-	SEB[illegible]10007[illegible]	Plastic Bag	061	
[illegible]	[illegible]	1	-	SDB[illegible]	Commanders Checklist	01[illegible]A	
6[illegible]	[illegible]	[illegible]	-	SDB[illegible]100040	Flight Plan	01[illegible]	
[illegible]1	1	1	-	V16-[illegible]301	Container Flt Data File	[illegible]	
6	[illegible]	1	-	V16-601140-11	Tee Handle	805C	
[illegible]	[illegible]	-	[illegible]	V16-601[illegible]	Noise Limiter Adapter Cables		
[illegible]	[illegible]	[illegible]	[illegible]	V16-601[illegible]01-[illegible], -8[illegible], -[illegible]	Umbilical Assy	877	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	O_2 Hose Inlet Nozzle	40[illegible]	- On umbilicals
68	[illegible]	[illegible]	3	[illegible]36	O_2 Hose Exhaust Nozzle	410	- On umbilicals
68		[illegible]	[illegible]	V16-601263-41	Cobra Cable	8[illegible]	
68	[illegible]	1	1	V16-601263-[illegible]	Cobra Cable	878	
68	[illegible]	[illegible]	[illegible]	V16-60[illegible]	T-Adapter Elect	1000	- Center Crewman cobra cable ONLY on [illegible]
6[illegible]	[illegible]			ME[illegible]	[illegible] Cartridges	[illegible]68	- [illegible] numbers [illegible] installed for [illegible]. Non-flight [illegible] number
6[illegible]	-	-	[illegible]	Non-flight	GSE [illegible]		- On all [illegible] umbilicals. Made of nylon. Each had "Remove before flight" streamer

ENCLOSURE 1-8a

LOWER EQUIPMENT BAY

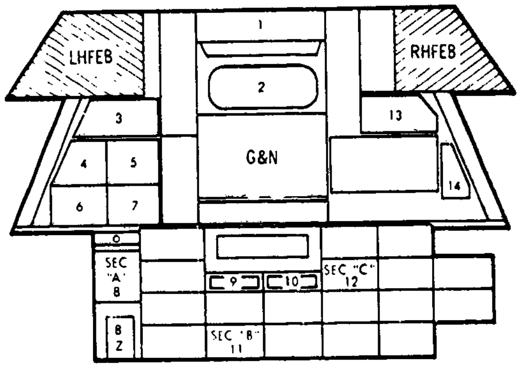


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

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	
1	[illegible]	[illegible]	1	2012699	SXT Mirror Housing	017A	
2A	1	1	1	SDB33100065-201	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]	-	-	V16-601118	Food Container "A"	814	
[illegible]	[illegible]	-	-	V16-601116	Food Container "B"	816	
[illegible]	[illegible]	-	-	V16-601117	Food Container "C"	815	
6	[illegible]	-	-	V16-601114	Food Container "D"	818	
7	1	-	-	V16-601115	Food Container "E"	817	
8	1	1	-	SEB33100031-201	Ring Sight	008	
8A		1	1	SEB33100021-207/208	16 MM Seq Cam with Film	001	Stowed on floor of area 8Z, LEB for 0021-1
8B	1	1	1	SEB33100026-201	16 MM Power Cable	005	Stowed on floor of area 8Z, LEB
8C	1	1	-	SEB33100023-201	18MM Lens	003	
8D	[illegible]	1	-	SEB33100054-201	[illegible] MM Lens	202	
8E	1	1	-	SEB331000[illegible]-[illegible]	100 MM Lens	004	
8F	[illegible]	1	-	SEB33100051-201	Mirror Mtg Bracket	037	
8G	[illegible]	1	-	SEB331000[illegible]-206	16 MM Magazine	002	1 stowed in area 90, crew couch, on 0034A-1
8H		1	-	SEB331000[illegible]-201	10 MM Camera	006	
8I	[illegible]	1	-	SEB33100032-201	250 MM Lens	009	
8J		-	-	SEB33100030-201, -202, -203	70 MM Magazine	212	
8K	[illegible]	1	-	SEB33100027-201	Exp Dial	011	
8L	1	1	-	SEB33100028-201	Spotmeter	010	
8M	1	1	-	EC-0155	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[illegible]	1	1	-		Gas Chromatograph		Not installed on 0021-1
9	1	1	-	V16-334137	Crew Flt Data File Cont.	839	

LOWER EQUIPMENT BAY (CONT.)

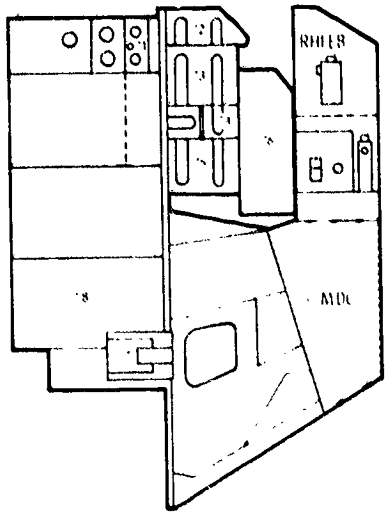


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 1725 (MAR 67)(OT)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	OCP K-0034A-1	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 02 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	-	SDB3310004[illegible]	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	-	V16-601310-21	Tool "F"	803F	
10	1	1	-	V16-601134-11	Tool "H"	803H	
10	1	1	-	V16-601481-11	Tool "J"	803J	
10	[illegible]	1	-	V16-6011[illegible]-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	-	V16-601404	Work/Food Shelf	820	
10	1	1	-	SEB12100049-[illegible]	Inspection Mirror	068	
11	1	-	-	EX75036	Goggles	204	
11	[illegible]	-	-	EX75037	Mouthpiece	205	
11	8		-	SEB331000[illegible]0-201, -202 or -[illegible]	70 MM Magazine	008	
11	7	7	-	SEB33100022-[illegible]	16 MM Magazine	002	
12	1	1	1	SD511076	MDAS	600	
13	1	1	-	SEB42100004-201	Physiological Monitoring Kit	024	
13	[illegible]	[illegible]	-	14-149	UCD Clamp	029	
13	1	1	-	14-0207	Urine Receptacle	035	
13	1	1	-	14-0[illegible]09	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



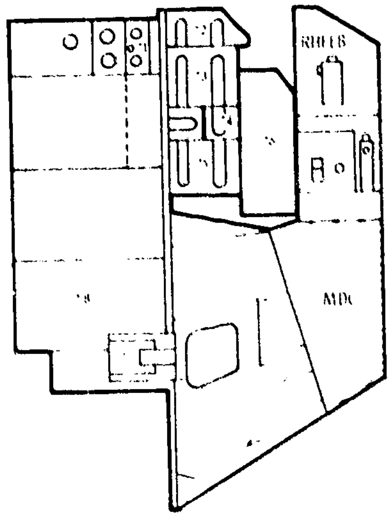
CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible] (MAR [illegible])

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	OCP K-0084A-1	OCP K-0021-1				
[illegible]					Vacuum Cleaner Compartment		
[illegible]	[illegible]	[illegible]	-	V16-611[illegible]	Vacuum Clnr Ref Stow Bag Assy	8[illegible]	
[illegible]		[illegible]	-	ME19[illegible]-00[illegible]-0001	Vacuum Clnr Debris Bag	8[illegible]A	
[illegible]		[illegible]	-	ME[illegible]1-07[illegible]-000[illegible]	Fecal Outer Bag	8[illegible]B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-[illegible]	Vacuum Clnr Germicide Pouch	8[illegible]C	
[illegible]	[illegible]		-	M7[illegible]	Tie Band	8[illegible]D	
[illegible]					Medical Accessories Kit Com[illegible]		
[illegible]	1	1	-	10[illegible]70[illegible]	Bio Instrumentation Acc Kit	0[illegible]	
[illegible]	[illegible]	[illegible]	-	SEB[illegible]10001[illegible]-[illegible]01	Electrodes	0[illegible]A	
[illegible]	[illegible]	[illegible]	-	SEB[illegible]10001[illegible]-[illegible]01	Micropore Disks	0[illegible]B	
[illegible]	8	8	-	14-0[illegible]	Wet Wipe Towels	0[illegible]C	
[illegible]		[illegible]	-	SEB[illegible]10001[illegible]-[illegible]01	Paste	0[illegible]D	
[illegible]	[illegible]	1	-	SEB[illegible]1000[illegible]-[illegible]01	Stoma Seal Disk	0[illegible]E	
[illegible]		1	-	SEB[illegible]1000[illegible]-[illegible]01	Bio Instr Stowage Bag	0[illegible]F	
[illegible]	[illegible]	1	1	V16-611[illegible]	Vacuum Cleaner Nozzle	8[illegible]A	
[illegible]	1	1	-	EA[illegible]008-1	Nephelometer(Aerosol Particle)	[illegible]01	
[illegible]	10	10	-	V16-601[illegible]-101	Sanitation Supply Assy	811	
[illegible]	10	10	-	V16-601[illegible]78-11	Inner Fecal Bag	811A	
[illegible]	10	10	-	ME[illegible]-0001-0001	Germicide Pouch	811B	
[illegible]	10	10	-	ME901-07[illegible]-0001	Outer Fecal Bag	811C	
[illegible]	10	10	-	V16-601[illegible]-[illegible]	Outer Tie Band	811D	
[illegible]	[illegible]	1	-	14-011[illegible]	Dry Utility Towels	[illegible]31	
[illegible]	[illegible]		-	V16-611[illegible]8	Vacuum Cln Ref Stow Bag Assy	8[illegible]	
[illegible]			-	ME19[illegible]-003[illegible]-0001	Vacuum Clnr Debris Bag	8[illegible]A	
[illegible]		[illegible]	-	ME901-07[illegible]-0001	Fecal Outer Bag	8[illegible]B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Vacuum Clnr Germicide Pouch	8[illegible]C	
[illegible]	[illegible]	[illegible]	-	M7[illegible]	Tie Band	8[illegible]D	
[illegible]		[illegible]	-	V16-601[illegible]8	Elect Adapters, Sleep	88[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	V16-601[illegible]	Adapter-CWG-Elect	8[illegible]1	
[illegible]	2	[illegible]	[illegible]	V[illegible]-601[illegible]	Cobra Cable	878	- On 0021-1, both spares removed from stowage by crew, both found on couch
[illegible]					Sanitation Supplies Compt.	80[illegible]	
[illegible]	1	1	-	V16-60111[illegible]-501	Box San Sup Storage A	808	
[illegible]	1	1	-	V16-60111[illegible]-401	Box San Sup Storage B	809	
[illegible]	1	1	-	V16-60111[illegible]-301	Box San Sup Storage C	811	
[illegible]	[illegible]	[illegible]	-	V16-601419-11	Sanitation Supply Assy	811A	
[illegible]	[illegible]	[illegible]	-	V16-601[illegible]78-11	Inner Fecal Bag	811B	
[illegible]	[illegible]	[illegible]	-	ME[illegible]-0001-0001	Germicide Pouch	811C	
[illegible]	[illegible]		-	ME[illegible]01-07[illegible]-0001	Outer Fecal Bag		

ENCLOSURE 1-8c

RIGHT HAND EQUIPMENT BAY (CON'T)

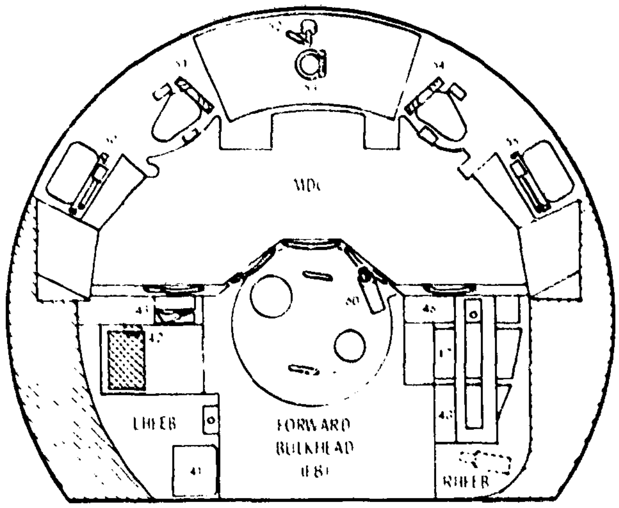


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible]

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED [illegible]	OCP K-0084-1	OCP K-0021-1				
76	62	62	-	V16-601419-1	Outer Tie Band	811D	
76	2	2	-	V16-601120-51	Cover	810	
76	1	1	-	V16-601120-61	Cover	80[illegible]	
76	1	-	-	V16-601619	Aux Food Comp RHEB	81[illegible]	
77							
77	1	1	-	V16-601491	Crew Flt Data File Container	8[illegible]	
77A	1	1	-	SDB3310[illegible]	Sys Eng Checklist	012C	
77B	1	1	2	SDB3310[illegible]	Mission Log & Data	012E	-Found on LH and center couches after 0021-1.
76A	2	2	1	LSC-360-12	DSEA (Voice Recorder)		-Installed in alternate position - Primary installation position taped with "Boat Tape" on 0021-1.
76A	1	1	1		DSEA Adaptor Cable		-Not connected on 0021-1
78	-	-	8	Non-flight	Plastic Dust Caps		-On pyro and circuit interrupter connectors

FORWARD BULKHEAD, SIDEWALL AND HATCH

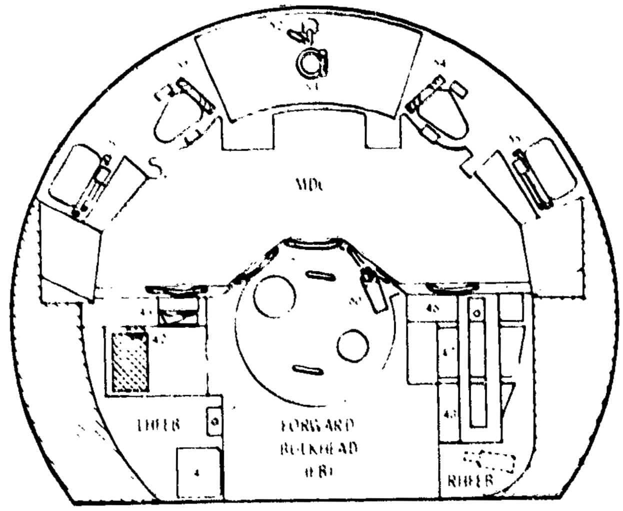


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM 1725 (MAR 67)(OT)

STOWAGE AREA	QUANTITY PLANNED LAUNCH	OCP K-0034A-1	OCP K-0021-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
41					LHFEB--Loose Parts Compart.		
41A	1	1	1	2014764-011	Short Handhold	013	
41B	1	1	1	2014764-021	Long Handhold	014	
41C	1	1	1	V16-334100	EVT Rot Cont Mount	831	
41D	1	1	1	101178-1	1/8 Long Eyerelief Eyepiece Set	018	
42	1	1	1	14-0104-02	Metering Water Dispenser	400	Not connected to hose of 0021-1. Hose fitting covered by plastic bag
4[illegible]					RHFEB-Stow. Area - Survival Kits		
4[illegible]	1	1		V16-601371-101	Container Survival Kit A	84	
4[illegible]	1	1		SEB40100011-201	Rucksack No. 1	025A	
4[illegible]A	1	1		SEB40100010-201	Rucksack	025A	
4[illegible]	2	2		20538	Combination Survival Assy	025A	
4[illegible]	16	16		SEB40100021-001	Desalter Kit Tablets	025A	
4[illegible]D	2	2		SEB40100021-002	Desalter Kit Process Ba.	025A	
4[illegible]E	2	2		SEB40100021-003	Mending Kit	025A	
4[illegible]F	3	3		SEB40100020-201	Sunglasses	025A	
4[illegible]	1	1		2588218	Radio Beacon Assy	025A	
4[illegible]H	1	1		2588254	Radio/Beacon Spare Battery	025A	
4[illegible]I	1	1		2555952	Radio/Beacon Cable Assy	025A	
4[illegible]J	2	2		SEB40100004-201	Machete	025A	
4[illegible]K	2	2		SEB40100001-201	Machete Sheat	025A	
4[illegible]	1	1		SEB40100013-201	Rucksack No. 2	025B	
4[illegible]A	1	1		SEB40100012-201	Rucksack	025B	
4[illegible]	2	2		SEB40100022-201	Water Container	025B	
4[illegible]	1	1		SEB40100052-201	Water Container	025B	
4[illegible]D	[illegible]	1N			Water	025B	
4[illegible]E	3	3		SEB40100048-201	Water Container Stoppers	025B	
4[illegible]F	1	1		SEB40100058-201	Medical Kit	025B	
4[illegible]	1	1		281SSAR	Filler Material	025B	
4[illegible]	1	1		ME281-0023-0001	Sea Water Pump	848	
4[illegible]	1	1		V16-601372-101	Container Survival Kit [illegible]	818	
4[illegible]	1	1		SEB4010001[illegible]-201	Rucksack No. 3	025[illegible]	
4[illegible]A	1	1		SEB4010001[illegible]-201	Rucksack	[illegible]	

FORWARD BULKHEAD, SIDEWALL AND HATCH (CONT.)

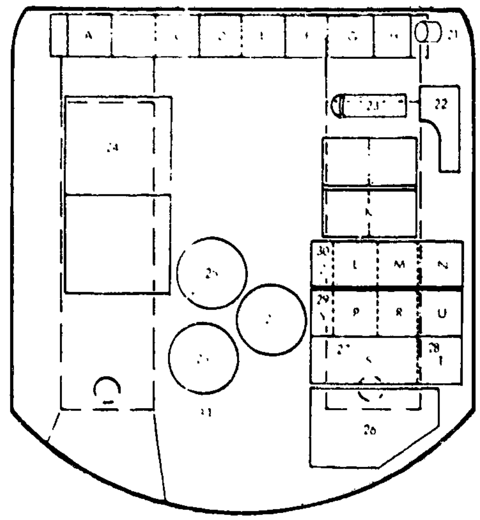


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible]

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	OCP K-[illegible]A-1	OCP K-[illegible]-1				
4[illegible]	1	1		SFB6010003l-001	Life Raft Kit - 3 Man	0250	
4[illegible]	1	1		SFB60100040-001	Life Raft Inflation Assy	0250	
4[illegible]	[illegible]	[illegible]		SFB60100023-201	Sea Anchor	0250	
4[illegible]	[illegible]	[illegible]		SFB60100005-001	Sea Dye Marker	0250	
4[illegible]	[illegible]	[illegible]		SFB60100002-201	Air Bailer	0250	
4[illegible]	[illegible]	[illegible]		SFB60100014-201	Lanyard	0250	
4[illegible]	1	1		SFB60100015-001	Mooring Lanyard	0250	
4[illegible]	[illegible]	[illegible]		SFB60100055-001	[illegible]	0250	
4[illegible]	[illegible]	[illegible]		SFB60100063-001	Strap Assy	0250	
4[illegible]	[illegible]	[illegible]		SFB60100064-001	Strap Assy	0250	
48	1	1		V16-[illegible]013[illegible]3-101	Container Survival Kit [illegible]	340	
50	1	1		V16-[illegible]1339-21	Left Side View Window Shade	[illegible]	[illegible] Mylar covers installed in lieu of aluminized mylar flight window covers on windows in areas 50, 51, 53, and 55. Hatch window cover (53) removed by crew after ingress and stowed somewhere in the spacecraft.
51	1	1		V16-[illegible]1341-11	Shade-LH Rendezvous	[illegible]	
53	1	1		V16-[illegible]1340-21	Shade-Hatch	[illegible]	
55	1	1		V16-[illegible]1339-21	Rt. Side View Window Shade	[illegible]	
[illegible]	1			V16-[illegible]01636	Tool "[illegible]" Wrench Assy	303	
[illegible]	1	1		V16-[illegible]1341-1[illegible]	Shade--RH Rendezvous	[illegible]	
[illegible]	1			[illegible]	[illegible] Camera	[illegible]	
48	1	1		SFB6010003l-001	3 Man Life Raft		
4[illegible]	1[illegible]	10		SFB[illegible]100015-001	Urine Storage [illegible]		
[illegible]	[illegible]	[illegible]		[illegible]40106-1	Urine Receiver		
[illegible]	[illegible]	3		SFB [illegible]0100001-001	[illegible] Stowage [illegible]		
48	[illegible]	[illegible]		[illegible]	Roll of [illegible]		
MDC			1	Non-flight	FDAI Cover		Removed from FDAI by Command Pilot and placed on aft bulkhead after crew ingress.

AFT BULKHEAD

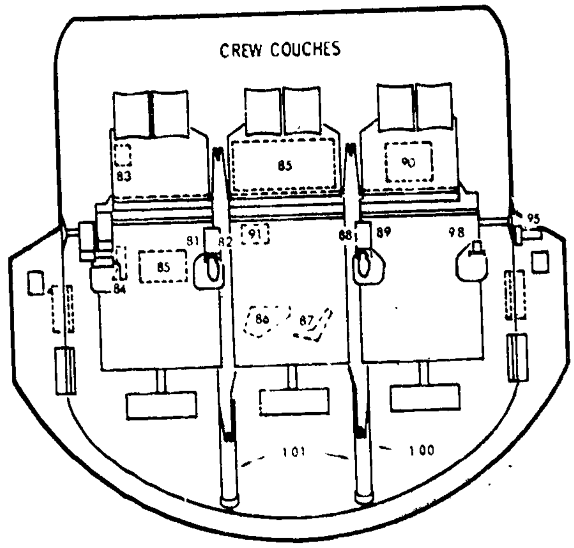


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible]

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	PLANNED LAUNCH	OCP K-0034A-1	OCP K-00[illegible]-1				
[illegible]							
[illegible]	1	1	-	EC[illegible]	Inflight Exerciser	[illegible]7	
[illegible]	1	1	-	SEB[illegible]1000[illegible]01	Inflight Exerciser Pouch	[illegible]8	
[illegible]	[illegible]	[illegible]	1	ME[illegible]-00[illegible]	TV Optics Container	8[illegible]7	
[illegible]	[illegible]	[illegible]	1	ME[illegible]01-[illegible]-00[illegible]	TV Zoom Lens	8[illegible]8	
[illegible]	[illegible]	[illegible]	-	V1[illegible]-601-18-[illegible]01	Fecal Cannister	860	
[illegible]		[illegible]	-	V1[illegible]	PGA Stowage Bag	801	
[illegible]	[illegible]	[illegible]	-	V16-601-1[illegible]	Crew Waste Basket	[illegible]	
[illegible]	[illegible]	[illegible]	-	V16-601[illegible]	Crew Restraint	[illegible]	
[illegible]		[illegible]	-	V1[illegible]	Pad Fecal Cannister	58[illegible]	
A	[illegible]		[illegible]	A[illegible]-000	Skull Cap Assy	[illegible]	
[illegible]	[illegible]	1	1	A[illegible]-00[illegible]	Skull Cap Assy	04[illegible]	
[illegible]	[illegible]	[illegible]	1	A[illegible]-000	Skull Cap Assy	[illegible]	
	[illegible]	[illegible]	[illegible]	A[illegible]-000	Head Set	[illegible]	
	[illegible]	[illegible]		A[illegible]011-000	Helmet Stowage Container	[illegible]	
[illegible]	[illegible]	[illegible]	1	V1[illegible]	Sleep Restraint	8[illegible]	
[illegible]	[illegible]	[illegible]	-	V1[illegible]	PGA Stowage Bag	80[illegible]	
[illegible]	[illegible]	-	-	SEB[illegible]000[illegible]	70 MM Film Pack	[illegible]	
[illegible]		[illegible]	-	SEB[illegible]	70 MM Camera	[illegible]	
[illegible]	[illegible]	1	-	SEB[illegible]	Ring Sight	[illegible]	
[illegible]	[illegible]	[illegible]	1	ME[illegible]	COAS	[illegible]	
[illegible]	[illegible]	-	-	SEB[illegible]000[illegible]	16 MM Magazine	[illegible]	
[illegible]	[illegible]	-	-	SEB[illegible]000[illegible]	16 MM Magazine	[illegible]	
[illegible]		1	1	[illegible]-00[illegible]	COAS Bulb	[illegible]A	
[illegible]		1	-	V16-[illegible]	16 MM Camera Bracket	[illegible]	
[illegible]	[illegible]	[illegible]	-	FC[illegible]	Pen Lights	[illegible]	
[illegible]	[illegible]	[illegible]	-	SEB[illegible]1000[illegible]-01	Tool Kit	[illegible]	
[illegible]	[illegible]	[illegible]	-	SEB[illegible]00018-01	PPK	[illegible]	
	-	-	IN	Non-Flight Installation of Flight material	Velcro pile covering velcro hook over large portion of aft bulkhead		*Installed to protect velcro hook.
A-[illegible]	[illegible]	[illegible]	-	ME[illegible]-[illegible]18-00[illegible]1	LiOH Cartridge*	[illegible]	*Stowage cannister not installed on 00[illegible]-1
J,K	[illegible]	4	-	ME[illegible]-[illegible]18-00[illegible]	LiOH Cartridge	[illegible]	
L,M,N	[illegible]	[illegible]	-	ME[illegible]-00[illegible]1	LiOH Cartridge	[illegible]	
P,R,U	[illegible]	[illegible]	-	ME[illegible]01-[illegible]18-00[illegible]1	LiOH Cartridges	[illegible]	
AA-[illegible]	[illegible]	-	-	ME[illegible]01-[illegible]18-[illegible]	LiOH Cartridge	[illegible]	
D-F	-	-	[illegible]	Non-Flight	Battery Instrumentation Cable & Transducer		*Stowed in [illegible] on aft bulkhead

CREW COUCHES GIRTH SHELF

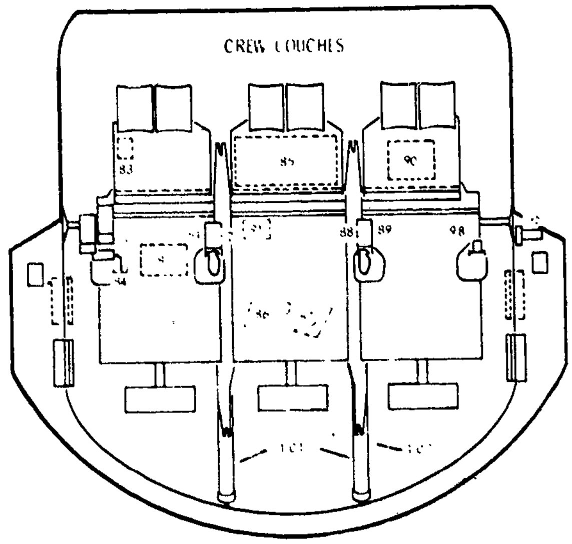


CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

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
Crew Couches	2	1	1	V16-601472-151	Couch Pad Assy	879	
	2	2	2	V16-601472-161	Couch Pad Assy	879	
	2	1	1	V16-601472-171	Couch Pad Assy	879	
	2	2	2	V16-601472-181	Couch Pad Assy	879	
	3	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
[illegible]	-	-	1	Non-flight	OCP K-0021-1 Checklist		-Multilith process paper
[illegible]	-	-	1	Non-flight	OCP K-0021-1 Checklist		-Multilith process paper
[illegible]	-	-	1	Non-flight	Malfunction Procedures Document		-Zerox and Bruning process paper in manila folder.
81	1	1	1	V16-531750-?	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 8? in LEB for 0021-1, stowed w/loaded magazine for 0034A-1

CREW COUCHES GIRTH SHELF (CON'T)



CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

MSC FORM [illegible]

STOWAGE AREA	QUANTITY PLANNED LAUNCH	QUANTITY OCP K-0034A-1	QUANTITY OCP K-00[illegible]1-1	PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
90	1	1	-	SEB331000[illegible]5-[illegible]01	70 MM Super Wide Angle Cam	048	
90	1	1	-	SEB331000[illegible]6-[illegible]01	[illegible] MM Lens, 16MM Camera	04[illegible]	
90	[illegible]	-	-	SEB33100030-[illegible]01, -[illegible]02 or -[illegible]03	70 MM Film Magazine	[illegible]	
90	[illegible]	-	-	SEB331000[illegible]-[illegible]0[illegible]	Interference Filter	[illegible]	
90	1	-	-	SEB331000[illegible]0-[illegible]	Filter	[illegible]30	
90	1	1	-	V16-754[illegible]	Vol "G" Foam Cushion	888	
90	[illegible]	[illegible]	-	SEB331000[illegible]0-[illegible]01	Haze Filter (on camera)	[illegible]	
90	[illegible]	[illegible]	-	EL[illegible]0170	Goggles Assy	[illegible]31	
91	1	1	-	ME[illegible]80-0008-000[illegible]	Sensor Unit-Temp Evaporator	884	
9[illegible]	1	1	-	V16-601501-[illegible]1	Tool "F" Handle Ext.	803F	
96	1	-	-	V16-771[illegible]8	Floodlight		-Stowage bag only stowed for 00[illegible]1-1
96	1	-	-	V16-[illegible]0[illegible]	Floodlight Cable		
97	1	-	-	V16-752080	Camera Brkt ([illegible]051)		
98	1	1	1	V16-[illegible]317[illegible]0-[illegible]	Arm Rest, Crew Couch	871	
9[illegible]	1	1	-		Rotational Controller		
100	-	-	1	Non-flight	Dust Cap		-Plastic - on SCS junction box connector
101	-	-	[illegible]	Non-flight	Foam Rubber Pads		-Covered with velostat, clean room tape, laid over 2-2 struts

ENCLOSURE 1-8f

CARRIED ON CREWMEN

CREW COMPARTMENT STOWAGE AND LOOSE EQUIPMENT CONFIGURATION

STOWAGE AREA	QUANTITY			PART NUMBER	NOMENCLATURE	STOWAGE ITEM NUMBER	REMARKS
	[illegible]	OCP K-[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		Ratchet Wrench		On Command Pilot
	-	3	3	Non-flight	Personal Watchband		1 per crewman
	3	3	3	Non-flight	Bioinstrumentation System	407	1 per crewman

ENCLOSURE 1-8g

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

ENCLOSURE 1-9

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

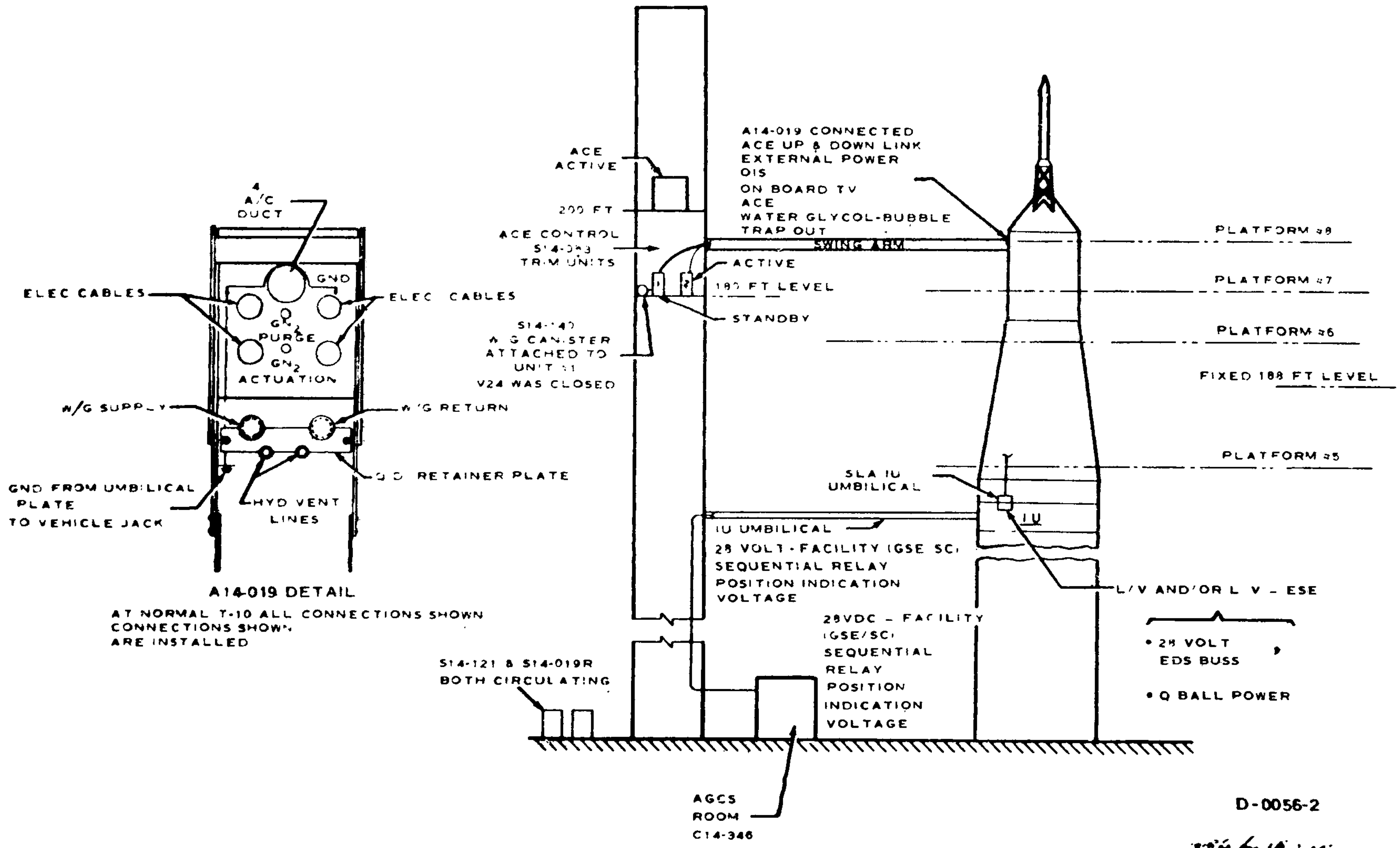
PYROS SHORTED, CONNECTORS TIED BACK

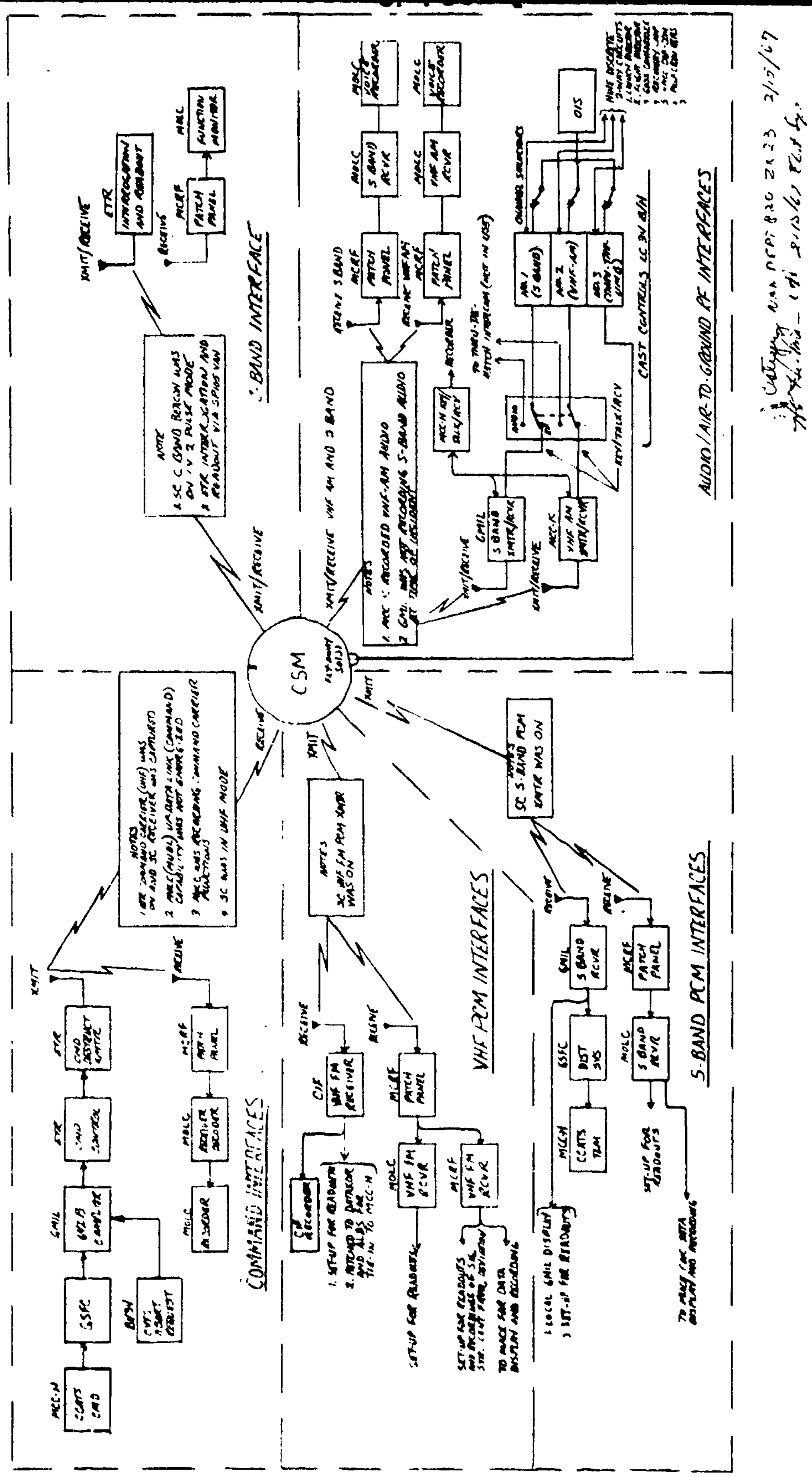
COMMAND MODULE OXYGEN SUPPLIED THROUGH ONE UMBILICAL LINE

1-D-0056-1

ENCLOSURE 1-9a

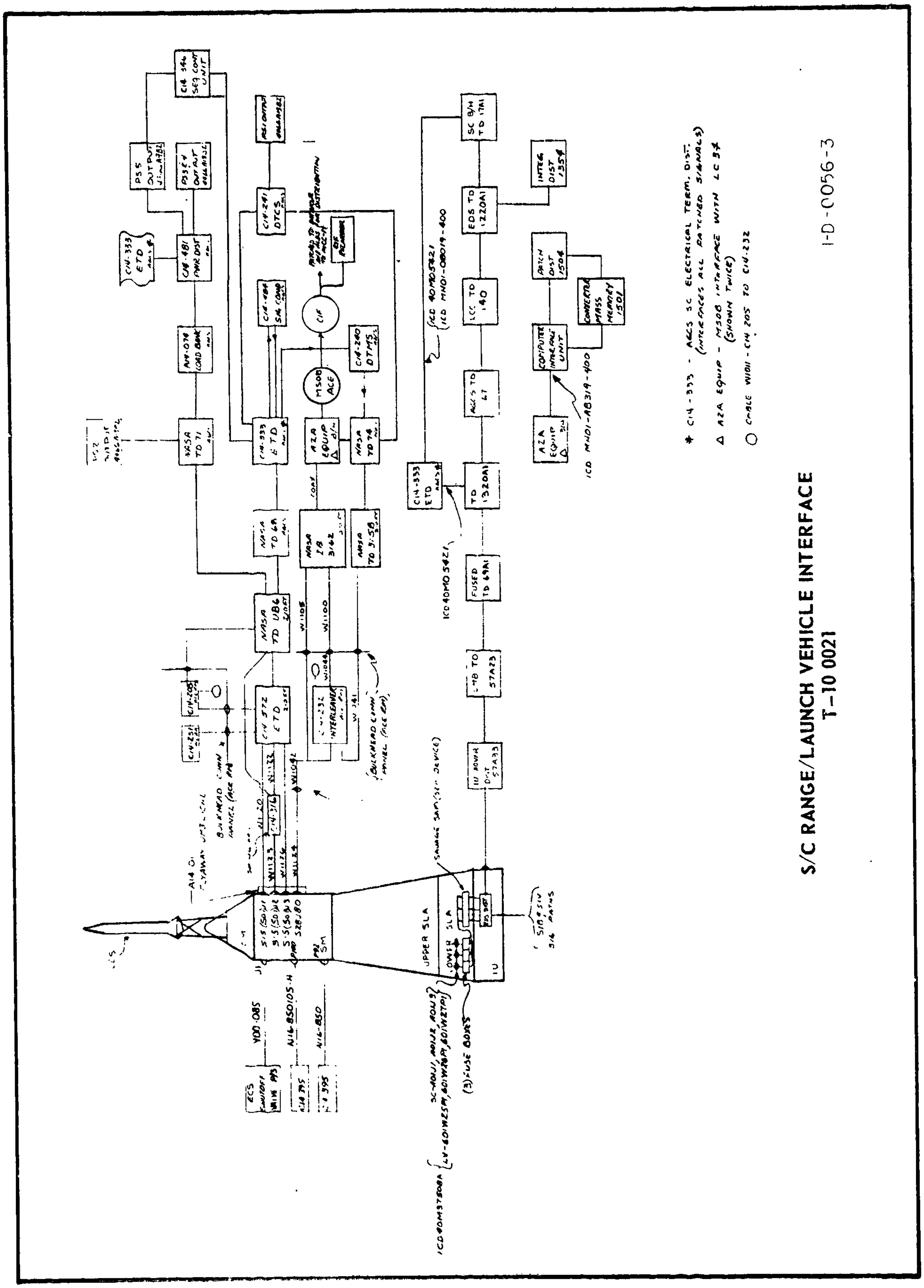
L/C 34
SPACECRAFT GSE CONFIGURATION DURING T-10 OCP0007



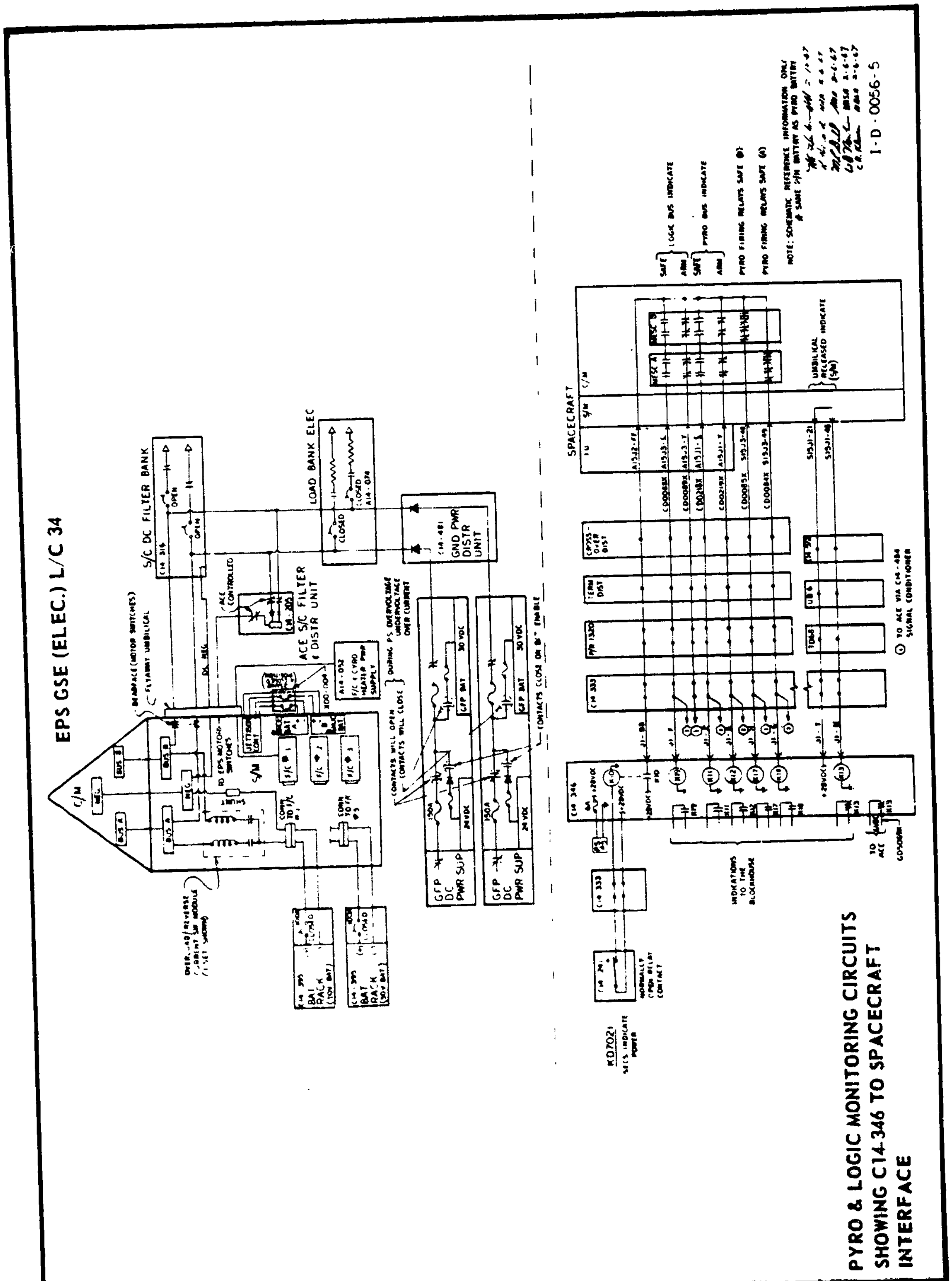


RF/AUDIO INTERFACES

ENCLOSURE 1-5b



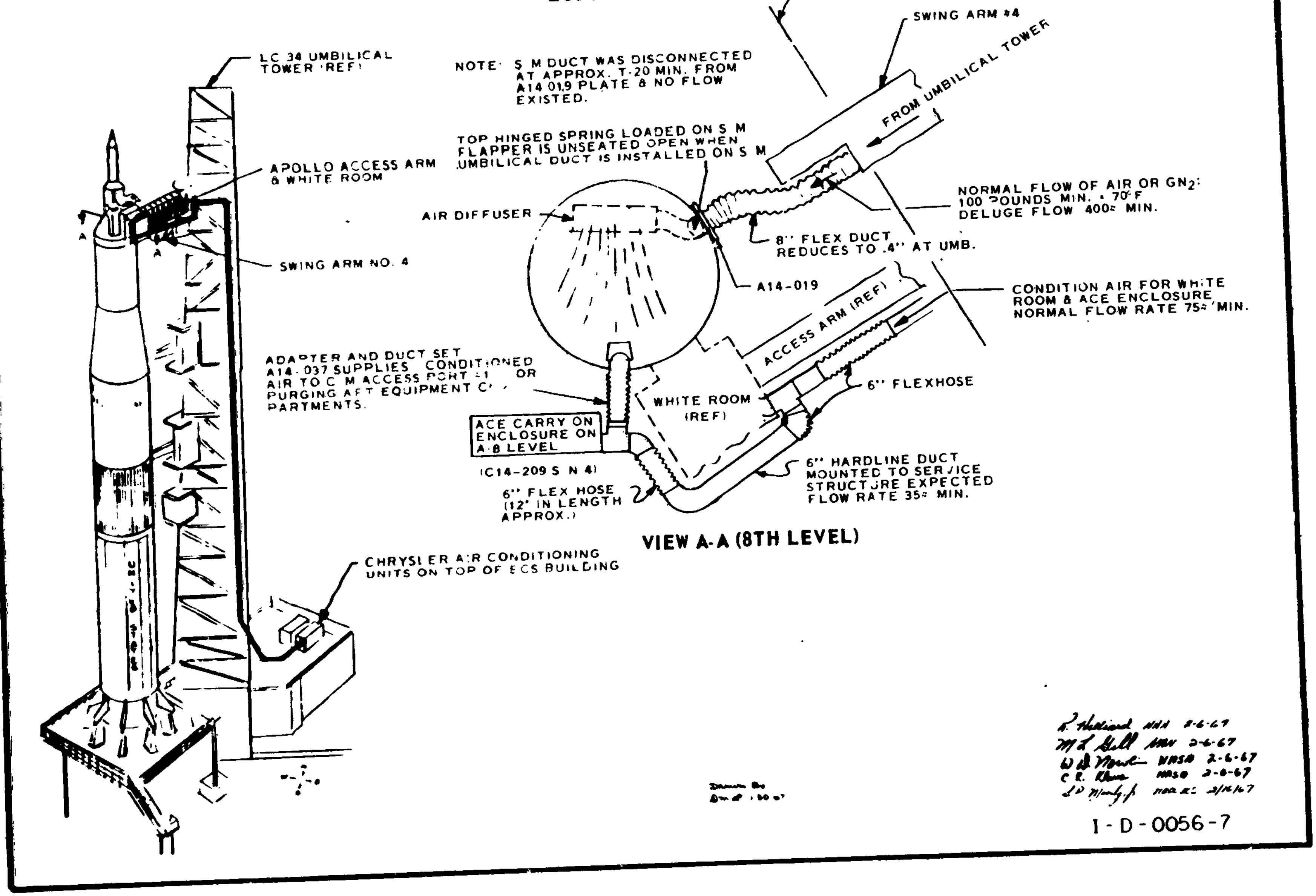
S/C RANGE/LAUNCH VEHICLE INTERFACE
T-10 0021

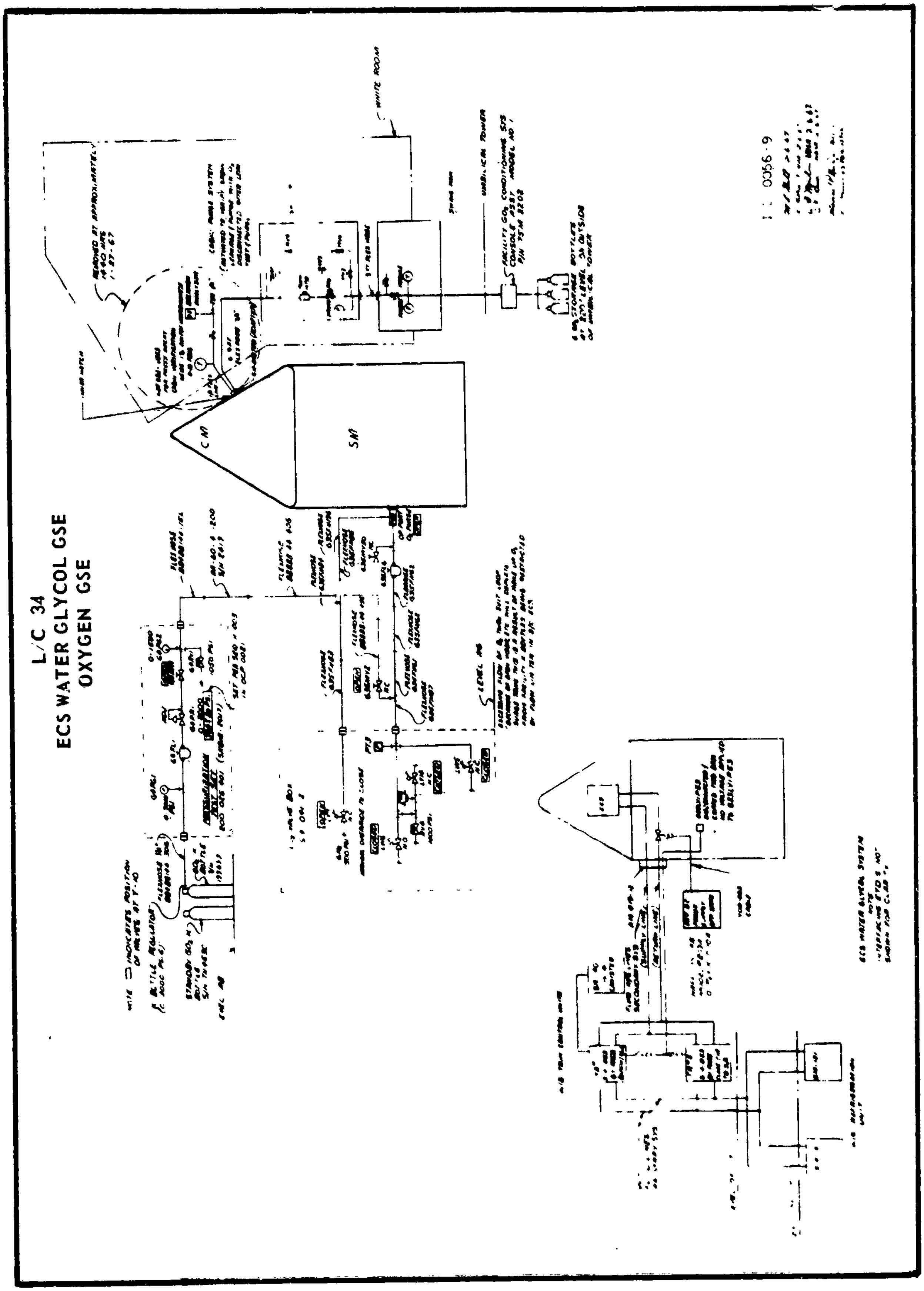


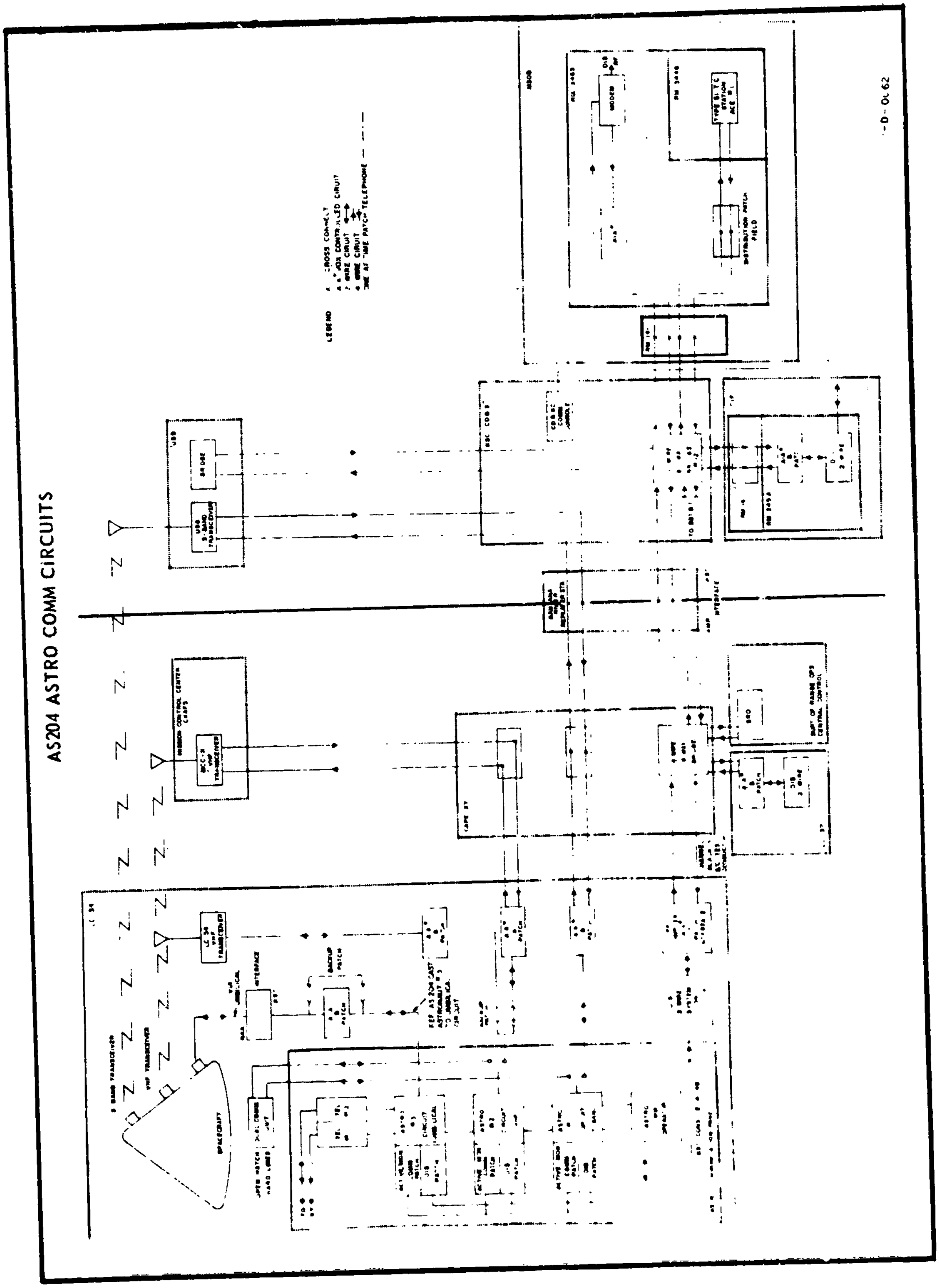
PYRO & LOGIC MONITORING CIRCUITS SHOWING C14-346 TO SPACECRAFT INTERFACE

ENCLOSURE 1-9d

L/C 34 ECS AIR DUCT




L/C 34
ECS WATER GLYCOL GSE
OXYGEN GSE
CM
SM
WHITE ROOM
UMBILICAL TOWER



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 10011", Oct. 25, 1966, North American Aviation, Inc., (Panel 7 Data).
1-6	"GSE Functional Integrated System Schematics, Spacecraft 012 & 014, ETR LC-34", 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)

ENCLOSURE 1-10

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	SID66-175	1 (Unmanned)	90 or greater	14.7 or above	95+	Approx. 6.5	Comm. (up link) Electrical 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

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 O_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	App. sea lev.		1.2 hrs.	
			75	6.2	75	28 hrs.	
		b) Manned Alt. Run (220,000')	Approx 100	App. sea lev.		1 hr.	
			95	5.5	75 - 77	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	App. sea lev.		1.5 hrs.	
			75	6.2	77	6 hrs.	
		b) Manned Alt. Run (220,000')	Approx 100	App. sea lev.		1.5 hrs.	
			95	5.5	75 - 77	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.

ENCLOSURE 2-2

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.

ENCLOSURE 2-4

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 II. 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.

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	ME0414-0265-5550	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.

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 untreateed 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	Gemini 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 III Qualification Test Procedure AiResearch Rpt. SS-1507-R, Rev. 1 dtd. 8-30-65.

2-15 Group III 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