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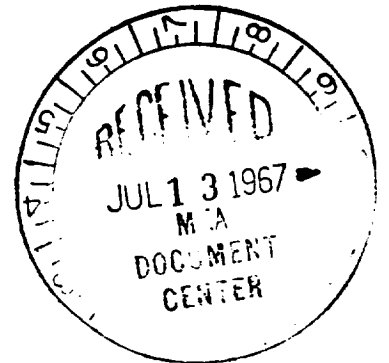
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUPPORT MANUAL

# APOLLO SPACECRAFT FAMILIARIZATION



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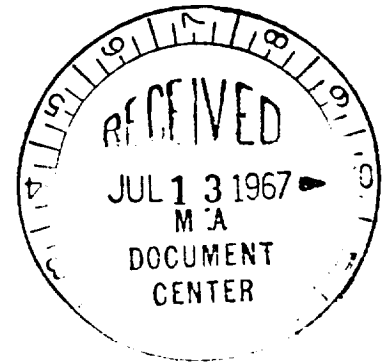
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TECHNICAL REPORT INDEX/ABSTRACT

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DESCRIPTIVE TERMS  Section titles are Project Apollo, Apollo Space Vehicle, Spacecraft Systems, Lunar Module, Apollo Spacecraft Manufacturing, Apollo Training Equipment, Apollo Test Program, Lunar Landing Mission, Apollo Support Manuals, and Glossary of Abbreviations, Symbols, and Terms.							
ABSTRACT  This issue of the Apollo Spacecraft Familiarization manual provides introductory data for personnel associated with the Apollo program. Each command and service module system is discussed in general terms, but with sufficient detail to convey a clear understanding of the systems. In addition, the Apollo earth orbit and lunar landing missions are described, planned, completed, and test programs or missions are identified. Manufacturing, training equipment, ground support equipment, space vehicles, and the lunar module are all covered in gross terms.							





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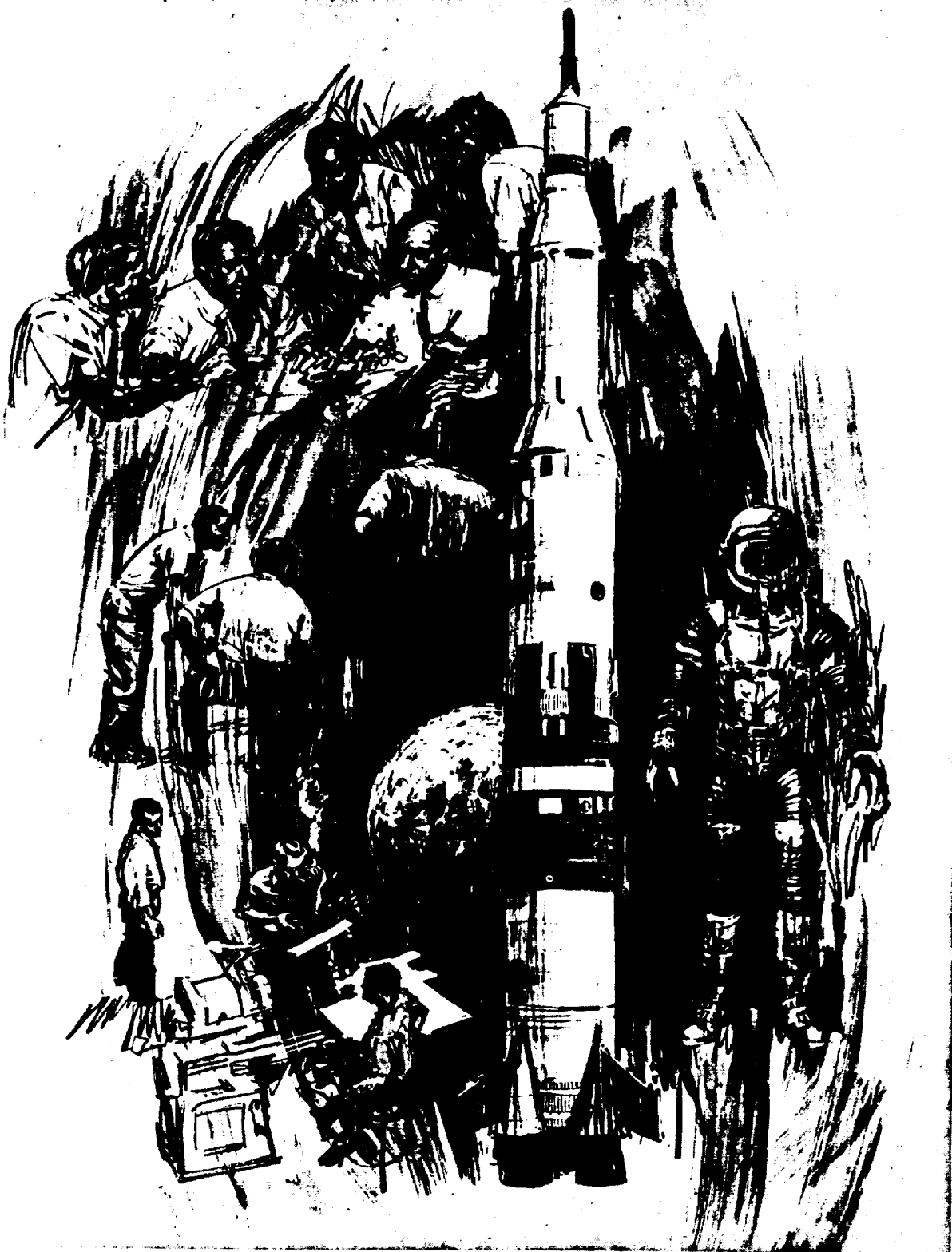
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## INTRODUCTION

This manual provides general introductory data for personnel associated with the Apollo program. Each command and service module system is discussed in general terms, but with sufficient detail to convey a clear understanding of the systems. In addition, the Apollo earth orbit and lunar landing missions are described, planned, completed, and test programs or missions are identified. Manufacturing, training equipment, ground support equipment, space vehicles, and the lunar module are all covered in gross terms. The source information used in the preparation of this manual was that available as of November 1, 1966.

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## PROJECT APOLLO

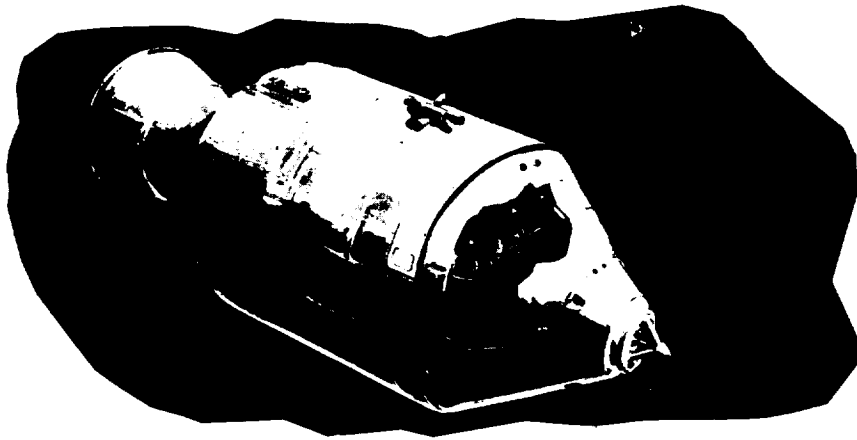


Figure 1-1.

Apollo Spacecraft

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1-1. The ultimate objective of Project Apollo is to land men on the moon for limited observation and exploration in the vicinity of the landing area and assure their subsequent safe return to earth. (See figure 1-1.) This objective will climax a series of earth suborbital and orbital missions. Although each of these missions will have specific objectives, they will be flown primarily for state-of-the-art advancement and qualification of systems for the ultimate lunar landing mission.

1-2. The project consists of three phases designed to obtain these ultimate goals:

- The first phase consisted of a number of boilerplate missions for research and developmental purposes. Boilerplates were preproduction spacecraft similar to their production counterparts in shape, size, mass, and center of gravity.
- Phase two is being conducted with limited production spacecraft. These spacecraft are being utilized for systems development and qualification in an earth orbital environment with man in the loop and without the lunar module.
- The third and final phase consists of those missions with the lunar module which will culminate in a manned lunar landing.

1-3. THE APOLLO TEST PROGRAM.

1-4. The Apollo test program is designed to confirm the overall structural integrity, systems performance, compatibility, and intermodular compatibility of the three-man spacecraft. The program follows a path of developmental progress from initial structural

integrity confirmation to the complex testing of each module and system for reliability and compatibility. Three basic phases are scheduled for spacecraft testing. The first is research and developmental testing conducted to verify the engineering concepts and basic design employed in the Apollo configuration. The second phase is the qualification testing of the spacecraft hardware and components. The third phase of the test program will verify the production spacecraft systems operation and the man-machine compatibility of the spacecraft. A full test program summary is presented in section VII.

#### 1-5. EARTH SUBORBITAL MISSIONS.

1-6. Two unmanned spacecraft earth suborbital missions have been accomplished to evaluate the command module heat shield performance, and the structural compatibility and integrity of the spacecraft and launch vehicle. These missions also served to qualify and confirm compatibility of the spacecraft-launch vehicle combinations.

1-7. The earth suborbital missions aided in the determination of structural loading, systems performance, and separation characteristics of the launch escape system and boost protective cover from the command module, service module from the adapter, and the command module from the service module. Also, the command module adequacy for manned entry from a low earth orbit was evaluated as well as performance of the service module reaction control system ullage maneuver, service propulsion start, and service propulsion system operation.

1-8. An example of a mission profile for one particular earth suborbital mission is presented in figure 1-2.

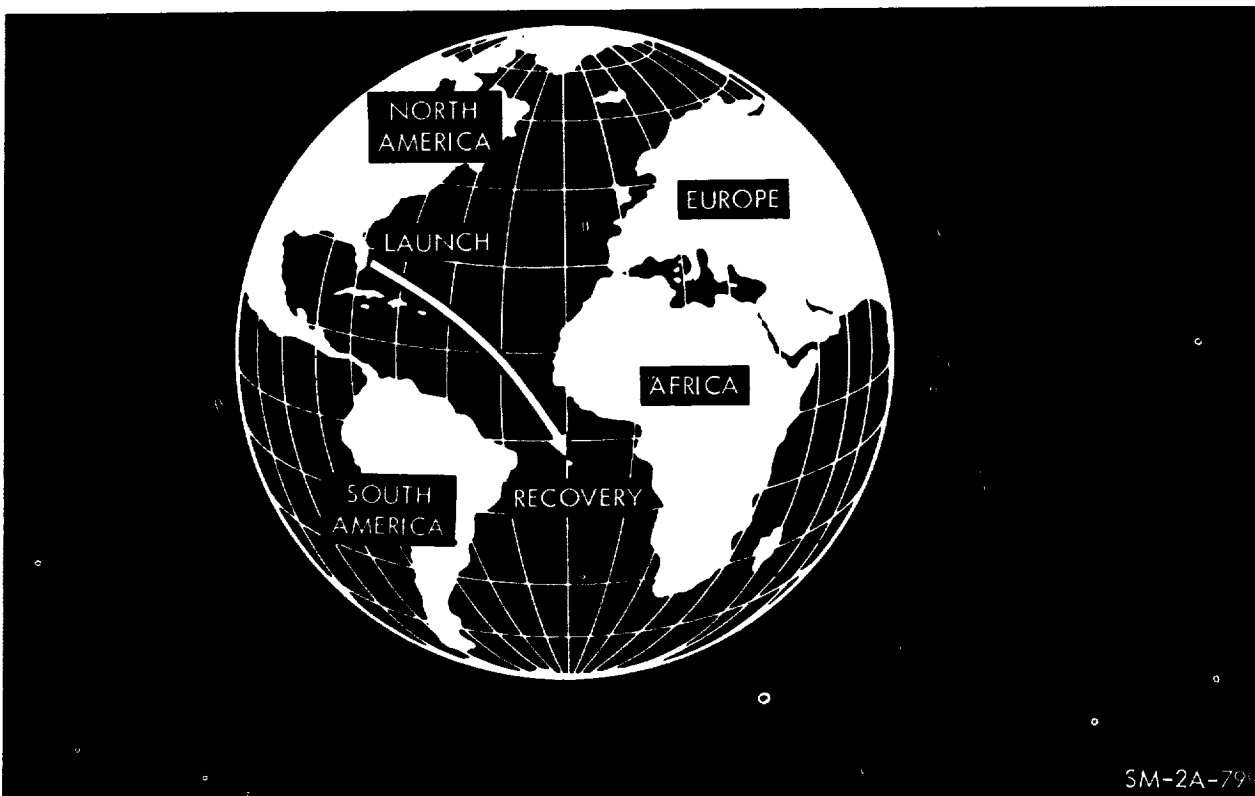


Figure 1-2. Earth Suborbital Mission Profile (Typical)

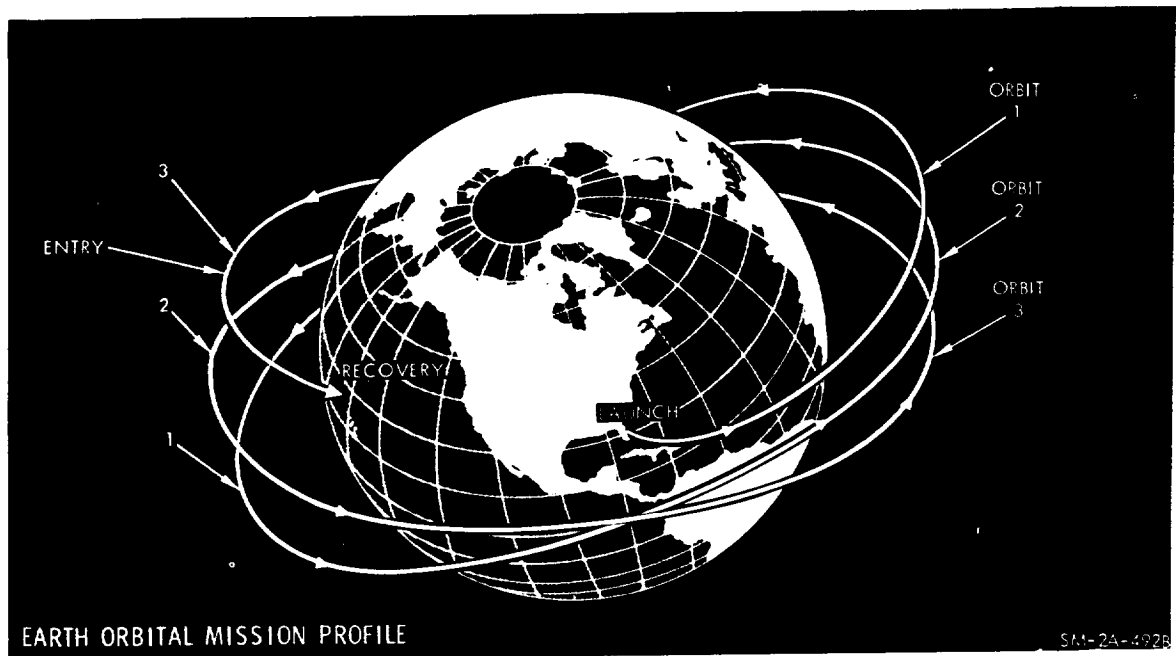


Figure 1-3. Earth Orbital Mission Profile (Typical)

1-9. EARTH ORBITAL MISSIONS.

1-10. Unmanned and manned spacecraft earth orbital missions (figure 1-3) are programmed to confirm the compatibility of the spacecraft-launch vehicle and spacecraft-LM combinations to demonstrate spacecraft and lunar module (LM) performance, and to develop flight crew proficiency.

1-11. The unmanned missions will serve to qualify the launch vehicle and confirm spacecraft-launch vehicle compatibility. Operating procedures will be analyzed during these missions to determine the adequacy, feasibility, and overall performance of the launch vehicle and the unmanned spacecraft.

1-12. Manned missions will be conducted to determine crew and manned space-flight network (MSFN) proficiency in ascent, earth orbit injection, transposition and docking, rendezvous and docking, entry, and recovery-phase task requirements. Flight crew MSFN interface will be constantly conditioned and prepared for deep-space operations.

1-13. The individual mission profile will be determined by the mission objectives for a given flight. The profiles of earth orbital missions range from circular orbits to elliptical orbits.

1-14. LUNAR LANDING MISSIONS.

1-15. The lunar landing mission will be accomplished after all other tests and missions have been satisfactorily completed. The purpose of this mission is to explore the lunar surface in the vicinity of the LM, and to evaluate the effect of the deep-space environment upon the flight crew, spacecraft, and the MSFN.

1-16. The lunar landing mission will be of much greater complexity than previous missions. In addition to those tasks required for an earth orbital mission, translunar injection, translunar midcourse corrections, lunar orbit insertion and coast, LM descent, lunar exploration, LM ascent, transearth injection, and transearth midcourse corrections must be accomplished.

1-17. The velocity required for the proper mission profile will be determined by MSC and verified by the Apollo guidance computer of the CSM navigation and control system. After achieving lunar orbit, the flight crew will make observations of a preselected landing site to determine the adequacy of the landing area and/or possible alternate site. Two crew members will then enter the LM through the forward tunnel of the command module, perform a check of the LM systems, and extend the landing gear. At a predetermined point in lunar orbit, the LM will separate from the command and service modules (CSM) and descend to the surface of the moon. The CSM, under control of the remaining crew member, will continue to orbit the moon.

1-18. After landing on the lunar surface, the LM crewmen will alternately egress to the lunar surface and explore the landing site area. During this time, samples of the lunar crust will be taken for subsequent analysis upon return to earth.

1-19. After lunar exploration has been completed, the crew members will re-enter the LM, which will then ascend to rendezvous with the CSM. When docking is completed, the two LM crew members enter the CSM, which is then separated from the LM. Transearth injection (for return to earth), transearth midcourse corrections, entry, and recovery, will then be accomplished.

1-20. The navigation tasks required for the lunar landing mission far exceed those of earth orbital missions. During this mission, the proficiency of flight crew navigation will undergo its severest test of the Apollo program. Figure 1-4 illustrates the typical lunar exploration mission profile with emphasis placed upon the major navigational tasks of the earth-moon relationship. The detailed requirements of the lunar landing (and exploration) mission are described in section VIII.

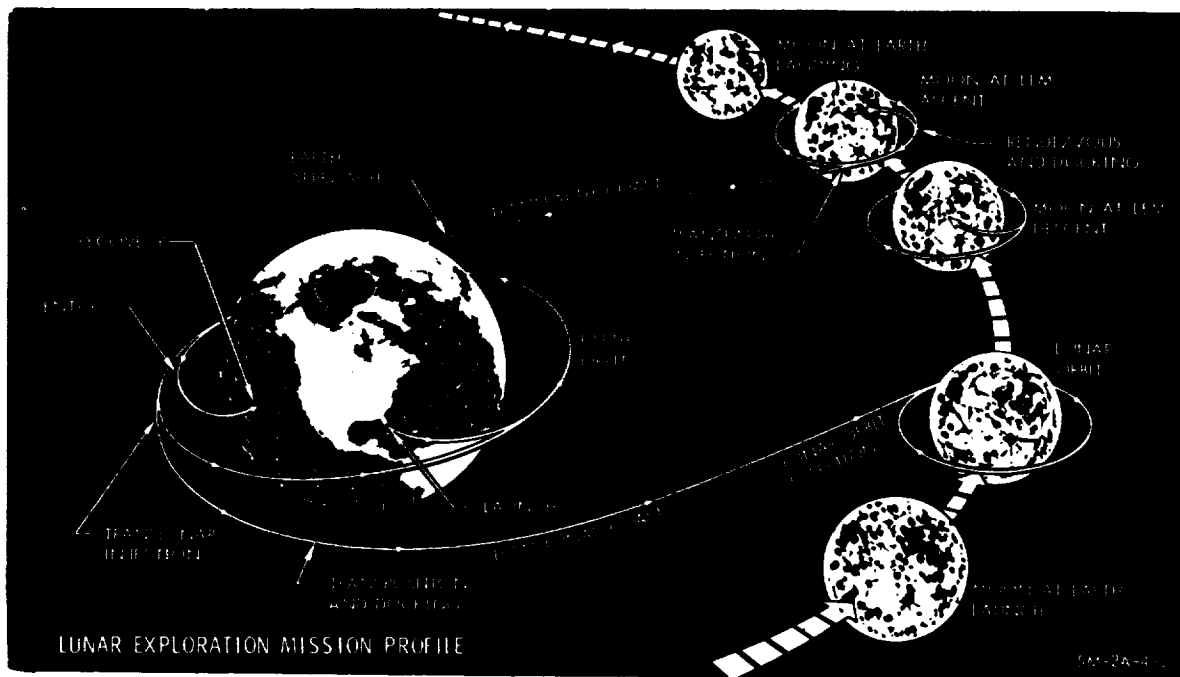


Figure 1-4. Lunar Exploration Mission Profile (Typical)

## APOLLO SPACE VEHICLE

### 2-1. GENERAL.

2-2. The Apollo space vehicles are comprised of various spacecraft and launch vehicle modules. The spacecraft (at launch), based upon mission objectives, may consist of a launch escape system, command module, service module, spacecraft LM adapter (SLA), and lunar module. (See figure 2-1.) The launch vehicle consists of a Saturn booster configuration. The overall height and weight of the space vehicle is directly related to the flight trajectory dictated by mission objectives. Major variances in height and weight are based on the selection of the launch vehicle and configuration of the spacecraft.

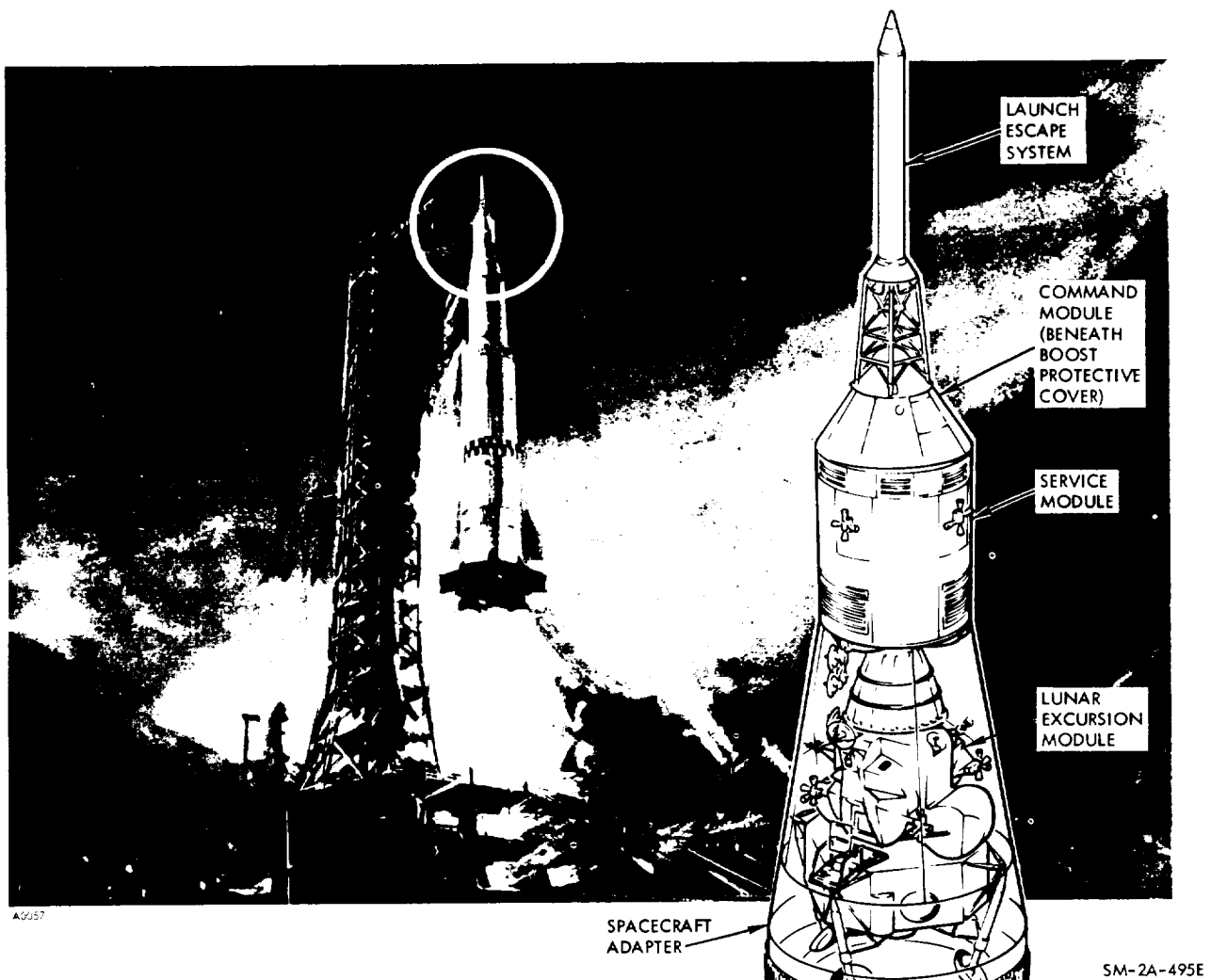


Figure 2-1. Apollo Space Vehicle

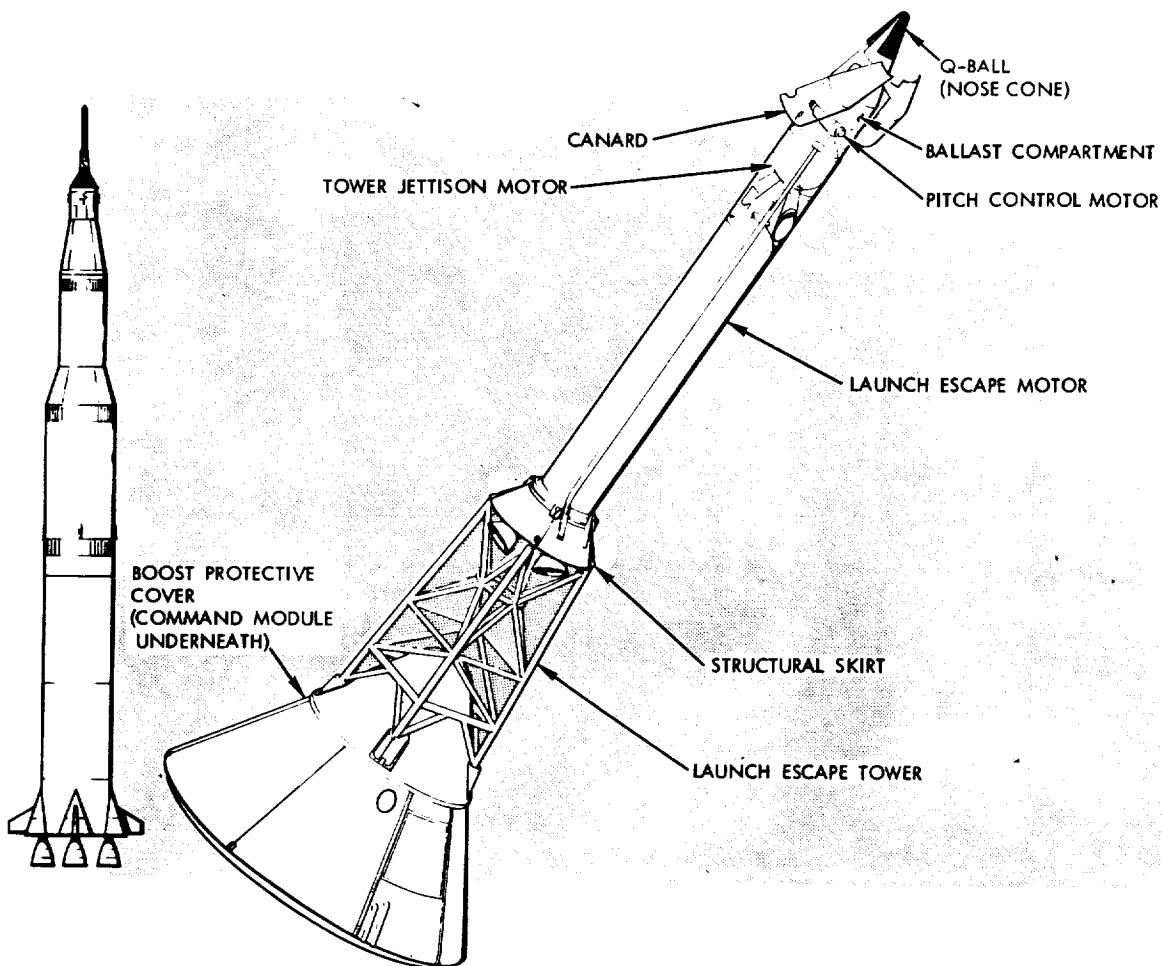
2-3. The external dimensions of the LES, C/M, S/M, and SLA remain constant. The LM is housed within the SLA and will be installed in the space vehicle for some earth orbital rendezvous and docking missions, and the lunar landing missions.

2-4. Figure 2-1 depicts the lunar landing space vehicle configuration and geometry of the spacecraft. The launch vehicle configurations are illustrated later within this section. Refer to the description of launch vehicles for booster configuration variances.

2-5. APOLLO SPACECRAFT.

2-6. LAUNCH ESCAPE SYSTEM.

2-7. The launch escape system provides a means of removing the command module from the space vehicle during a pad abort or atmosphere flight abort. The launch escape vehicle (figure 2-2) consists of a Q-ball (nose cone), ballast compartment, canard system, three rocket motors, a structural skirt, an open-frame tower, and a boost protective cover. The structural skirt is secured to the launch escape tower (LET), which transmits stress loads



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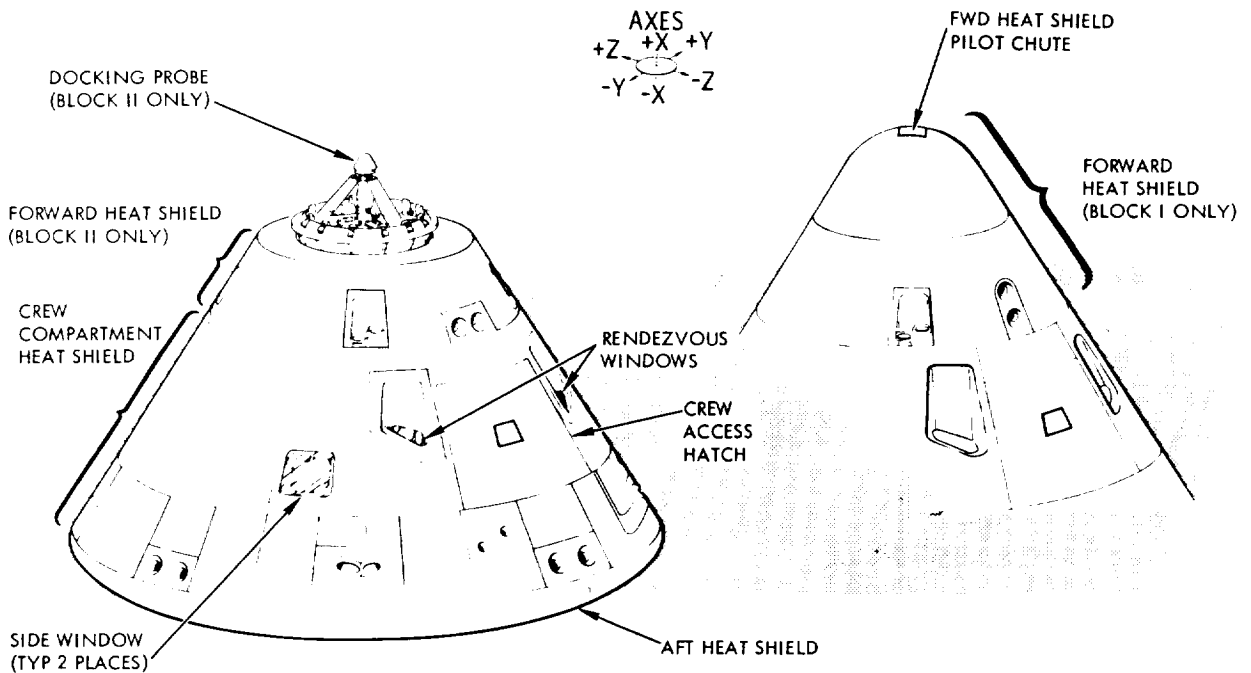
Figure 2-2. Launch Escape Vehicle

between the launch escape motor and the command module. The boost protective cover (BPC), which protects the C/M exterior during launch and boost, is fastened to the lower end of the tower. Four studs and frangible nuts, one in each tower leg well, secure the tower to the command module structure. After a successful launch or abort mode initiation, explosive detonators fracture the nuts and free the tower. The rocket motors, canards, and explosive squibs are activated by electronic sequencing devices within the CSM. Refer to section III for system operational data.

## 2-8. COMMAND MODULE.

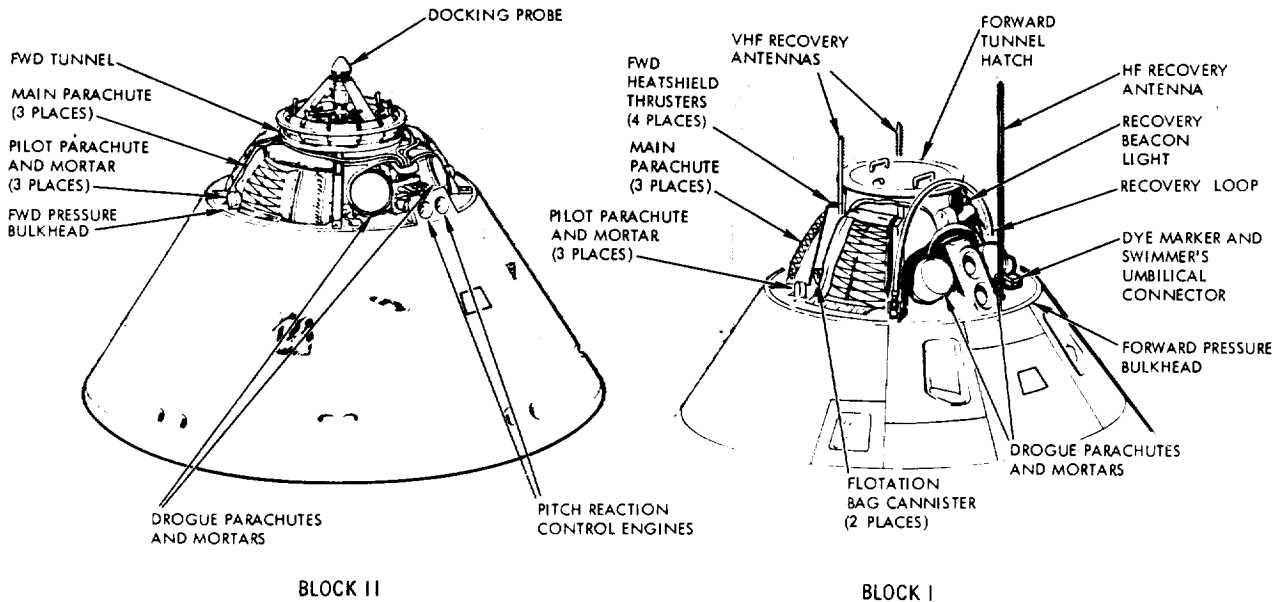
2-9. The command module (figure 2-3) is the recoverable portion of the spacecraft and, houses the flight crew, the equipment necessary to control and monitor the spacecraft systems, and equipment required for the comfort and safety of the crew. The primary structure of the command module is encompassed by three heat shields, forming a conical-shape exterior. The forward, crew, and aft heat shield structures are coated with ablative material and joined to the primary structure. An insulation material is installed between the primary structure and the heat shields. The C/M consists of three compartments: forward, crew, and aft.

2-10. FORWARD COMPARTMENT. The forward compartment (figure 2-4) is a section between the forward heat shield and the forward side of the forward pressure bulkhead. The center portion is occupied by a tunnel which permits crew members to transfer to the LM and return to the crew compartment during the performance of lunar mission tasks. The interior of the forward compartment is divided into four 90-degree segments which



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Figure 2-3. Command Module



## NOTE:

- 1 FORWARD HEAT SHIELD REMOVED FOR CLARITY
- 2 RECOVERY AIDS TYPICAL FOR BOTH BLOCKS

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Figure 2-4. Command Module Forward Compartment

contain earth landing system (ELS) components, recovery equipment, two reaction control motors, and the forward heat shield jettisoning mechanism. The major portion of this section contains the active components of the ELS consisting of three main parachutes, three pilot parachutes, two drogue parachutes, as well as drogue and pilot parachute mortars, risers, and the necessary hardware. The recovery equipment, installed in the forward compartment, consists of three flotation bags of the uprighting system, a beacon light, a sea dye marker, a swimmer umbilical, three recovery antennas and a recovery pickup loop. Four thruster-ejectors are installed in the forward compartment to eject the forward heat shield during landing operations. The thrusters operate to produce a rapid, positive release of the heat shield, preventing parachute fabric damage.

2-11. CREW COMPARTMENT. The crew compartment (figure 2-5) is a sealed, three-man cabin with pressurization maintained by the environmental control system. The crew compartment contains the necessary systems, spacecraft controls and displays, observation windows, access hatches, food, water, sanitation, and survival equipment. The compartment incorporates windows and equipment bays as a part of the structure. The following listing contains specific items contained in the crew compartment and their locations. Items marked (Block I) or (Block II), indicate the specific block in which they are included; all others are included in both blocks.



## Aft Equipment Storage Bay (See figure 2-5.)

Space suits (two)	TV zoom lens
Space suit spare parts	Portable life support system (Block II)
Umbilicals	CO <sub>2</sub> -odor absorber filters
Rest station restraint	Fecal canister
Drogue and probe stowage (Block II)	Helmet storage (two)
Life vests (three)	Communication helmet storage (Block I)

## Lower Equipment Bay (See figure 2-5.)

Power servo assembly (PSA)	Display electronics (Block II)
Computer control panel	Reaction jet driver (Block II)
Signal conditioning equipment	Apollo guidance computer (AGC) (Block I)
Rate gyro assembly (RGA) (Block II)	CMC Command Module Computer (Block II)
Electronic control assemblies (five) (Block I)	Medical supplies
Gas chromatograph (Block I)	Medical refrigerator (Block II)
Workshelf (Block I)	Data distribution panel (Block I)
Pulse-code modulation (PCM) units (two)	Attitude gyro-accelerometer assembly (AGAA)
S-band power amplifier	Crew flight data file (CFDF)
Unified S-band equipment and spares	VHF multiplexer (Block I)
Junction box	C-band transponder (Block I)
Motor switches (three)	Audio center equipment
Battery charger	Central timing equipment (CTE)
Sextant and scanning telescope	Entry batteries (three)
Rendezvous radar control (Block II)	Circuit breaker panel
TVC servo amplifier (Block II)	Guidance and navigation (G&N) control panel
Control electronics (Block II)	Coupling display unit (CDU) (Block II)
Gyro display (Block II)	Data storage equipment

Food storage	
Scientific equipment	R-F switch
Flight qualification recorder (Block I)	Inverters (three)
Up-data link	A-C power box
Premodulation processor	Pyrotechnic batteries (two)
VHF/AM transceiver and VHF recovery beacon	Lighting control (Block II)
Triplexer (Block II)	Clock and event timer (Block II)
VHF/FM transmitter and HF transceiver	In-flight tool set

Left-Hand Forward Equipment Bay (See figure 2-5.)

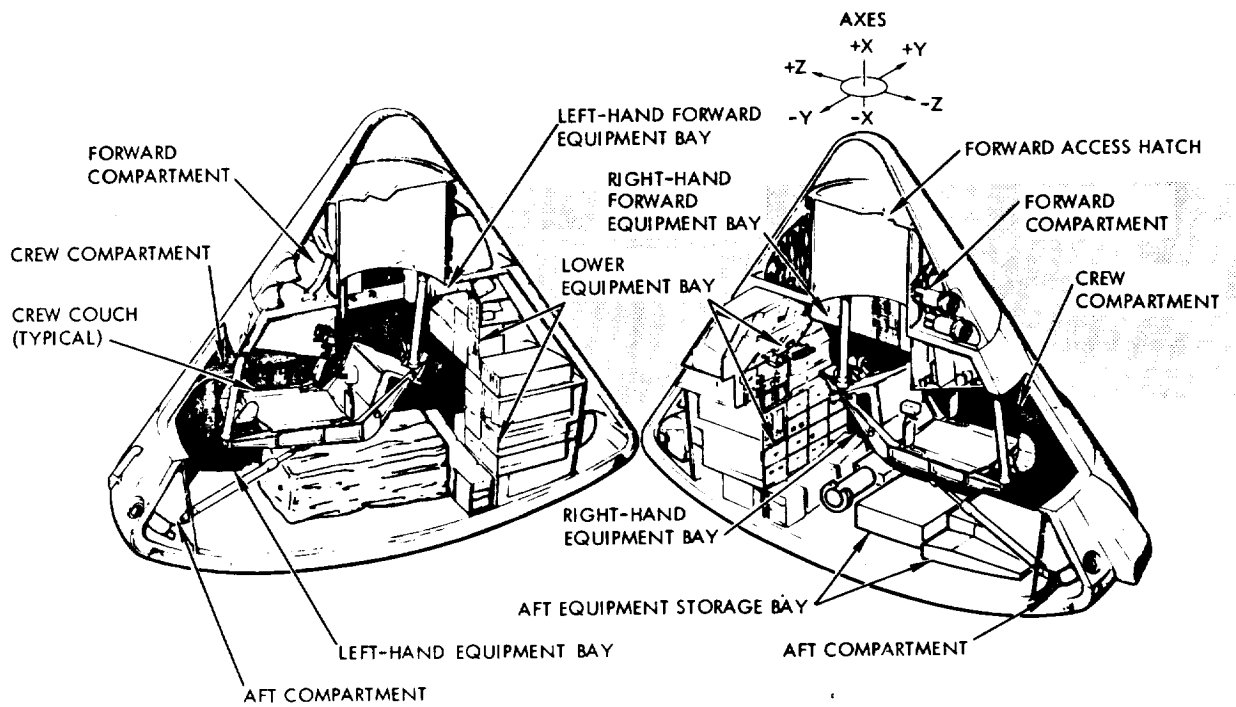
Cabin air fan	Food reconstitution device
Optical storage (Block I)	Clothing (storage)
Translation controller connector panel	Cabin heat exchanger
Loose parts storage (Block I)	Clock and event-timer panel (Block I)
Pressure suit connectors (three)	Thermal radiation coverall (storage) (Block I)
Water delivery assembly	Radiation survey meter (Block II)

Left-Hand Equipment Bay (See figure 2-5.)

Cabin pressure relief valve	Environmental control unit
Fixed shock attenuation panel	Pressure hatch stowage (Block II)
Environmental control system (ECS) water and oxygen control panels	CO <sub>2</sub> sensor
Surge tank	Removable shock attenuation panels (two)

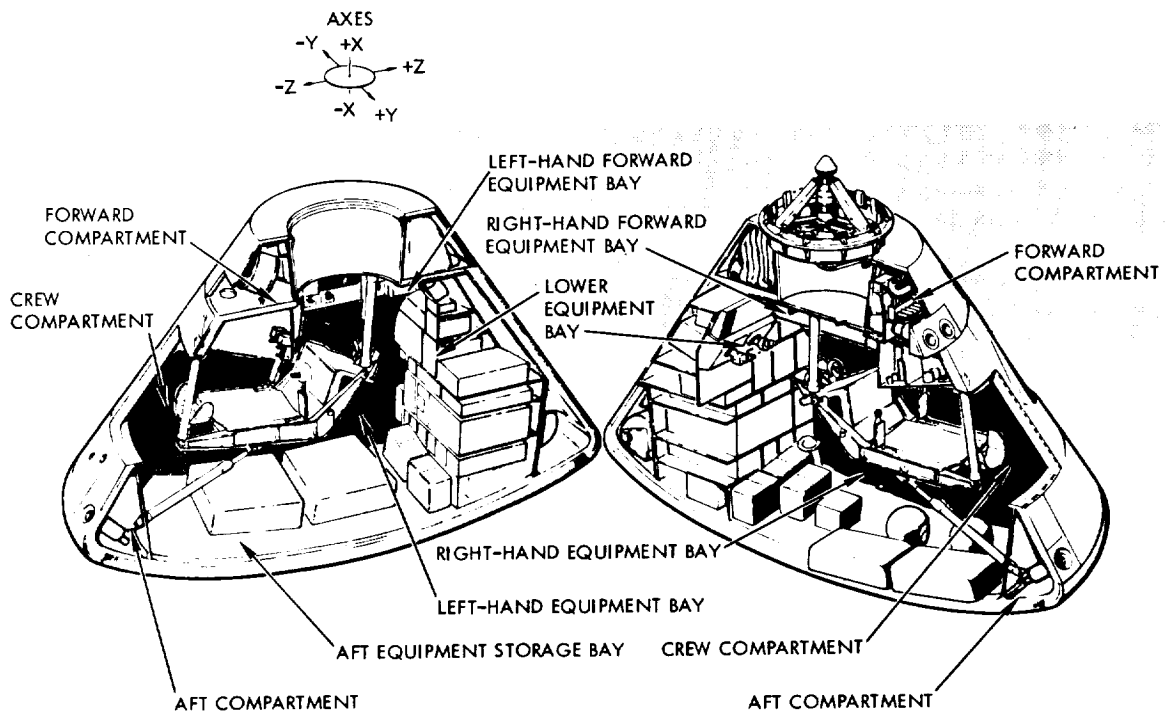
Right-Hand Forward Equipment Bay (See figure 2-5.)

Individual survival kits (three on Block I S/C) (two on Block II S/C)	Medical supplies
System test equipment (Block I)	LM docking target storage (Block II)
Waste storage inlet	Bio-instrument accessories (Block II)
TV camera and mount food (Block I)	Sanitary supplies
Optical storage (Block II)	Tools and belt (Block II)



NOTE:  
CENTER COUCH REMOVED FOR CLARITY

BLOCK I



NOTE:  
CENTER COUCH OMITTED FOR CLARITY

BLOCK II

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Figure 2-5. Command Module Compartments and Equipment Bays (Typical)

## Right-Hand Equipment Bay (See figure 2-5.)

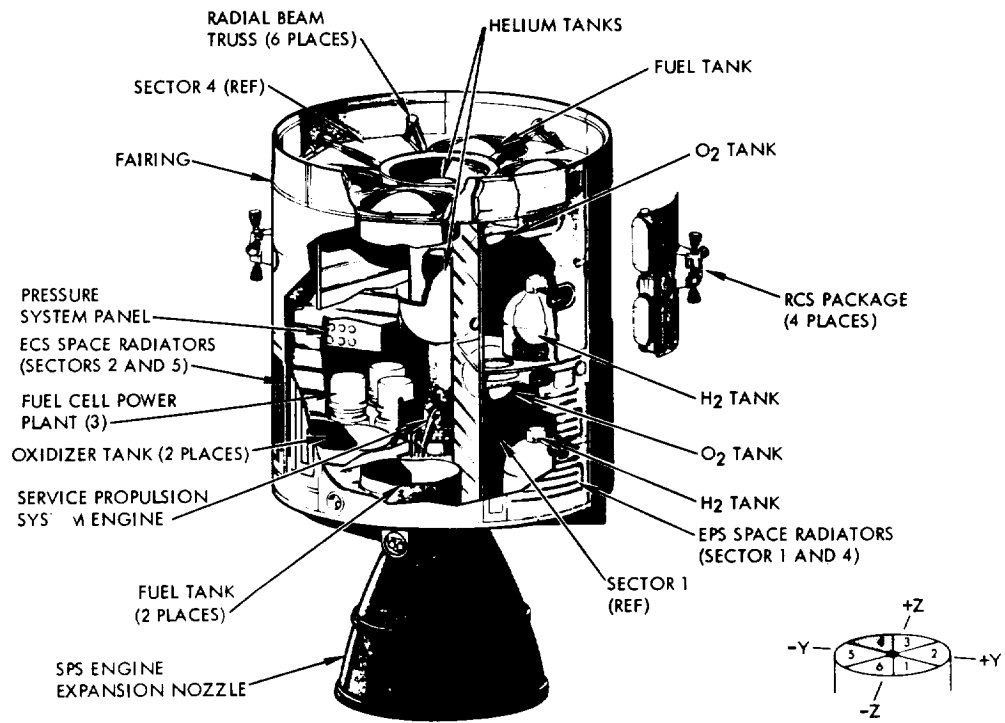
Vacuum cleaner	Fuse box
Electrical power equipment	Food (Block II)
Master Event Sequencers	Waste storage compartment
Power distribution box	ELS sequencers
Circuit utilization box	Master Event Sequencers
Phase correction capacitor box	Signal conditioners
Waste management system controls	Thermal hatch stowage (Block II)

2-12. AFT COMPARTMENT. The aft compartment (figure 2-5) is an area encompassed by the aft portion of the crew compartment heat shield, aft heat shield, and aft sidewall of the primary structure. This compartment contains 10 reaction control motors, impact attenuation structure, instrumentation, and storage tanks for water, fuel, oxidizer, and gaseous helium.

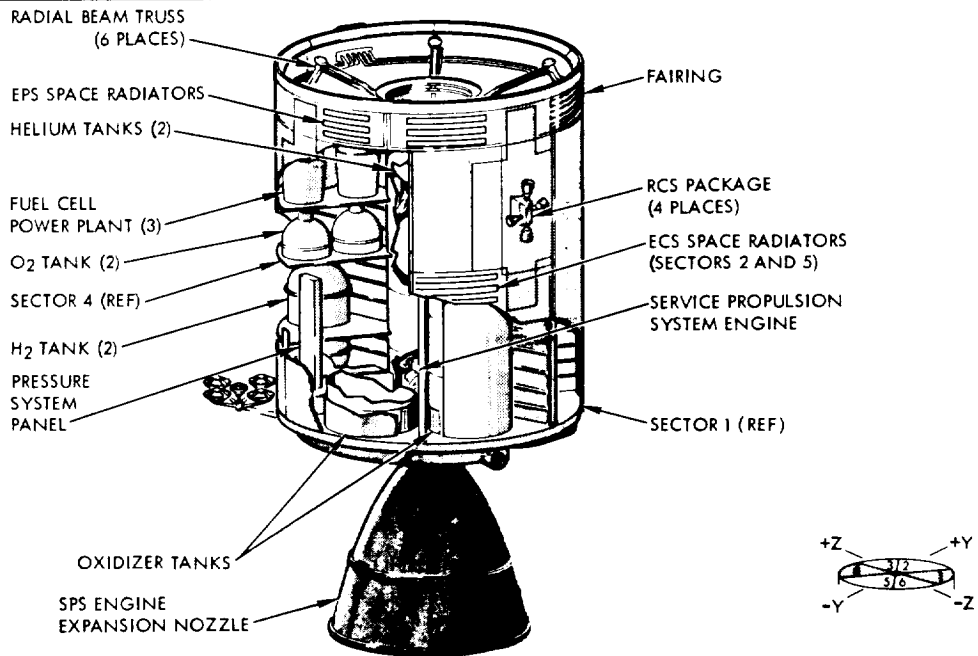
2-13. SERVICE MODULE.

2-14. The service module structure is a cylinder formed by panels of one-inch aluminum honeycomb. (See figure 2-6.) Its interior is unsymmetrically divided into six sectors by radial beams, or webs made from milled aluminum alloy plate. The interior consists of diametrically opposed sectors around a circular section 44 inches in diameter. Sectors 1 and 4 are 50-degree segments and sectors 2 and 5 are 70-degree segments. The remaining sectors, 3 and 6, are 60-degree segments. The equipment contained within the S/M is accessible through maintenance doors located strategically around the exterior surface of the module. The specific items contained in the S/M compartments, and their location, are listed in paragraph 2-16.

2-15. An area between the service and command modules provides space for radial beam trusses connecting these two modules. Beams one, three, and five have compression pads for support of the C/M; beams two, four, and six have compression pads, shear pads, and tension ties. A flat center section in each tension tie, incorporates redundant explosive charges for service module-command module separation. The entire separation system is enclosed within a fairing 26 inches high and 12'-10" in diameter.



BLOCK I



BLOCK II

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Figure 2-6. Service Module

2-16. Items and their locations contained in Block I and Block II service modules (manned S/C only) are listed as follows.

Location	Contents	
	Block I	Block II
Sector 1	Electrical power system space radiators Cryogenic oxygen tank (two) Cryogenic hydrogen tank (two)	
Sector 2	Environmental control system space radiator Service propulsion system oxidizer tank Reaction control system engine cluster (+Y-axis) Reaction control system helium tank Reaction control system fuel tank Reaction control system oxidizer tank Space radiator isolation valve (two)	Environmental control system space radiator Service propulsion system oxidizer tank Reaction control system engine cluster (+Y-axis) Reaction control system helium tank Reaction control system fuel tank Reaction control system oxidizer tank Space radiator isolation valve (two)
Sector 3	Service propulsion system fuel tank Reaction control system engine (cluster (+Z-axis)) Reaction control system helium tank Reaction control system fuel tanks Reaction control system oxidizer tanks Rendezvous radar transponder	Service propulsion system oxidizer tank Reaction control system engine cluster (+Z-axis) Reaction control system helium tank Reaction control system fuel tanks Reaction control system oxidizer tanks Rendezvous radar transponder
Sector 4	Electrical power system space radiator Fuel cell power plant (three) Helium distribution system Reaction control system control unit Electrical power system power control relay box Service module jettison controller (SMJC) sequencer (two)	Fuel cell power plant (three) Cryogenic oxygen tank (two) Cryogenic hydrogen tank (two) Reaction control system control unit Electrical power system power control relay box High-gain antenna (stowed under) Service module jettison controller (SMJC) sequencer (two)
Sector 5	Environmental control system space radiator Service propulsion system oxidizer tank	Environmental control system space radiator Service propulsion system fuel tank

Location	Contents	
	Block I	Block II
Sector 5 (Cont)	Reaction control system engine cluster (-Y-axis) Reaction control system helium tank Reaction control system fuel tank Reaction control system oxidizer tank	Reaction control system engine cluster (-Y-axis) Reaction control system helium tank Reaction control system fuel tanks Reaction control system oxidizer tanks Helium distribution system
Sector 6	Space radiator selection valve (two) Glycol shutoff valve (two) Reaction control system engine cluster (-Z-axis) Reaction control system helium tank Reaction control system fuel tank Reaction control system oxidizer tank Service propulsion system fuel tank	Space radiator selection valve (two) Glycol shutoff valve (two) Reaction control system engine cluster (-Z-axis) Reaction control system helium tank Reaction control system fuel tanks Reaction control system oxidizer tanks Service propulsion system fuel tank
Center section	Service propulsion system helium tank (two) Service propulsion system engine	Service propulsion system helium tank (two) Service propulsion system engine

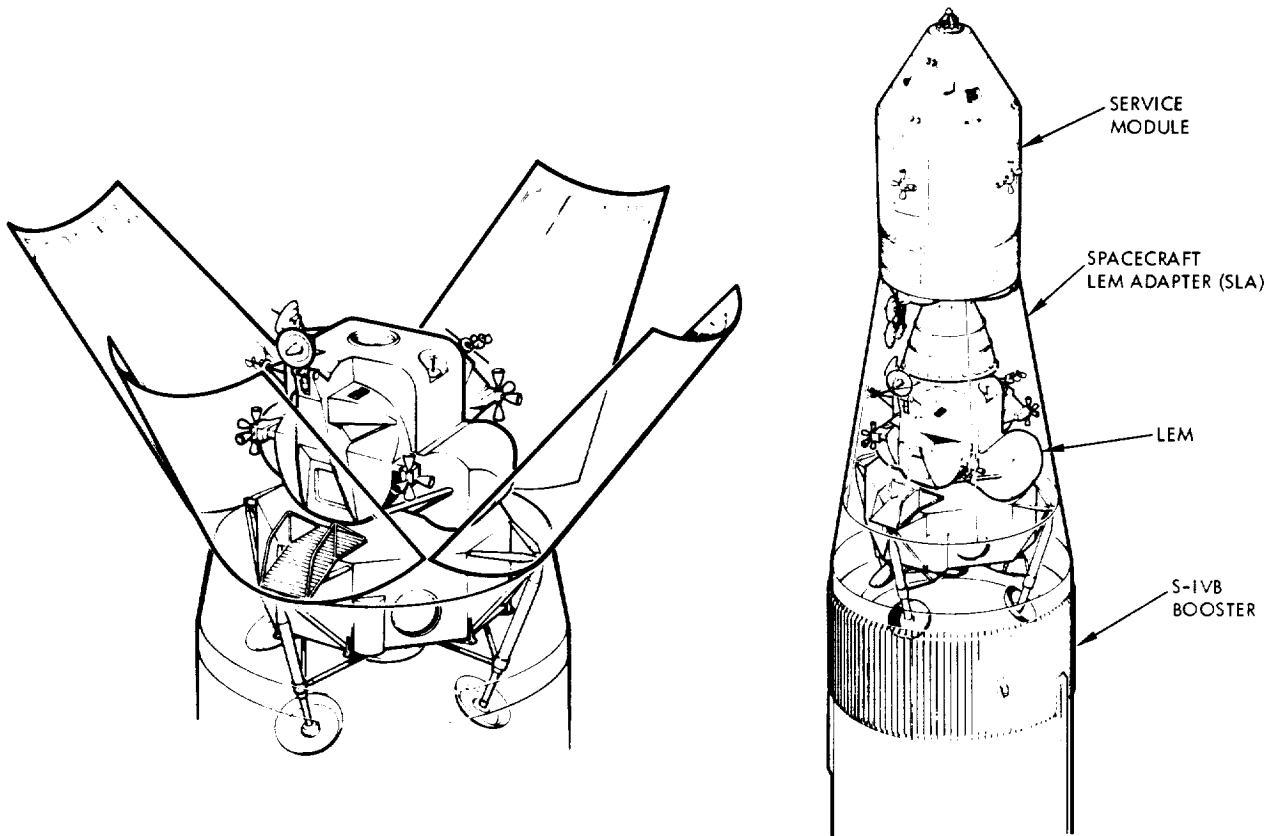
#### 2-17. LUNAR MODULE.

2-18. The LM, manufactured by Grumman Aircraft Engineering Corp., is a space vehicle which provides a means of transportation for two crewmembers of the Apollo spacecraft to leave the command module, land on the lunar surface, and return to the command module. The LM is then jettisoned from the C/M and left as a lunar satellite. A description of the LM is presented in section IV.

#### 2-19. SPACECRAFT LM ADAPTER.

2-20. The spacecraft LM adapter (figure 2-7) is the structural interstage between the launch vehicle and the spacecraft. The spacecraft LM adapter (SLA) is required on Apollo spacecraft using an uprated Saturn I or Saturn V launch vehicle. (See figure 2-8.) The SLA will house the service propulsion engine expansion nozzle, high-gain antenna, and LM. An umbilical cable is incorporated in the adapter to connect circuits between the launch vehicle and the spacecraft.

2-21. The SLA (figure 2-7) is a tapered cylinder comprised of eight panels, four of which have linear explosive charges installed at panel junctions. During CSM/SLA separation, the charges are fired to open the four panels, free the spacecraft from the launch vehicle, and expose the LM.



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Figure 2-7. Spacecraft LM Adapter

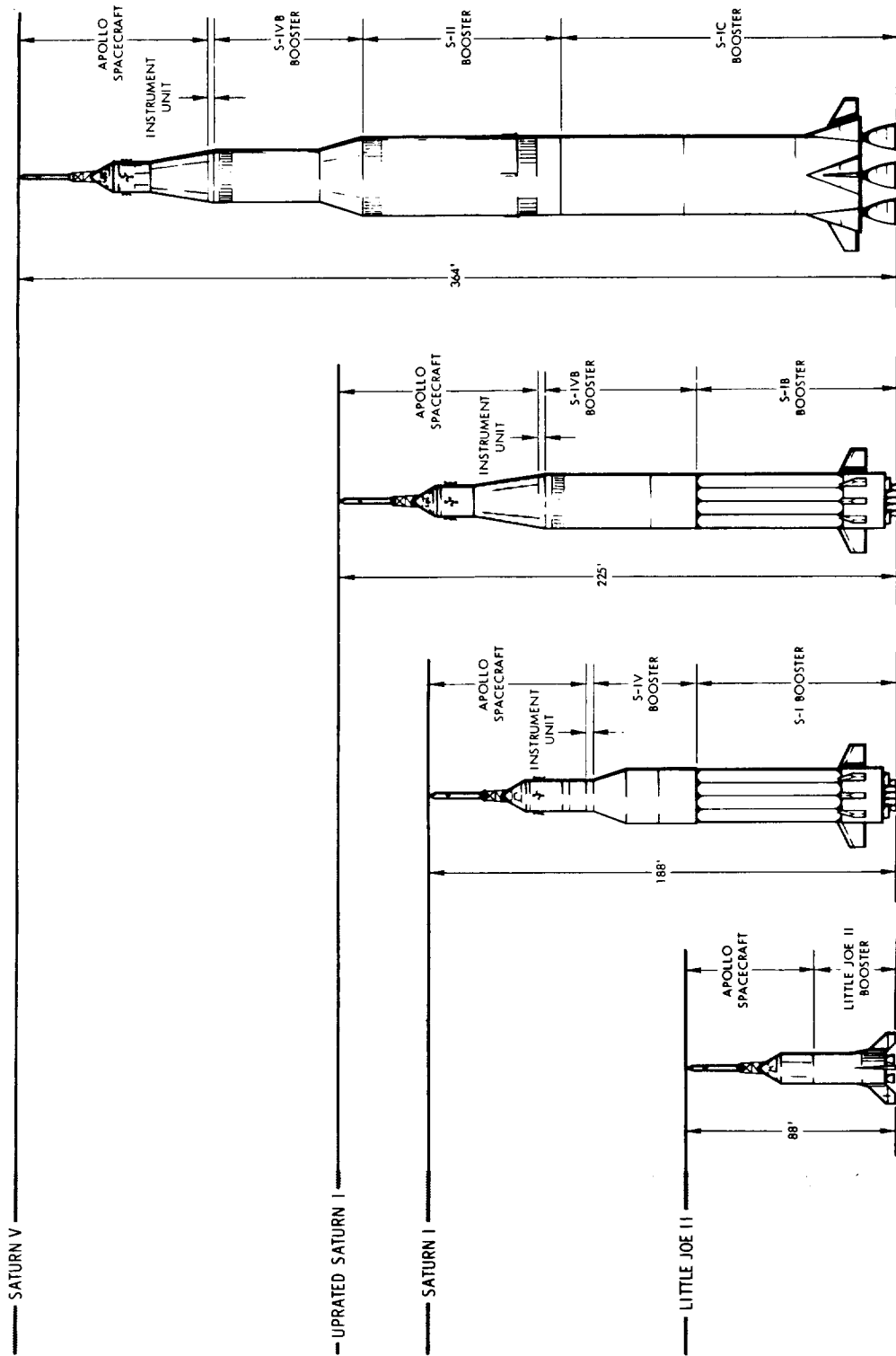
## 2-22. LAUNCH VEHICLES.

2-23. Launch vehicles used in the Apollo program are illustrated in figure 2-8. The earlier test evaluation and qualification flight vehicles were powered by the launch escape vehicle Little Joe II, Saturn I, and Saturn uprated I launch vehicles. As the Apollo program progresses, the extended lunar mission performance and greater payload necessitates the use of the Saturn V. The general configurations of the launch vehicle boosters are summarized in paragraphs 2-24 through 2-32.

## 2-24. LAUNCH ESCAPE VEHICLE.

2-25. The launch vehicle used for pad-abort tests (figure 2-2) consisted of a C/M, boost protective cover, launch escape tower, launch escape system motor, a pitch control motor, and a tower jettison motor. Each of the motors used a solid propellant. The LES motor, manufactured by Lockheed Propulsion Corporation, provided up to 155,000 pounds thrust. The pitch control motor, also manufactured by Lockheed Propulsion Corporation, provided up to 3000 pounds thrust. The tower jettison motor, manufactured by Thiokol Chemical Corporation, provided up to 33,000 pounds thrust.





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Figure 2-8. Launch Vehicle Configurations

## 2-26. LITTLE JOE II.

2-27. The Apollo transonic and high-altitude abort tests utilized the Little Joe II launch vehicle. (See figure 2-8.) The launch vehicle was approximately 13 feet in diameter and 29 feet in length. Little Joe II, manufactured by General Dynamics, Convair, used a combination of Algol and Recruit solid-propellant motors. One Algol and six Recruit motors provided an initial boost of 310,000 pounds thrust.

## 2-28. SATURN I.

2-29. Saturn I consisted of an S-I first-stage booster and an S-IV second stage. (See figure 2-8.) The S-I, manufactured by Chrysler Corporation, was 257 inches in diameter and approximately 82 feet in length. Eight Rocketdyne H-I engines were used, each burning RP-1 and liquid oxygen, and each producing 188,000 pounds thrust. Total boost for the S-I was 1,500,000 pounds thrust. The S-IV, manufactured by Douglas Aircraft Company, was 220 inches in diameter and 40 feet in length. Six Pratt & Whitney RL-10 engines were used, each burning liquid hydrogen and liquid oxygen, and each producing 15,000 pounds thrust. The total boost for the S-IV was 90,000 pounds. An instrument unit, located between the S-IV and the boilerplate adapter, controlled each of the two stages during flight.

## 2-30. UPRATED SATURN I.

2-31. The uprated Saturn I is a more powerful version of Saturn I, consisting of an S-IB first-stage booster and an S-IVB second stage. (See figure 2-8.) The S-IB, manufactured by Chrysler Corporation, is a lightweight version of the S-I booster, but approximately the same size. A weight reduction of 15,000 pounds per engine, or 120,000 pounds total, is realized while maintaining 1,600,000 pounds thrust. The S-IVB, manufactured by Douglas Aircraft Company, is 260 inches in diameter, 58 feet in length, and of an entirely different configuration than the S-IV. S-IVB employs a single Rocketdyne J-2 engine, burning liquid hydrogen and liquid oxygen, to produce approximately 200,000 pounds thrust. An instrument unit, located between the S-IVB and the SLA, controls each of the two stages during flight.

## 2-32. SATURN V.

2-33. Saturn V is a three-stage launch vehicle consisting of an S-IC first-stage booster, S-II second stage, and an S-IVB third stage. (See figure 2-8.) The S-IC, manufactured by the Boeing Company, is 33 feet in diameter and 138.5 feet in length; it uses five Rocketdyne F-1 engines. Each F-1 engine, burning RP-1 and liquid oxygen, produces 1,500,000 pounds thrust for an overall boost of 7,500,000 pounds. The S-II, manufactured by the Space and Information Systems Division of North American Aviation, Inc., is 33 feet in diameter and approximately 82 feet in length and employs five Rocketdyne J-2 engines. Each J-2 engine, burning liquid hydrogen and liquid oxygen, produces 200,000 pounds thrust for an overall boost of 1,000,000 pounds. The S-IVB is similar to the second stage of uprated Saturn I, producing 200,000 pounds thrust. An instrument unit, located between the S-IVB and the SLA, controls each of the three stages during flight.

## SPACECRAFT SYSTEMS



### 3-1. GENERAL.

3-2. This section contains data relative to the basic nature of the operational command and service module spacecraft systems. The purpose of each system, its functional description, and interface information are presented with a minimum of detailed text consistent with understanding. Concepts are supported by illustrations, listings, and diagrams. Also illustrated are the various panel arrangements within the command module that contain the controls and displays. Data presented covers each complete system as it will be installed in a manned spacecraft for an earth orbital or a lunar landing mission. Systems and components will be tested and qualified prior to manned missions. Other missions, using boilerplates or unmanned S/C, are not covered in this section as these vehicles may contain incomplete or modified systems. Physical differences between Block I and Block II S/C are illustrated in this section. For an explanation of Block I and Block II, refer to section VII.

3-3. Redundancy is necessary for mission critical items throughout the spacecraft systems in order to maintain the high reliability rates prescribed for the Apollo program. Included are redundant components, power sources, paths for fluids and electrical signals, and redundant operational procedures.

### 3-4. LAUNCH ESCAPE SYSTEM.

3-5. The launch escape system (LES) provides immediate abort capabilities from the launch pad, or away from the path of the launch vehicle in the event of an abort shortly after launch. (See figure 3-1.) Upon abort initiation, the command module will be propelled to a sufficient altitude and lateral distance away from the danger area for the effective operation of the earth landing system. Upon completion of an abort, or a successful launch, the launch escape assembly is jettisoned from the C/M.

3-6. The LES consists of two major structures, plus electrical control equipment located in the C/M. The forward structure is cylindrical, housing three rocket motors (pitch control, tower jettison, launch escape) and a ballast compartment topped by a Q-ball (nose cone). Two canard surfaces are installed below the nose cone. The rocket motors are loaded with solid propellants of various grain patterns, depending upon motor performance requirements. The aft structure is a four-leg, welded, tubular titanium tower. It serves as an intermediate structure, transmitting loads between the C/M and the launch escape assembly, and positioning the C/M a suitable distance from the launch escape motor exhaust. (See figure 3-1.) At its forward end, the tower is attached to a structural skirt that covers the exhaust nozzles of the launch escape motor, and at the aft end, attached to the C/M by four frangible nuts and studs. A boost protective cover is also attached to the aft end of the tower to protect the C/M from the launch escape motor exhaust and boost heating. The LES sequence controllers are located in the C/M and control the system by transmitting signals that ignite the rocket motors, deploy the canard surfaces, and detonate the separation devices. The Q-ball has four static ports for measuring  $\Delta P$  which is a function of angle of attack. An angle-of-attack indicator is located on the main display console and displays the combined pitch and yaw vectors in terms of percentages.

### 3-7. LES OPERATION.

3-8. The LES is initiated automatically by the emergency detection system (EDS) of the launch vehicle up to 90 seconds from lift-off, or manually by the astronauts at any time from pad to launch escape tower jettison as shown in figure 3-3. Upon receipt of an abort signal, regardless of its source, the booster is cut off (after the first 40 seconds of flight), and the launch escape systems is activated. Three basic modes for sequencing of the launch escape system are shown in figure 3-3. They are: pad to 30,000 feet, 30,000 feet

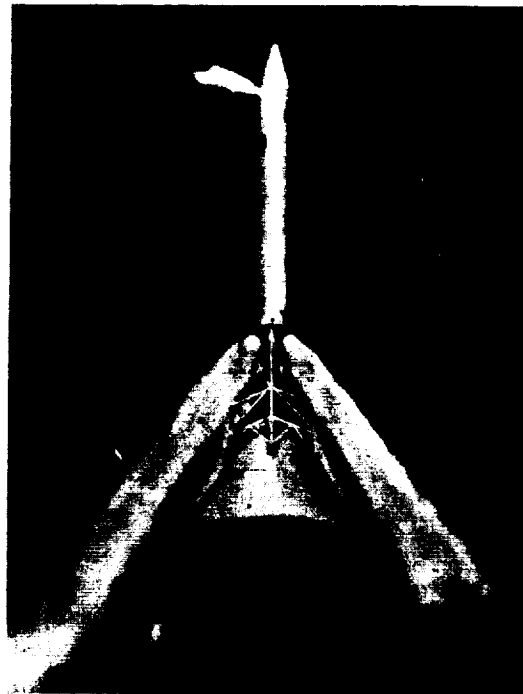
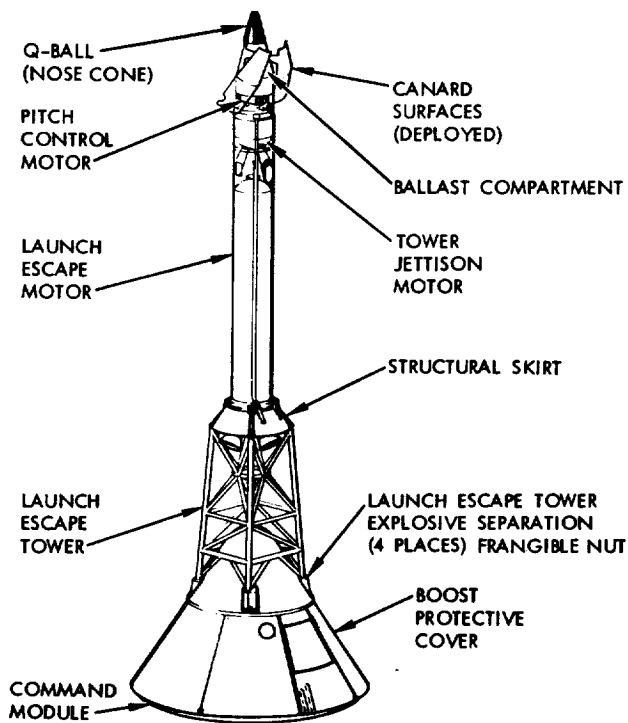
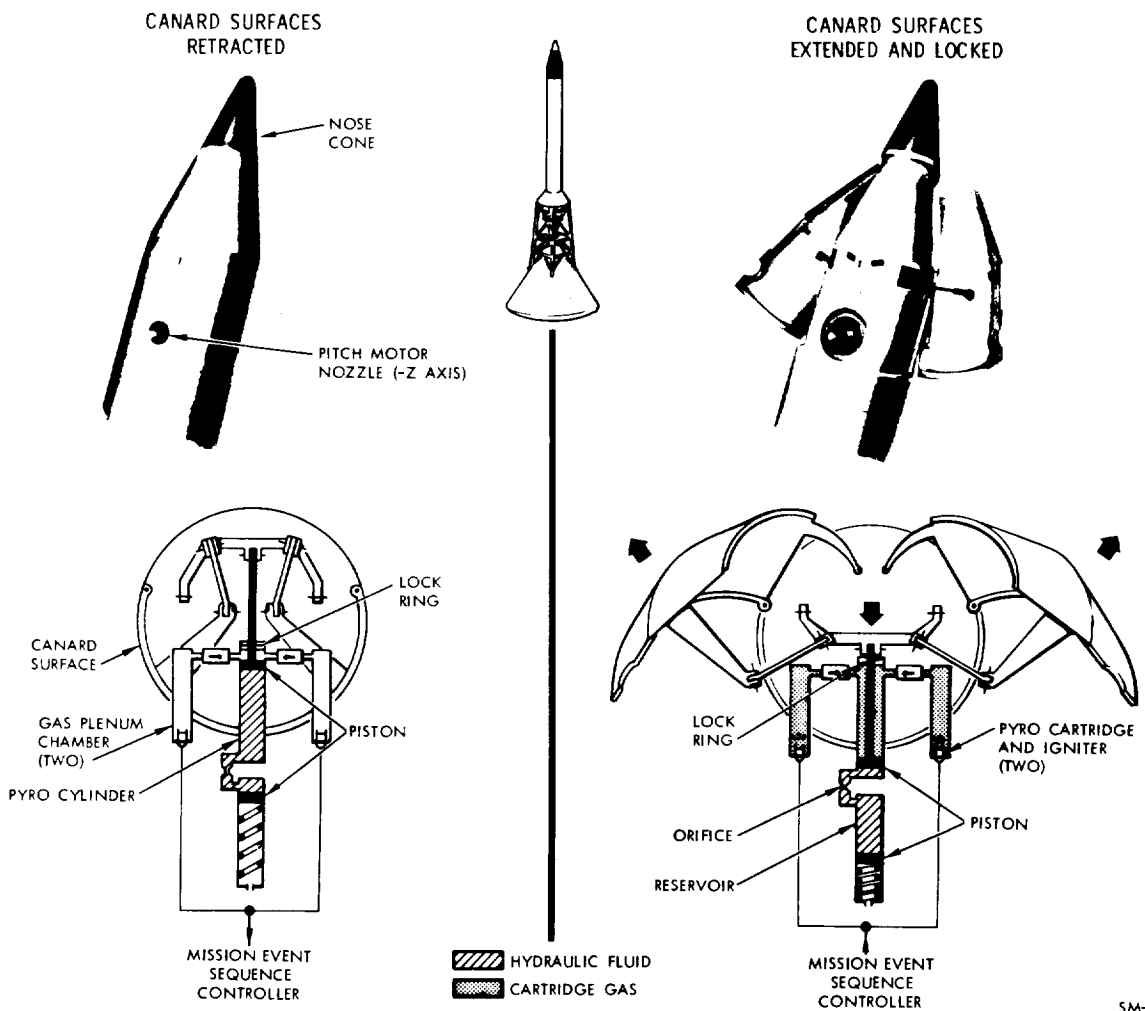


Figure 3-1. Launch Escape Vehicle

to 100,000 feet, and 100,000 feet to tower jettison. Activation of the earth landing system is automatically initiated by the sequencing units of the launch escape system.

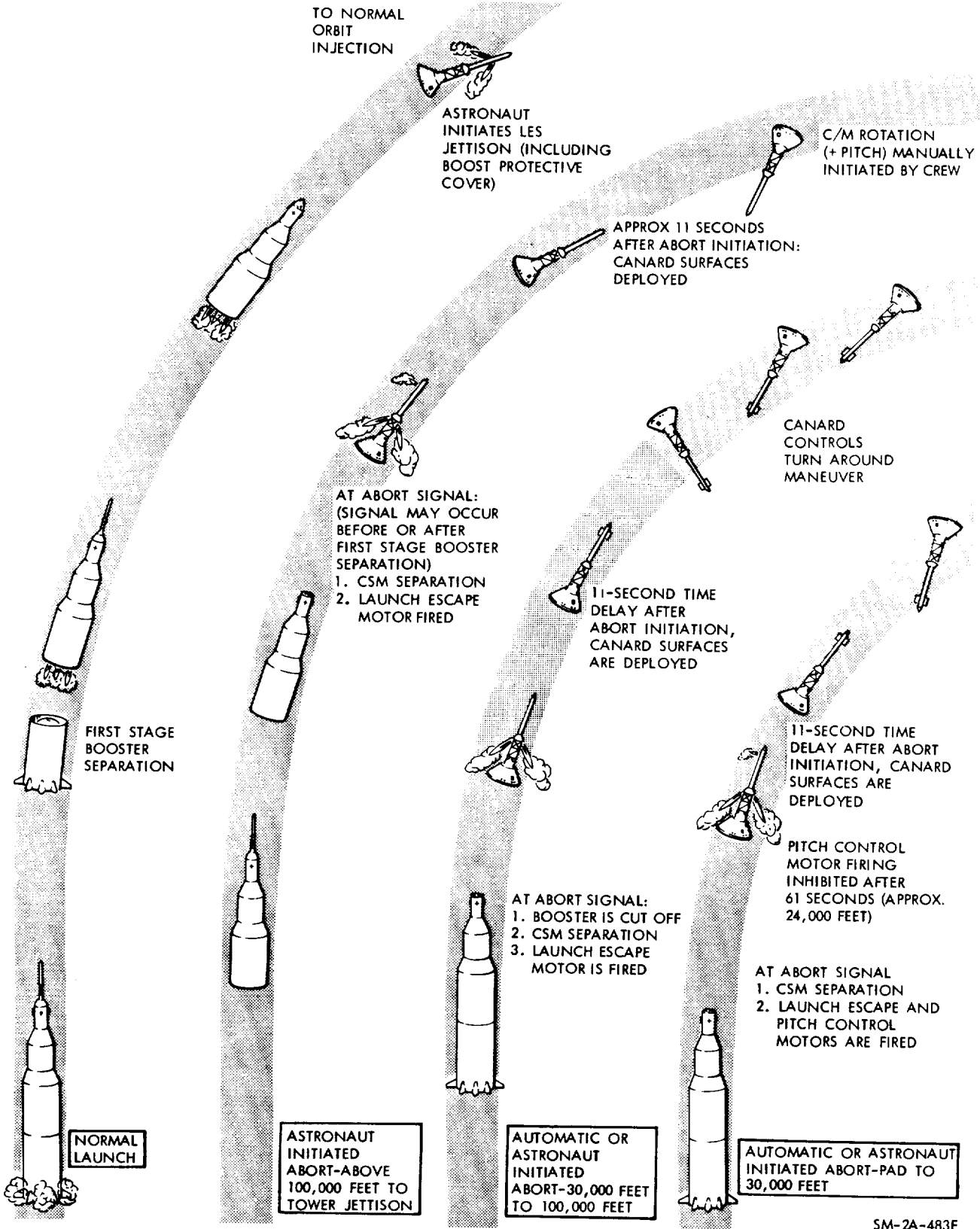
3-9. During a successful launch, the launch escape assembly will be jettisoned after reaching a prescribed altitude. The tower explosive devices will be detonated, the jettison motor ignited, and the launch escape assembly (including the boost protective cover) will be propelled away from the path of the spacecraft and booster.

3-10. CANARD OPERATION. The canard (figure 3-2) consists of two deployable surfaces and an operating mechanism. The surfaces are faired into the outer skin of the launch escape assembly below the nose cone and the operating mechanism is inside the cylindrical-shaped assembly. Each surface is mounted on two hinges and is opened by a pyro cylinder that operates the opening mechanism. The pyro cylinder piston is normally in the extended position with the canard surfaces closed. Eleven seconds after an abort signal is received by the launch escape system, an electrical current fires two pyro cartridges to open the canard surfaces. Gas from the cartridges causes the piston to retract, operating the



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Figure 3-2. Canard Operation



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Figure 3-3. Launch Escape and Earth Landing Systems Functional Diagram (Sheet 1 of 2)

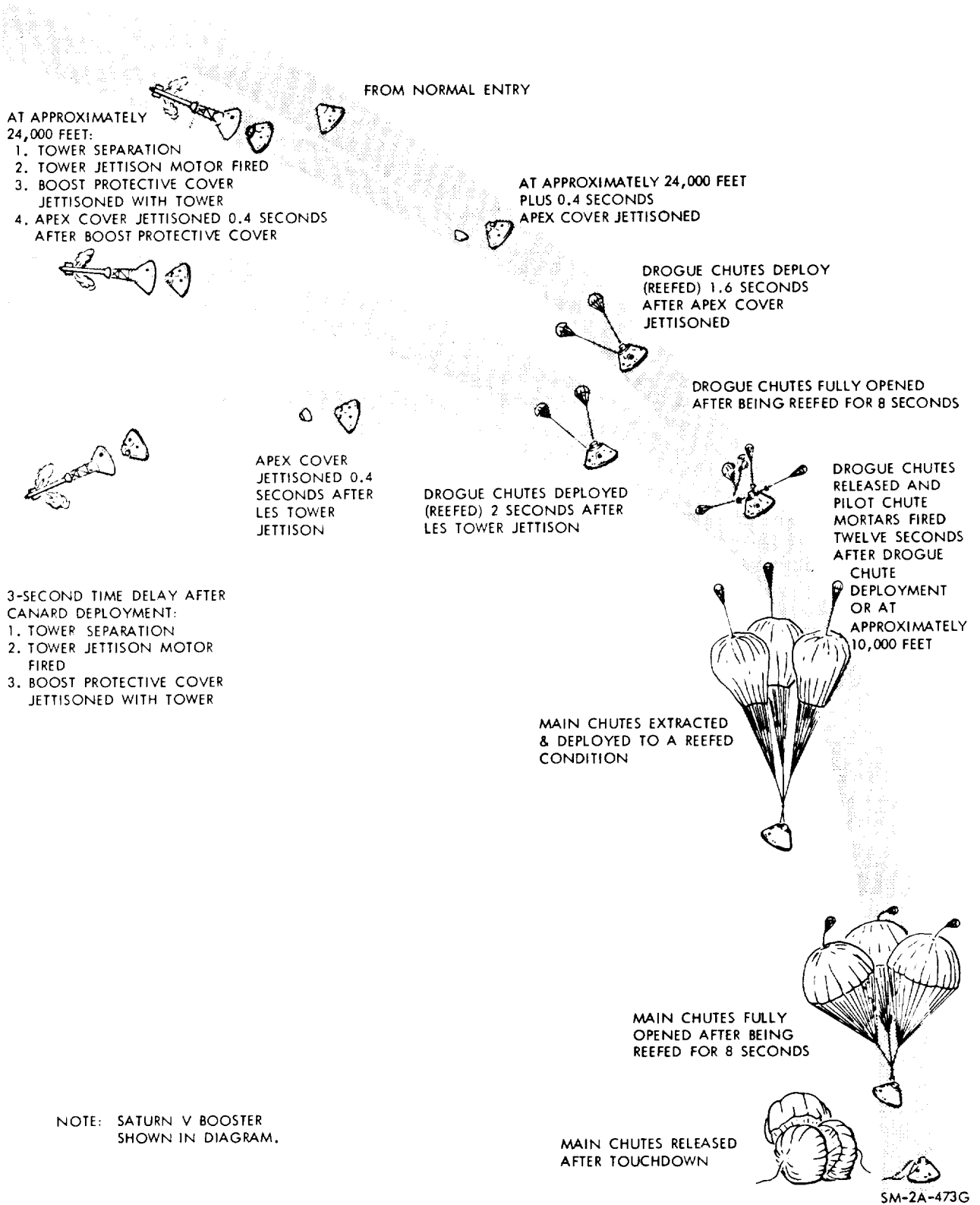


Figure 3-3. Launch Escape and Earth Landing Systems Functional Diagram (Sheet 2 of 2)

opening mechanism. The cylinder is filled with hydraulic fluid downstream of the piston and, as the piston retracts, the fluid is forced out through an orifice into a reservoir. Metering the fluid through the orifice controls the speed of the canard operation. When fully open, the two canard surfaces are locked in place by gas pressure in the cylinder, a lock ring on the piston shaft, and an overcenter linkage. The induced aerodynamic forces acting on the canard surfaces will orient the C/M to a blunt-end-forward trajectory before launch escape assembly jettison and ELS activation. (See figure 3-3.)

### 3-11. EMERGENCY DETECTION SYSTEM.

3-12. The emergency detection system (EDS) is designed to detect and display emergency conditions of the launch vehicle to the astronaut. The EDS also provides automatic abort initiation, under certain conditions, between lift-off and 90 seconds from launch. The display circuitry and automatic abort capabilities are enabled at lift-off. A lockout system is provided to prevent enabling the automatic abort circuitry prior to lift-off. The astronaut may initiate an abort manually at any time with the commanders translation control.

### 3-13. AUTOMATIC ABORT.

3-14. The emergency detection system (EDS) will initiate an automatic abort signal after launch by sensing excessive vehicle rates or two engines out. The abort signal will cause booster cutoff, event timer reset, and launch escape system activation.

### 3-15. MANUAL ABORT.

3-16. A manual abort (figure 3-4) can be initiated prior to, or during launch by manual CCW rotation of the commanders translation control. The launch escape system can be utilized until approximately normal tower jettison. During a normal mission, the LES tower is jettisoned shortly after second booster stage ignition (280,000 feet with uprated Saturn I or 320,000 feet with Saturn V), and any abort thereafter is accomplished by utilizing the SPS engine in the service module. An SPS abort must be manually initiated. Upon abort initiation, the booster automatically separates from the spacecraft, S/M-RCS engines fire to accomplish the ullage maneuver, and the SPS engine ignites to thrust the S/C away from the booster.

### 3-17. ABORT REQUEST INDICATOR LIGHT AND EVENT TIMER.

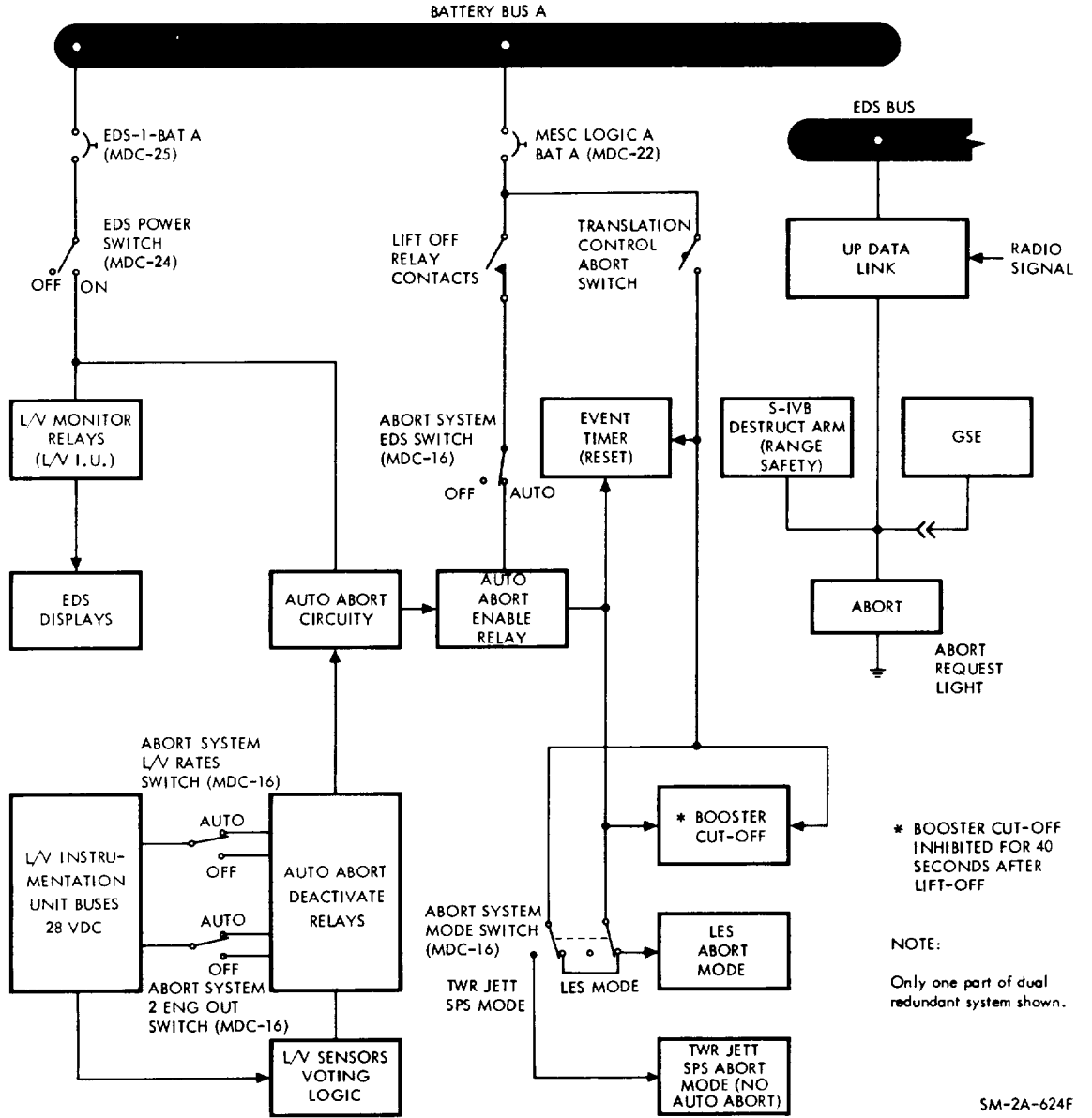
3-18. The ABORT request indicator light is illuminated by ground control, or the range safety officer, using GSE or a radio command through the up-data link. When illuminated, the light indicates an abort request and serves to alert the crew of an emergency situation.

3-19. Initiation of an abort (automatic or manual) will automatically reset the event timer to provide a time reference for manual operations.

### 3-20. EARTH LANDING SYSTEM.

3-21. The purpose of the earth landing system (ELS) is to provide a safe landing for the astronauts and the command module following an abort, or a normal entry from an earth orbital or lunar landing mission. (See figure 3-3.) Included as a part of the ELS are several recovery aids which are activated after impact on either land or water. The ELS operation is automatically timed and activated by sequence controllers. There are, however, backup components and manual override controls to ensure system reliability and to provide astronaut control.





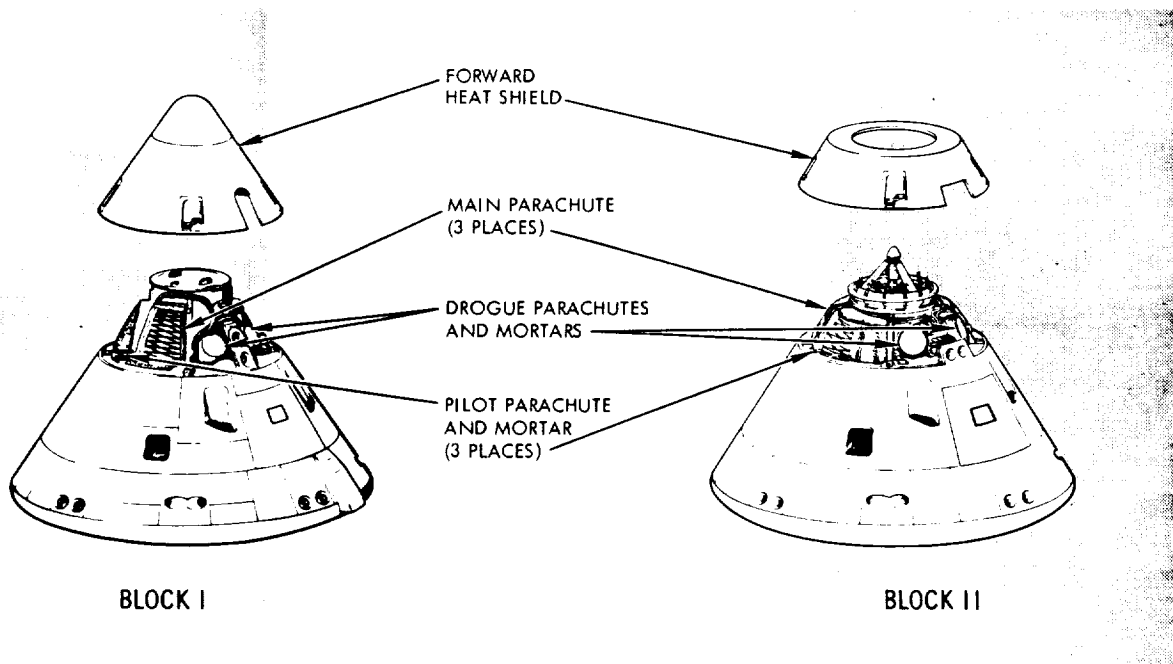
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Figure 3-4. Emergency Detection System Automatic and Manual Abort Block Diagram

3-22. With the exception of the controls and sequence controllers in the C/M crew compartment, ELS components are located in the forward compartment of the C/M as shown in figure 3-5. The ELS consists of the forward heat shield ejection subsystem, the sequence controllers, recovery aids, and the parachute subsystem. The parachute subsystem, is comprised of two fist ribbon nylon drogue parachutes, 13.7 feet in diameter; three ring slot nylon pilot parachutes, 7.2 feet in diameter; three ring sail nylon main parachutes, 83.5 feet in diameter; deployment bags, harness, mortars, and the necessary hardware for attachment to the C/M.

### 3-23. ELS OPERATION.

3-24. The C/M-ELS begins operation upon descending to approximately 24,000 feet +0.4 second, or in the event of an abort, 0.4 second after launch escape assembly jettison. (See figure 3-3.) The apex cover (forward heat shield) is jettisoned by four gas-pressure thrusters. This function is imperative, as the forward heat shield covers and protects the ELS parachutes up to this time. At 1.6 seconds later, the drogue mortar pyrotechnic cartridges are fired to deploy two drogue parachutes in a reefed condition. After 8 seconds, the reefing lines are severed by reefing line cutters and the drogue parachutes are fully opened. These stabilize the C/M in a blunt-end-forward attitude and provide deceleration. At approximately 10,000 feet, drogue parachutes are released, and the three pilot parachute mortars are fired. This action ejects the pilot parachutes which extract and deploy the three main parachutes. To preclude the possibility of parachute damage or failure due to the descent velocity, the main parachutes open to a reefed condition for 8 seconds to further decelerate the C/M. The three parachutes are then fully opened (disreefed) to lower the C/M at a predetermined descent rate. At 27-1/2-degree hang angle of the C/M is achieved by the main parachute attachment points. In the event one main parachute fails to open, any two parachutes will safely carry out the prescribed function.



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Figure 3-5. Earth Landing System

The main parachutes are disconnected following impact. The recovery aids consists of an uprighting system, swimmers umbilical, sea (dye) marker, a flashing beacon light, a VHF recovery beacon transmitter, a VHF transceiver, and an H-F transceiver. A recovery loop is also provided on the C/M to facilitate lifting. If the command module enters the water and stabilizes in a stable II (inverted) condition, the uprighting system is activated (manually), inflating three air bags causing the command module to assume a stable I (upright) condition. Each bag has a separate switch for controlling inflation. The sea (dye) marker and swimmer's umbilical are deployed automatically when the HF recovery antenna is deployed (manually initiated by crew). The marker is tethered to the C/M forward compartment deck and will last approximately 12 hours. The swimmer's umbilical provides the electrical connection for communication between the crew in the C/M and the recovery personnel in the water.

### 3-25. ENVIRONMENTAL CONTROL SYSTEM.

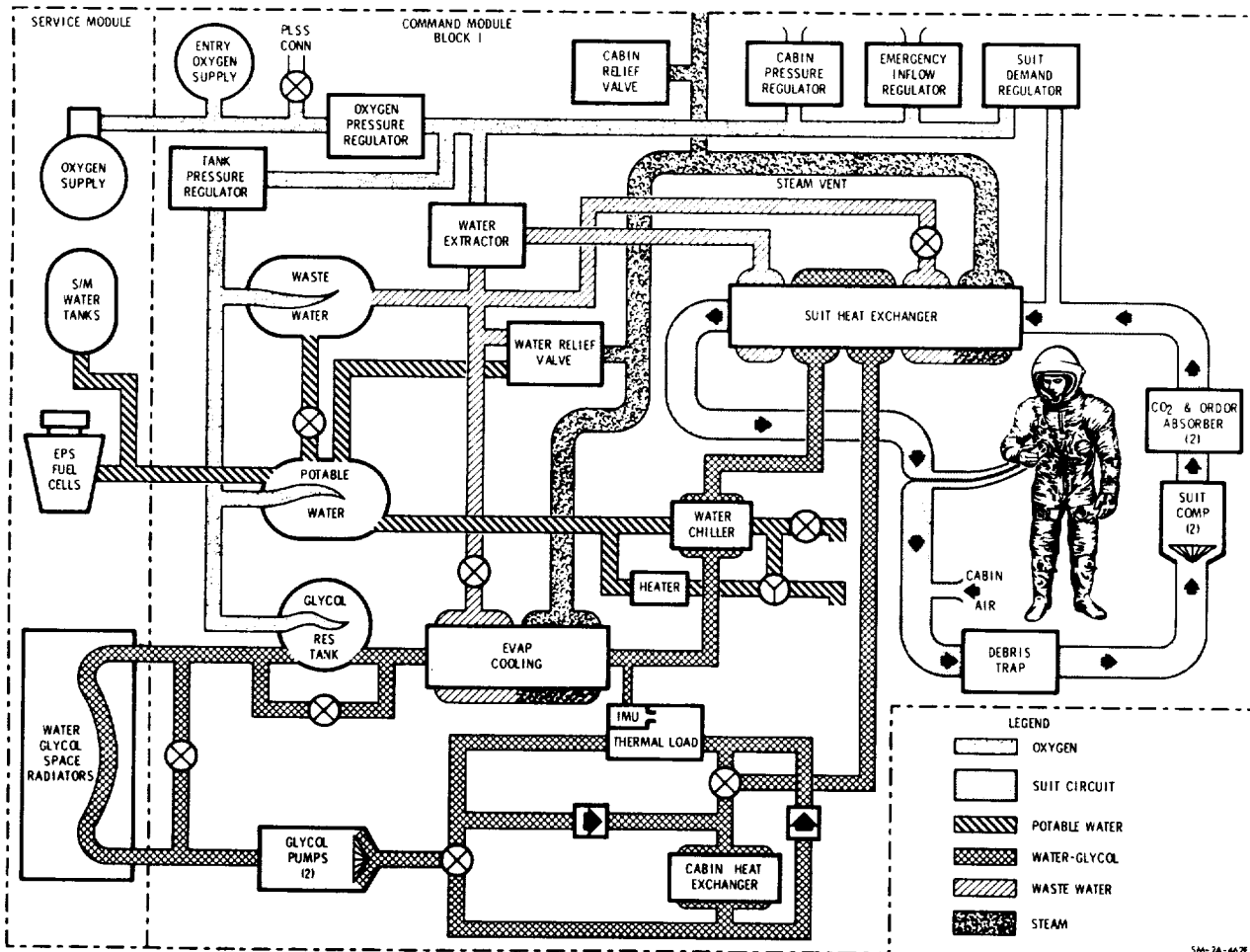
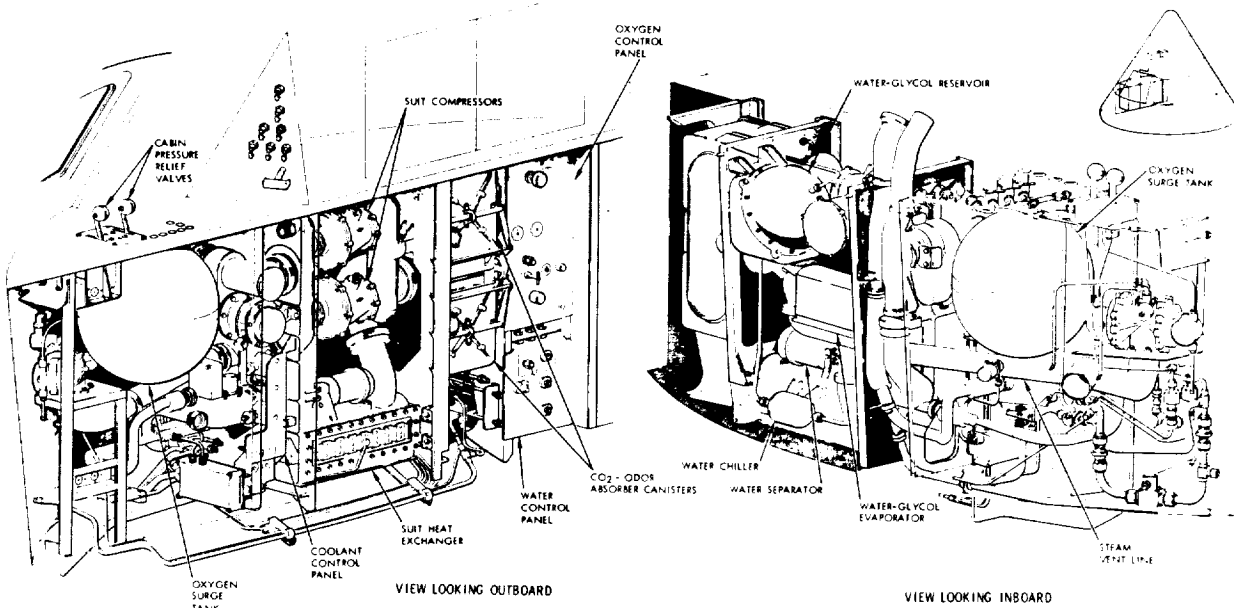
3-26. The basic purpose of the environmental control system (ECS) is to provide a controlled environment for three astronauts in the Apollo spacecraft during missions of up to 14 days duration. This environment consists of a pressurized suit circuit for use during normal or emergency conditions, and a pressurized shirtsleeve cabin atmosphere used only when normal conditions exist. Metabolically, the system is responsible for supplying oxygen and hot and cold potable water; as well as removing carbon dioxide, odors, water production, and heat output. The ECS also disperses electronic equipment heat loads.

### 3-27. ECS OPERATION.

3-28. The ECS is so designed that a minimum amount of crew time is required for normal system operation. Electrical and mechanical override and backup capabilities exist throughout the system to maintain the required reliability level. Oxygen and potable water are supplied to the ECS by components of the electrical power system (EPS). (See figure 3-6.) The oxygen originates in the cryogenic storage tanks and the potable water is a by-product of the fuel cell modules. All are located in the S/M. Waste water is collected from moisture that condenses within the pressure suit circuit, and is stored for ECS utilization. Block I S/C incorporates additional water tanks in the S/M. This supply permits the accomplishment of maximum duration earth orbital missions.

3-29. In maintaining the pressure suit and cabin shirtsleeve environments, the ECS continually conditions the atmospheres of both. This is accomplished by automatically controlling the supply of oxygen; regulating the flow, pressure, temperature, and humidity; and removing unwanted items such as carbon dioxide, odors, heat, and moisture. The pressure suit and cabin gases are processed for re-use by being routed through the suit circuit debris trap, CO<sub>2</sub>-odor absorber filters, and heat exchanger. Additional components installed on Block II S/C permit the CSM ECS to pressurize the LM.

3-30. A continuous circulating mixture of water-glycol provides the ECS with a heat transport fluid loop. This flow is used to cool the cabin atmosphere, pressure suit circuit, electronic equipment, and a portion of the potable water. It also serves as a heat source for the cabin, when required. All unwanted heat absorbed by the water-glycol is transported to the ECS space radiators located on the surface of the S/M. (These radiators are not to be confused with the EPS radiators also located on this surface.) Should cooling by radiation be inadequate, supplemental cooling takes place within the water-glycol evaporator where heat is rejected by the evaporation of waste water. In addition to this primary coolant loop, Block II S/C are provided with a completely independent, secondary coolant loop. The redundant loop routes water-glycol to certain critical components that are absolutely necessary to complete a safe return to earth.



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Figure 3-6. Environmental Control System Simplified Flow Diagram

3-31. The water supply subsystem is concerned with the storage and distribution of potable water produced by the fuel cell modules, and waste water recovered from the suit heat exchanger. These supplies are used by the ECS to furnish hot and cold potable water for crew consumption, and waste water for evaporative cooling by the water-glycol evaporator and suit heat exchanger (Block I only).

3-32. ECS ENTRY PROVISION. CSM separation prior to entry removes the capability of cooling the water-glycol by space radiation, and cuts off the source of potable water and oxygen. Provision is therefore made to enable the ECS to carry out its functions following separation. Before separation occurs, the C/M cabin is cold-soaked using a flow of cold water-glycol. This provides a heat sink for the aerodynamically developed heat that penetrates the C/M during entry. After separation, the water-glycol and the suit circuit are cooled exclusively by water evaporation. A tank in the C/M supplies all the oxygen required during entry and descent. Upon landing, a postlanding ventilation system is activated. This consists of two valves and a fan which will circulate ambient air through the C/M. The postlanding ventilation system is activated by the crew.

### 3-33. ELECTRICAL POWER SYSTEM.

3-34. The primary purpose of the electrical power system (EPS) is to provide the electrical energy sources, power generation and controls, power conversion and conditioning, and power distribution to a-c and d-c electrical buses to meet the requirements of the various spacecraft systems during the mission flight and postlanding phases. This is shown in figures 3-7 and 3-9 and described in paragraph 3-43. For ground checkout, all d-c electrical power will be supplied by ground support equipment prior to activation of the fuel cells. During this same period, a-c electrical power will be supplied by the S/C inverters for some checkout functions and by ground support equipment for other checkout functions. The secondary purpose of the EPS is to furnish the environmental control system with potable water required by the three astronauts during the mission. This water is obtained as a by-product of the three fuel cell powerplants. Paragraph 3-43 provides a list of the various power sources and the power-consuming devices connected to each bus.

### 3-35. D-C POWER SUPPLY.

3-36. Two d-c power sources provide the S/C with 28-volt d-c power. The first source consists of three Bacon-type, hydrox (hydrogen-oxygen) fuel cell powerplants. The second source is obtained from silver oxide-zinc-type storage batteries. The fuel cell powerplants are connected in parallel and used throughout the mission until command-service module (CSM) separation. Any two of the three fuel cells will provide sufficient power for normal mission loads. In the event two fuel cells fail, the third is capable of furnishing emergency power; however, this is contingent upon removing all nonessential loads from the bus, in addition to supplying battery power to the bus at peak loads above the capacity of the one operating fuel cell powerplant. The d-c power system is controlled, regulated, and protected by appropriate switching circuits, undervoltage detection, and circuit breakers. Two nonrechargeable batteries (Block I only), the fuel cell powerplants, the cryogenic storage system for the hydrogen and oxygen, and the glycol coolant space radiators are located in the service module. (See figure 3-8.)

3-37. CRYOGENIC GAS STORAGE SYSTEM. The cryogenic gas storage system supplies the hydrogen and oxygen consumed by the three fuel cell powerplants. In addition, the oxygen used by the ECS is also supplied from this source. The hydrogen and oxygen subsystems are very similar, each consisting of storage tanks, associated valves, pressure

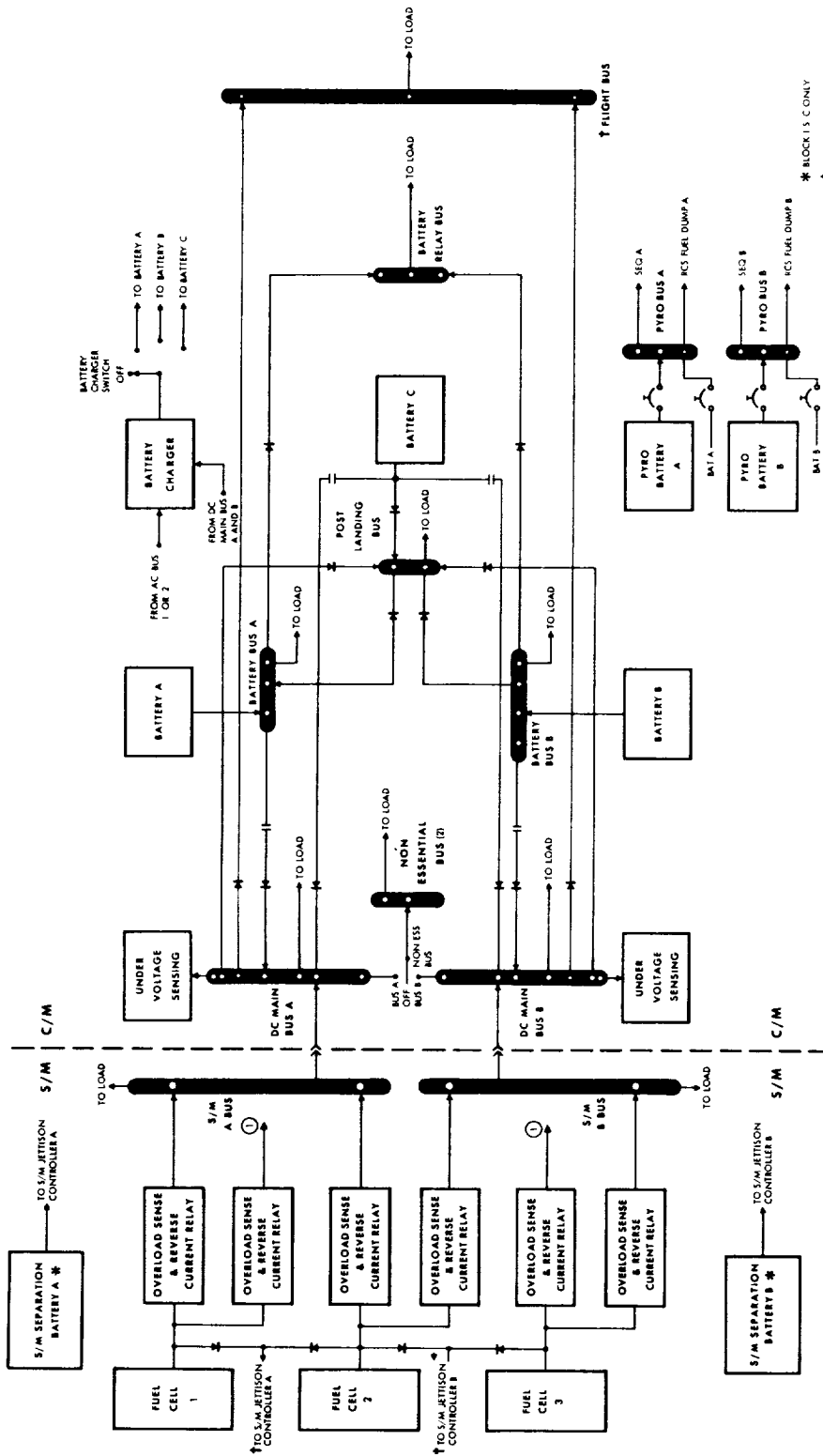


Figure 3-7. Electrical Power System - D-C Power Distribution Diagram

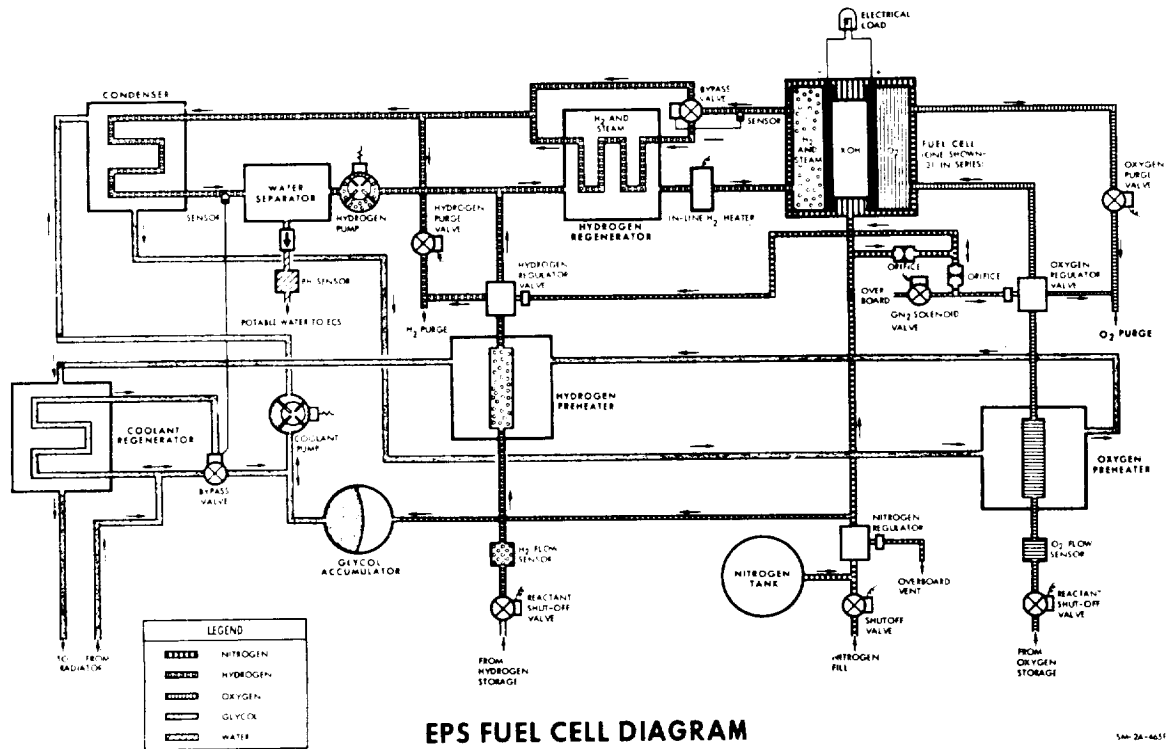
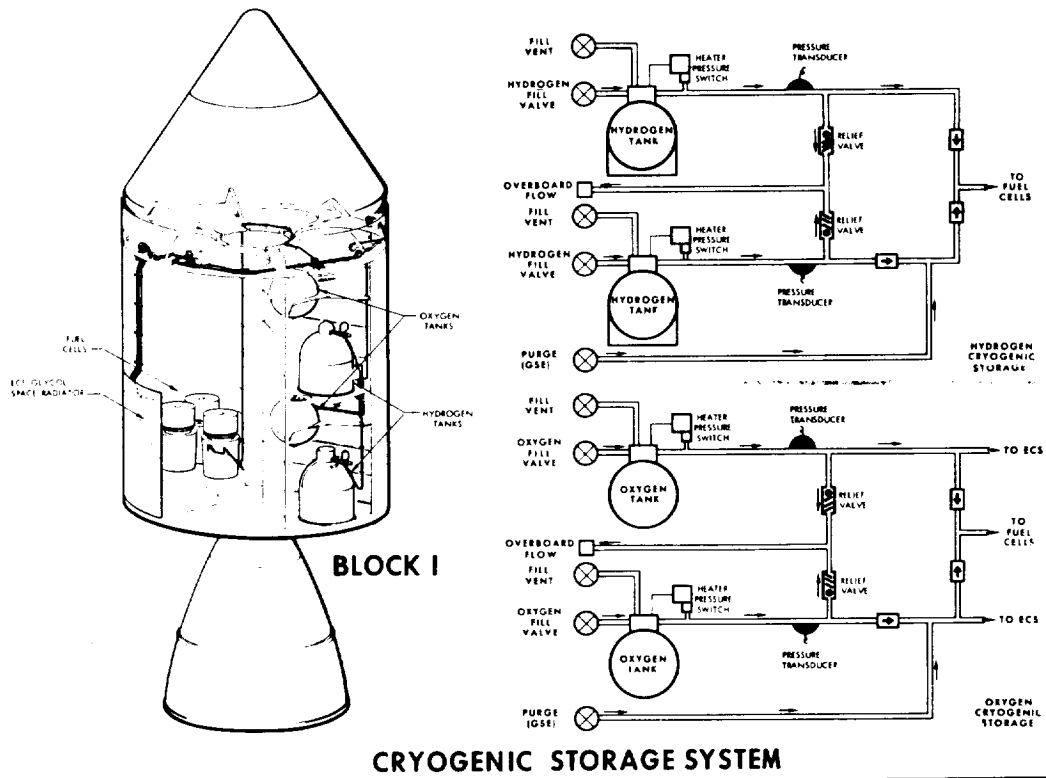


Figure 3-8. Electrical Power System – Cryogenics Storage and Fuel Cell Functional Diagram

switches, motor switches, lines, and other plumbing components. (See figure 3-8.) The hydrogen and oxygen are stored in a cryogenic state. However, by the time both reactants reach the fuel cells, they have warmed considerably and are in a gaseous state.

3-38. FUEL CELL POWERPLANTS. Each of the three fuel cell powerplants consist of 31 single cells connected in series. Each cell consists of a hydrogen compartment, an electrolyte compartment, an oxygen compartment, and two electrodes. (See figure 3-8.) The electrolyte is composed of potassium hydroxide (78 percent) and water (22 percent) and remains constant in cell reaction by simply providing an ionic conduction path between the electrodes. The hydrogen electrode is composed of nickel, while the oxygen electrode is composed of nickel and nickel oxide. This electrode structure also remains constant throughout fuel cell operation. The consumable reactants of hydrogen and oxygen are supplied to the cell under regulated pressure, using nitrogen pressure as a reference as well as for pressurizing the powerplants. By chemical reaction, electricity, water, and heat are produced, with the reactants being consumed in proportion to the electrical load. The by-products, water and heat, are utilized to maintain the supply of potable water and to keep the electrolyte at the proper operating temperature. The 31 fuel cells and the required pumps, valves, regulators, and other components are housed in a container.

3-39. BATTERIES. Three batteries, located in the lower equipment bay of the C/M, can be selected and switched to a variety of buses and circuits. The circuitry which ignites the S/C pyrotechnic devices is generally completely independent and isolated from the remainder of the d-c system, and receives power from two pyrotechnic batteries. There are two nonrechargeable batteries in the S/M (Block I only) whose sole function is to furnish power to the service module jettison controllers. In Block II, S/C power to the S/M jettison controllers is furnished by the fuel cell powerplants. This will sustain the firing of those S/M reaction control engines that provide S/M retrograde following C/M-S/M separation.

3-40. BATTERY CHARGER. A battery charger, located in the lower equipment bay of the C/M, is utilized to assure that the entry batteries are fully charged before entry begins.

3-41. A-C POWER SUPPLY.

3-42. Three solid-state inverters, located in the lower equipment bay of the C/M, are the source of the 115/200-volt 400-cycle 3-phase a-c power used in the S/C. These inverters operate from the two 28-volt d-c main buses, and supply power to two 400-cycle a-c buses. (See figure 3-9.) The a-c electrical power system is complete with adequate switching arrangements, overvoltage and overload sensing circuits, as well as circuit breakers for protection of the inverters. Under normal conditions, one inverter has the capability of supplying all S/C primary 400-cycle a-c electrical power needs. The other two inverters act as redundant standby units. In the event of inverter failure, input and load are manually switched to another inverter. Although the inverters cannot be paralleled on a single bus due to circuitry provisions, two inverters can operate simultaneously if each supplies a separate a-c bus.

3-43. SPACECRAFT POWER SOURCES AND POWER CONSUMING DEVICES.

3-44. The following list contains Block I and Block II spacecraft power sources and power-consuming devices.



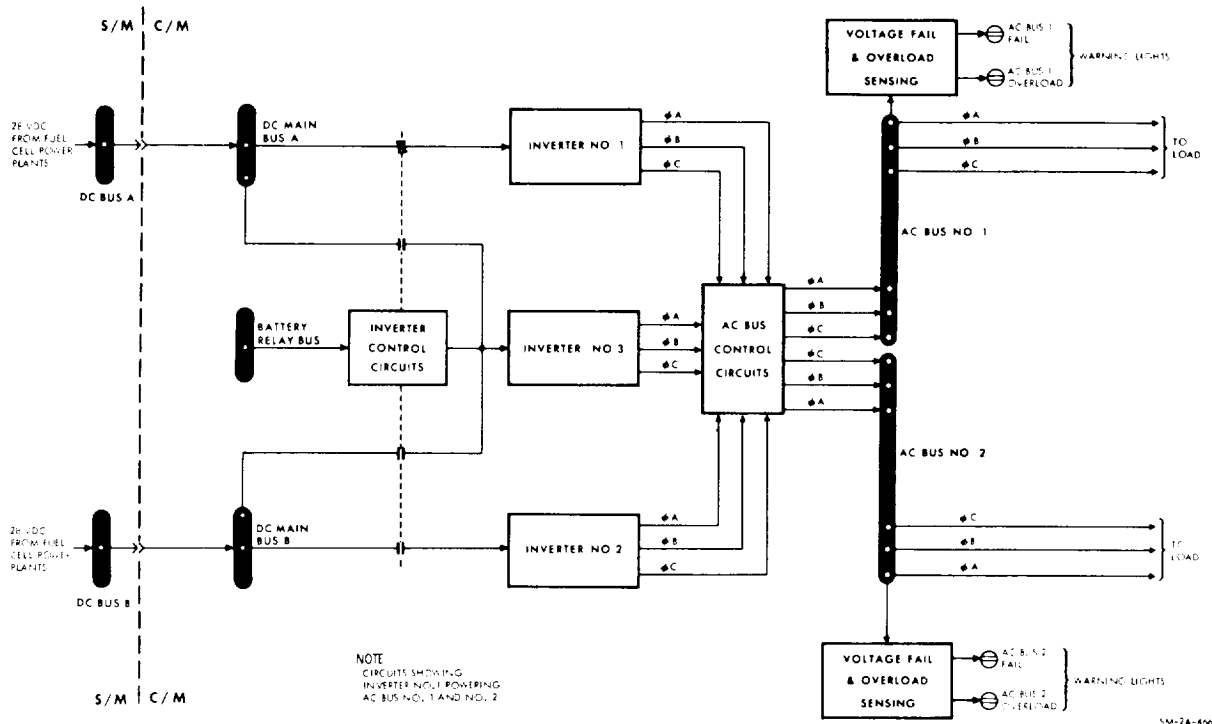


Figure 3-9. Electrical Power System - A-C Power Distribution Diagram

Block I	Block II
Command Module D-C Main Bus A (Powered by fuel cells 1, 2, and 3, and backed up by batteries A, and C, when necessary)	
Environmental control system Pressure and temperature transducers Water separator No. 1 S/M water tank control Steam duct heater No. 1 Flight and postlanding bus Pyro interrupter switch Oxygen and hydrogen purge - fuel cell power plants No. 1, 2, and 3 Inverters No. 1 and No. 3 Battery charger Nonessential bus switch	Environmental control system Pressure and temperature transducers Emergency loop temperature transducers Water accumulator Steam duct heater No. 1 and water-glycol temperature control Compressor inverter Flight and postlanding bus Pyro interrupter switch Oxygen and hydrogen purge - fuel cell powerplants No. 1, 2, and 3 Inverters No. 1 and No. 3

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Block I	Block II
Interior floodlighting	Battery charger
D-C sensing unit and voltmeter switch	Nonessential bus switch
Stabilization and control system	Interior floodlighting
Direct control	D-C sensing unit and voltmeter switch
Pitch	Stabilization and control system
Roll-channel A&C	Direct control
Roll-channel B&D	Pitch
Yaw	Roll-channel A&C
Group 1	Roll-channel B&D
Group 2	Yaw
	Logic
Potable water heater	Potable water heater
Caution and warning detection unit	Caution and warning detection unit
Event timer	Event timer
Central timing equipment	Central timing equipment
Reaction control system	Reaction control system
Propellant isolation	Propellant isolation
RCS transfer	RCS transfer
RCS heaters	RCS heaters
Essential instrumentation	Essential instrumentation
Cryogenic oxygen and hydrogen tank heaters	Cryogenic oxygen and hydrogen tank heaters
Service propulsion system	Service propulsion system
Gauging	Gauging
Helium shutoff valve	Helium shutoff valve

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Block I	Block II
<p>Guidance and navigation system</p> <p style="padding-left: 40px;">Inertial measurement unit-coupling display unit</p> <p style="padding-left: 40px;">Inertial measurement unit heaters</p> <p style="padding-left: 40px;">Optics</p> <p style="padding-left: 40px;">Computer</p> <p>Space suit communications and biomed instrumentation</p> <p>Crew couch attenuation</p>	<p>Guidance and navigation system</p> <p style="padding-left: 40px;">Inertial measurement unit-coupling display unit</p> <p style="padding-left: 40px;">Inertial measurement unit heaters</p> <p style="padding-left: 40px;">Optics</p> <p style="padding-left: 40px;">Computer</p> <p>Entry monitor display</p> <p>Flight bus</p> <p>Crew couch attenuation</p> <p>Rendezvous radar transponder</p> <p>Docking lights</p>
<p>Command Module D-C Main Bus B (Powered by fuel cells 1, 2, and 3, and backed up by batteries B, and C, when necessary)</p>	
<p>Environmental control system</p> <p style="padding-left: 40px;">Pressure and temperature transducers</p> <p style="padding-left: 40px;">Water separator No. 2</p> <p style="padding-left: 40px;">S/M water tank control</p> <p style="padding-left: 40px;">Steam duct heater No. 2</p> <p>Flight and postlanding bus</p> <p>Pyro interrupter switch</p> <p>Oxygen and hydrogen purge - fuel cell powerplants No. 1, 2, and 3</p> <p>Inverters No. 2 and No. 3</p> <p>Battery charger</p> <p>Nonessential bus switch</p> <p>Interior floodlighting</p> <p>D-C sensing unit and voltmeter switch</p>	<p>Environmental control system</p> <p style="padding-left: 40px;">Pressure and temperature transducers</p> <p style="padding-left: 40px;">Emergency loop temperature transducers</p> <p style="padding-left: 40px;">Water accumulator</p> <p style="padding-left: 40px;">Steam duct heater No. 2 and water-glycol temperature control</p> <p>Flight and postlanding bus</p> <p>Pyro interrupter switch</p> <p>Oxygen and hydrogen purge - fuel cell powerplants No. 1, 2, and 3</p> <p>Inverters No. 2 and No. 3</p> <p>Battery charger</p> <p>Nonessential bus switch</p> <p>Interior floodlighting</p>

Block I	Block II
Stabilization and control system	D-C sensing unit and voltmeter switch
Direct control	Stabilization and control system
Pitch	Direct control
Roll-channel A&C	Pitch
Roll-channel B&D	Roll-channel A&C
Yaw	Roll-channel B&D
Group 1	Yaw
Group 2	Logic
Potable water heater	Potable water heater
Caution and warning detection unit	Caution and warning detection unit
Event timer	Event timer
Central timing equipment	Central timing equipment
Reaction control system	Reaction control system
Propellant isolation	Propellant isolation
RCS transfer	RCS transfer
RCS heaters	RCS heaters
Essential instrumentation	Essential instrumentation
Cryogenic oxygen and hydrogen tank heaters	Cryogenic oxygen and hydrogen tank heaters
Service propulsion system	Service propulsion system
Gauging	Gauging
Helium shutoff valve	Helium shutoff valve
Guidance and navigation system	Guidance and navigation system
Inertial measurement unit-coupling display unit	Inertial measurement unit-coupling display unit
Inertial measurement unit heaters	Inertial measurement unit heaters

Block I	Block II
<p>Optics</p> <p>Computer</p> <p>Space suit communications and biomed instrumentation</p> <p>Crew couch attenuation</p>	<p>Optics</p> <p>Computer</p> <p>Entry monitor display</p> <p>Crew couch attenuation</p> <p>Rendezvous radar transponder</p> <p>Docking lights</p> <p>LM power switch</p>
<p>Command Module A-C Bus No. 1 (Powered by inverter No. 1, 2, or 3)</p>	
<p>Reactant pump - fuel cell powerplants No. 1, 2, and 3</p> <p>Battery charger</p> <p>Stabilization and control - group 1 and group 2</p> <p>Guidance and navigation system</p> <p>Cryogenic fuel quantity amplifier</p> <p>Telecommunications</p> <p>Environmental control system</p> <p>    Glycol pumps</p> <p>    Suit compressors</p> <p>    Cabin air fans, water-glycol temperature control, suit temperature control, and waste management blower</p> <p>    Space radiator isolation valves</p> <p>Interior lighting</p> <p>SPS gauging</p> <p>A-C sensing unit and voltmeter switch</p> <p>Cryogenic oxygen and hydrogen tank fan motors (system 1)</p>	<p>Reactant pump - fuel cell powerplants No. 1, 2, and 3</p> <p>Battery charger</p> <p>Stabilization and control - group 1 and group 2</p> <p>Guidance and navigation system</p> <p>Cryogenic fuel quantity amplifier</p> <p>Telecommunications</p> <p>Environmental control system</p> <p>    Glycol pumps</p> <p>    Suit compressors</p> <p>    Cabin air fans, water-glycol temperature control, suit temperature control, and waste management blower</p> <p>    Water-glycol emergency loop</p> <p>    Space radiator isolation valves</p> <p>Interior lighting</p> <p>Exterior lighting</p> <p>SPS gauging</p>

Block I	Block II
Gas analyzer	A-C sensing unit and voltmeter switch Cryogenic oxygen and hydrogen tank fan motors (system 1)
Command Module A-C Bus No. 2 (Powered by inverter No. 1, 2, or 3)	
Reactant pump - fuel cell powerplants No. 1, 2, and 3 Battery charger Stabilization and control - group 1 and group 2 Guidance and navigation system Cryogenic fuel quantity amplifier Telecommunications SPS gauging Environmental control system Glycol pumps Space radiator isolation valves Cabin air fans, cabin temperature control and water-glycol temperature control Suit compressors Interior lighting A-C sensing unit and voltmeter switch Cryogenic oxygen and hydrogen tank fan motors (system 2)	Reactant pump - fuel cell powerplants No. 1, 2, and 3 Battery charger Stabilization and control - group 1 and group 2 Guidance and navigation system Cryogenic fuel quantity amplifier Telecommunications SPS gauging Environmental control system Glycol pumps Space radiator isolation valves Cabin air fans, cabin temperature control and water-glycol temperature control Water-glycol emergency loop Suit compressors EVT oxygen valve Interior lighting Exterior lighting A-C sensing unit and voltmeter switch Cryogenic oxygen and hydrogen tank fan motors (system 2)

Block I	Block II
Command Module Battery Bus A (Powered by entry battery A)	
<p>Flight and postlanding bus</p> <p>ELS sequencer A logic and SECS arm</p> <p>Battery charger and battery bus A tie switch</p> <p>Arm mission sequencer logic bus and EDS abort enable switch</p> <p>Logic mission sequencer A and voltmeter switch</p> <p>Battery relay bus</p> <p>EDS - bus No. 1</p> <p>D-C main bus A</p> <p>D-C sensing unit and voltmeter switch</p> <p>Main gimbal control - yaw, pitch</p> <p>Uprighting system - compressor No. 1</p>	<p>Flight and postlanding bus</p> <p>ELS sequencer A logic and SECS arm</p> <p>Battery charger and battery bus A tie switch</p> <p>Battery relay bus</p> <p>EDS - bus No. 1</p> <p>D-C main bus A</p> <p>D-C sensing unit and voltmeter switch</p> <p>Main gimbal control - yaw, pitch</p> <p>Uprighting system - compressor No. 1</p> <p>Flotation bag control</p>
Command Module Battery Bus B (Powered by entry battery B)	
<p>Flight and postlanding bus</p> <p>ELS sequencer B logic and SECS arm</p> <p>Battery charger and battery bus B tie switch</p> <p>Arm mission sequencer logic bus and EDS abort enable switch</p> <p>Logic mission sequencer B and voltmeter switch</p> <p>Battery relay bus</p> <p>EDS - bus No. 3</p> <p>D-C main bus B</p> <p>D-C sensing unit and voltmeter switch</p>	<p>Flight and postlanding bus</p> <p>ELS sequencer B logic and SECS arm</p> <p>Battery charger and battery bus B tie switch</p> <p>Battery relay bus</p> <p>ECS - bus No. 3</p> <p>D-C main bus B</p> <p>D-C sensing unit and voltmeter switch</p> <p>Auxiliary gimbal control - yaw, pitch</p> <p>Uprighting system - compressor No. 2</p> <p>Flotation bag control</p>

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Block I	Block II
Auxiliary gimbal control - yaw, pitch	
Uprighting system - compressor No. 2	
Command Module Flight and Postlanding Bus (Powered by entry battery C, d-c main buses A and B, and battery buses A and B)	
VHF recovery beacon D-C main bus A D-C main bus B Audio center (engineer) Audio center transmitter key relay VHF/AM transmitter receiver H-F transceiver Audio center (CMDR) Up-data link VHF/FM transmitter S-band power amplifier Unified S-band power relay Signal conditioning equipment (Block I) TV camera C-band transponder Data storage equipment Premodulation processor Audio center (NAV) Microphone amplifiers - NAV, CMDR, ENGR ECS postlanding ventilation system Flotation bag control	D-C main bus A D-C main bus B Microphone amplifiers - NAV, CMDR, ENGR Floodlights ECS postlanding ventilation system Flotation bag No. 3 EDS - bus No. 2



Block I	Block II
Command Module Battery Relay Bus (Powered by entry batteries A and B)	
<p>Control circuits - inverters No. 1, 2, and 3</p> <p>A-C buses No. 1 and No. 2 over-undervoltage and overload sensing</p> <p>Reactant shutoff valves - fuel cell powerplants No. 1, 2, and 3</p> <p>D-C main buses A and B undervoltage sensing unit</p> <p>D-C main buses A and B select switch, fuel cell powerplants No. 1, 2, and 3 and indicators</p>	<p>Control circuits - inverters No. 1, 2, and 3</p> <p>A-C buses No. 1 and No. 2 over-undervoltage and overload sensing</p> <p>Reactant shutoff valves - fuel cell powerplants No. 1, 2, and 3</p> <p>D-C main buses A and B undervoltage sensing unit</p> <p>D-C main buses A and B select switch, fuel cell powerplants No. 1, 2, and 3 and indicators</p> <p>Fuel cell powerplants No. 1, 2, and 3 radiator valves</p>
Command Module Nonessential Buses (Powered by d-c main bus A or B)	
<p>Nonessential instrumentation</p> <p>NASA scientific instrumentation</p> <p>Flight qualification recorder</p> <p>Special equipment bays No. 1 and No. 2 (S/C 012 and S/C 014)</p> <p>Special equipment hatch (S/C 012 and S/C 014)</p>	<p>Nonessential instrumentation</p> <p>NASA scientific instrumentation</p> <p>Special equipment bays No. 1 and No. 2</p> <p>Special equipment hatch</p>
Command Module MESC Pyro Bus A (Powered by pyro battery A)	
<p>Sequencer A</p> <p>RCS fuel dump and voltmeter switch</p> <p>LES, ELS, and RCS pressure initiators</p>	<p>Sequencer A</p> <p>HF orbital antenna deploy</p> <p>RCS fuel dump and voltmeter switch</p> <p>LES, ELS, and RCS pressure initiators</p>

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Block I	Block II
Command Module MESC Pyro Bus B (Powered by pyro battery B)	
Sequencer B RCS fuel dump and voltmeter switch LES, ELS, and RCS pressure initiators	Sequencer B HF recovery antenna deploy RCS fuel dump and voltmeter switch LES, ELS, and RCS pressure initiators
Command Module Entry Battery C	
D-C main bus A D-C main bus B Flight and postlanding bus EDS - bus No. 2 Voltmeter switch	D-C main bus A D-C main bus B Flight and postlanding bus Voltmeter switch
Service Module D-C Bus A (Powered by fuel cells 1, 2, and 3)	
SPS primary gimbal motors Overload or reverse current sensing - fuel cell powerplants No. 1, 2, and 3 D-C main bus A	SPS primary gimbal motors Overload or reverse current sensing - fuel cell powerplants No. 1, 2, and 3 S/M jettison controller A D-C main bus A
Service Module D-C Bus B (Powered by fuel cell 1, 2, or 3)	
SPS auxiliary gimbal motors Overload or reverse current sensing - fuel cell powerplants No. 1, 2, and 3 D-C main bus B	SPS auxiliary gimbal motors Overload or reverse current sensing - fuel cell powerplants No. 1, 2, and 3 S/M jettison controller B D-C main bus B
Service Module Jettison Controller Battery A	
Controller A	None

Block I	Block II
Service Module Jettison Controller Battery B	
Controller B	None
Flight Bus (Powered by d-c main buses A and B)	
None	Rendezvous radar transponder S-band PA No. 1 transponder S-band power amplifier No. 2 Up-data link Signal conditioning equipment Premodulation processor Data storage and S-band transmitter 2-KMC high-gain antenna

### 3-45. REACTION CONTROL SYSTEM.

3-46. The reaction control system (RCS) is comprised of two subsystems: the service module and the command module reaction control systems. (See figures 3-10 and 3-11.) The primary purpose of each subsystem is to provide propulsion impulses, as required, for the accomplishment of normal and emergency attitude maneuvers of the spacecraft or the C/M. Both subsystems operate in response to automatic control signals originating from the G&N or stabilization and control system. Manual control is provided by the crew rotation hand controllers. The subsystems are similar to the extent that both utilize pressure-fed, hypergolic propellants, and maintain total redundancy of critical components and rocket engine thrust vectors.

### 3-47. SERVICE MODULE REACTION CONTROL.

3-48. The S/M-RCS consists of four independent, equally capable, and functionally identical packages, as shown in figure 3-10. Each package contains four reaction control engines, fuel and oxidizer tanks (one each for Block I and two each for Block II), a helium tank, and associated components such as regulators, valves, filters, and lines. These components are mounted on a panel, or package that is installed on the exterior of the S/M near the forward end. All components, with the exception of the engines, are located inside the S/M. In each package, two of the engines are for roll control, and the other two are for pitch or yaw control, depending upon the location of the package. Hypergolic propellants for the S/M-RCS consist of a 50:50 blend of UDMH and hydrazine as fuel and nitrogen tetroxide as oxidizer.

3-49. During an Apollo lunar mission, the S/M-RCS will be used to accomplish many of the following maneuvers: the service propulsion system ullage maneuver, thrust vectors for three-axis stabilization and attitude control, separation of various combinations of modules and/or boosters under normal or abort conditions, LM docking and separation, and minor orbital or midcourse velocity corrections.

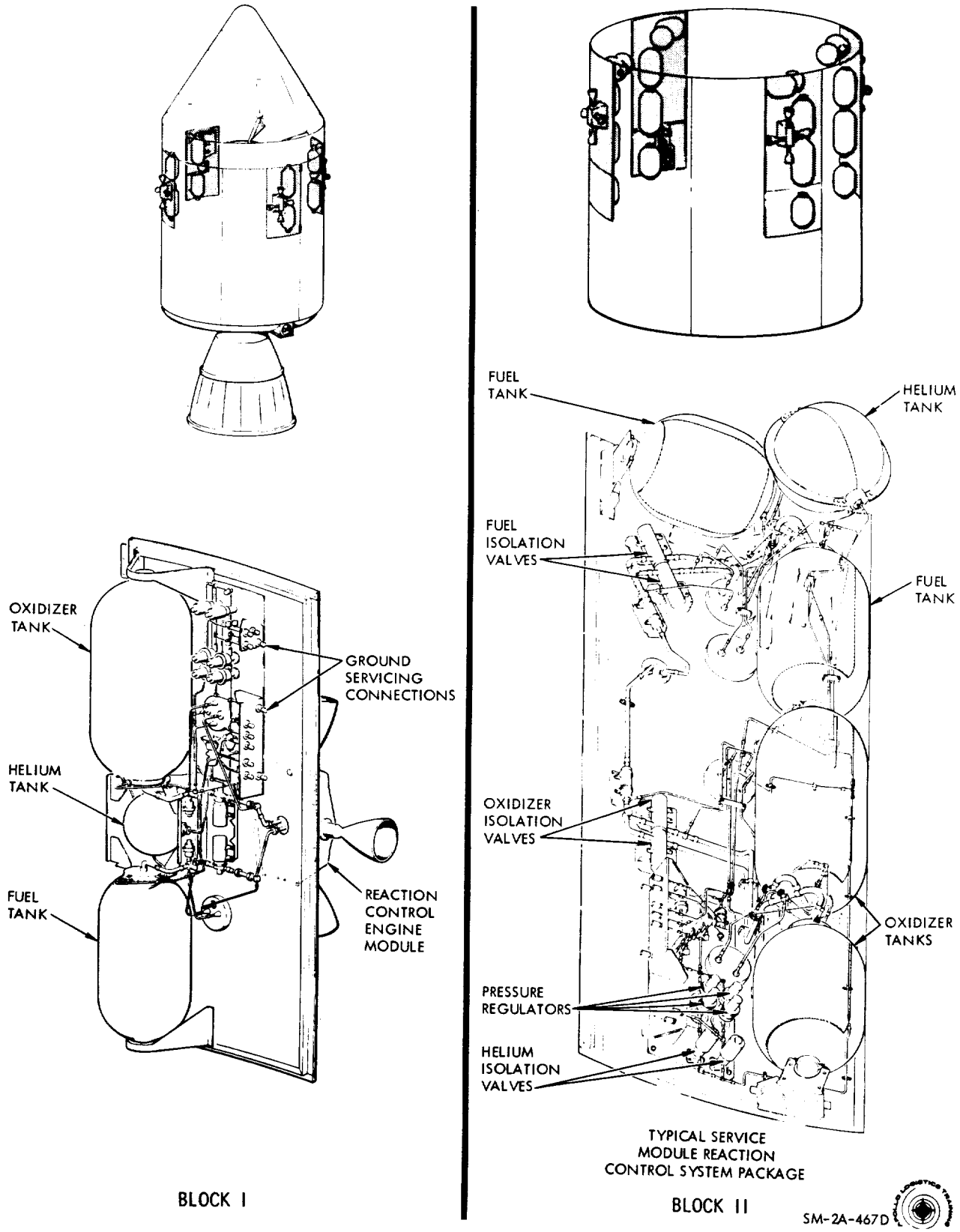
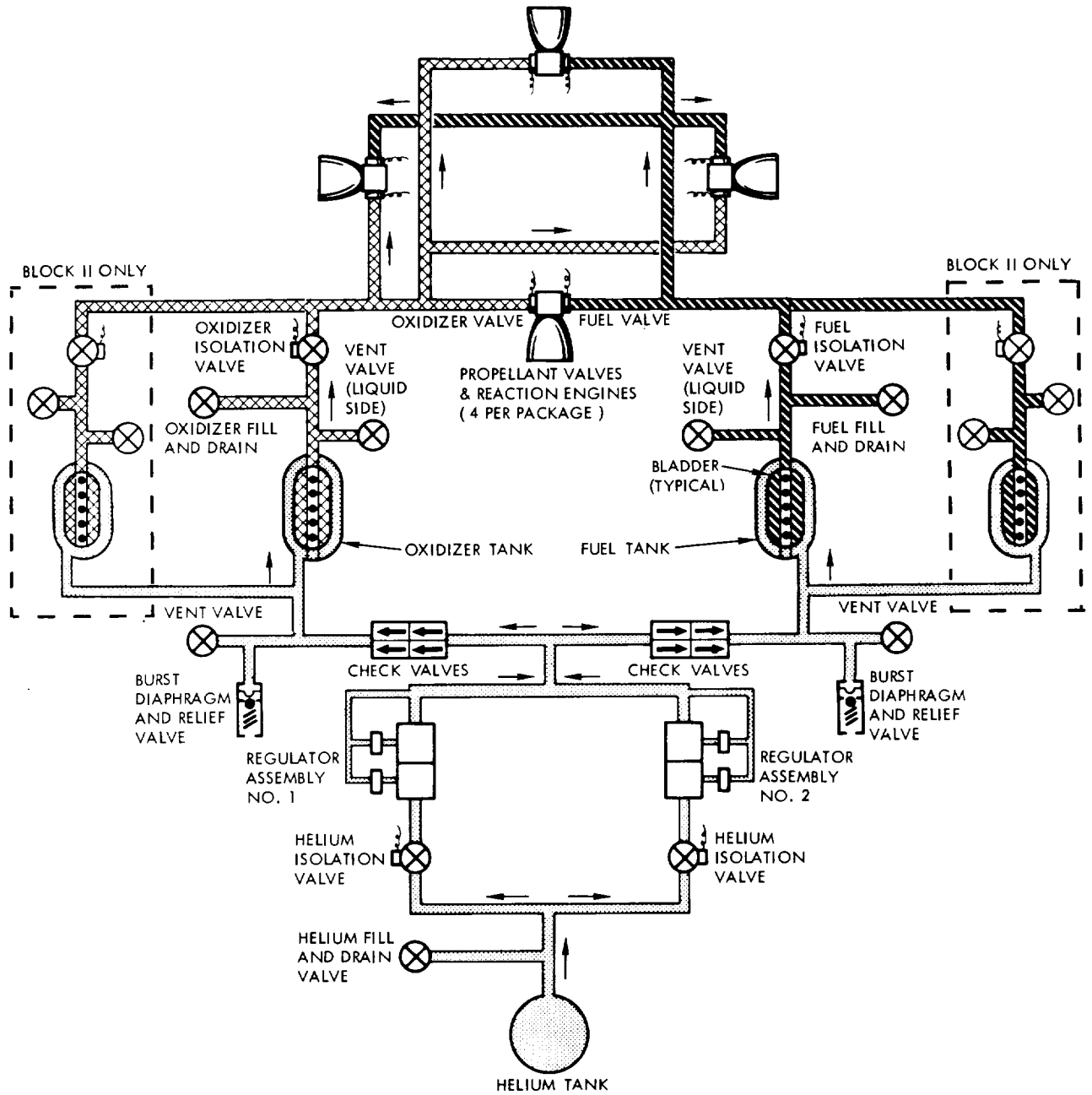


Figure 3-10. Service Module Reaction Control System (Sheet 1 of 2)



LEGEND	
	FUEL
	OXIDIZER
	HELIUM

Figure 3-10. Service Module Reaction Control System (Sheet 2 of 2)

3-50. COMMAND MODULE REACTION CONTROL.

3-51. The C/M-RCS, although similar to the S/M subsystem, is different in several respects including propellant distribution to the reaction control engines. (See figure 3-11.) The C/M contains two independent, equally capable, and functionally identical reaction control systems. Each system consists of two reaction control engines per axis (pitch, roll, and yaw), propellant storage and pressurization tanks, and associated components and lines. Hypergolic propellants for the C/M-RCS consist of nitrogen tetroxide as oxidizer, and monomethyl-hydrazine as fuel. All of the components of this subsystem are located in the aft compartment with the exception of the two negative pitch engines which are located in the forward compartment. For thrust in the pitch and yaw axes, engines from each system are mounted in pairs; whereas for roll, each pair of engines consist of a thrust left and a thrust right engine. In either case, the presence of the second system provides the required redundancy. The C/M-RCS is not activated until CSM separation takes place. The RCS is used to provide attitude maneuver capabilities during entry and, in the event of a high-altitude abort after launch escape system jettison, to provide three-axis control to aid in rate damping prior to deployment of the ELS parachutes. Due to the fact that no hypergolic propellant should be onboard the C/M at the time of earth impact, certain provisions are necessary that are not included in the S/M-RCS. Additional components, including squib-operated valves, accomplish burning of the fuel and oxidizer remaining after entry or high-altitude abort, or dump the propellant load after a pad or a low-altitude abort. On Block I the fuel is not dumped, but on Block II the total propellant load is dumped. Following either of these operations, other squib valves are activated to allow complete helium purging of the C/M-RCS fluid lines and engines.

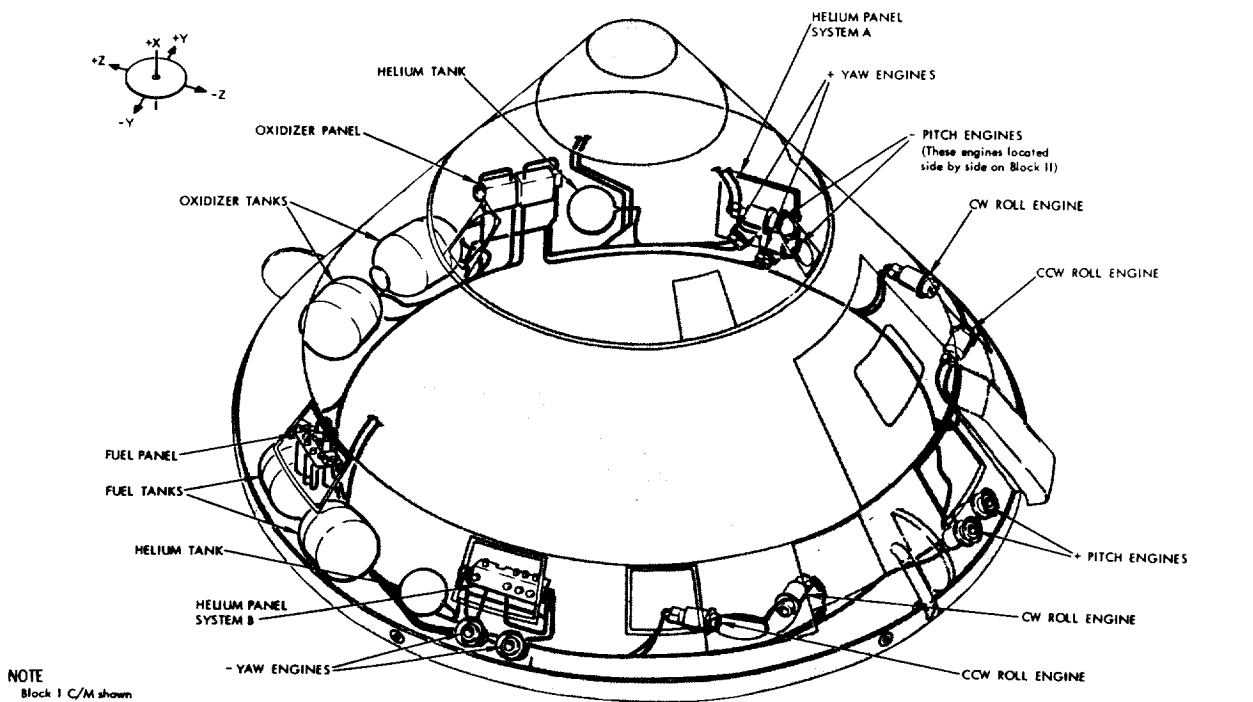
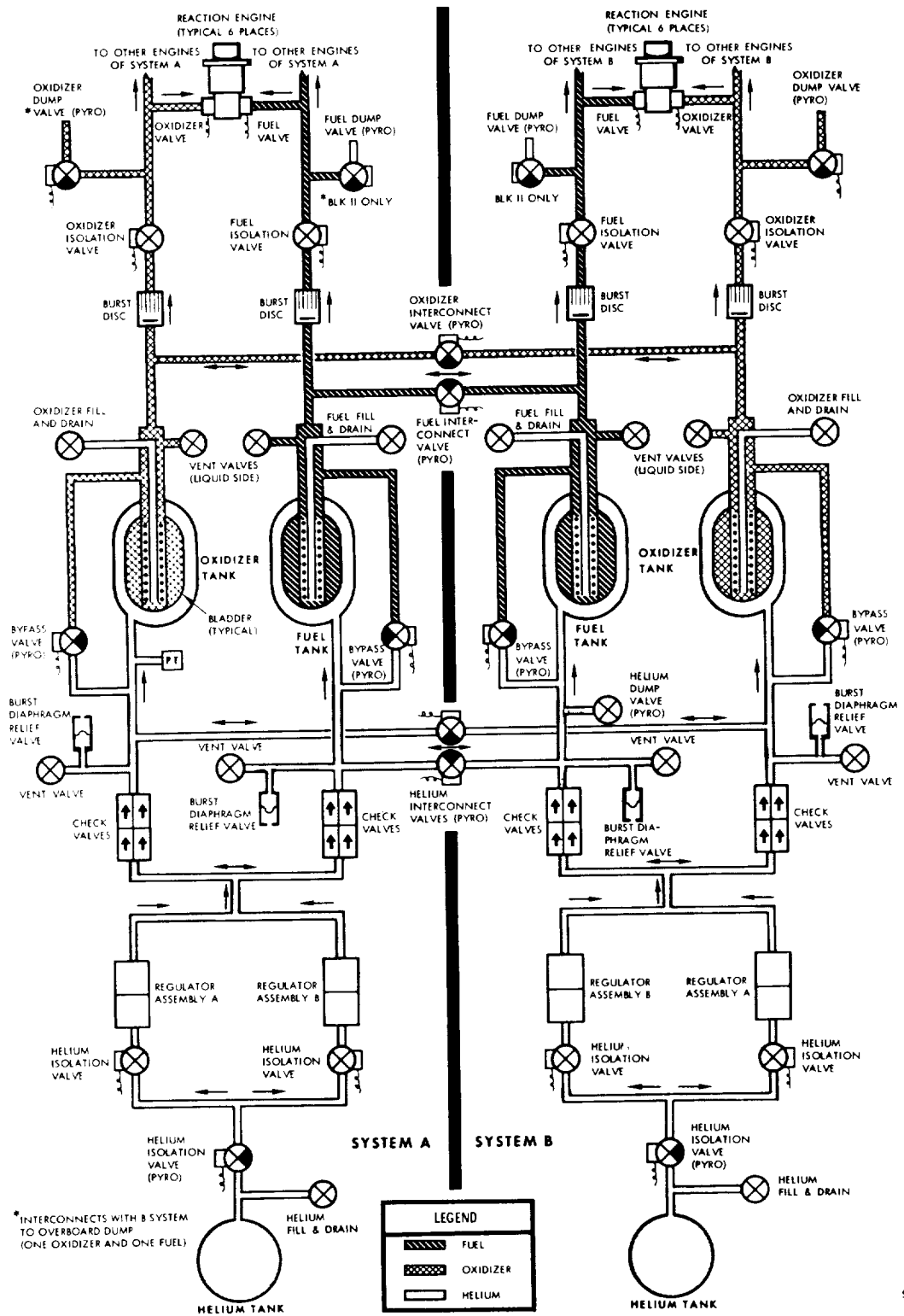


Figure 3-11. Command Module Reaction Control System (Sheet 1 of 2)



SM-2A-468F

Figure 3-11. Command Module Reaction Control System (Sheet 2 of 2)

### 3-52. SERVICE PROPULSION SYSTEM.

3-53. The service propulsion system (SPS) provides the thrust required for large changes in spacecraft velocity after booster separation. The SPS consists of a gimbal-mounted single-rocket engine, pressurization and propellant tanks, and associated components, all of which are located in the service module. (See figure 3-12.) Conditions and time will vary the use of the SPS thrust. During a lunar landing mission, for example, the SPS could conceivably be fired for many events. The first might occur shortly after booster separation to carry out an abort during the post-atmospheric portion of the launch trajectory. It could also be used for earth orbit injection or transferring from one earth orbit to another. Following translunar injection, normal midcourse corrections or a post-injection abort could be accomplished using the SPS. Further along on the mission, the SPS provides for insertion of the S/C into lunar orbit, as well as ejection from lunar orbit (transearth injection) into a transearth trajectory. During the lunar orbit phase, transfer from one orbit to another is also possible.

3-54. Hypergolic propellants for the SPS consist of a 50:50 blend of UDMH and hydrazine as fuel, and nitrogen tetroxide as oxidizer. The storage and distribution system for these propellants consist of two fuel tanks, two oxidizer tanks, two helium tanks, associated components, lines, and electrical wiring. Pressurization of the propellant tanks is accomplished using helium. Automatic control and regulation is utilized in the SPS, as well as backup components and operational modes. A quantity gauging system is provided for monitoring the amount of propellant remaining in the tanks.

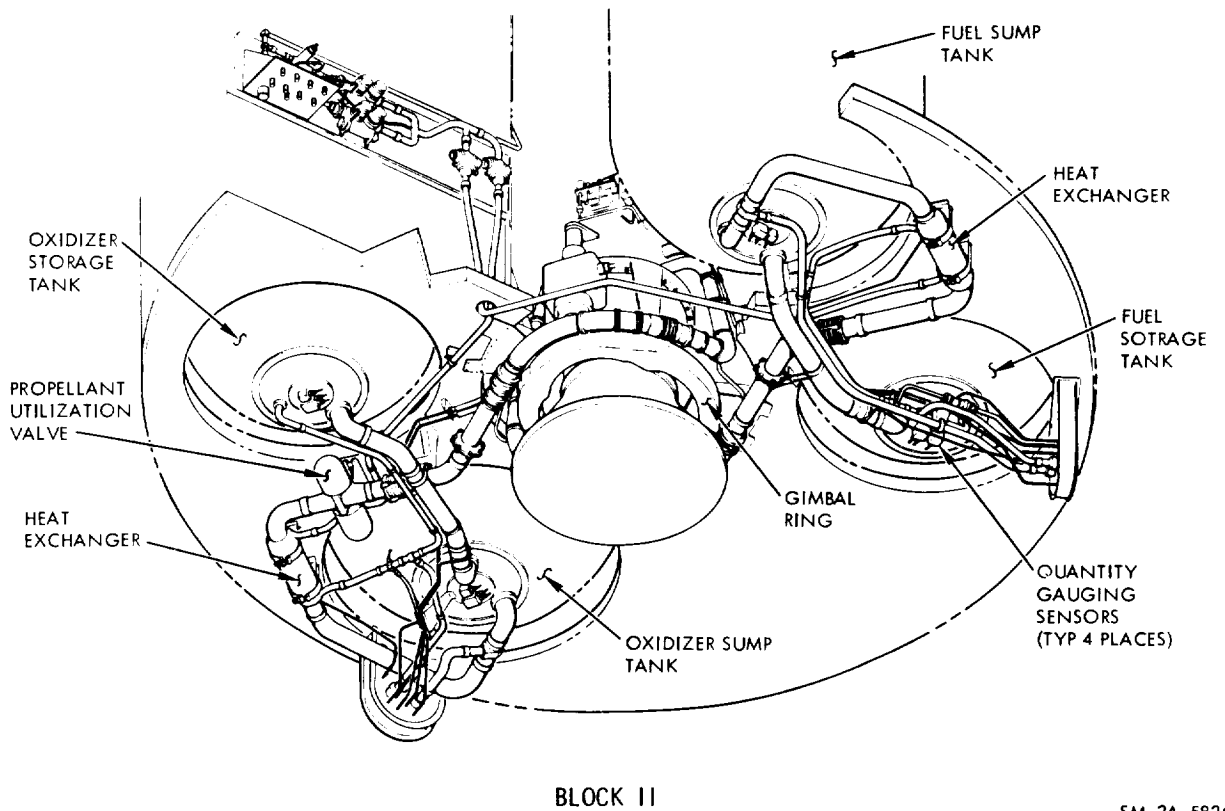
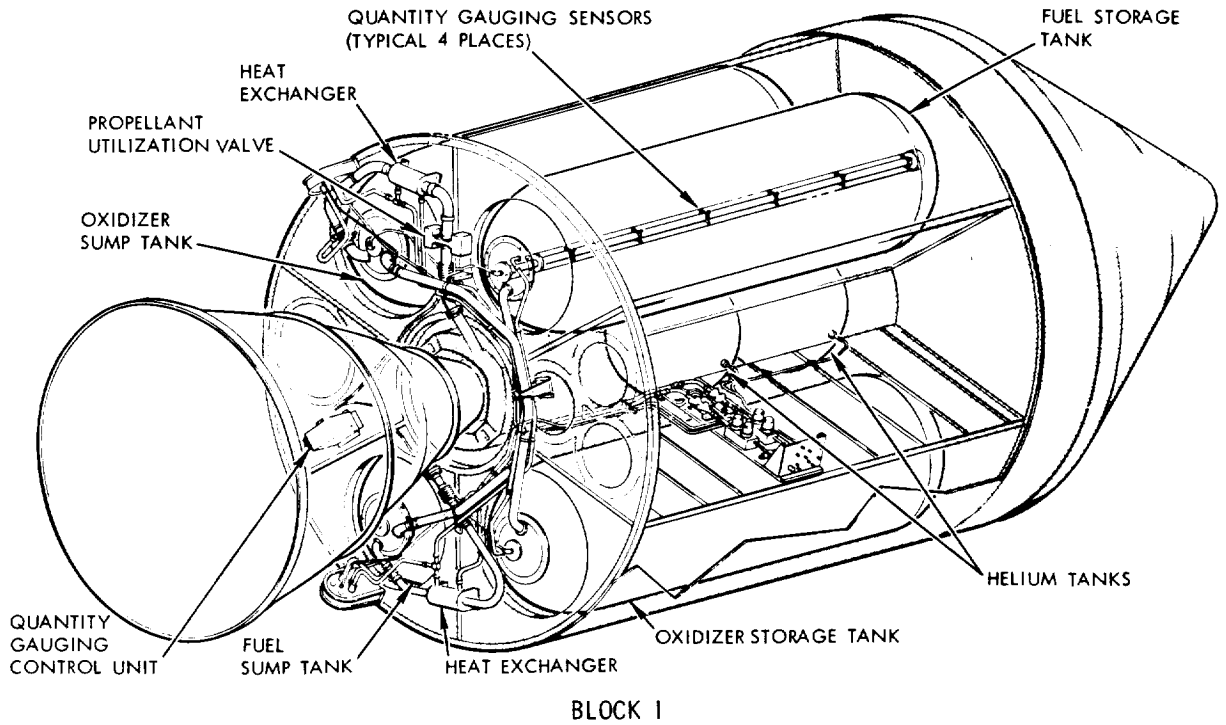
### 3-55. SERVICE PROPULSION SYSTEM OPERATION.

3-56. The operation of the SPS is in response to an automatic firing command generated by the G&N system, or manual initiation by the crew. The engine assembly is gimbal-mounted to allow engine thrust-vector alignment with the S/C center of gravity to preclude S/C tumbling. Thrust-vector control during firing is maintained automatically by the SCS or manually by the crew utilizing the hand controllers. The control and monitoring of the SPS from the C/M is the only point of SPS interface with the C/M. The engine has no throttle, thus it produces a single value of thrust for velocity increments.

3-57. SPS QUANTITY GAUGING AND PROPELLANT UTILIZATION SYSTEM. Service propulsion system propellant quantities are monitored and controlled by the system illustrated in figure 3-13. Propellant quantity sensing incorporates two separate systems: primary and auxiliary. The primary quantity sensors are cylindrical capacitance probes mounted axially in each tank. The auxiliary network utilizes impedance-type point sensors providing a step function impedance change when the liquid level passes their location centerline. Auxiliary system electronics provide time integration to permit a continuous measurement when the propellant level is between point sensors.

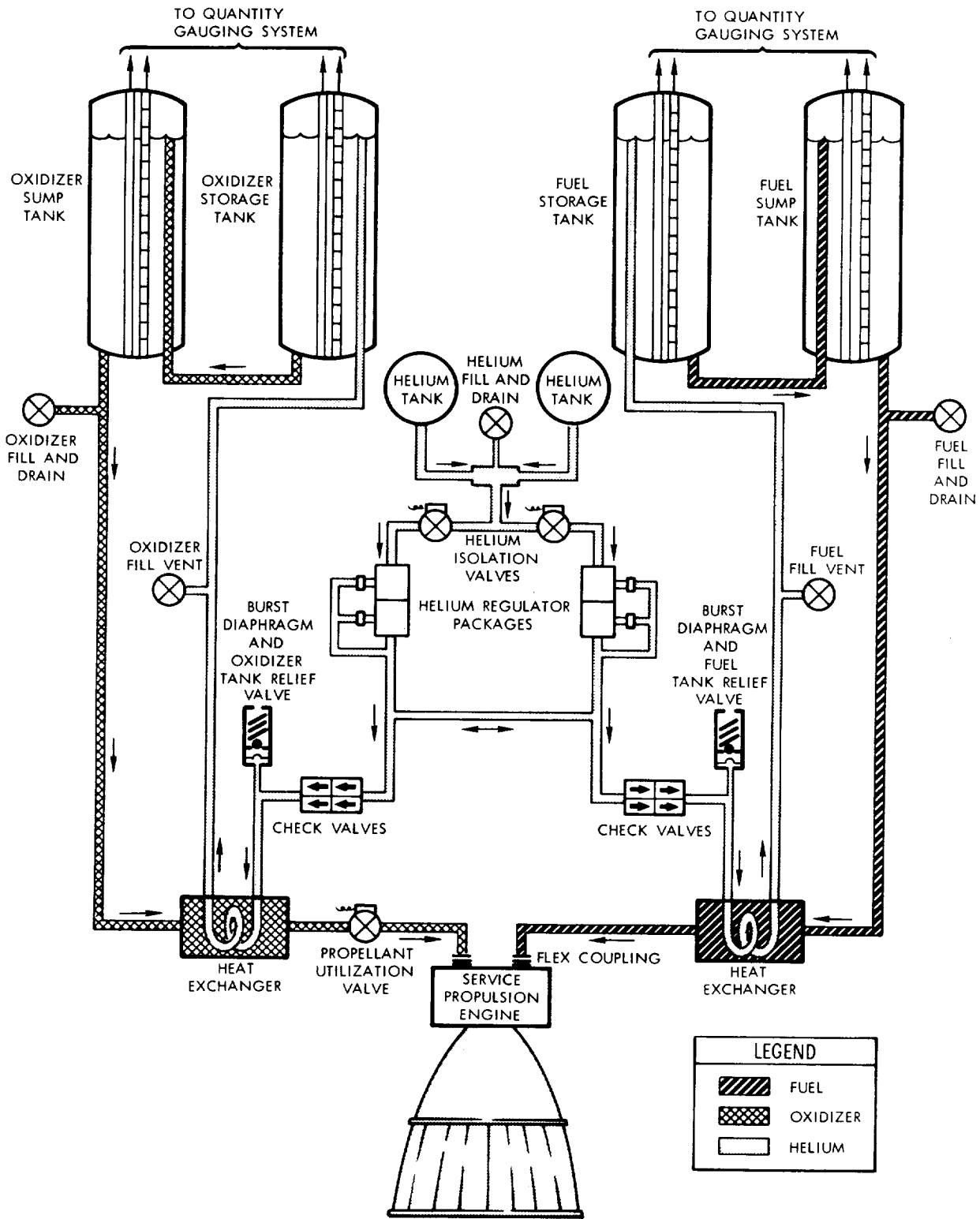
3-58. Sensor outputs are applied to a control unit containing servo loops which provide output signals representative of the propellant quantity. Two primary fuel servos and one auxiliary fuel servo provide an input signal to the fuel display servo, which, in turn, positions the digital fuel quantity display on the main display console. Two primary oxidizer servos and one auxiliary oxidizer servo provide an input to the oxidizer display servo, which, in turn, positions the digital oxidizer quantity display. The primary and auxiliary fuel and oxidizer servo outputs are also applied to the unbalance display servo, which will sense any unbalance in the remaining fuel-oxidizer quantities and display the amount of unbalance on the unbalance display dial. The propellant utilization valve assembly,





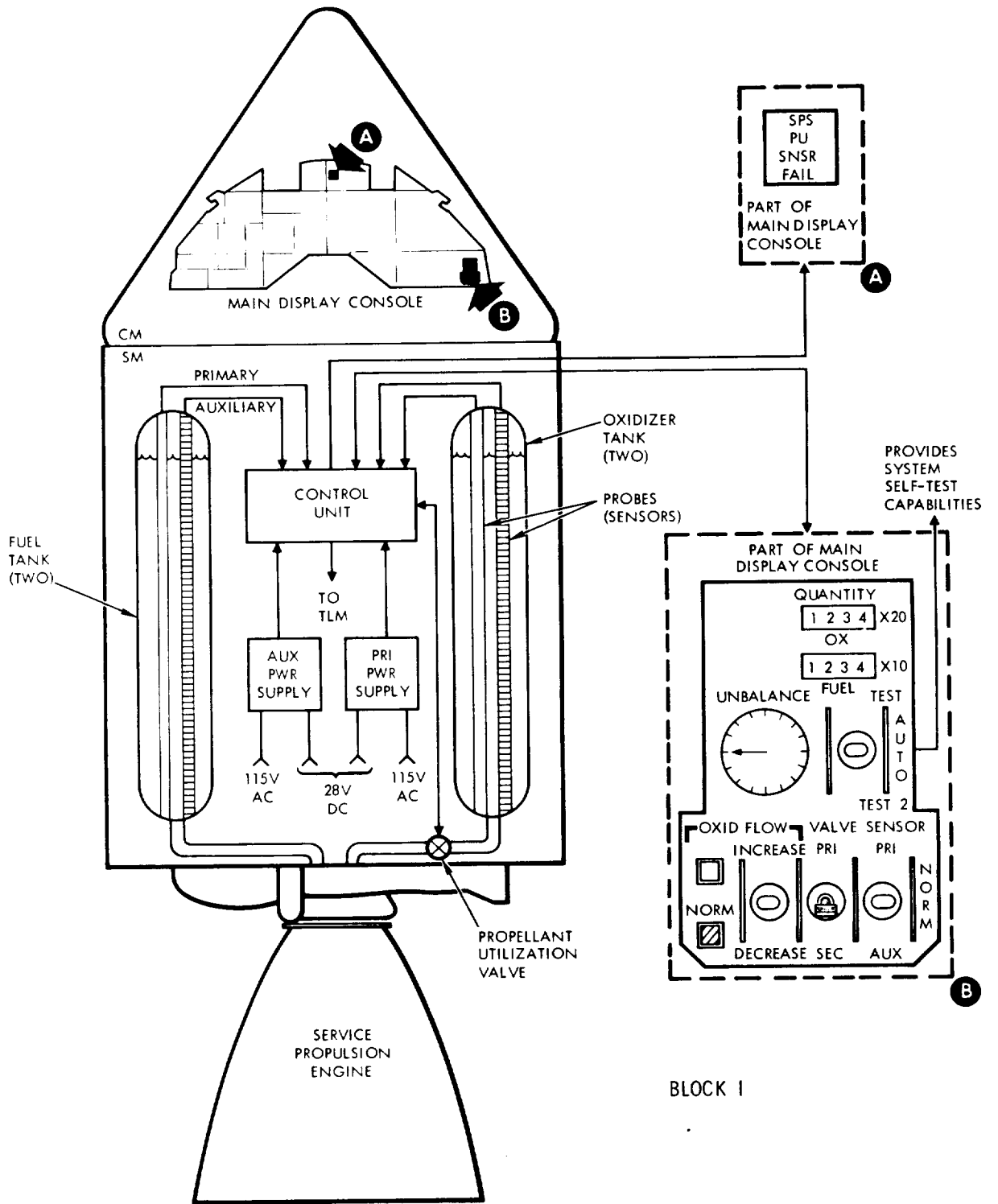
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Figure 3-12. Service Propulsion System (Sheet 1 of 2)



SM-2A-469C

Figure 3-12. Service Propulsion System (Sheet 2 of 2)



BLOCK 1

Figure 3-13. SPS Quantity Gauging and Propellant Utilization Systems – Block Diagram

installed in the oxidizer engine feed line, incorporates two identical, motor-operated gates to provide redundant oxidizer flow rate control. The two gates (one primary and one auxiliary) are operated manually; to allow oxidizer flow rates to be increased or decreased, to compensate for an unbalance condition in the oxidizer-fuel ratio, and to insure simultaneous propellant depletion. Gate position is controlled by switches on the main display console. The valve incorporates a position potentiometer and the output is applied to a valve position display servo which positions an oxidizer flow indicator. Propellant quantity signals are also routed to telemetry. Quantity and unbalance signals are monitored by the discrepancy warning lights which will provide an alarm in the event of an excessive propellant unbalance condition. A self-test system is incorporated which provides an operational check of the sensing system voltages to the different servos, electronics, and display readings. Self-tests are initiated manually by a test switch on the main display console.

### 3-59. GUIDANCE AND NAVIGATION SYSTEM.

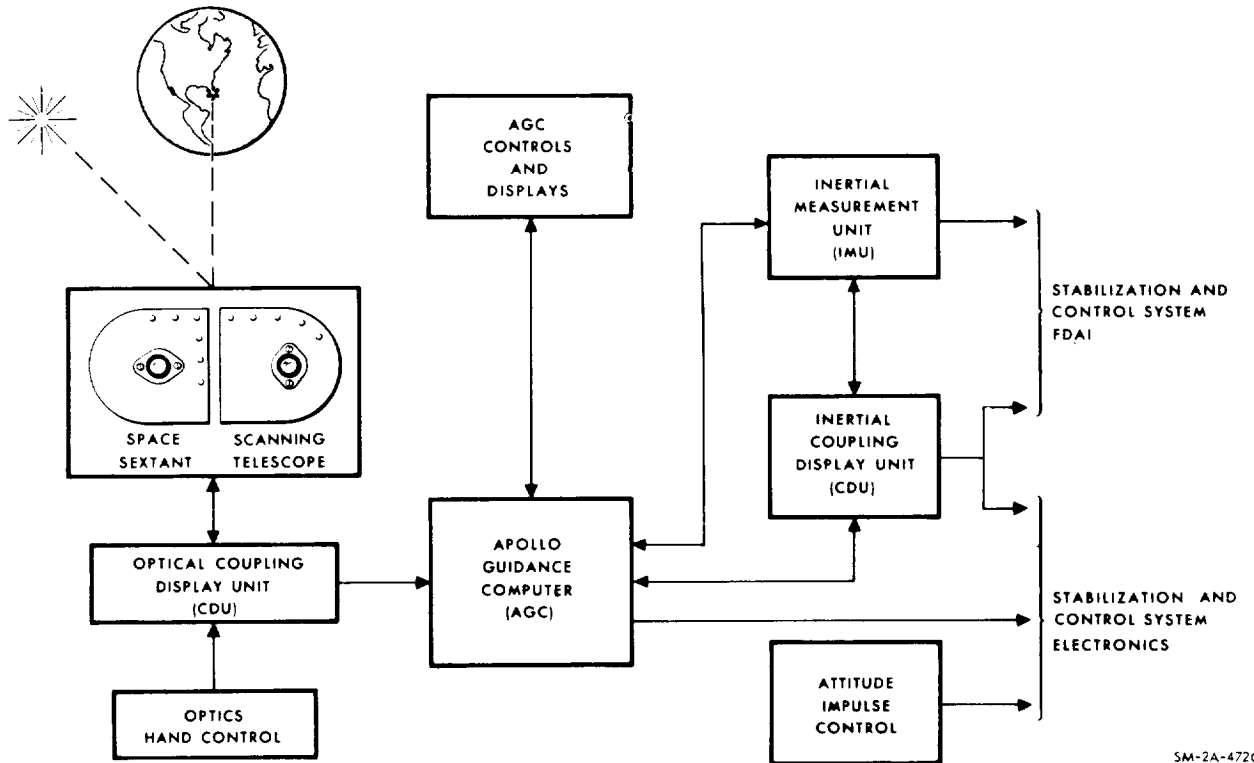
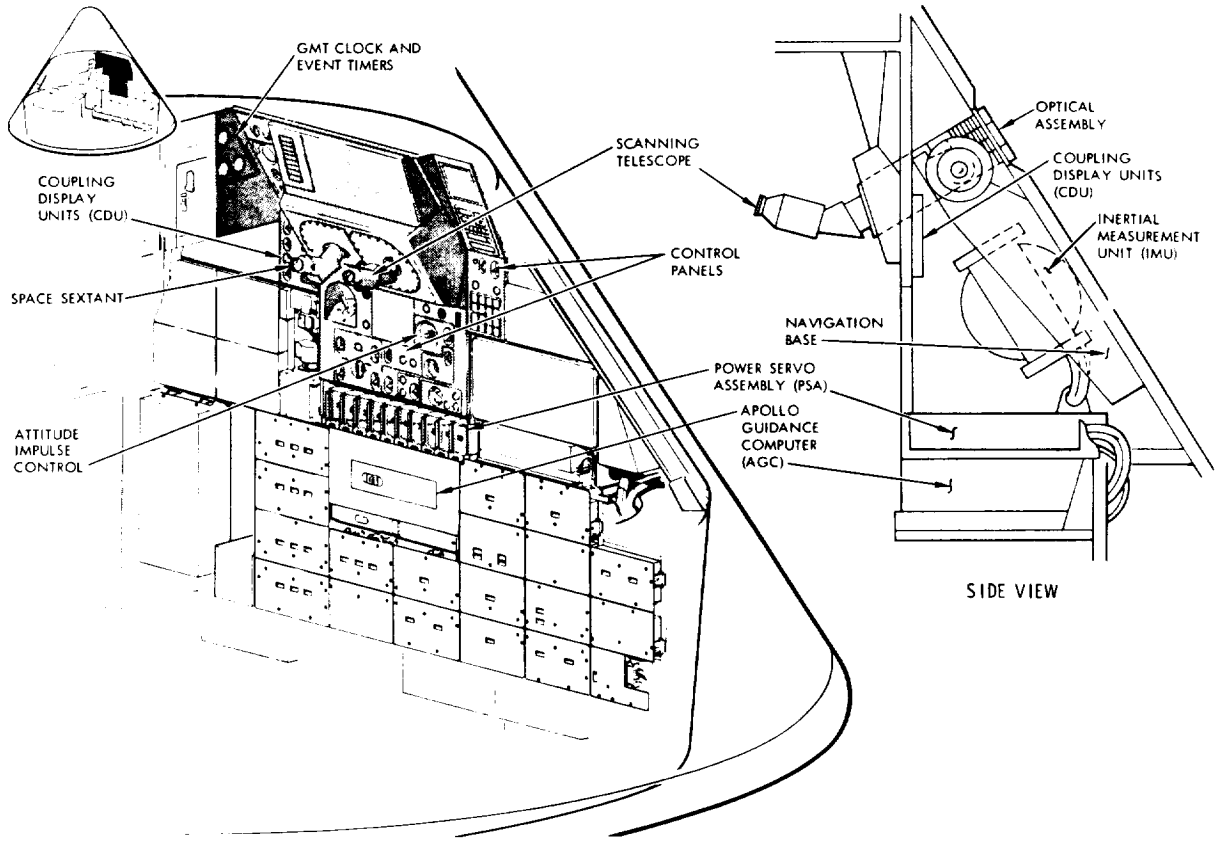
3-60. The guidance and navigation (G&N) system is a semi-automatic system, directed and operated by the flight crew, which performs two basic functions: inertial guidance and optical navigation. The system consists of inertial, optical, and computer subsystems, each of which can be operated independently, if necessary. Thus a failure in one subsystem will not disable the entire system. The G&N equipment is located in the lower equipment bay and on the main display console of the command module. (See figure 3-14.)

3-61. The three subsystems, individually or in combination, can perform the following functions:

- a. Periodically establish an inertial reference which is used for measurements and computations.
- b. Align the inertial reference by precise optical sightings.
- c. Calculate the position and velocity of the spacecraft by optical navigation and inertial guidance.
- d. Generate steering signal and thrust commands necessary to maintain the required S/C trajectory.
- e. Provide the flight crew with a display of data which indicates the status of the G&N problem.

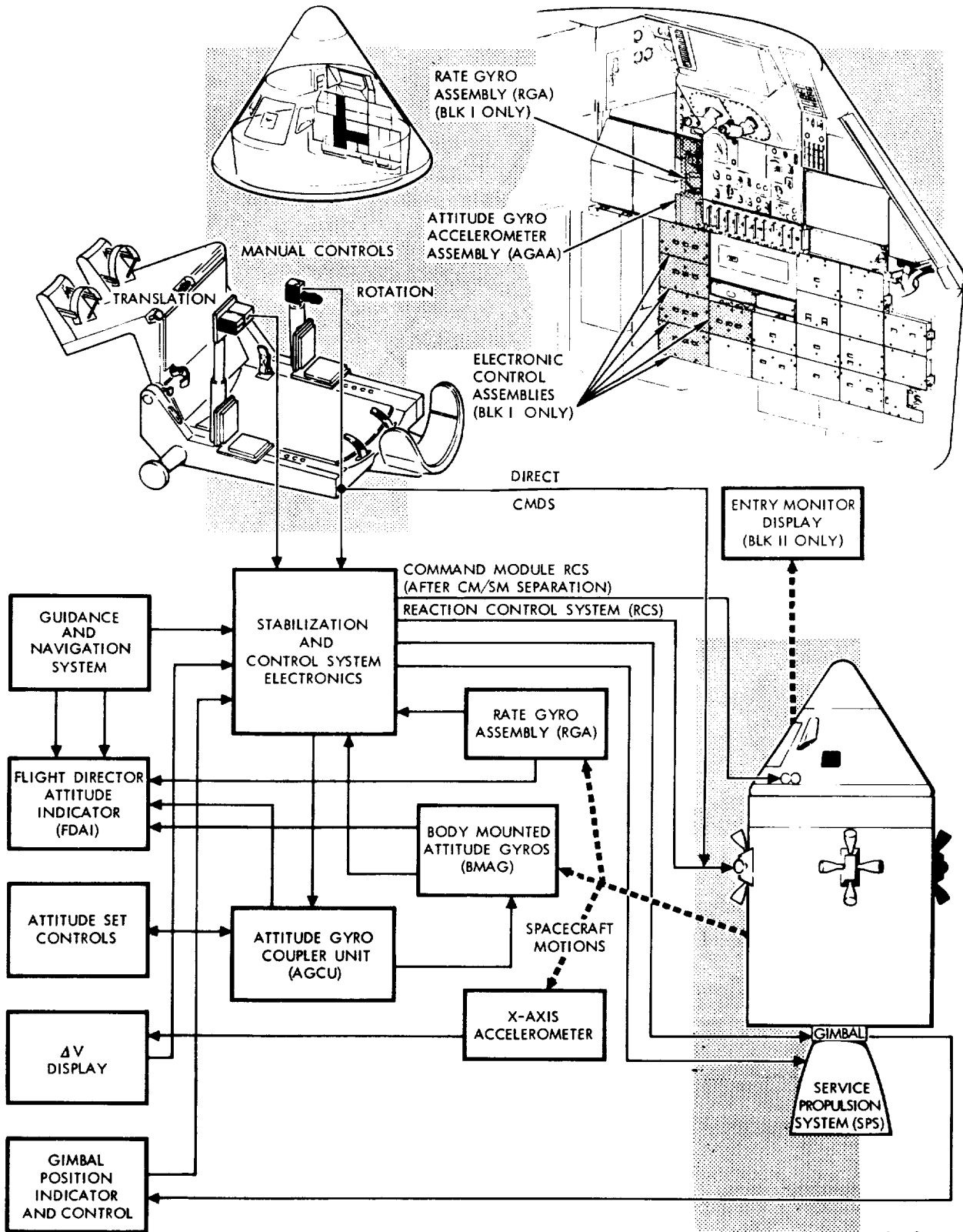
3-62. The inertial subsystem consists of an inertial measurement unit (IMU), associated hardware, and appropriate controls and displays. Its major functions involve: (1) measuring changes in S/C attitude, (2) assisting in the generation of steering commands for the S/C stabilization and control system (SCS), and (3) measuring S/C velocity changes due to thrust. Various subsystem modes of operation can be initiated automatically by the computer subsystem or manually by the flight crew, either directly or through appropriate programming of the computer subsystem.

3-63. The optical subsystem consists of a scanning telescope, a sextant, associated hardware, and appropriate controls and displays. Its major functions involve: (1) providing the computer subsystem with data obtained by measuring angles between lines of sight to celestial objects, and (2) providing measurements for establishing the S/C inertial reference. The scanning telescope and sextant are used by the flight crew to take sightings on celestial bodies, landmarks, and the LM subsequent to separation and during rendezvous. These sightings, when used in conjunction with a catalog of celestial bodies stored in the computer subsystem, enable determination of the S/C position and orientation in space.



SM-2A-472G

Figure 3-14. Guidance and Navigation System (Block I)



SM-2A-471F

Figure 3-15. Stabilization and Control System

Communication with ground tracking stations provides primary navigation information. The identity of celestial bodies and the schedule of measurements is based on an optimum plan determined prior to launch.

3-64. The computer subsystem consists of an Apollo guidance computer (AGC) and appropriate controls and displays. Its major functions involve: (1) calculating steering signals and discrete thrust commands to keep the S/C on a desired trajectory, (2) positioning the IMU stable platform to an inertial reference defined by optical measurements, (3) performing limited G&N system malfunction isolation, and (4) supplying pertinent S/C condition information to appropriate display panels. The AGC is a general purpose digital computer employing a core memory, parallel operation, and a built-in self-check capability. Programs are stored in the AGC and manually or automatically selected to control and solve flight equations. Using information from navigation fixes, the AGC computes a desired trajectory and calculates necessary corrective attitude and thrust commands. Velocity corrections are measured by the inertial subsystem and controlled by the computer subsystem. Velocity corrections are not made continuously but are initiated at predetermined checkpoints in the flight to conserve propellants. The G&N, SCS, SPS, and RCS systems combine to provide closed-loop control of the S/C velocity and attitude.

### 3-65. STABILIZATION AND CONTROL SYSTEM.

3-66. The stabilization and control system (SCS) for Block I S/C provides control and monitoring of the spacecraft attitude and rate control of the thrust vector of the service propulsion engine, and a backup inertial reference system. (See figure 3-15.) The system may be operated automatically or manually in various modes. The guidance and navigation system, service propulsion system, and the CSM reaction control system interface with the SCS. The major components of the SCS, all located in the C/M are: rate gyro assembly; attitude gyro/accelerometer assembly; pitch, yaw, and roll electronic control assemblies (ECAs); display/attitude gyro accelerometer assembly ECA; auxiliary ECA, velocity change indicator, gimbal position/attitude set indicator, flight director attitude indicator (FDAI), two rotation controls, and two translation controls. System controls and displays are located on the C/M main display console. The rate gyro assembly consists of three rate gyros mounted mutually 90 degrees apart in X-, Y-, and Z-axes. The rate gyros provide signals representative of S/C attitude change rates. The rate is displayed on the FDAI and is used by the SCS for damping and stabilization. The attitude gyro accelerometer assembly consists of three body-mounted gyros (BMAGs), and a pendulous accelerometer mounted coincident with the X-axis. The BMAGs sense pitch-, yaw-, and roll-attitude changes and provide attitude-error signals to the FDAI for display, and to the SCS for attitude control. The accelerometer provides acceleration data for automatic termination of SPS thrusting and for display on the  $\Delta V$  REMAINING indicator. The ECAs are electronic modules which process and condition the input and output electrical signals of the SCS components.

### 3-67. STABILIZATION AND CONTROL SYSTEM OPERATION.

3-68. The SCS may be used in any one of eight modes, which are selectable by the crew. The SCS attitude control mode automatically maintains S/C attitude within the minimum or maximum deadband limits, which are approximately  $\pm 0.5$  degrees or  $\pm 5.0$  degrees respectively. When the S/C exceeds the selected deadband limits, attitude-error signals generated by the BMAGs are applied to circuitry within the ECAs which initiates firing of the proper RCS engines to return the S/C within the selected deadband limits. During G&N attitude control mode, the attitude error consists of the difference between the inertial measurement unit (IMU) and coupling display unit (CDU) output signals. The SCS local

vertical mode operation is identical to the SCS attitude control mode with one exception. During local vertical mode operation, an orbit rate signal is generated in the attitude gyro coupling unit to maintain local vertical reference with respect to the earth. The G&N  $\Delta V$  mode is the primary mode when S/C velocity changes are required. The SPS thrust on-off signal is applied to the SCS electronics by the Apollo guidance computer (AGC). In the G&N mode, automatic thrust vector control (TVC) is accomplished with the G&N attitude error signals, the SCS rate gyro signals, and the TVC electronics. In the SCS  $\Delta V$  mode, SPS thrust-on signal is initiated manually by the crew. Thrust vector control is accomplished with the attitude error signals generated by the BMAGs, the SCS rate gyro signals, and the TVC electronics. Termination of SPS thrusting is automatic and occurs when the X-axis accelerometer senses that the desired velocity change and the  $\Delta V$  REMAINING indicator reads zero. Thrust on or off may be accomplished manually if automatic on or off functions fail to occur. Manual control of the SPS thrust vector with rate damping is available to the crew. The translation control is rotated CW for manual control (MTVC) and the rotation control is used to command the SPS engine in the pitch and yaw axis. During entry the G&N entry mode is the primary mode. After CSM separation, the G&N system provides automatic control of the S/C lift vector to effect a safe entry trajectory. In the SCS entry mode, the crew is required to manually control the S/C lift vector with the rotation controller. The SCS is considered a backup system during  $\Delta V$  maneuvers and entry. The monitor mode permits the crew to monitor S/C attitude, attitude error, and attitude change rate on the FDAI during ascent, and provides rate stabilization after S-IVB separation.

### 3-69. SPACECRAFT CONTROL PROGRAMERS.

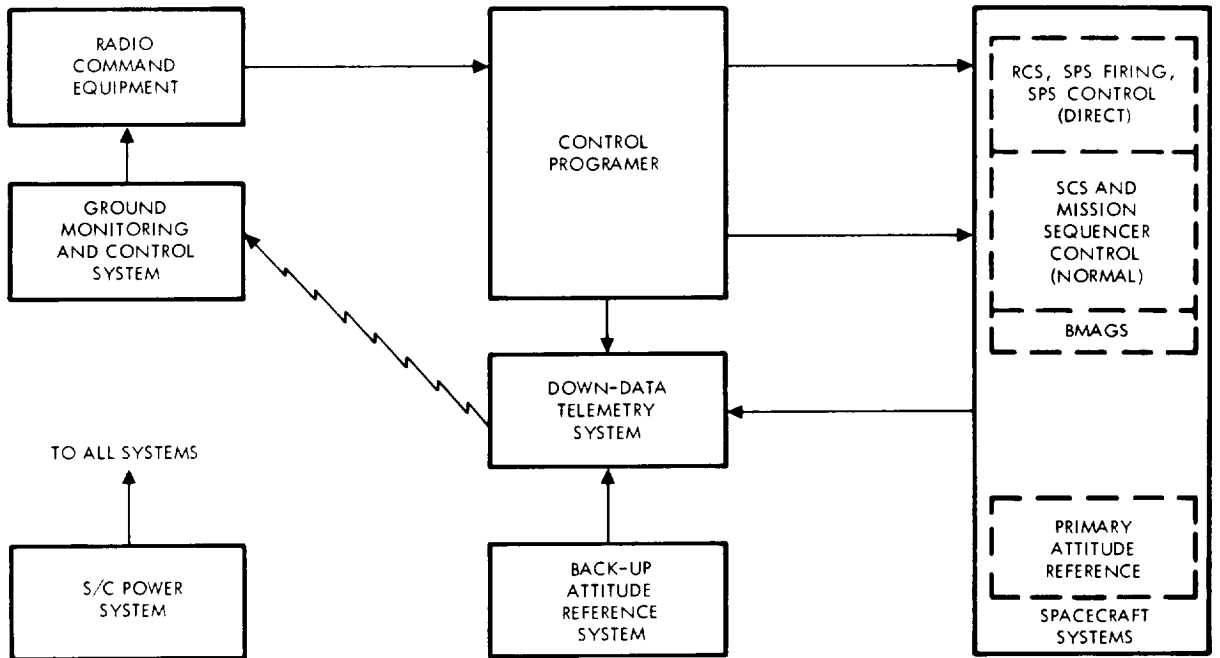
#### 3-70. CONTROL PROGRAMER.

3-71. The control programer (M1), installed in S/C 009, automatically controlled the stabilization control system (SCS) and mission sequencer, and conditioned ground command signals. The control programer consisted of a timer assembly, radio command control assembly, and automatic command control assembly. Equipment required with the control programer consisted of a backup attitude reference system (ARS), and radio command equipment. Redundancy was provided to preclude the possibility of losing a C/M due to a single failure. A functional block diagram of the control programer is shown in figure 3-16; the mission description for S/C 009 is presented in section VII.

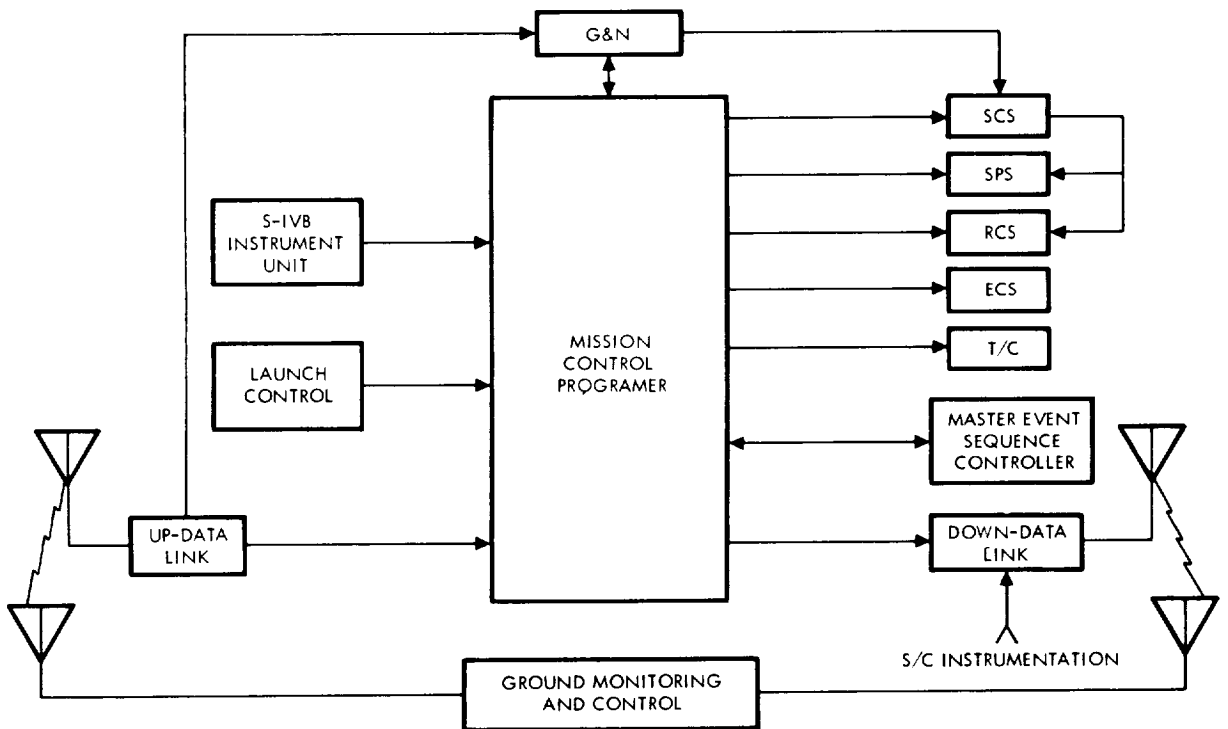
#### 3-72. MISSION CONTROL PROGRAMER.

3-73. The mission control programer (M3), installed in S/C 011, 017, and 020 programs spacecraft functions which are commanded by the G&N system, S-IVB instrument unit, and the up-data link. The guidance and control (G&C) functions are controlled by the G&N system. The S/C will have operational controls and displays. Characteristics incorporated in the mission control programer include relay switching of automated functions (relay logic) and fixed time-delay relays as required, minimum interference with S/C control and display operation, real time of control of functions computed for C/M recovery, and redundant critical functions. A functional block diagram of the mission control programer is shown in figure 3-16; the mission description for S/C 011 is presented in section VII.





SPACECRAFT 009 CONTROL PROGRAMMER



SPACECRAFT 011 MISSION CONTROL PROGRAMMER

SM-2A-626B

Figure 3-16. Control Programmer Functional Block Diagram for S/C 009 and S/C 011

## 3-74. SPACECRAFTS 009 and 011 PROGRAMER COMPARISON.

3-75. The following list provides a functional comparison of the control programers used in S/C 009 and S/C 011:

## Spacecrafts 009 and 011 Programer Comparison

Functions	Control Programer (S/C 009)	Mission Control Programer (S/C 011)
Mission director	Primary	None
S/C system sequencing	Primary	Initiated by G&N and S-IVB instrument unit
Attitude reference	SCS (Primary) and attitude reference system (backup)	G&N (Primary) and SCS (backup)
Corrective action	EPS only	Limited
Ground control	G&C and staging	Attitude control and staging
Abort capability (maneuvers)	Self-contained and ground control	Ground control
Displays and controls	Partial	Complete and operational

3-76. CREW SYSTEM.

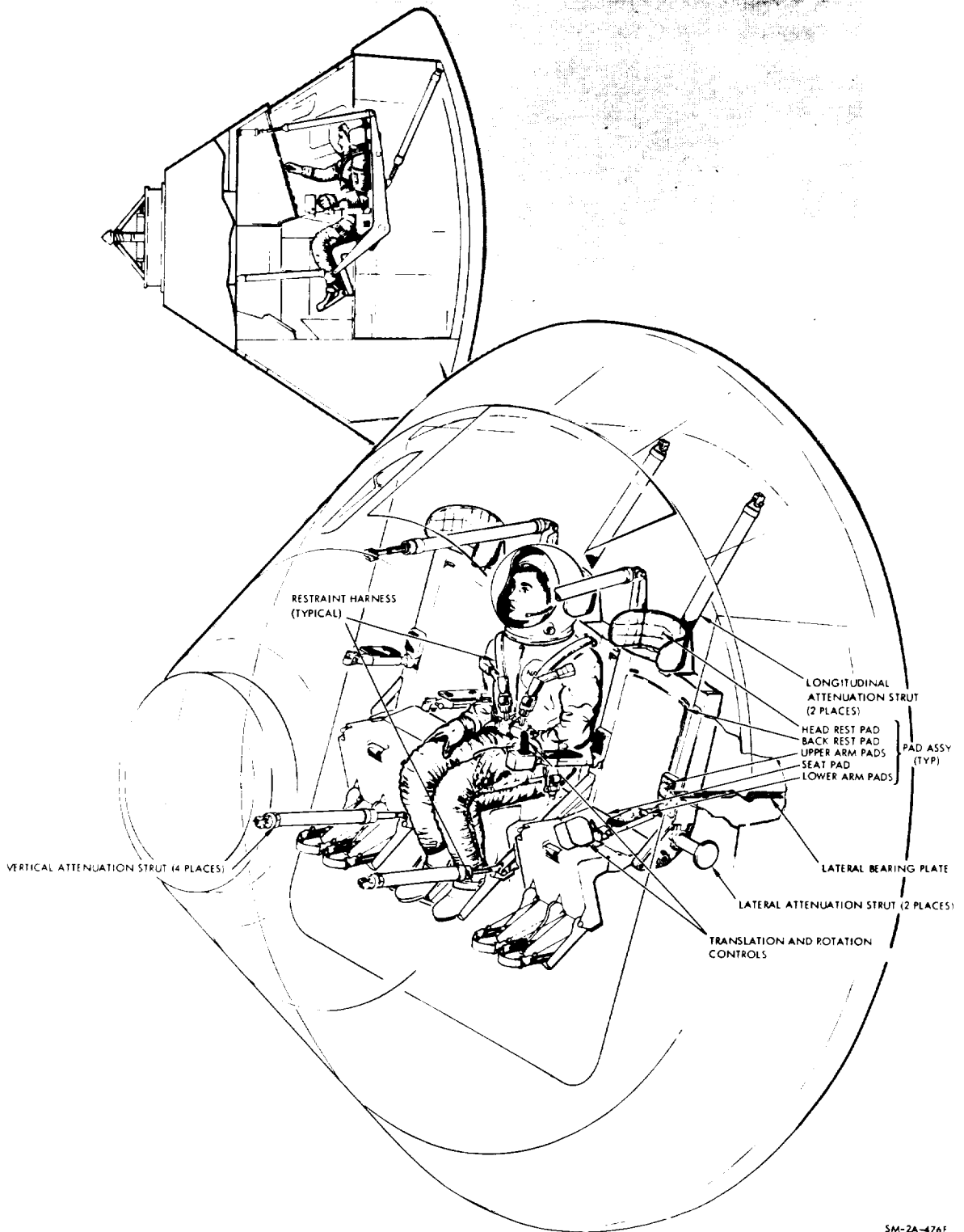
3-77. The purpose of the crew system is to provide for needs peculiar to the presence of the crew aboard the spacecraft. Crew system equipment includes certain degrees of physical protection against acceleration, impact, and sustained weightlessness. Equipment and provisions for the routine functions of eating, drinking, sleeping, body cleansing, and the elimination of waste are part of the crew system, as is the survival equipment which is provided for abnormal or emergency conditions.

## 3-78. CREW COUCHES.

3-79. The command module is equipped with three couches, each with adjustable headrests, restraint harness assemblies, seats, and foot-strap restraints. (See figure 3-17.) The basic support for all couches is a fixed frame suspended from shock attenuators. Angular adjustments for hips permit individual comfort during all flight modes. The attenuators lessen the impact forces imposed on the crew during C/M touchdown on water or land.

## 3-80. PERSONAL EQUIPMENT.

3-81. Each astronaut will have personal equipment available to him during the course of a 14-day mission. The equipment includes a communications (soft hat) assembly, a constant-wear garment, a pressure garment assembly (pressure suit), an umbilical assembly, a bioinstrument accessories kit, radiation dosimeters, an emergency medical kit, and a physiological clinical monitoring instrument set. In addition, a thermal insulation overgarment and a portable life support system (PLSS) will be included with the Block II spacecraft.



SM-2A-476F

Figure 3-17. Crew Couches and Restraint Equipment

3-82. The communications (soft hat) assembly provides communications between crewmembers and MSFN. The assembly consists of a adjustable strap helmet with two microphones and two earphones attached, and will be used in a shirtsleeve environment. During Block II missions, the communications soft hat will be worn in the PGA helmet also.

3-83. The constant-wear garment (CWG) provides the astronauts with a basic garment to be worn at all times during a mission. The CWG is a one-piece short-sleeved, close-fitting garment which covers the crewman's entire body with the exception of the arms and head.

3-84. The thermal insulation overgarment coverall is an overgarment which completely covers the pressure garment and PLSS. It provides thermal and micrometeoroid protection for the astronauts during extravehicular operations.

3-85. The pressure garment assembly (PGA) consists of a torso-and-limbs covering, integral boots, gloves, and helmet, and covers the entire body of an astronaut. The garment is air-tight to support life, in conjunction with the ECS or PLSS, during adverse mission conditions and lunar exploration.

3-86. The umbilical assembly provides the interface between the S/C systems and the PGA. The electrical link between the astronauts and the S/C communications equipment is provided by the electrical umbilical. The oxygen umbilical provides a means of transferring oxygen from the ECS to the PGA. Another hose assembly, provided on Block II manned S/C, is used to transfer oxygen from the ECS to the PLSS.

3-87. The biomedical harness consists of biomedical sensors, wire harness, and biomedical preamplifiers. Purpose of the sensors is to acquire the electrical signal required to determine the respiration rate and electrocardiograms of an astronaut. The preamplifier is used to condition and relay the signals received by the sensors to the telemetry system for transmittal to earth. A biomedical accessories kit is aboard to replace faulty biomedical harness components.

3-88. The radiation dosimeters measure and record the amount of radiation to which the astronaut is exposed. One is located at the right temple of the constant-wear communications assembly; others are located in pockets provided on constant-wear garments.

3-89. The emergency medical kit provides the equipment and medications required for emergency treatment of illness or injuries sustained by crewmen during a mission.

3-90. The physiological clinical monitoring instrument set consists of an aneroid sphygmomanometer, a stethoscope, and a thermometer, and is used to measure blood pressure, respiration rate or heart beat, and body temperature.

3-91. The portable life support system is a small self-contained environmental control system and communications unit, and provides life support during extravehicular activities and lunar surface exploration. The PLSS is worn as a backpack and is capable of maintaining the PGA in a pressurized condition for 4 hours without recharging.

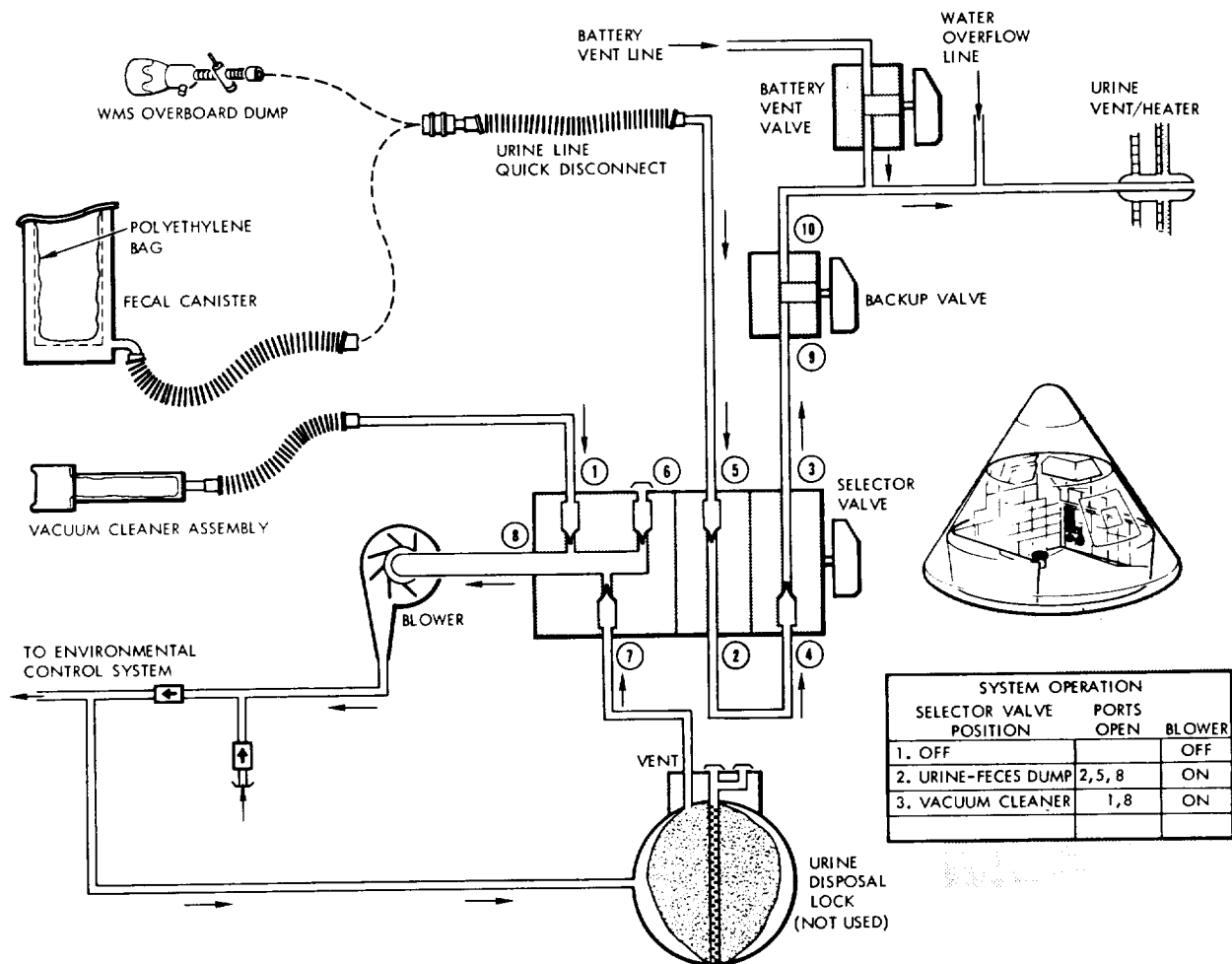
3-92. CREW COUCH AND RESTRAINT EQUIPMENT.

3-93. Crew couch and restraint equipment consists of crew couch pad assemblies, restraint harness assemblies, foot-strap restraint assemblies, and restraint sandals. A

pad assembly is installed on each crew couch for crewman comfort. Restraint harness assemblies and foot-strap restraint assemblies are installed on each crew couch primarily to restrain the crewmen during critical phases of the mission. Restraint sandals, worn over the feet of constant-wear garments, have soles made of Velcro pile material, which adheres to Velcro hook material installed on the C/M floor, and parts of structural surface.

3-94. WASTE MANAGEMENT SYSTEM.

3-95. The waste management segment of the crew system consists of the means for urine disposal, collecting and storing fecal matter and personal hygienic wastes. Fecal matter is collected in plastic (polyethylene) bags, disinfected, and stored in a compartment. Personal hygienic wastes are also collected and stored in this manner. The urine is expelled overboard by differential pressure method. This is accomplished by properly positioning two manually controlled waste management valves. (See figure 3-18.) A vent line interfaces the WMS to the WMS overboard dump line, and provides for the removal of odors originating as a result of waste management functions.



SM-2A-477E

Figure 3-18. Waste Management System Functional Diagram

### 3-96. CREW SURVIVAL EQUIPMENT.

3-97. Two survival kits are stowed in the C/M and are available to the crew during the postlanding phase (water or land) of a mission. The major items provided include a container with 5 pounds of water, a desalter kit, three one-man liferafts (one three-man liferaft is provided in Block II C/Ms), a radio-beacon, portable light, sunglasses, machete (and sheath), and a medical kit. The liferaft includes additional equipment such as a sea anchor, dye marker, sunbonnet, etc.

### 3-98. FOOD, WATER, AND ASSOCIATED EQUIPMENT.

3-99. Adequate food, water, and personal hygiene aids will be provided for the total length of the mission. Small polyethylene bags containing "freeze dried" food will be stored in the C/M. By adding water and kneading, the food mixtures can be squeezed into the crewmember's mouth. Either hot or cold water is available at the potable water supply panel for food reconstitution. Chilled drinking water will be supplied to the astronauts by a single flexible hose assembly from the water delivery unit. This water source, a by-product of the fuel cell powerplants, will furnish the crew up to 36 pounds (17 quarts) of water per day. A folding shelf is provided as a convenient surface for tools, food packages, and equipment. Personal hygiene aids consist of items for oral hygiene and body cleansing such as chewing gum, interdental stimulators, and cleansing pads.

### 3-100. CREW ACCESSORIES.

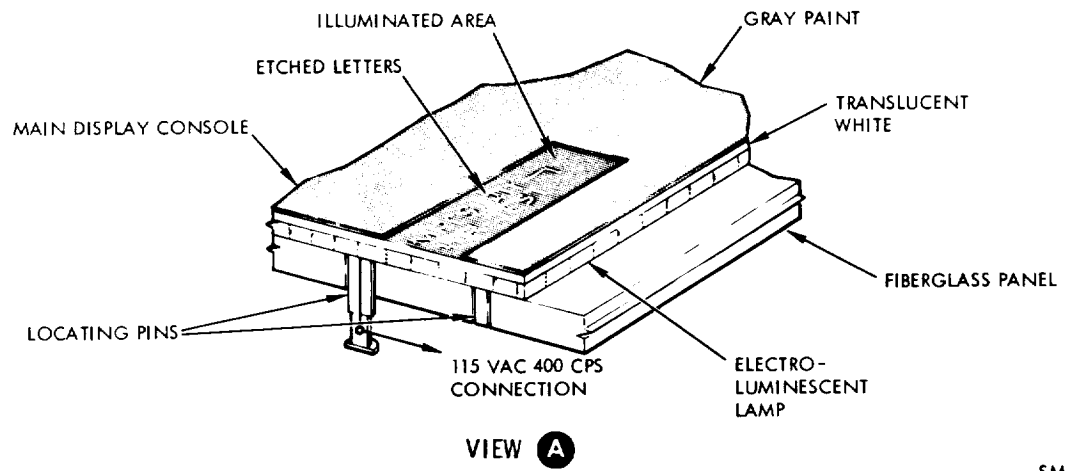
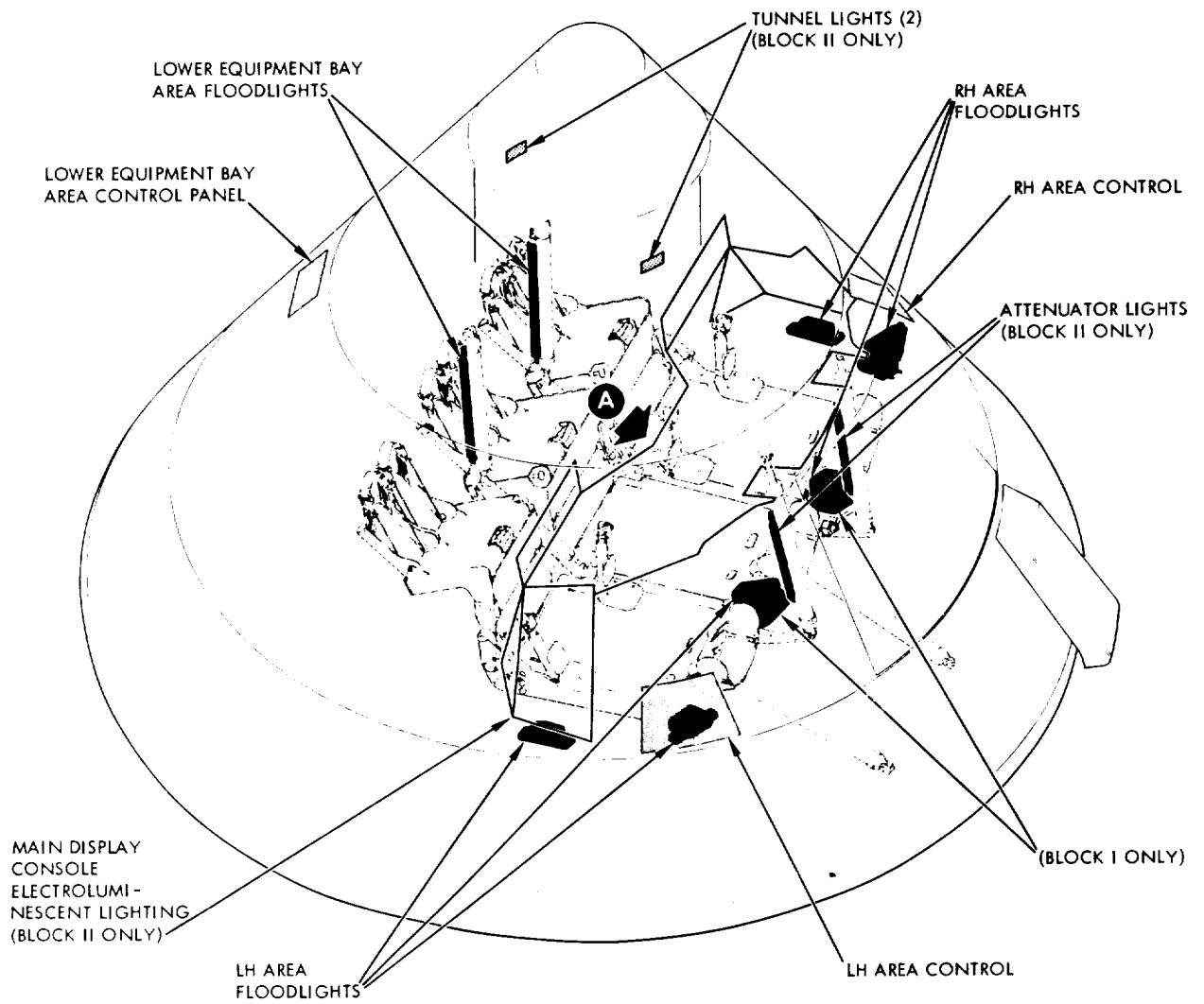
3-101. Several accessory items are considered to be part of the crew system. These consist of the following: in-flight tool set, extra vehicular crew transfer mechanism, mirror assemblies for increased interior and exterior vision, main display console handhold straps, and an optical alignment sight. The handhold straps are installed as an aid to crewman mobility within the C/M, and the optical alignment sight is utilized to properly orient and align the CSM with the LM while accomplishing docking maneuvers.

### 3-102. COMMAND MODULE INTERIOR LIGHTING.

3-103. Block I C/M interior lighting equipment (figure 3-19) provides light for the main control panels in the command module and consists of eight floodlight fixture assemblies and three control panels. Each fixture assembly contains two fluorescent lamps (one primary and one secondary) and a converter. The interior lighting is powered by d-c main buses A and B, assuring a power source for lights in all areas in the event that either bus fails. The converter in each floodlight fixture converts 28 volts dc to a-c power to operate the fluorescent lamps. The floodlights are used to light three areas: the main display console (left and right areas) and the LEB area.

3-104. Each control panel has a primary and secondary control for the floodlights in its respective area. The primary control is a rheostat that controls brightness of the primary floodlights. The secondary control is an on-off switch for the secondary floodlights and is set to on when additional brightness is desired.

3-105. Interior lighting for Block II S/C (figure 3-19) is essentially the same as Block I S/C, with the addition of electroluminescent lighting to the control and display panels.



SM-2A-851A

Figure 3-19. Command Module Interior Lighting Configuration

3-106. TELECOMMUNICATION SYSTEM.

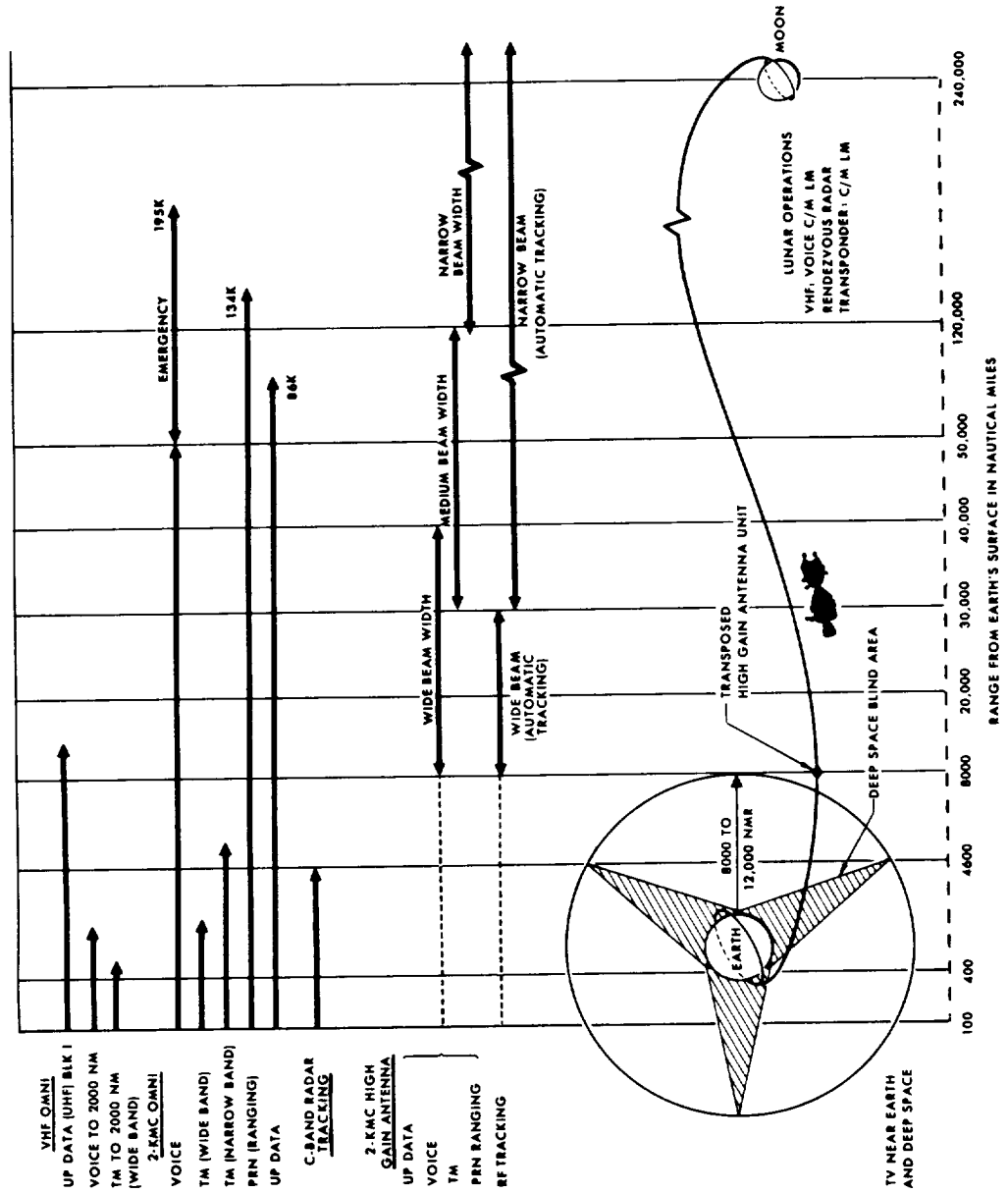
3-107. The function of the telecommunication system (figure 3-20) is to provide for the communication of voice, television, telemetry, and tracking and ranging data between the S/C and the MSFN, the LM and EVA PLSS. It also provides for S/C intercommunications and, includes the central timing equipment for synchronization of other equipment and correlation of telemetry data. The T/C system contains the following equipment, listed in four groups:

- a. Data equipment group
  - Signal conditioning equipment (SCE)
  - Pulse code modulation/telemetry (PCM/TLM) equipment
  - Television (TV) equipment
  - Up-data link (UDL) equipment
  - Premodulation processor (PMP) equipment
  - Data storage equipment (DSE)
  - Flight qualification recorder (FQR)
  - Central timing equipment (CTE)
- b. Intercommunications equipment group
  - Audio center equipment
  - Headsets and connecting electrical umbilicals
- c. RF electronics equipment group
  - VHF/AM transmitter - receiver equipment (2) (Block II)
  - VHF/FM transmitter equipment (Block I)
  - HF transceiver equipment
  - VHF recovery beacon equipment
  - Unified S-band equipment (USB)
  - S-band power amplifier (S-band PA) equipment
  - C-band transponder equipment
  - Rendezvous radar transponder equipment (Block II only)
- d. Antenna equipment group
  - VHF/2-KMC omni-antenna equipment
  - 2-KMC high-gain antenna equipment (Block II only)
  - VHF recovery antenna equipment
  - HF recovery antenna equipment
  - C-band beacon antenna equipment
  - Rendezvous radar antenna equipment (Block II only)

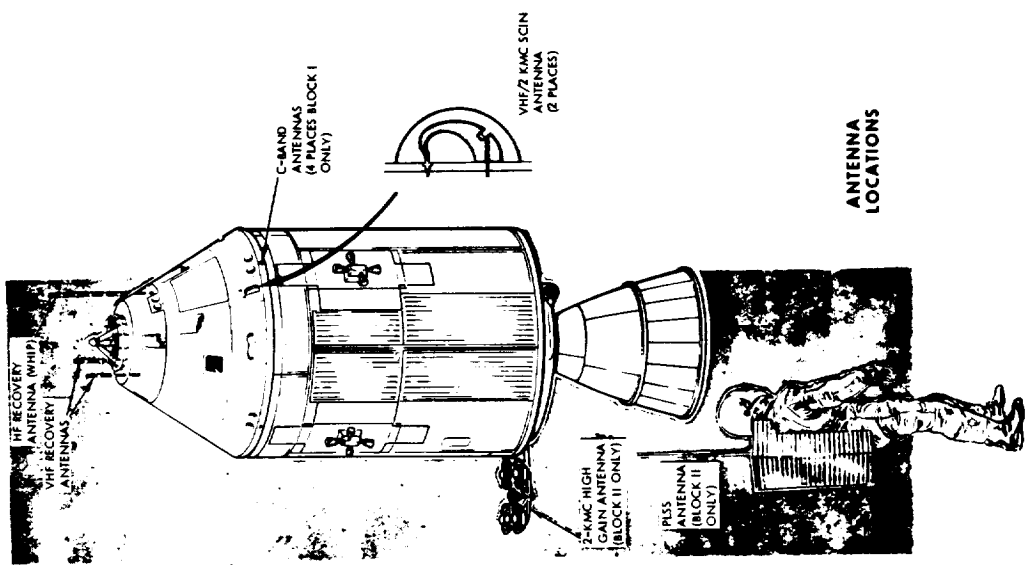
Controls and switches for operation of the T/C system are located near the pilots station in the crew compartment. Also, there are three separate groups of controls (one for each crewmember) for individual control of audio inputs and outputs of the crewmembers headsets.



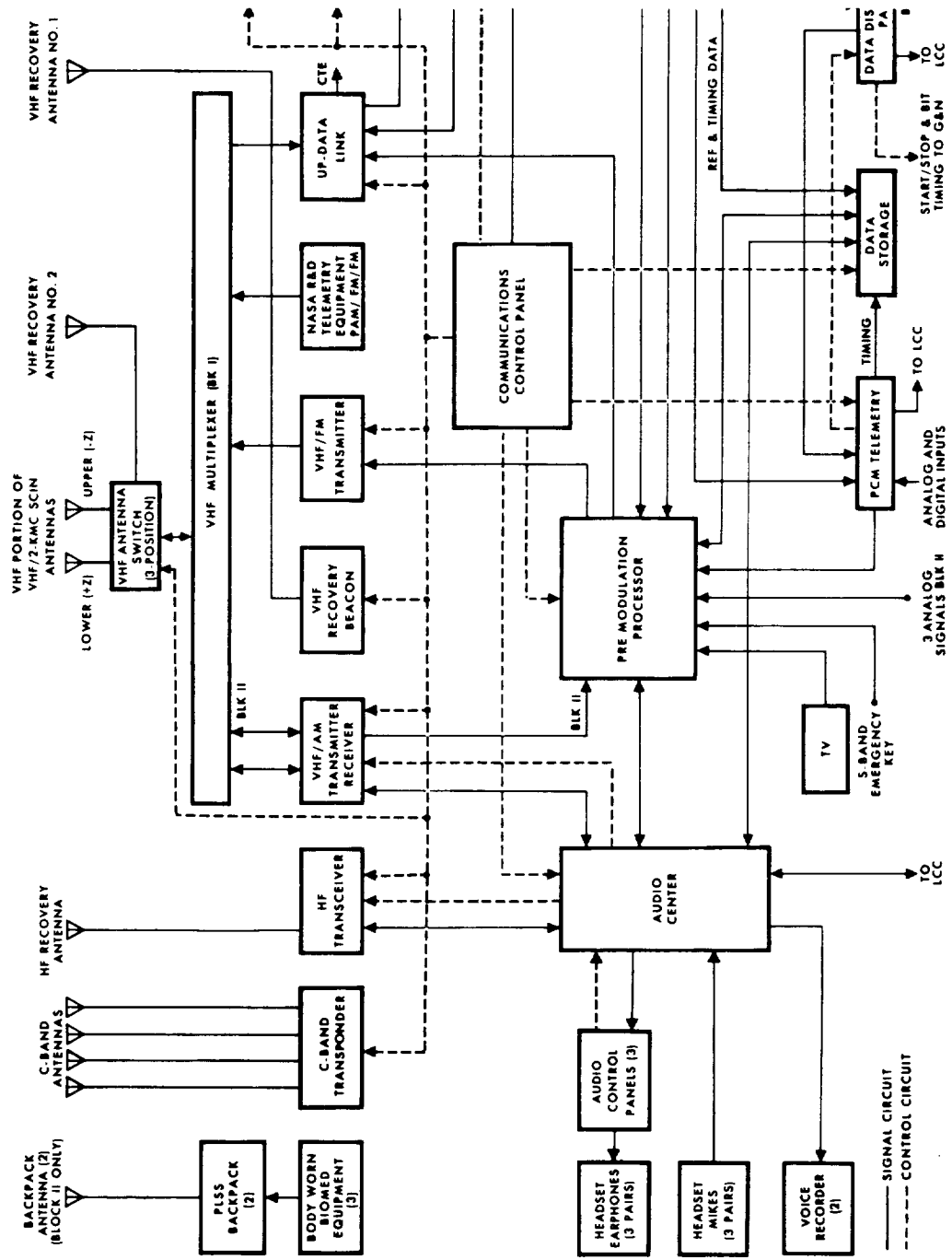
**COMMUNICATION RANGES**



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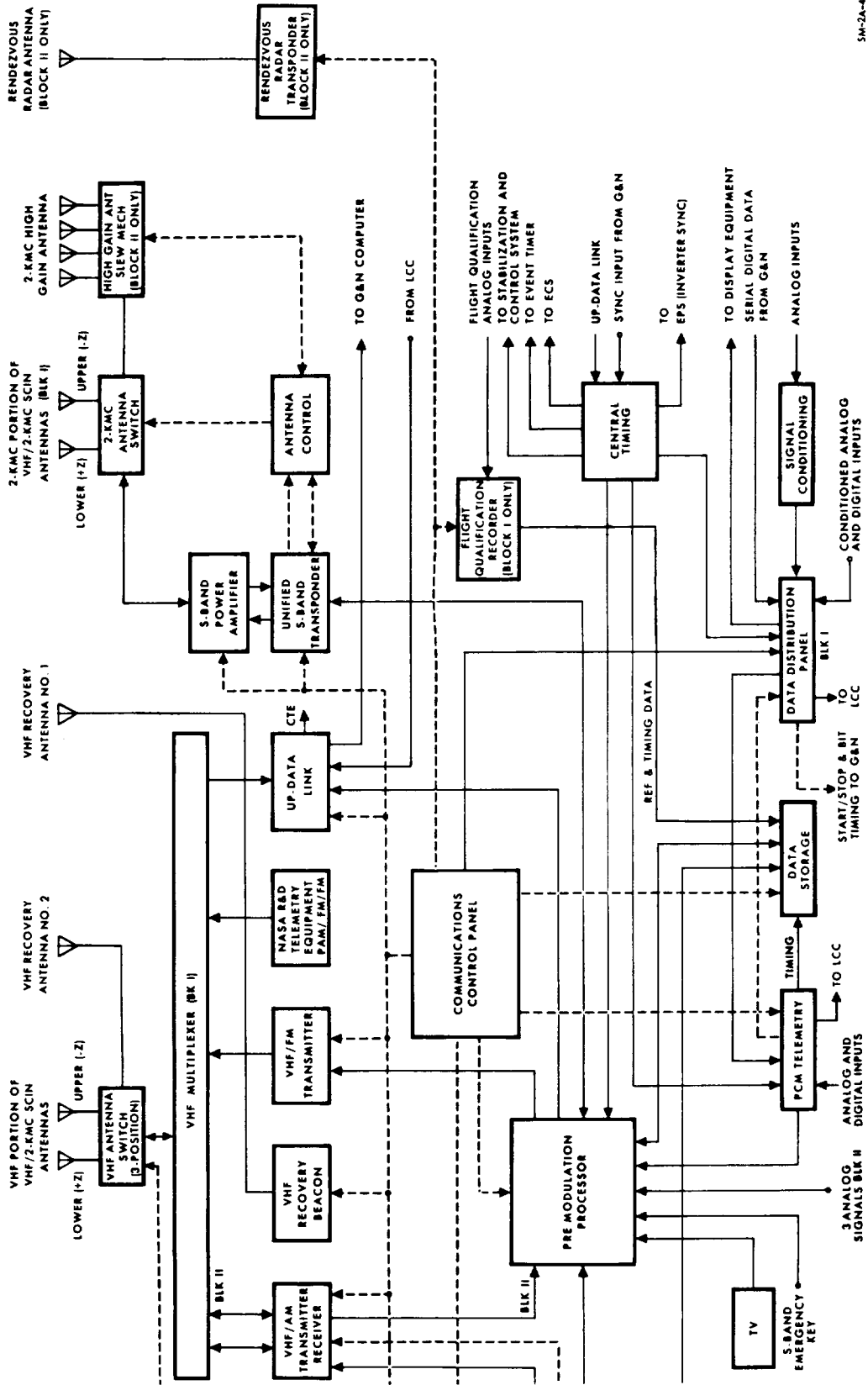


Figure 3-20. Telecommunications Systems - Antenna Location, Range, and Block Diagram



## 3-108. VOICE OPERATIONS.

3-109. S/C voice communications originate and terminate in the astronauts headsets. They are used for all voice transmission and reception, S/C intercommunications, and hardline communications with the launch control center (LCC) during prelaunch checkout. Each astronaut has an individual audio control panel, on the main display console (MDC), which enables him to select and control the inputs and outputs of his headset.

3-110. The headsets and audio control panels are connected to the audio center equipment which contains three identical audio center modules, one for each audio control panel and headset. The audio center equipment serves as the common assimilation and distribution point for all S/C audio signals. It is controlled by the audio control panels and the T/C controls on MDC panel No. 20. Depending on the mode of operation, the audio signals are routed to and from the applicable transmitter and receiver, the LCC, the recovery forces intercom, or the data storage equipment.

3-111. Three methods of voice transmission and reception are possible: the VHF/AM transmitter-receiver, the HF transceiver, or the S-band transmitter and receiver in the unified S-band equipment. Transmission is controlled by either the push-to-talk (PTT) switch, located in the electrical umbilical cord provided for each astronaut, or the voice-operated relay (VOX) circuitry. The PTT switch also serves as a keying switch during USBE emergency key transmission.

3-112. The VHF/AM transmitter-receiver equipment is used for voice communications with the MSFN during launch, ascent, and near-earth phases of the mission. The USBE is used during deep space phases of the mission when the S/C is not within VHF range of a ground station. When communications with the MSFN are not possible, limited capability exists to store audio signals on tape in the DSE for later transmission or playback on the ground after the mission is completed. For recovery operations during the post-landing phase of the mission, voice communications with the MSFN and recovery personnel are conducted over the VHF/AM transmitter-receiver equipment, the HF transceiver equipment, or the recovery forces intercom via the swimmers umbilical connector in the C/M forward compartment.

## 3-113. DATA OPERATIONS.

3-114. The S/C structure and operational systems are instrumented with sensors and transducers which gather data on their physical status. Biomedical data from sensors worn by the astronauts, TV data from the TV camera, and timing data from the central timing equipment are also acquired. These various forms of raw data are assimilated by the system, processed, and then transmitted to the MSFN. Data from the operational instrumentation may be stored in the DSE for later transmission or analysis. Analog data from the flight qualification instrumentation is stored in the flight qualification recorder for postflight analysis only.

3-115. Unconditioned analog and on-off event signals from instrumentation sensors are fed into the signal conditioning equipment where they are conditioned to a standard 5-volt d-c level. These signals are then sent to the data distribution panel which routes them to the pulse code modulation telemetry equipment and C/M displays. The PCM telemetry equipment combines the inputs from the SCE with other low-level analog inputs and converts them to a single, digital, modulating signal which is then routed to the premodulation processor equipment.

3-116. The PMP is the common assimilation, integration, and distribution center for nearly all forms of S/C data and provides the necessary interface with the RF equipment. In addition to the input from the PCM telemetry equipment, the PMP accepts recorded PCM and analog data from the DSE, video signals from the TV equipment, timing signals from the CTE, and audio signals from the audio center equipment when audio is transmitted by the USBE. These signals are modulated, mixed, and switched to the applicable transmitter or the DSE according to the mode of operation. Voice signals and up-data commands received over the USBE receiver from the MSFN are also supplied to the PMP which routes them to the audio center equipment and up-data link equipment, respectively. The UDL also contains its own receiver which is normally used during near-earth phases of the mission. S-band reception of up-data commands is used in deep space.

3-117. PCM/TLM data is transmitted to the MSFN by the VHF/FM transmitter equipment during near-earth phases of the mission. Transmission of TV or analog data is possible only by the USBE which is normally used in deep space but can also be used during launch and near-earth phases of the mission when within sight of an S-band equipped ground station. If the USBE is used, PCM/TLM data and voice signals can be transmitted with TV or analog data over the S-band link.

### 3-118. TRACKING AND RANGING OPERATIONS.

3-119. The T/C tracking and ranging equipment assists the MSFN in accurately determining the angular position and range of the S/C. Two methods are used: C-band tracking and S-band tracking.

3-120. C-band tracking is accomplished by the C-band transponder equipment and is used during all near-earth phases of the mission. It operates in conjunction with earth-based radar equipment. The C-band transponder transmits an amplified RF pulse in response to a properly coded, pulsed interrogation from the radar equipment. The range and accuracy of this equipment is thereby greatly extended over what would be possible by using skin-tracking techniques.

3-121. S-band tracking utilizing the USBE transponder is used in deep space. It operates in conjunction with MSFN equipment by providing responses to properly coded interrogations from the earth. When the USBE is in a ranging mode, the USBE transponder will receive PRN ranging code signals from the MSFN and respond by transmitting a similar signal. This method is used initially to establish an accurate measure of range to the S/C and subsequently at periodic intervals to update the doppler ranging data at the MSFN. The doppler measurements are obtained from the S-band carrier.

3-122. A VHF recovery beacon and an HF transceiver is provided to aid in locating the S/C during the recovery phase of the mission. The VHF recovery beacon equipment provides for line-of-sight direction finding capabilities by emitting a 2-second, modulated, RF transmission every 5 seconds. The HF transceiver equipment can be operated in a beacon mode to provide for beyond-line-of-sight direction finding by emitting a continuous wave signal.

### 3-123. INSTRUMENTATION SYSTEM.

3-124. The instrumentation system consists of those means required for the collection of data and is comprised of: operational, special, flight qualification, and scientific instrumentation. Equipment requirements include a variety of sensors, transducers, and photo-



graphic equipment which will be qualified prior to manned flight. Sensors and transducers are used for converting physical and electrical measurements into electrical signals. These signals are conditioned (by signal conditioners) to proper values for distribution to data utilization equipment and S/C displays.

3-125. Sensors and transducers, located strategically throughout the S/C, are positioned on the structure, within the operational systems, and for biomedical purposes are attached to the astronauts. Data may be transmitted to MSFN by way of the telecommunications system, displayed to the astronauts, or stored for evaluation at the completion of the mission.

3-126. The photographic equipment carried aboard the command module is provided for still photo and moving picture coverage.

### 3-127. OPERATIONAL INSTRUMENTATION.

3-128. Operational instrumentation consists of approximately 24 classes of transducers and is based on the following specific measurements:

Pressure	Attitude	Angular Position	Voltage
Temperature	Rates	Current	Frequency
Flow	Events	Quantity	RF Power

### 3-129. SPECIAL INSTRUMENTATION.

3-130. Special instrumentation consists of the equipment required for the checkout and monitoring of proton radiation detection and gas chromatograph. Requirements for additional equipment such as photographic, biomedical, fire-detection, and anthropomorphic dummies will vary, depending on the mission.

### 3-131. SCIENTIFIC INSTRUMENTATION.

3-132. Scientific instrumentation consists of the equipment required for various scientific experiments. The photographic equipment included in this group consists of a 35-mm still-photo camera and a 16-mm movie camera. Also included are data recorders which are installed when required.

### 3-133. FLIGHT QUALIFICATION.

3-134. Flight qualification consists of evaluation tests to ensure that the systems will furnish the instrumentation system with the required information in the specified form, from the source to the utilization point. The systems to be tested include sensors, associated equipment, subsystems, and special instrumentation such as optical, scientific, and biomedical. This data will be recorded on the flight qualification recorder for post-flight analysis.

### 3-135. CAUTION AND WARNING SYSTEM.

3-136. The caution and warning system (C&WS) monitors critical parameters of most S/C systems. Each malfunction or out-of-tolerance condition is brought to the attention

of the crew by visual and aural means. The crew acknowledges the condition and resets the system for subsequent malfunction alerting.

### 3-137. C&WS OPERATION.

3-138. Malfunctions or out-of-tolerance conditions are sent to the C&WS as analog and discrete event inputs. This results in illumination of status lights that identify the abnormal condition, and activation of the master alarm circuit. Master alarm lights on the panels and an audio alarm tone in the headsets serve to alert the crew to each abnormal condition. Crew acknowledgement of the condition consists of resetting the master alarm circuit, thereby placing it in readiness should other malfunctions occur. C&WS operational modes are selected by the crew to meet varying conditions during the mission. The system also contains its own failure sensing signal.

### 3-139. CONTROLS AND DISPLAYS.

3-140. The operational spacecraft systems, located in the C/M and in the S/M, interface in varying degrees with control and display panels in the C/M cabin. This interface is provided to the extent necessary for the astronauts to adequately control and monitor the functions of the various systems. The controls and displays for most of the S/C systems are located on the main display console situated above the couches. (See figure 3-21.) This location permits frequent attention and quick control by the astronauts. Several of the S/C systems also have additional controls and displays elsewhere in the C/M cabin, as shown in figure 3-22. The majority of guidance and navigation system controls and displays are located on panels in the lower equipment bay adjacent to the G&N telescope and sextant. Those manual controls of the environmental control system that do not require frequent or time-critical actuation, are located in the left-hand equipment bay and the left-hand forward equipment bay. All of the controls in the waste management segment of the crew system are located on a panel in the right-hand equipment bay.

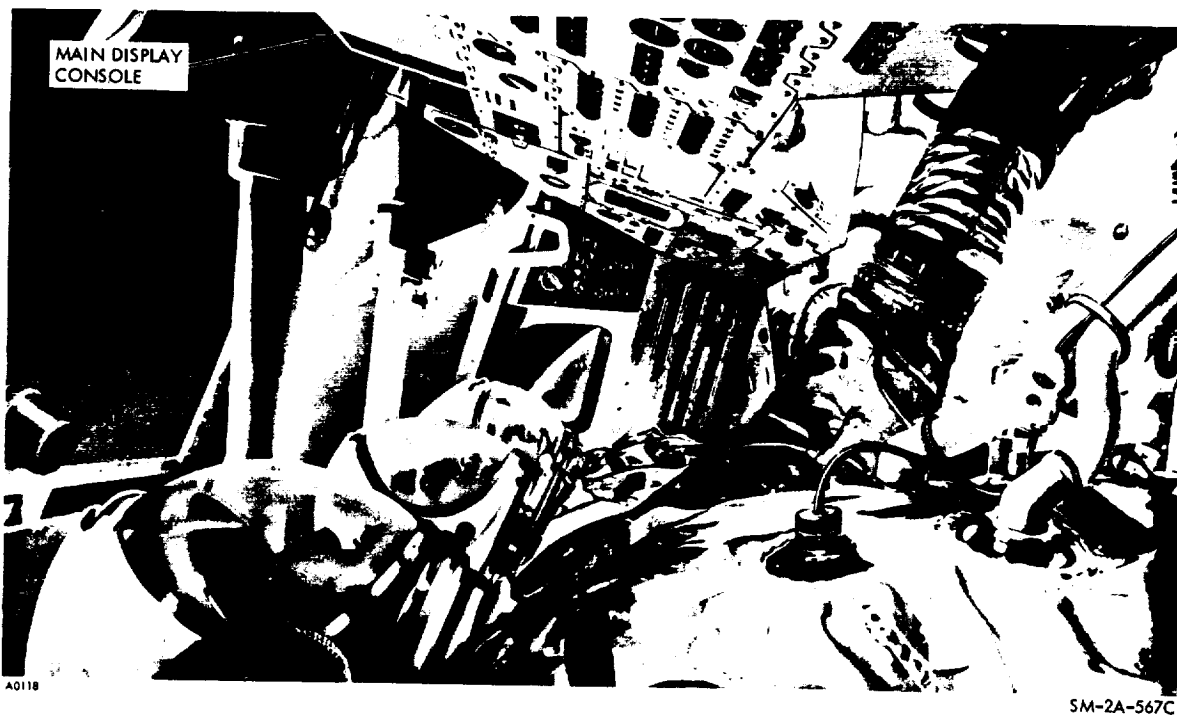
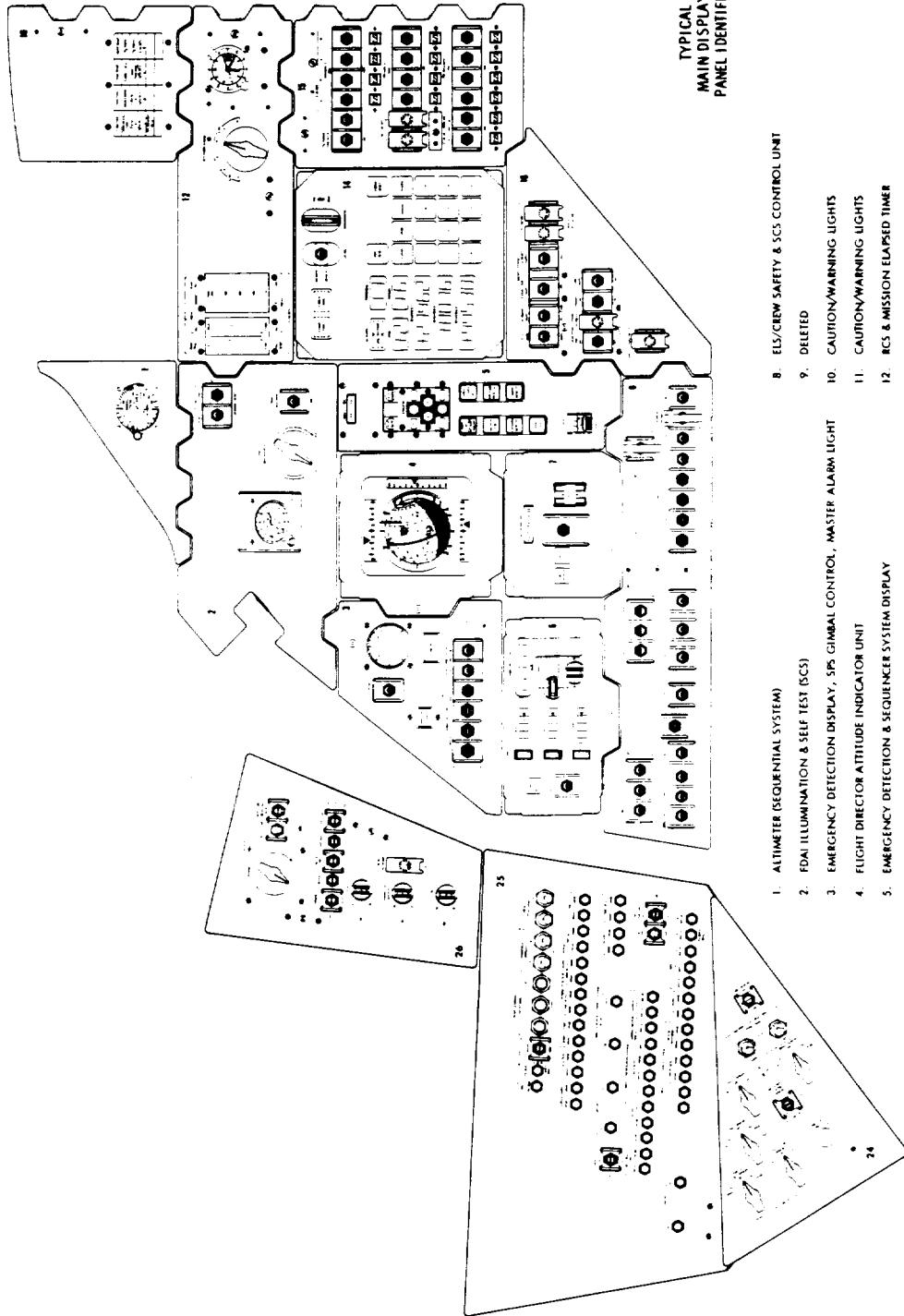


Figure 3-21. Controls and Displays - Main Display Console (Sheet 1 of 3)

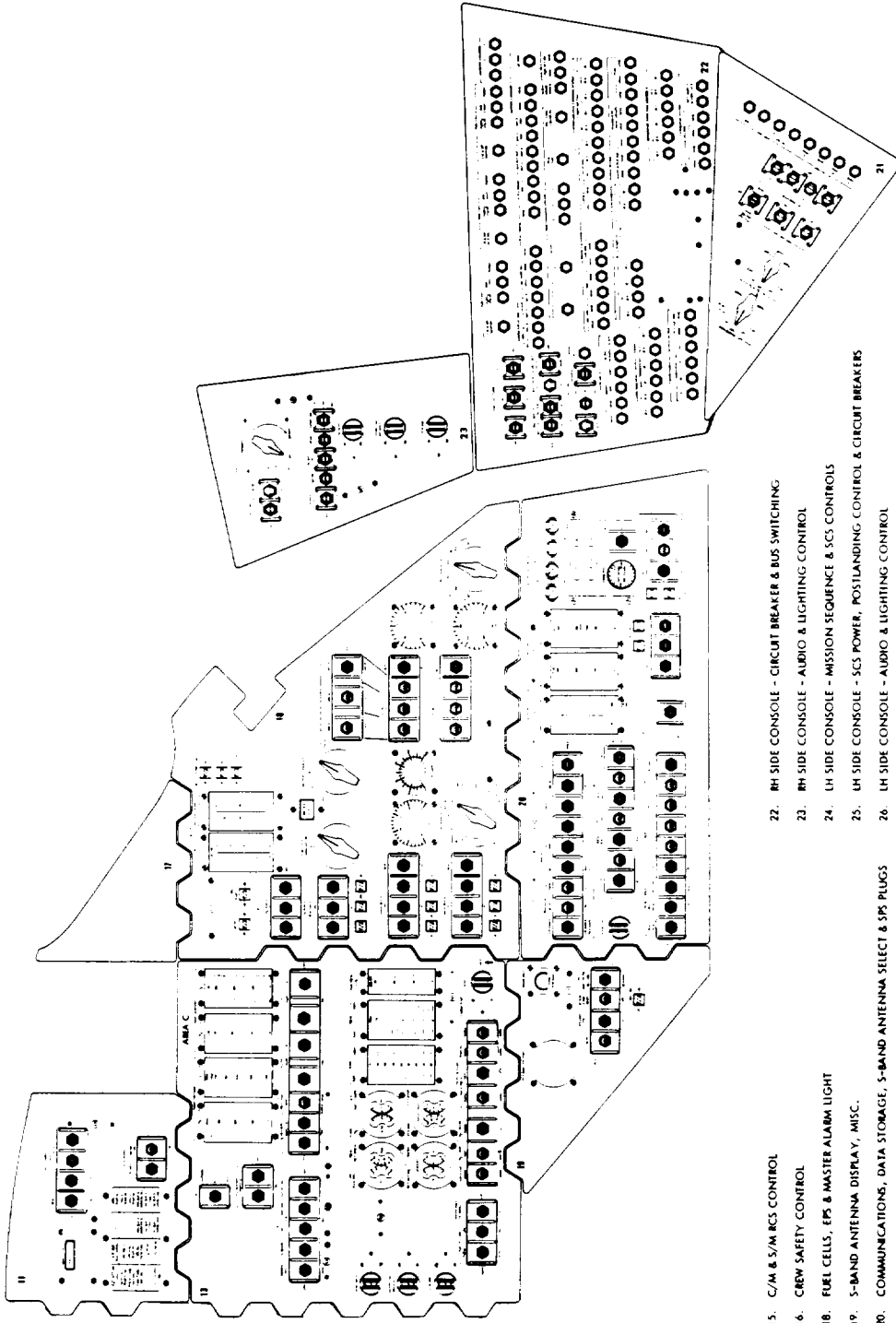


TYPICAL BLOCK I  
MAIN DISPLAY CONSOLE—  
PANEL IDENTIFICATION LIST

- 1. ALTIMETER (SEQUENTIAL SYSTEM)
- 2. FDI ILLUMINATION & SELF TEST (SCS)
- 3. EMERGENCY DETECTION DISPLAY, SPS GIMBAL CONTROL, MASTER ALARM LIGHT
- 4. FLIGHT DIRECTOR ATTITUDE INDICATOR UNIT
- 5. EMERGENCY DETECTION & SEQUENCER SYSTEM DISPLAY
- 6. ATTITUDE SET & GIMBAL POSITION DISPLAY UNIT
- 7. AV DISPLAY UNIT
- 8. ELS/CREW SAFETY & SCS CONTROL UNIT
- 9. DELETED
- 10. CAUTION/WARNING LIGHTS
- 11. CAUTION/WARNING LIGHTS
- 12. RCS & MISSION ELAPSED TIMER
- 13. CAUTION & WARNING, AUDIO, CRYOGENIC & ECS
- 14. G&N COMPUTER CONTROL UNIT

3-53-a



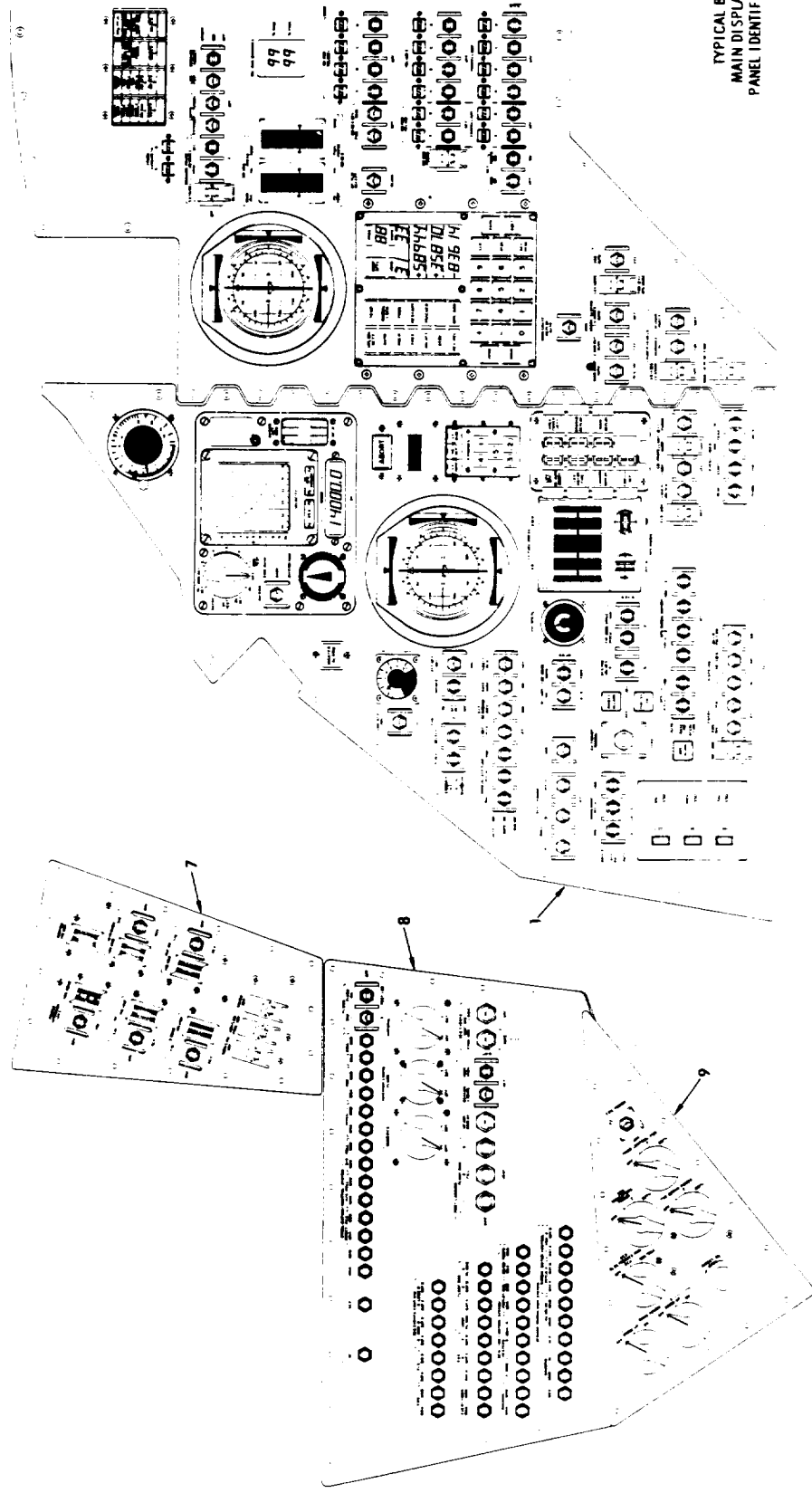


- 15. C/M & S/M RCS CONTROL
- 16. CREW SAFETY CONTROL
- 18. FUEL CELLS, EPS & MASTER ALARM LIGHT
- 19. S-BAND ANTENNA DISPLAY, MISC.
- 20. COMMUNICATIONS, DATA STORAGE, S-BAND ANTENNA SELECT & SPS PLUGS
- 21. RH SIDE CONSOLE - CIRCUIT BREAKER & BUS SWITCHING
- 22. RH SIDE CONSOLE - CIRCUIT BREAKER & BUS SWITCHING
- 23. RH SIDE CONSOLE - AUDIO & LIGHTING CONTROL
- 24. LH SIDE CONSOLE - MISSION SEQUENCE & SCS CONTROLS
- 25. LH SIDE CONSOLE - SCS POWER, POSTLANDING CONTROL & CIRCUIT BREAKERS
- 26. LH SIDE CONSOLE - AUDIO & LIGHTING CONTROL

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Figure 3-21. Controls and Displays - Main Display Console (Sheet 2 of 3)





TYPICAL BLOCK II  
MAIN DISPLAY CONSOLE  
PANEL IDENTIFICATION LIST

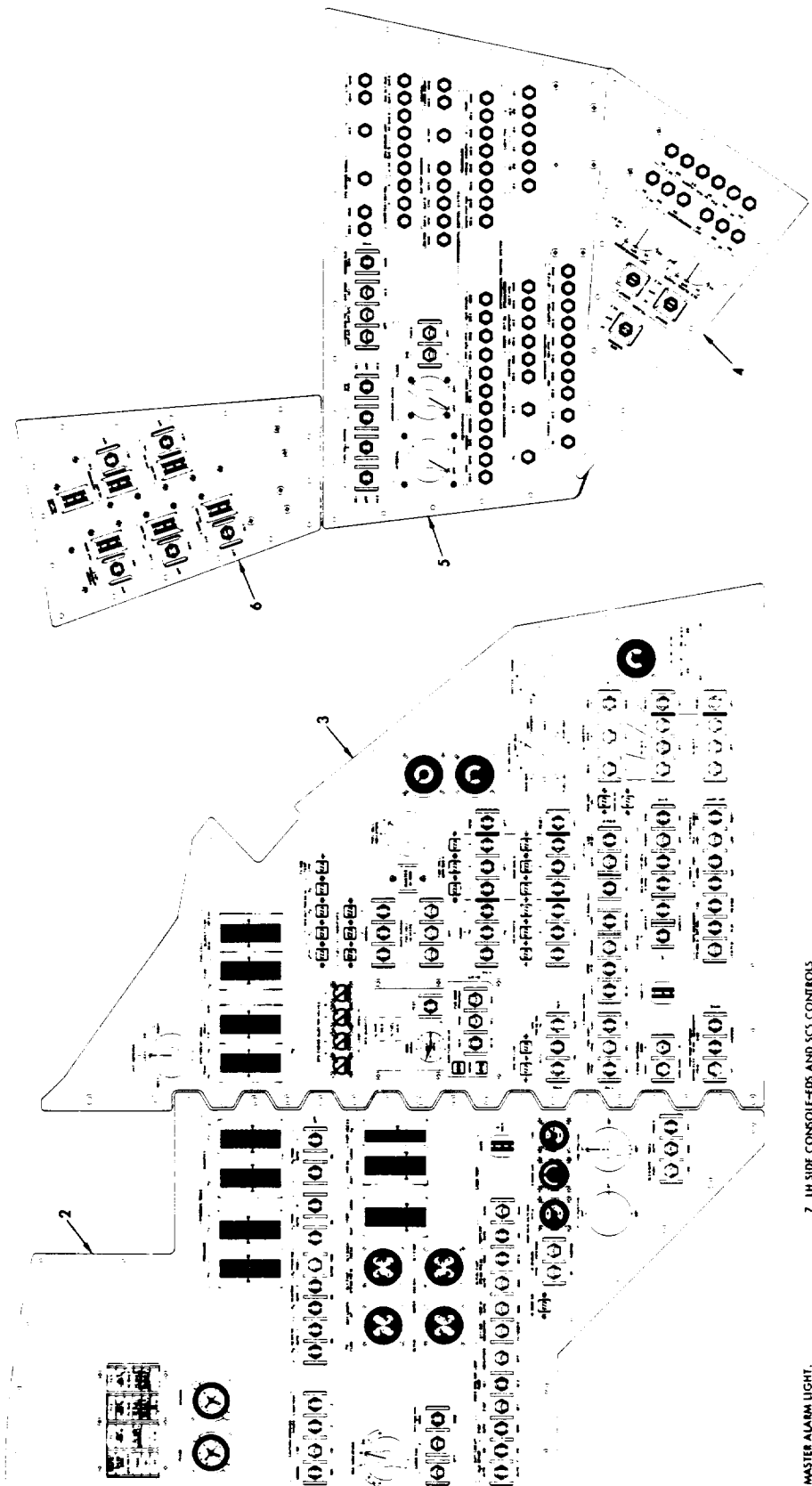
- 1 ALTIMETER, ERS AND AV REMAINING INDICATOR, EDAL, L/V FUEL AND ENGINES, SEQUENCER SYSTEM CONTROLS AND DISPLAYS, SIP GIMBAL CONTROL, ATTITUDE SET, G AND C, MASTER ALARM LIGHT, AND ABORT LIGHT.
- 2 CAUTION/WARNING LIGHTS, EDAL, G AND C DSKY, SEQUENCER SYSTEM, DOCKING SYSTEM, S/M AND C/M ECS, PHASE AND MISSION ELAPSED TIMERS, CRYOGENIC SYSTEM, ECS, AND HIGH GAIN ANTENNA.

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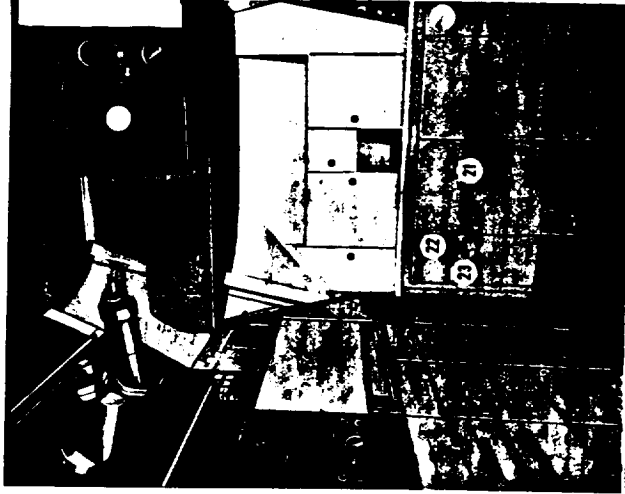
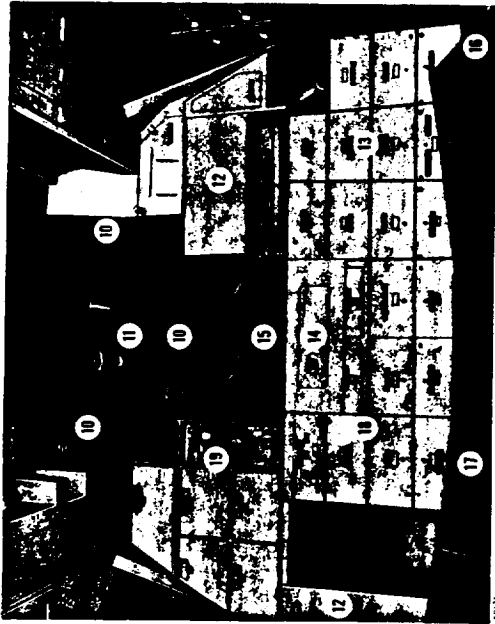
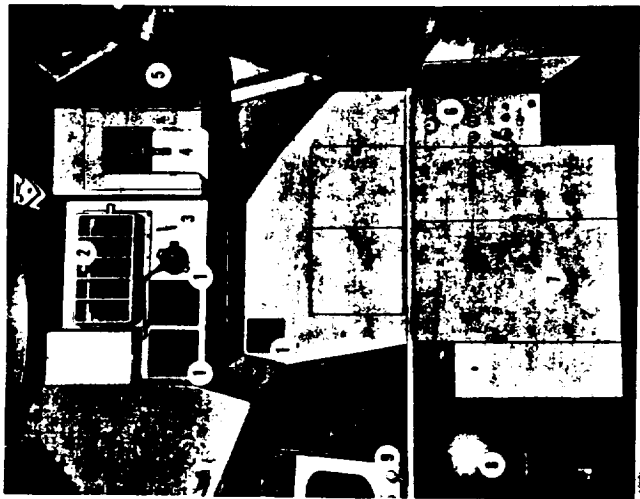
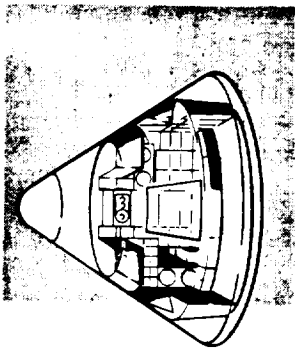
- 3 SP, FUEL CELLS, EP, T/C, AND MASTER ALARM LIGHT.
- 4 RH SIDE CONSOLE-SPS, T/C, AND ECS, BUS SWITCHING AND ECS CIRCUIT BREAKERS.
- 5 RH SIDE CONSOLE-BUS SWITCHING, CIRCUIT BREAKERS, AND INTERIOR LIGHT CONTROLS.
- 6 RH SIDE CONSOLE-T/C CONTROLS.

- 7 LH SIDE CONSOLE-EDS AND SCS CONTROLS.
- 8 LH SIDE CONSOLE-SCS, SEQUINER SYSTEM, EDS, RCS, AND SPS CIRCUIT BREAKERS, POSTLANDING CIRCUIT BREAKERS AND SWITCHES, AND INTERIOR LIGHT CONTROLS.
- 9 LH SIDE CONSOLE-T/C CONTROLS.

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Figure 3-21. Controls and Displays - Main Display Console (Sheet 3 of 3)





EQUIPMENT IDENTIFICATION LIST

- LF FORWARD EQUIPMENT BAY**
- 1 PRESSURE TEST CONNECTOR (BEC)
  - 2 CABIN MAT EXCHANGES (WATER) (BEC)
  - 3 CABIN TEMPERATURE CONTROL PANEL (BEC)
  - 4 PORTABLE WATER SUPPLY PANEL (BEC)
  - 5 GASE CLOZE AND EVENT TIMER (IGAN)
- LF EQUIPMENT BAY**
- 6 OXYGEN CONTROL PANEL (BEC)
  - 7 ENVIRONMENTAL CONTROL SYSTEM INCREASE (BEHIND PANEL)
  - 8 OXYGEN SUIBT TANK (BEC)
  - 9 CABIN PRESSURE RELIEF VALVE CONTROLS (BEC)

- LOWER EQUIPMENT BAY**
- 10 CONTROL PANEL (IGAN)
  - 11 GAN OPTICS
  - 12 DATA STORAGE EQUIPMENT
  - 13 COMMUNICATIONS MODULES
  - 14 APOLLO GUIDANCE COMPUTER (IGAN)
  - 15 POWER SERVO ASSEMBLY (IGAN)
  - 16 BATTERY AND FUSE CONTROLS
  - 17 CO2 ABSORBENT CARTRIDGE STORAGE (BEC)
  - 18 SC3 MODULES
  - 19 MAT AND ATTITUDE CONTROL ASSEMBLY (BEC)
- RH FORWARD EQUIPMENT BAY**
- 20 SYSTEM MANAGEMENT
- RH EQUIPMENT BAY**
- 21 RESONANCE AND SCINTILLATION EQUIPMENT (BEHIND PANEL)
  - 22 WASTE MANAGEMENT CONTROL PANEL
  - 23 VACUUM CLEANER STORAGE
  - 24 BUS TR AND INVERTER POWER CONTROLS

Figure 3-22. Command Module Equipment and Storage Bays (Block 1)



3-141. The displays that read out within given parameters are range-marked to aid the crew in more rapidly determining slight out-of-tolerance conditions. This is in addition to the caution/warning lights that will call the crew's attention to out-of-tolerance conditions. Regardless of the various types of controls in the C/M, provisions have been made for all controls to be operated with an astronaut's gloved hand.

### 3-142. DOCKING SYSTEM (BLOCK II).

3-143. The purpose of the docking system (figure 3-23) is to provide a means of connecting and disconnecting the LM/CSM during a mission and to provide a passageway to and from the LM when it is connected to the CSM. The docking system consists of the primary structure and the necessary hardware required to support the complete docking function between the CSM and LM.

3-144. The primary structure consists of the tunnel required for LM ingress and egress. The system contains hatches, latches, probe, drogue, illumination, and required sealing surfaces. The docking structure will be able to withstand load imposition from the docking maneuvers and from the modal characteristics that will exist between the LM and CSM.

3-145. Once the probe is engaged in the drogue, the probe attenuation system is activated to pull the LM against the CSM. This operation will lock the C/M to the LM with four semi-automatic latches, of the 12 latches around the forward circumference of the forward tunnel, providing an airtight seal. After the LM and CSM are latched together and sealed (initial docking), the following operations are accomplished: the pressure is equalized between the LM and C/M, the C/M forward tunnel hatch is removed, the eight remaining

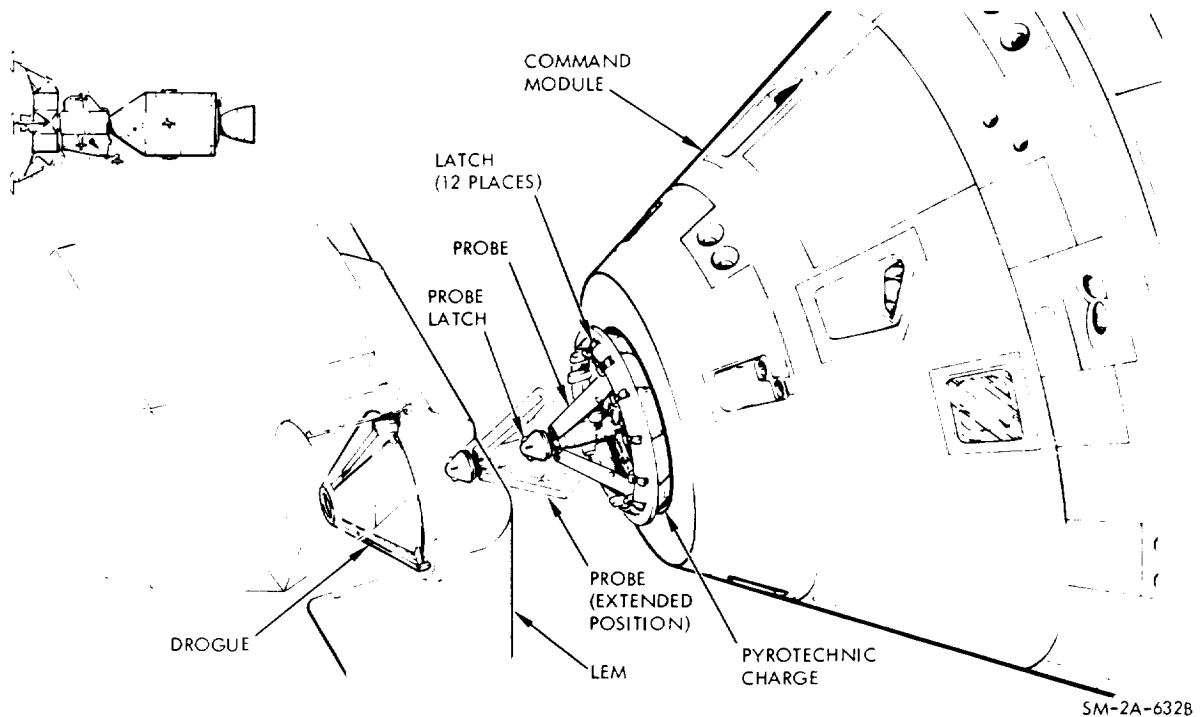


Figure 3-23. Docking System (Block II)

manual and four semi-automatic latches are locked in place (final docking), an electrical umbilical is connected to the LM from the C/M, the probe and drogue mechanism is removed from the center of the tunnel, and the LM hatch is removed opening a passageway between the C/M and LM which allows transfer of equipment and crewmembers. In case a malfunction occurs which prevents docking or removal of the probe and drogue mechanism, provision has been made for emergency vehicular transfer (EVT). EVT involves transferring from one vehicle to another by way of the side hatches.

3-146. To release the LM from the CSM for lunar landing operations, the 12 manual latches are released, the hatches, probe, and drogue mechanisms are installed in their respective places, and the probe attenuation system is electrically released allowing the LM to separate from the CSM.

3-147. To release the LM from the CSM in preparation for the return trip to earth, all equipment with no further use to the astronauts is placed in the LM, including the probe and the drogue. After transfer of equipment and crewmembers, the C/M forward tunnel hatch is installed in place, resealing the C/M crew compartment. The LM is then released from the C/M by firing a pyrotechnic charge which is located around the circumference of the docking assembly.

#### 3-148. CREWMAN OPTICAL ALIGNMENT SIGHT (BLOCK II).

3-149. The crewman optical alignment sight (COAS) is a sighting aid required for docking maneuvers after transposition of the CSM to assist the astronauts in accurately aligning the CSM with the LM. The LM also has an alignment sight that will be used in a similar manner after rendezvous is accomplished in lunar orbit. The COAS is a collimator-type optical device and provides the astronaut with a fixed line-of-sight attitude reference image. When viewed through the rendezvous window, the reference image appears to be the same distance away from the C/M as the LM target. It also has an elevation scale adjacent to the reference image, or reticle, with a range of +30° and -10°.

3-150. The COAS can be mounted on the inboard side of either the LH or RH rendezvous windows, and is designed to project an optical collimated alignment image. A light source with adjustable brightness control allows for proper brightness against all exterior background lighting conditions.

3-151. When the LM is the active docking vehicle, the COAS can be used as a backup to check the alignment of the LM with the CSM. The COAS can also be used as a replacement for the scanning telescope when necessary. Additional uses include: manual delta velocity reference, aiming cameras, and spacecraft and manual entry reference backup.

## LUNAR MODULE

### 4-1. GENERAL.

4-2. This section contains basic data concerning the lunar module (LM). Information is given to indicate configuration, function, and interface of the various components in gross terms. For more detailed LM information, refer to the Lunar Module Familiarization Manual, LMA790-1.

4-3. The LM, illustrated in Figure 4-1, will carry two Apollo crewmembers from the orbiting CSM to the surface of the moon. The descent from lunar orbit will be powered by a gimbal-mounted rocket engine in the LM descent stage. As the LM nears the lunar surface, the descent engine will provide braking and hovering to allow lateral movement to a suitable landing area. The LM will provide a base of operations for lunar explorations. Food, water, electrical power, environmental control, and communications relay will sustain the crewmembers for a period up to 48 hours. One astronaut will explore the lunar surface while the other remains inside the LM. After 3 hours, the first astronaut will return and the second man will continue the exploration. Upon completion of exploration, the astronauts will prepare the LM ascent stage for ascent to intercept the orbiting CSM with power provided by the ascent rocket engine. The entire LM descent stage and other nonreturnable equipment is left on the moon. Upon rendezvousing and docking with the CSM, the crew will transfer from the LM to the CSM and, the LM will then be jettisoned and left as a lunar satellite.

### 4-4. LM CONFIGURATION.

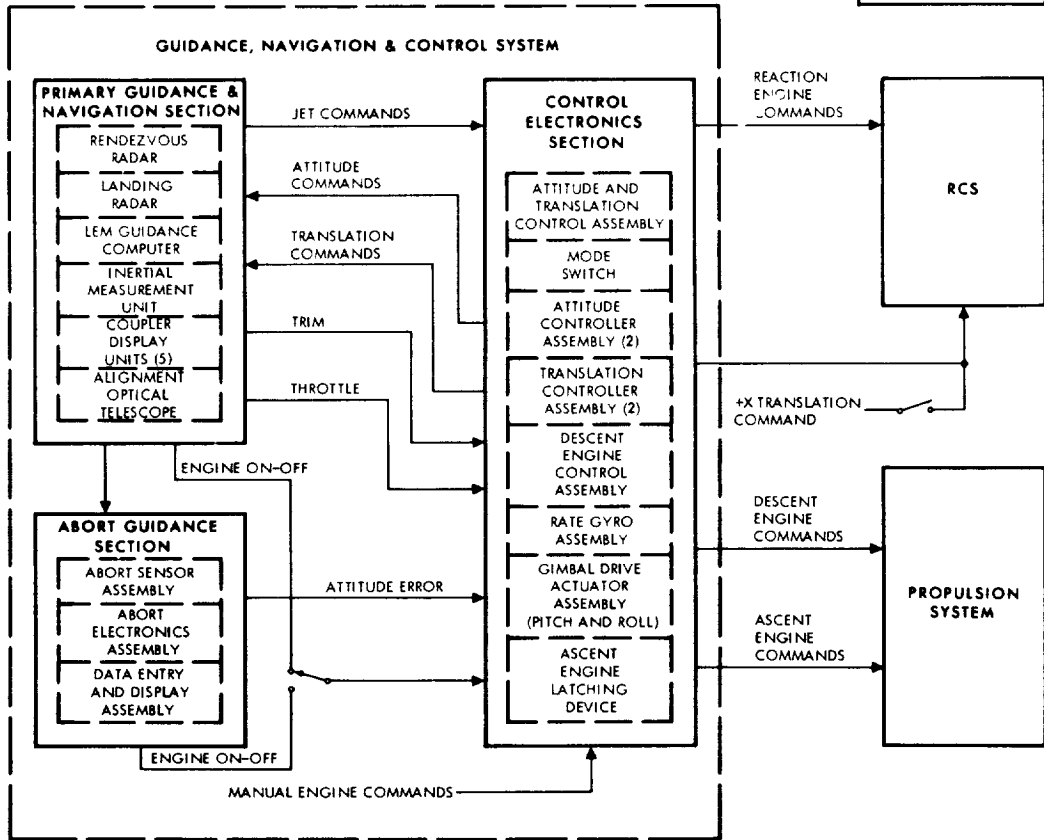
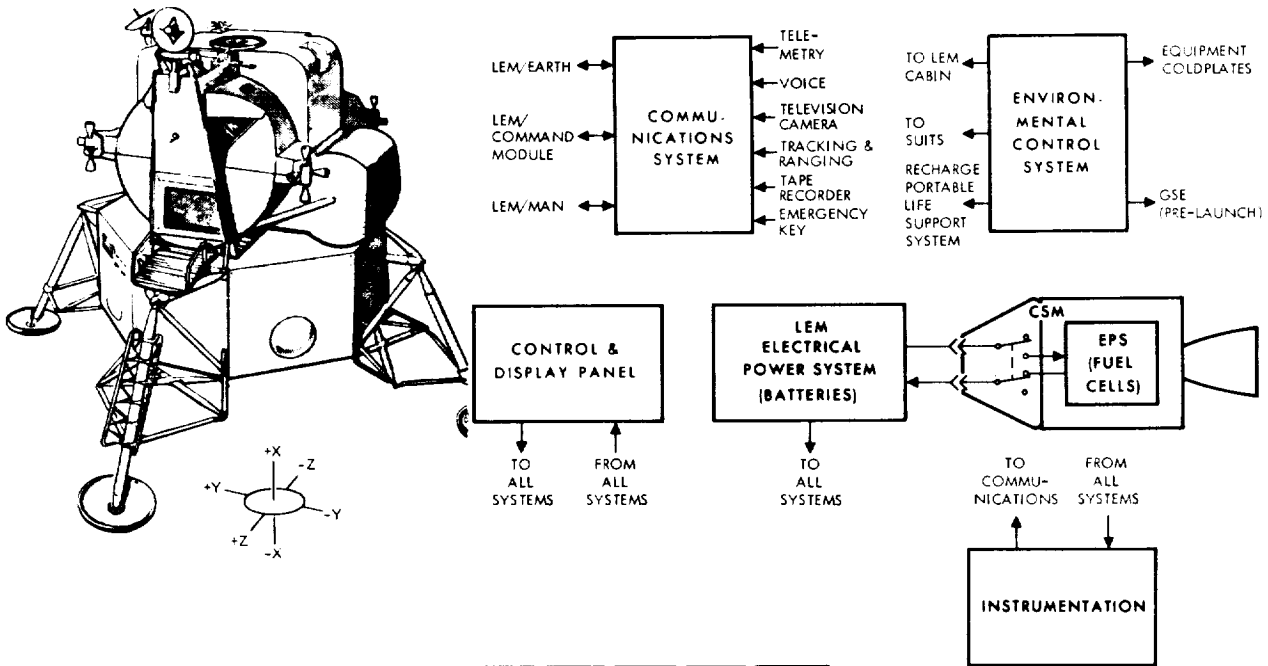
### 4-5. STRUCTURE.

4-6. LM structural components are divided into ascent-stage and descent-stage structures. (See figure 4-2.) The ascent-stage structure consists of the following components:

- Crew compartment pressure shell
- Ascent tanks and engine support
- Equipment bay
- Equipment compartment
- Electronic replaceable assembly
- Oxygen, water, and helium tanks
- Reaction control system tanks and engine supports
- Windows, tunnels, drogue mechanism, and hatches
- Docking target recess
- Interstage fittings

The descent-stage structure consists of the following components:

- Descent engine tanks and engine support
- Landing gear assembly
- Secondary oxygen, water, and helium tanks



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Figure 4-1. Lunar Module and Systems Block Diagram



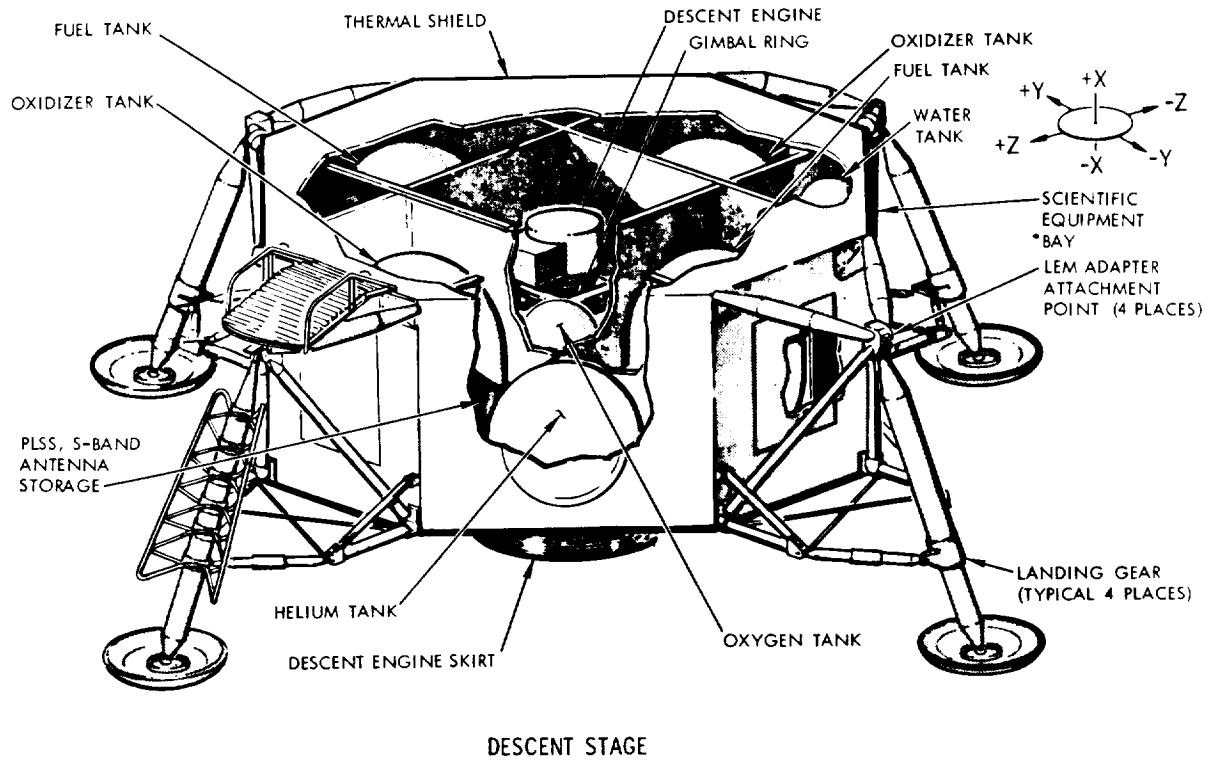
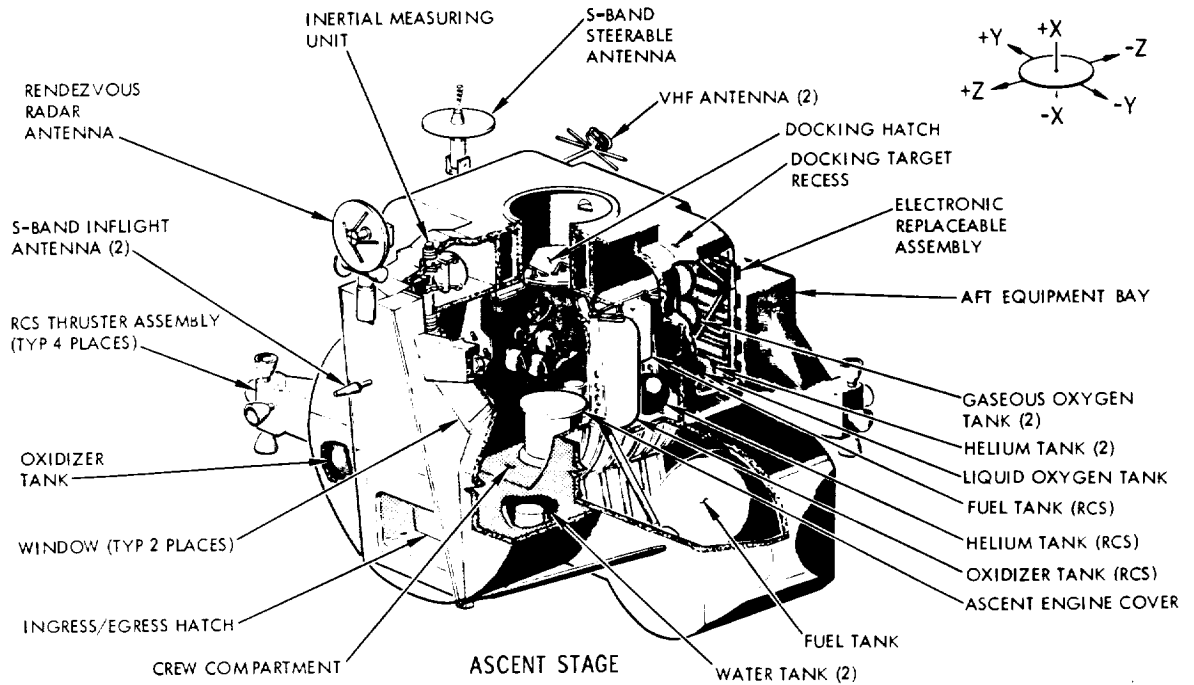


Figure 4-2. LM Ascent and Descent Stages

- Scientific equipment bay
- Interstage fittings
- Antenna storage bay
- Battery storage bay

#### 4-7. LM OPERATION.

4-8. Operation of the LM is under crew control. Controls and displays provide monitoring and allow control of the various systems. Warning and caution lights are provided on two centrally located panels. A malfunction in any of the systems will light a specific indicator, denoting the malfunctioning system. General operation of the various systems (figure 4-1) is explained in paragraphs 4-9 through 4-29.

#### 4-9. GUIDANCE, NAVIGATION, AND CONTROL SYSTEM.

4-10. The guidance, navigation and control system is an inertial system aided by optical sighting equipment and radar. The function of the guidance, navigation, and control system is to provide and/or maintain the following:

- Position data
- Velocity
- LM attitude
- Altitude
- Rate of ascent/descent
- Range (from command/service module)
- Range rate
- Control command

The system consists of three sections; a primary guidance and navigation section, a control electronics section, and an abort guidance section. A LM guidance computer (LGC), inertial measurement unit (IMU), coupling display units (CDU), optical telescope, rendezvous radar, and landing radar comprise the primary guidance and navigation section.

4-11. The guidance, navigation, and control system monitors and controls the attitude of the LM, provides guidance backup, enables automatic or manual control modes, and controls propulsion engine gimbals. Attitude error signals are generated in the primary guidance and navigation section and the abort guidance section, and routed to the control electronics section. The control electronics section provides attitude error correction signals and propulsion commands. An attitude and translation control assembly provides signal routing and mode control for the guidance, navigation, and control system. Mode control enables manual or automatic control of the LM attitudes through the reaction control system and LM velocity through the propulsion system. Rate gyros and an in-flight monitor provide control and display information. If the primary guidance and navigation section fails, the abort guidance section mode may be selected to take over the guidance functions. Propulsion engine, gimbal controls, and firing commands are controlled by the primary guidance and navigation section and control electronics section to ensure thrusting through the LM center of gravity. Backup control is provided by the abort guidance section.

4-12. RADAR SYSTEMS. There are two separate radar systems which aid the guidance, navigation, and control system. The rendezvous radar provides range and range-rate information, as well as azimuth (target bearing) information, utilizing a gimbal-mounted

antenna. The landing radar provides altitude and altitude change-rate information utilizing a two-position antenna. The control and display panels provide crew control of the radar system and display of the information received. A storage buffer receives the acquired information from signal conditioners; then a high-speed counter, timer by the LGC, converts the information into representative digital form which is fed into the LGC.

#### 4-13. PROPULSION SYSTEM.

4-14. Two rocket engines provide the power required for descent and ascent. The engines use pressure-fed liquid propellants. The propellants consist of a 50:50 mixture of UDMH and hydrazine as fuel, and nitrogen tetroxide as the oxidizer. Ignition is by hypergolic reaction when the fuel and oxidizer are combined. The descent engine, fuel tanks, oxidizer tanks, and associated components are located in the LM descent stage. Provision is made to throttle the descent engine to enable velocity control. Gimbal mounting of the engine provides hovering stability. The ascent engine is centrally mounted in the LM, and is of fixed-thrust, nonthrottling configuration, mounted in a fixed position. The propellant supply of the ascent engine is interconnected with the reaction control system propellant supply. Control of the engines may be either manual or automatic, with automatic control maintained by the LGC through the guidance, navigation, and control system.

#### 4-15. REACTION CONTROL SYSTEM.

4-16. LM attitude control is provided by 16 small rocket engines mounted in four clusters. Each cluster consists of four engines mounted 90 degrees apart. The engines are supplied by two pressure-fed propellant systems. The propellants are the same as those used by the propulsion engines. The propellant supply to the reaction control system engines is also interconnected to the ascent engine propellant supply, allowing extended use of the reaction control engines. Reaction engine commands may be manual or automatic, and are applied through the guidance, navigation, and control system.

#### 4-17. ENVIRONMENTAL CONTROL SYSTEM.

4-18. Environmental control is maintained inside the LM cabin. Portable life support systems, in the form of backpacks, supply a controlled environment in the pressure suits to allow exploration of the lunar surface. Oxygen, water, and water-glycol are used for environmental control. Pure oxygen is stored in a tank located in the ascent stage. The pure oxygen is conditioned for use by mixing it with filtered oxygen. The descent stage contains a tank which stores additional oxygen in the super-critical (liquid or extremely cold) state. Potable water for drinking, food preparation, and the backpacks, is stored in a water tank. Temperature control of the cabin and electronic equipment is provided by a water-glycol cooling system. The coolant is pumped through the electronic equipment coldplates and heat exchangers, and filtered. Cabin temperature control is monitored by temperature sensors and maintained by a temperature controller. The portable life support system (PLSS) provide necessary oxygen, water, electrical power, and a communications link to enable the LM crewmembers exploring the lunar surface to remain in contact with each other, the CSM and MSFN. The backpacks can be used approximately 4 hours, after which the oxygen tank must be refilled and the batteries recharged from the environmental control system.

#### 4-19. ELECTRICAL POWER SYSTEM.

4-20. Electrical power is provided by six silver oxide-zinc, 28-vdc batteries, four in the descent stage and two in the ascent stage. Two additional batteries are provided specifically for explosive devices. The batteries will supply sufficient power to maintain essential

functions of the LM. Power distribution is provided by three buses; the commander bus, the system engineer bus, and the a-c bus. The commander and system engineer buses (28 vdc) supply power to components which must operate under all conditions. Power to all other components is provided by the a-c bus. The a-c bus is provided with 115-vac 400-cps power by one of two inverters selected by a crewmember. The two electroexplosive device batteries provide power to fire explosive devices for the landing gear uplock, stage separation, and helium pressurizing valves in the propulsion and reaction control systems.

#### 4-21. COMMUNICATIONS.

4-22. Communications aboard the LM are divided into three systems, listed as follows:

- LM-earth system
- LM-command module system
- LM-crewmember system

The LM-earth system will provide telemetry, television, voice, taped playback, hand-key, and transponder communication to earth. Return from earth will be in the form of voice and digital up-data. The LM-C/M system will provide voice communications between the orbiting C/M and LM. PCM telemetry data at 1.6 kilabits per second can be transmitted from the LM to the command module. The LM-crewmember system provides inter-communication for the LM crew, and voice suit telemetry communication is provided by the backpacks when one crewmember is on the lunar surface conducting explorations.

#### 4-23. INSTRUMENTATION.

4-24. Operational instrumentation senses physical data, monitors the LM subsystems during the unmanned and manned phases of the mission, prepares LM status data for transmission to earth, stores time-correlated voice data as required, and provides timing frequencies for the other LM subsystems. The instrumentation subsystem consists of sensors, signal conditioning electronics assembly, caution and warning electronics assembly, pulse code modulation and timing electronics assembly, and the data storage electronics assembly.

#### 4-25. CONTROL AND DISPLAY PANELS.

4-26. The controls and display panels contain controls, monitoring instruments, and warning indicators to enable the crewmembers to maintain full knowledge of the status of various systems. Manual overrides allow the crewmembers to compensate for any deviations not allowed in automatic systems operation, or to take over a malfunctioning operation.

#### 4-27. CREW PROVISIONS.

4-28. The crew provisions consist of miscellaneous equipment necessary to support two crewmen in the descent, the 24- to 48-hour exploration, and the ascent phases. The items included are listed as follows:

- Extravehicular mobility unit (Includes space suits, garments, and PLSS)
- Astronaut supports and restraints
- Lighting
- First-aid kit

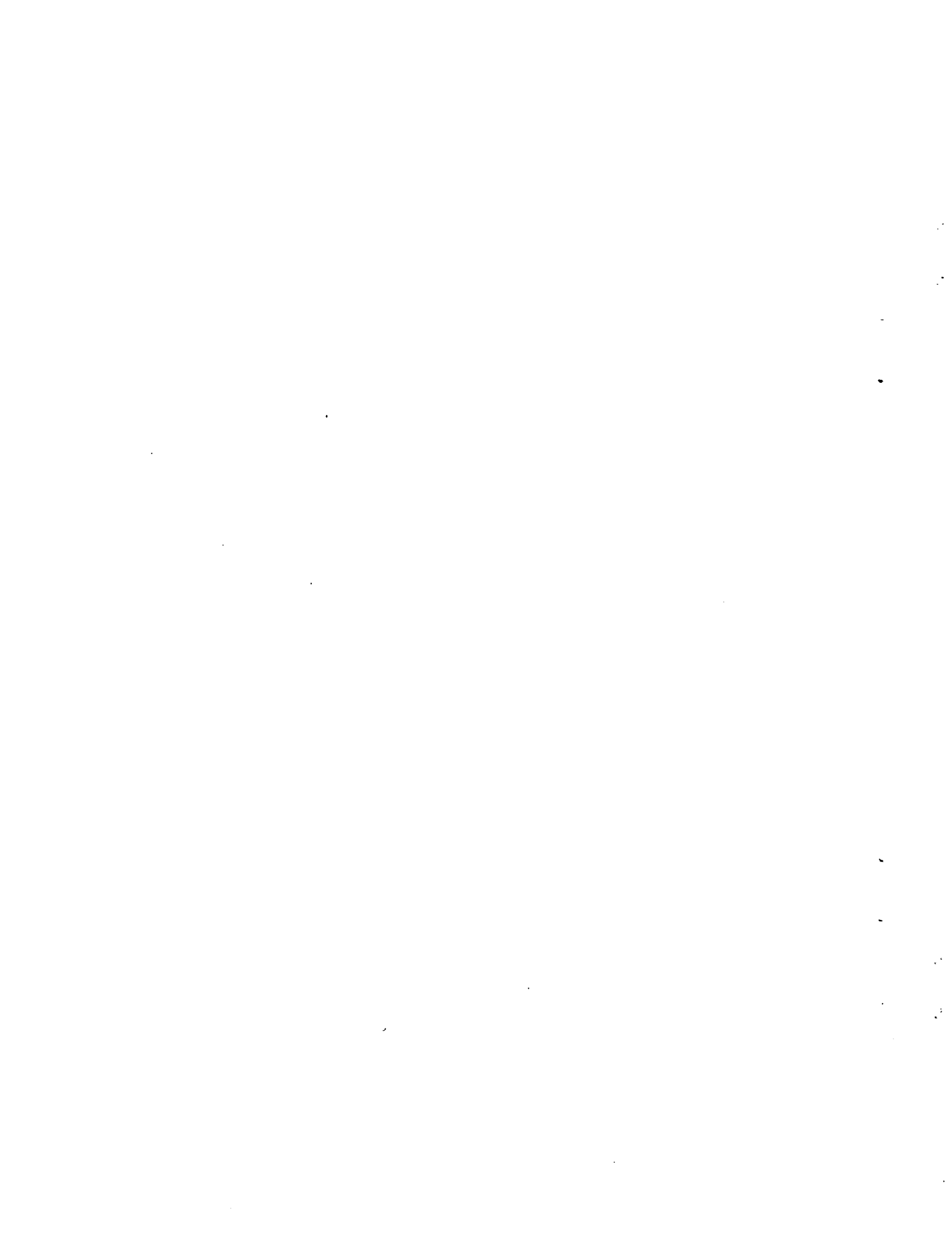
- Food storage and water dispensing
- Waste management section
- Medical kit

4-29. SCIENTIFIC INSTRUMENTATION.

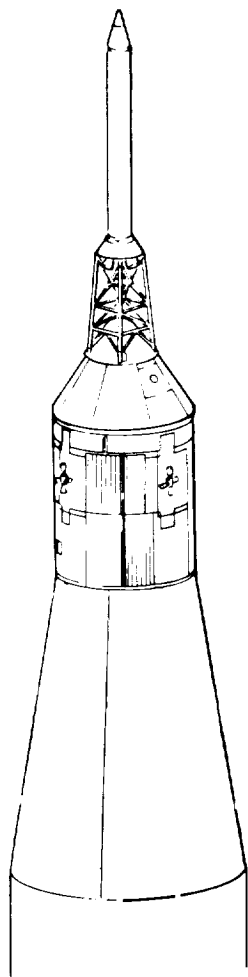
4-30. Scientific instrumentation will be carried to the lunar surface aboard the LM to enable the crewmembers to acquire samples and data concerning the lunar environment. A list of typical instrumentation to be used is as follows:

- Lunar atmosphere analyzer
- Gravimeter
- Magnetometer
- Penetrometer
- Radiation spectrometer
- Specimen return container
- Rock and soil analysis equipment
- Seismograph
- Soil temperature sensor
- Self-contained telemetering system
- Camera
- Telescope

As additional data concerning the lunar environment become available, this list will be altered.



## APOLLO SPACECRAFT MANUFACTURING



### 5-1. GENERAL.

5-2. This section describes the manufacturing fabrication, assembly, subsystems installation, and functional checkout of Apollo spacecraft structures and systems. Manufacturing techniques and processes utilized, incorporate features applicable to the special requirements of the Apollo spacecraft. Final assembly, subsystems installation, and functional checkout is performed in environmentally controlled cleaning rooms, providing control of humidity, temperature, and sources of contamination.

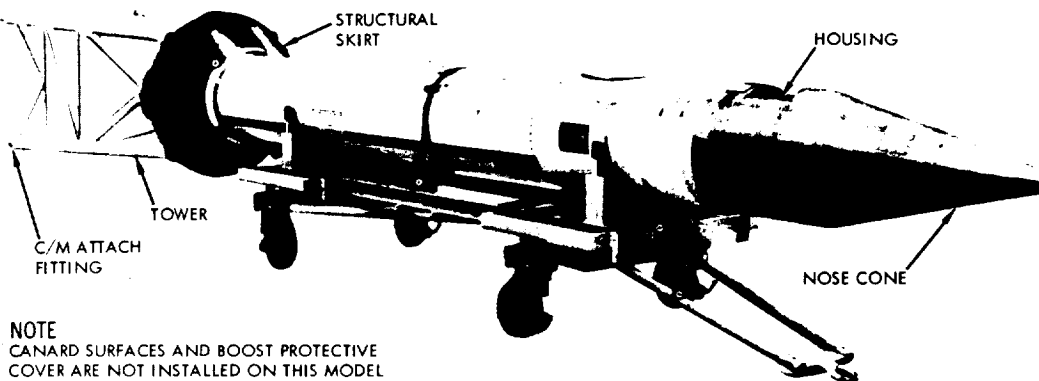
### 5-3. SPACECRAFT MAJOR ASSEMBLIES.

5-4. The spacecraft is comprised of four major assemblies consisting of the launch escape system, the command module, service module, and spacecraft LM adapter (SLA). The SLA houses the lunar module.

### 5-5. LAUNCH ESCAPE SYSTEM STRUCTURE.

5-6. The launch escape system structure (figure 5-1) consists of a nose cone, canard assembly, pitch control motor, tower jettison motor, launch escape motor, skirt structure assembly, tower structure assembly, and hard and soft boost protective covers. The entire system is 33 feet long.

5-7. The canard assembly is made from Inconel nickel and stainless steel skins riveted together. The tower structure assembly is a fusion-welded, titanium tubing structure with fittings at each end for attachment to the skirt structure assembly and the



NOTE  
CANARD SURFACES AND BOOST PROTECTIVE  
COVER ARE NOT INSTALLED ON THIS MODEL

Figure 5-1. Launch Escape System Structure



SM-2A-610A

Figure 5-2. Command Module Inner Crew Compartment Structure



command module release mechanism. The ballast enclosure and pitch control motor structure assemblies are fabricated from nickel alloy steel sheet metal skins, which are riveted to ring bulkheads and frames. The skirt assembly is made from titanium and is welded and riveted during construction. The boost protective covers, constructed of glass cloth, phenolic honeycomb, and ablative cork, are fastened to the bottom of the tower.

#### 5-8. COMMAND MODULE STRUCTURE.

5-9. The basic structure of the command module consists of a nonpressurized outer heat shield and a pressurized inner crew compartment. Bolted frame assemblies secure the heat shield to the aft compartment while I-beam stringers are used to mechanically fasten the inner and outer structures in the forward crew compartment area. A two-layer micro-quartz fiber insulation is installed between the inner and outer structures. Ablative materials are applied to the outer heat shield to protect the C/M against aerodynamic heating during entry into the atmosphere of the earth.

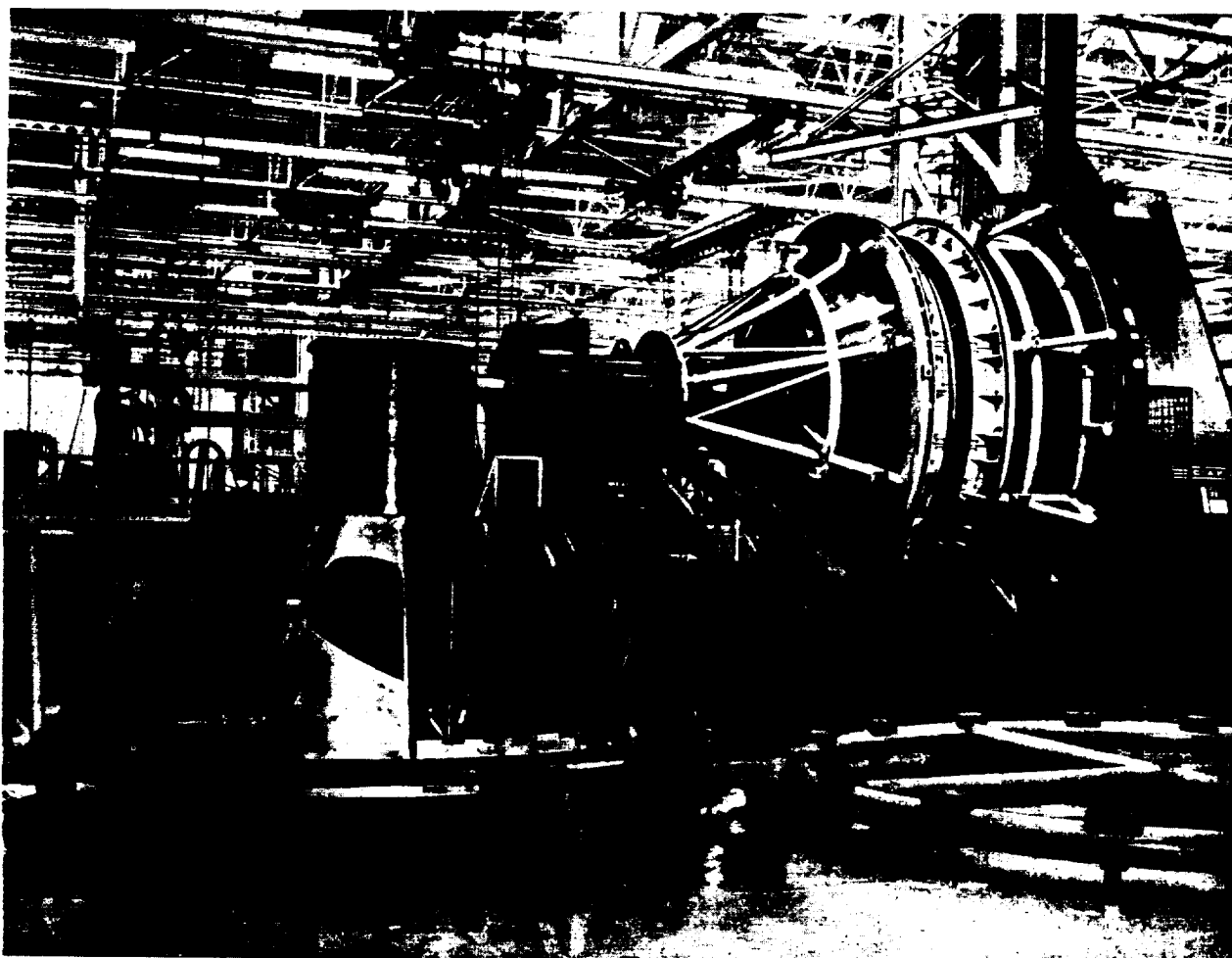
5-10. INNER CREW COMPARTMENT STRUCTURE. The inner crew compartment consists basically of a forward section containing an access cylinder welded to the forward bulkhead and cone, and an aft section containing the sidewall and bulkhead. (See figure 5-2.) These two sections are welded into subassemblies, then honeycomb bonded, trimmed, butt-fusion welded (figure 5-3), and the closeout area is filled with aluminum honeycomb material. Face sheets of aluminum alloy overlap the two sections and are bonded in place. Secondary structure equipment bays, housing the various subsystems and storage areas, are located within the inner crew compartment. Refer to section III for a description of the systems installed in the C/M.

5-11. HEAT SHIELD STRUCTURE. The heat shield structure (figure 5-4) of the command module consists of the apex cover, forward heat shield, crew compartment heat shield, and aft heat shield. The apex cover, used on Block I S/C, is replaced with the C/M portion of the docking system on Block II S/C.

5-12. The forward heat shield consists of four honeycomb panels, two rings, and four launch escape tower leg wells. The panels are placed in a jig singly and trimmed longitudinally. The tower leg wells are installed, trimmed, and welded. The panels are then installed in a jig which accommodates all four panels, trimmed longitudinally, and butt-fusion welded. The welded panels and the rings are placed in another jig for circumferential trim, and the rings are then welded to the top and bottom of the panels. The completed assembly is fit-checked to the crew compartment and aft heat shields, and then removed for the application of ablative material.

5-13. The crew compartment heat shield is formed from steel honeycomb panels and rings. The panels are joined together by machined edge-members which provide door-opening lands and are attached to the inner crew compartment structure. The panels and rings are installed in a series of jigs for assembly, trimming, and welding. The welded sections are then placed in a large fixture for precision machining of the top and bottom rings. The assembly is fit-checked with the inner crew compartment, forward heat shield, and aft heat shield, and then removed for the application of ablative material.

5-14. The aft heat shield assembly consists of four brazed honeycomb panels joined laterally by fusion welds and attached to a 360-degree machined ring by spot-welded sheet metal fairings, using conventional mechanical fasteners. Holes for the inner and outer C/M component attach points and the tension tie locations are cut through the assembly by (tre-pan) machining. The completed aft heat shield is fit-checked with the crew compartment heat shield prior to the application of ablative material.



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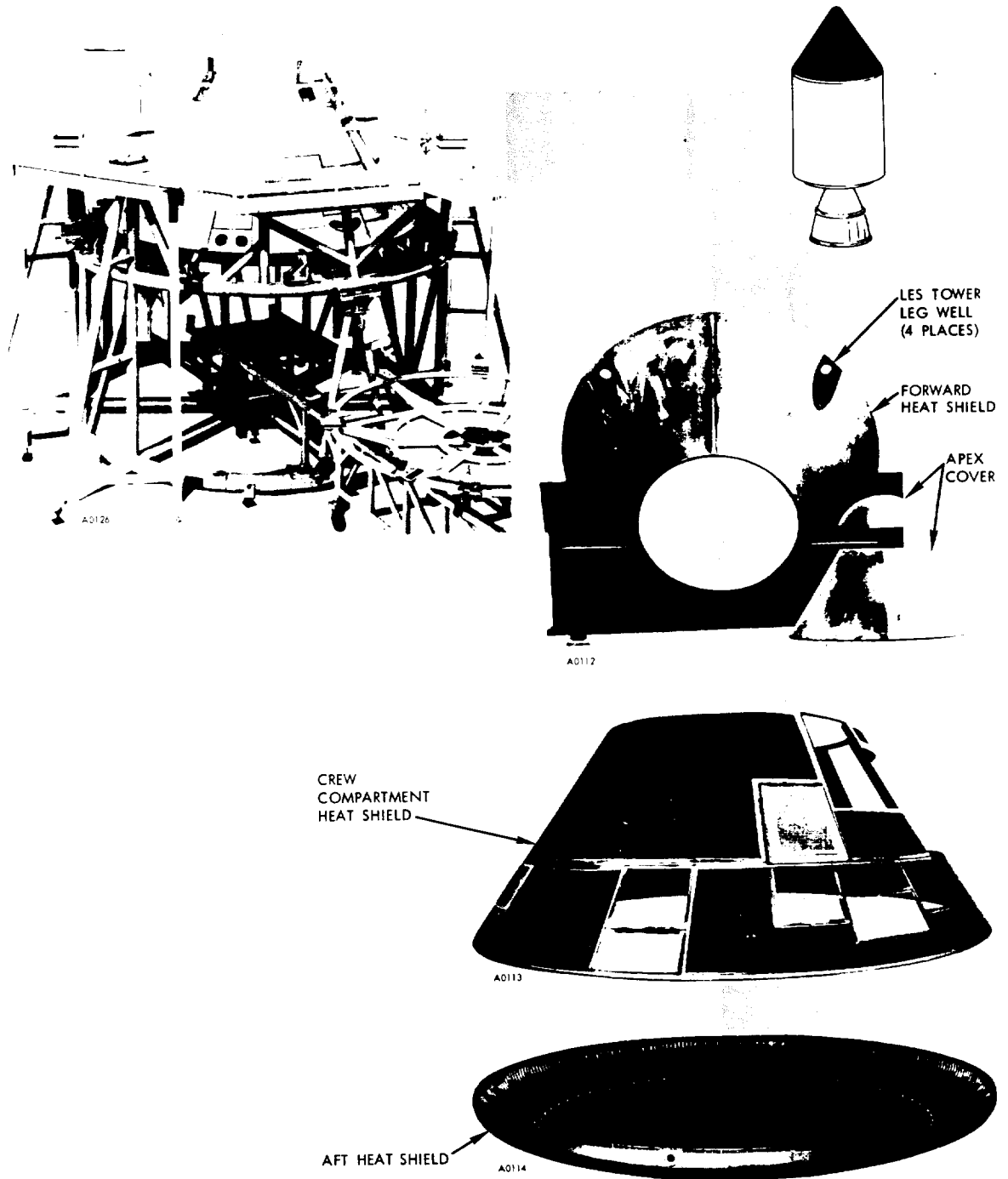
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Figure 5-3. Trim and Weld Closeout Operation

#### 5-15. SERVICE MODULE STRUCTURE.

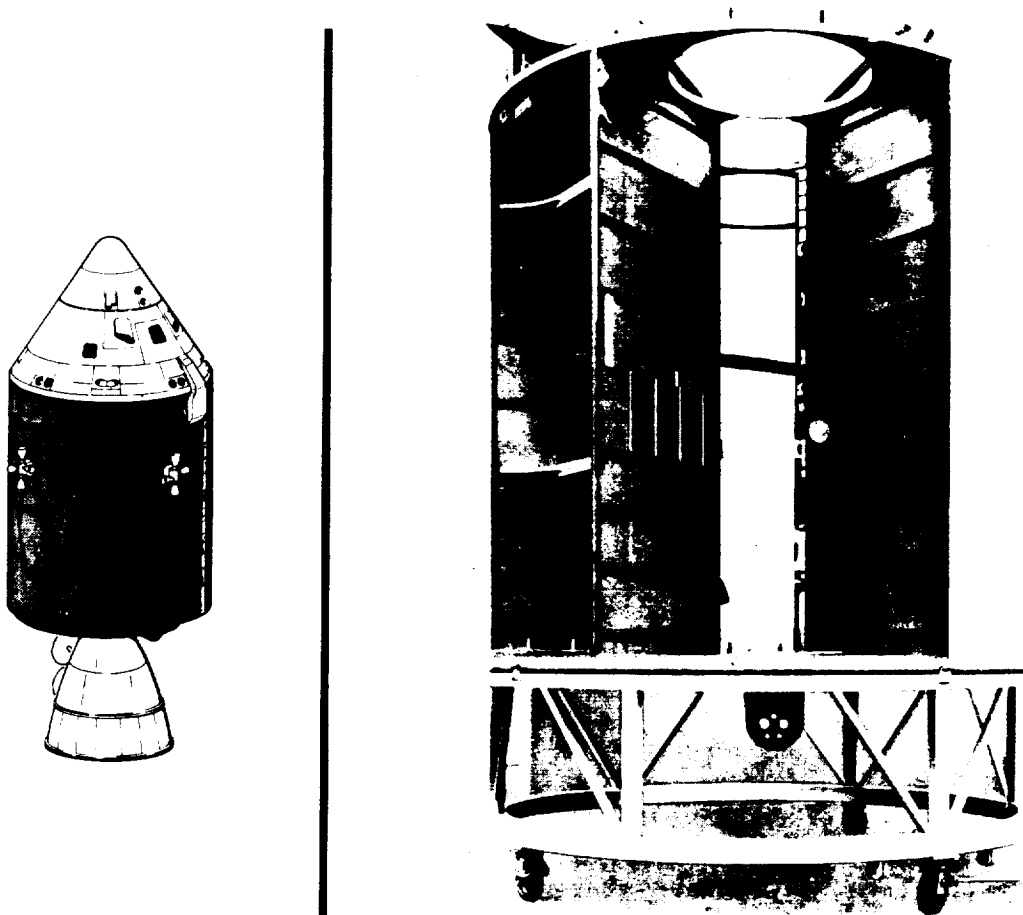
5-16. The service module consists basically of a forward and aft bulkhead, radial beams and outer panels, and is constructed primarily of aluminum alloy which is honeycomb bonded. The eight outer panels are aluminum honeycomb bonded between aluminum face sheets. The forward bulkheads of the Block II S/M will be constructed of sheet metal with the aft bulkhead remaining aluminum-bonded honeycomb. Six radial beams, which divide the cylinder into compartments, are machined and chem-milled to reduce weight in non-critical stress areas. Beams, bulkheads, and support shelves form the basic structure. (See figure 5-5.)

5-17. The fuel and oxidizer tanks, hydrogen and oxygen tanks, fuel cells, reaction control system, service propellant system, antenna equipment, electrical power system, and part of the environmental control system, are housed in the service module.



SM-2A-613B

Figure 5-4. Command Module Heat Shield Structure



A0125

SM-2A-612 A

Figure 5-5. Service Module Structure

#### 5-18. SPACECRAFT LM ADAPTER.

5-19. The spacecraft LM adapter (SLA) is a truncated cone, constructed of bonded aluminum honeycomb, which connects the S/M with the S-IVB instrument unit and houses the LM. The adapter is 28 feet in length, 12 feet 10 inches in diameter at the forward end, and 21 feet 8 inches in diameter at the aft end. The SLA consists of eight 2-inch-thick bonded aluminum honeycomb panels, which are joined together with riveted inner and outer doublers. Linear-shaped charges will be installed on four of the panels, which are hinged at the aft end, to provide a means of exposing the LM and separating the S/M from the SLA.

#### 5-20. MODULE MATING AND FINAL ASSEMBLY.

5-21. Upon completion of structural assembly, the modules are cleaned and sent to a cleanroom for installation and checkout of all systems. The modules are then mated for fit-check and alignment to ensure conformance to design. Alignment is checked optically

with theodolites, sight levels, or autocollimators. Each module is also given a weight and balance check to determine its center-of-gravity. Following completion of individual and combined systems checkout, a detailed prelaunch integrated systems check is performed. After assurance that all systems perform according to design criteria, the modules are demated, packaged, and shipped to the designated test site.



## APOLLO TRAINING EQUIPMENT

### 6-1. GENERAL.

6-2. The nature of the Apollo missions demands completely competent personnel for the program. A training program has been established to provide total competence and integration between management, staff, flight crew, flight and ground operations control, and test and operations personnel. Equipment for the training program includes Apollo mission simulators and Apollo systems trainers for various Apollo systems.

### 6-3. APOLLO MISSION SIMULATORS.

6-4. The Apollo mission simulator (figure 6-1) is a fixed-base training device, capable of simulating the characteristics of space vehicle systems performance and flight dynamics. The simulator provides training of Apollo flight crew members in the operation of spacecraft systems, space navigation, and crew procedures for space missions. In addition to normal spacecraft operation, the AMS simulates malfunctioning systems and degraded systems performance. To extend the simulators to full mission-training capability, telemetry data link, added visual window simulation and waste management have been added.

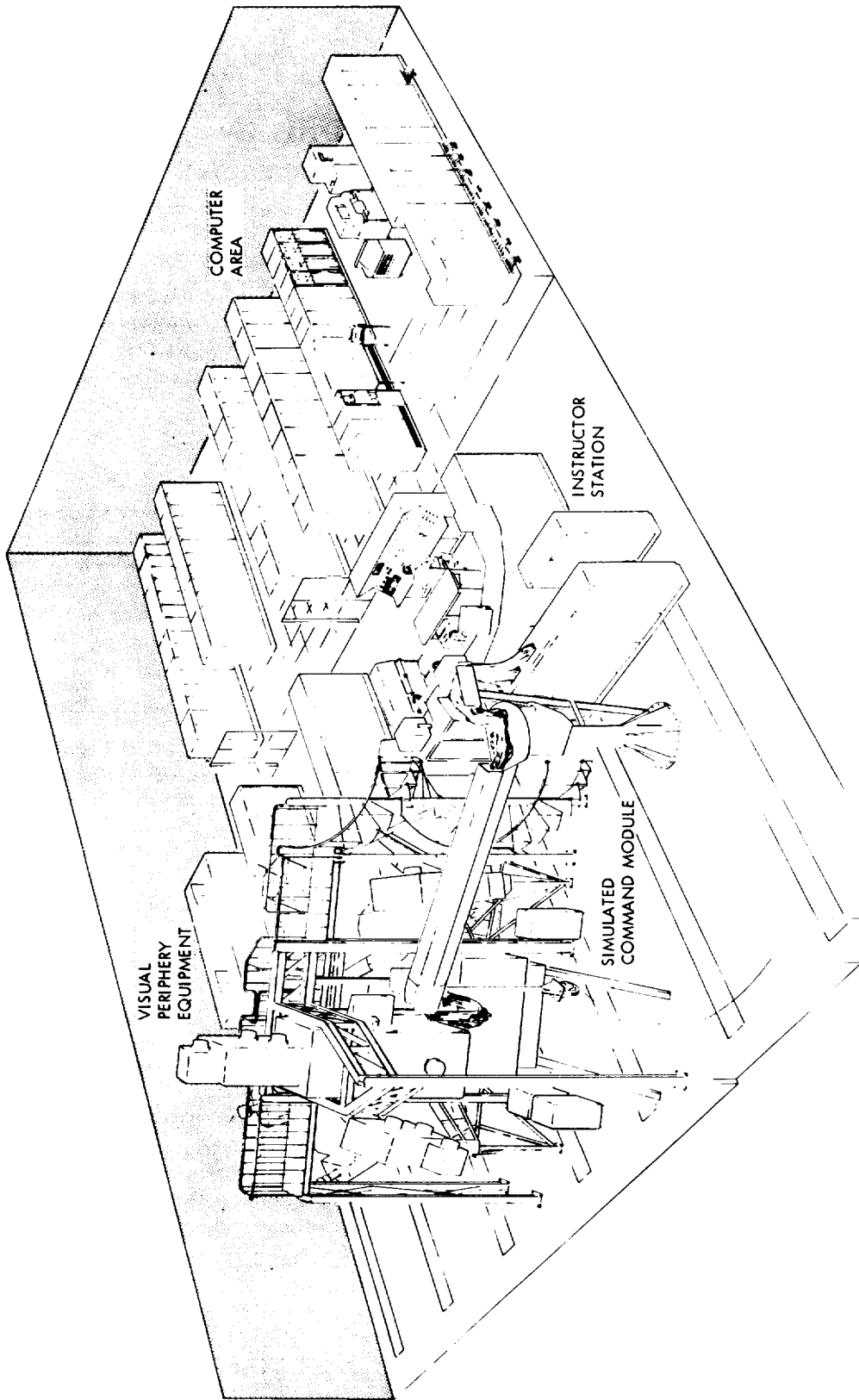
6-5. Although the Apollo mission simulators are intended to operate independently as full mission trainers for flight crews, they may also be used in an integrated mode with the mission control center (MCC) to simulate the spacecraft and provide flight crew training in conjunction with the operations support personnel operating the MCC and manned space-flight network.

6-6. One mission simulator is installed at MSC, Houston, Texas, and one at the Eastern Test Range, Kennedy Space Center, Florida.

### 6-7. SYSTEMS TRAINER.

6-8. The Apollo systems trainer complex is comprised of five display trainers, each having its own respective system control console. These training devices are intended to familiarize Apollo project personnel with the functional relationship of spacecraft systems, subsystems and components, the effects of malfunctions, and procedures of system management. The five display trainers are provided for the following spacecraft systems:

- Sequential flow, including the following integrated systems: launch escape, earth landing, emergency detection, and crew safety systems
- Stabilization and control system
- Electrical power system



SM-2A-480C

Figure 6-1. Apollo Mission Simulators Installation



- Environmental control system
- Spacecraft propulsion systems (service propulsion and reaction control systems)

6-9. The sequential flow display trainer is capable of accurately displaying a schematic diagram of all sequential operations of the launch escape, earth landing, emergency detection, and crew safety systems. Two panels are incorporated in the trainer to demonstrate normal launch, pad abort, high-altitude abort, early-mission termination, and normal earth landing sequence. Sequence malfunction simulation is limited to circuit interruption, disrupting component operation presented on the panel displays.

6-10. The stabilization and control display trainer presents a functional flow diagram depicting system operation including various switching functions. Simulated spacecraft panels are incorporated in the trainer to simulate the normal operation and malfunction of system components which control and stabilize the spacecraft flight attitude.

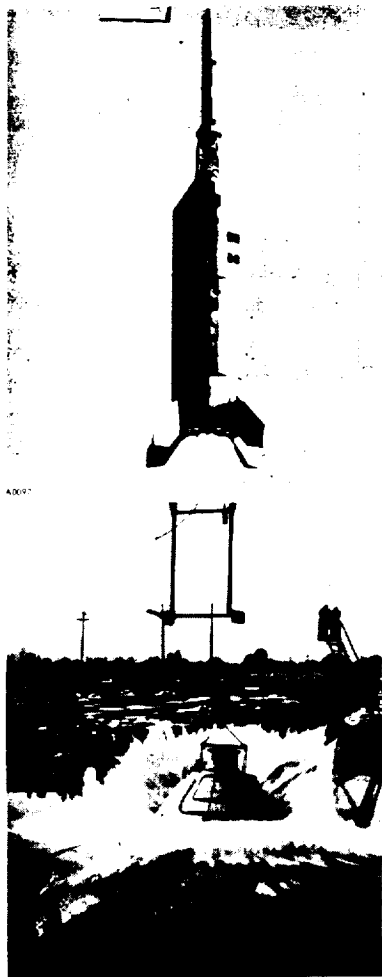
6-11. The electrical power system display trainer accurately depicts a schematic flow diagram showing d-c and a-c power distribution to the main buses, including fuel cell and cryogenic storage system flow diagrams. Panels on the trainer demonstrate fuel cell operation, inverter operation, battery recharging, bus switching, and systems management through use of spacecraft panel monitors. Malfunction inputs provide high or low voltage, overload, reverse current, and out-of-tolerance fuel cell monitoring conditions.

6-12. The environmental control system display trainer utilizes two panels to depict, by flow diagram, the pressure suit supply system, oxygen supply system, oxygen cryogenic input system, water-glycol system, and water system during normal ascent operation from the launch pad, while in space, and during entry. Simulated spacecraft panel monitors will be activated to show the pressures and temperatures for the operating modes. A malfunction capability is incorporated in the trainer to indicate high- or low-system parameters and, emergency conditions such as cabin pressure loss and contaminated potable water.

6-13. The propulsion system display trainer utilizes three display panels to present plumbing diagrams of the command module reaction control system, service module reaction control system, and service propulsion system in both manual and automatic modes of operation. Malfunction switches are incorporated in the panels to demonstrate visual malfunction of system components as indicated on spacecraft panel monitors.



## APOLLO TEST PROGRAM



### 7-1. GENERAL.

7-2. This section delineates the test program for the development of Apollo spacecraft. The development program is divided essentially into two blocks, with three interrelated phases: Block I boilerplate and spacecraft missions, Block II spacecraft missions, and propulsion system testing for both blocks. A description of ground support equipment categories and completed Apollo missions is also presented.

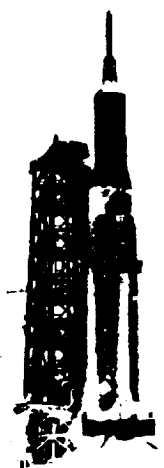
7-3. Boilerplates were research and development vehicles which simulated production spacecraft in size, shape, structure, mass, and center of gravity. Each boilerplate was equipped with instrumentation to record mission parameter data for engineering review and evaluation. The data gained from the testing of boilerplate configurations was used in determining production spacecraft flight parameters.

7-4. Spacecraft are production vehicles. These vehicles incorporate numerous modification, flight profile changes, and operating technique revisions deemed necessary as a result of boilerplate mission evaluations. Spacecraft configurations vary in order to meet interface requirements of Saturn V and up-rated Saturn I boosters. Variations are made in the spacecraft adapters and the inserts required to satisfy booster interface. C/M and S/M size remain constant.

7-5. Propulsion system testing is accomplished with propulsion system test fixtures. The fixtures are not ground support equipment items, but are unique test platforms for the spacecraft propulsion system. The fixtures are fully instrumented to record engine and propellant system operation through varied operating ranges.

### 7-6. SPACECRAFT DEVELOPMENT.

7-7. Spacecraft development includes tests and vehicles used for the development of manned spacecraft. The relation between test vehicles, boilerplates, spacecraft, and the Apollo spacecraft development program is shown in figure 7-1.



- MAJOR GROUND TESTS**  
(BP14)  
HOUSE SPACECRAFT  
HARDWARE DEVELOPMENTAL TOOL  
VIBRATION AND ACOUSTIC TESTS  
(COMPLETED)
- ENVIRONMENTAL PROOF TESTS**  
(THERMAL VACUUM) (S/C 008)  
EVALUATE S/C UNDER SIMULATED  
MISSION ENVIRONMENTAL CONDITIONS
- PROPULSION TESTS (F-1,  
F-2, F-3, S/C 001)**  
SYSTEM COMPATIBILITY TESTS
- RECOVERY AND IMPACT TESTS**  
(BP1, BP2, BP3, BP6A, BP6B, BP12A, BP19,  
BP28, BP29, S/C 002A, S/C 007)
- MODAL, LAND AND WATER IMPACT TESTS,  
AND FLOTATION/UPRIGHTING TESTS
- PARACHUTE RECOVERY TESTS
- STRUCTURAL TESTS (S/C 004, S/C 004A), S/C 006**  
VERIFY RIGIDITY AND STRUCTURAL  
INTEGRITY UNDER SIMULATED  
LOADING CONDITIONS
- DYNAMIC TESTS (BP9,  
BP27)**  
DETERMINE STRUCTURAL  
COMPATIBILITY WITH LAUNCH  
VEHICLES
- MICROMETEOROID EXPERIMENT**  
BP16, BP26, AND BP9A MISSIONS  
SUCCESSFUL
- ABORT TESTS (BP6, BP12, BP22,  
BP23, BP23A, S/C 002)**  
ABORT CAPABILITIES FOR PAD,  
TRANSONIC, HI-ALTITUDE, AND  
HI-Q VERIFIED. (BP6, BP12, BP22, BP23,  
AND BP23A MISSIONS COMPLETED)
- LAUNCH ENVIRONMENT TESTS**  
(BP13, BP15)  
QUALIFY LAUNCH VEHICLES  
(BP13 AND BP15 MISSIONS COMPLETED)
- UNMANNED FLIGHTS S/C 009,  
S/C 011, S/C 017, S/C 020)**  
SUPERCIRCULAR ENTRY  
FLIGHT TO QUALIFY S/C  
SYSTEMS & HEATSHIELD  
PRIOR TO MANNED FLIGHT
- MANNED CONFIGURATION (S/C 012,  
S/C 014)**  
MANNED CONFIGURED FLIGHT TO  
DEMONSTRATE OPERATION AND PERFORMANCE  
OF S/C AND SYSTEMS.

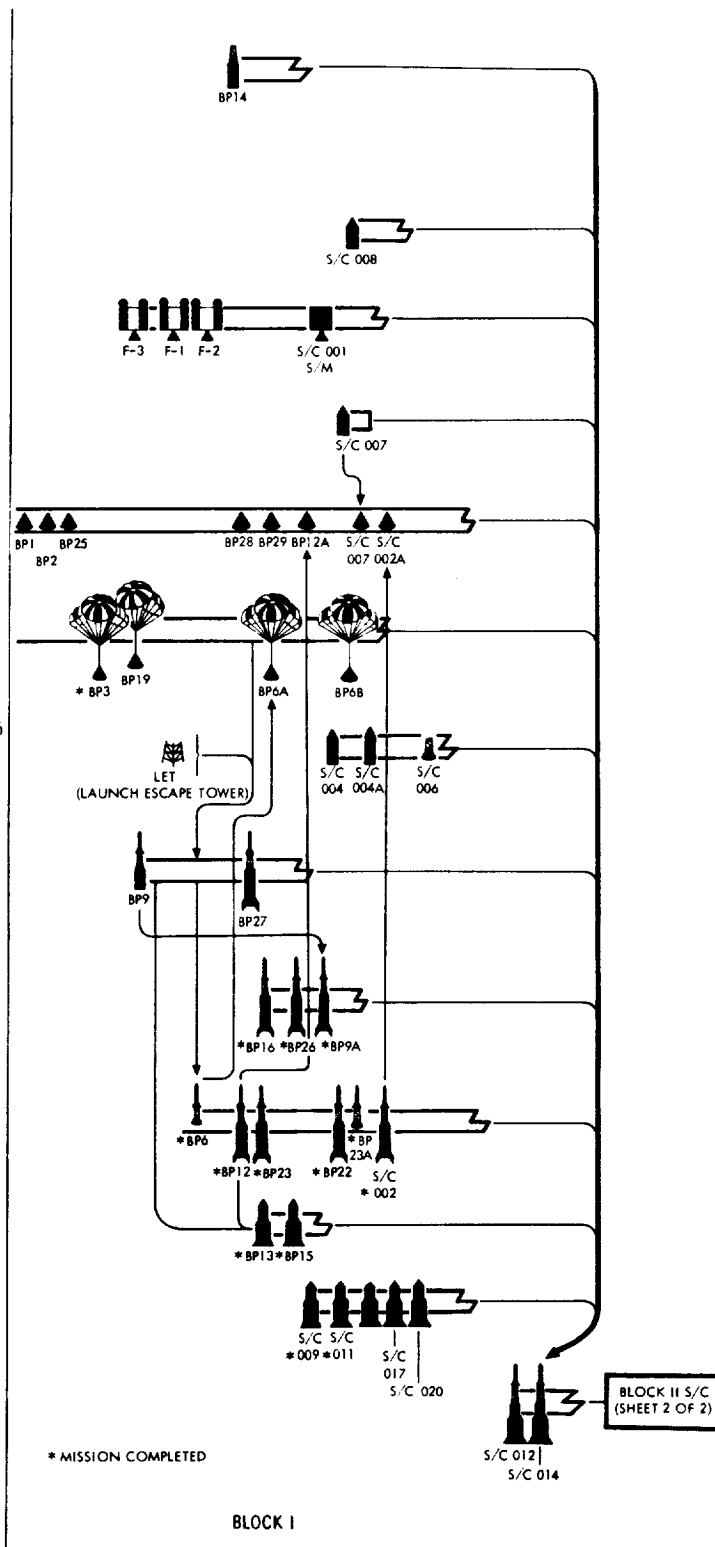
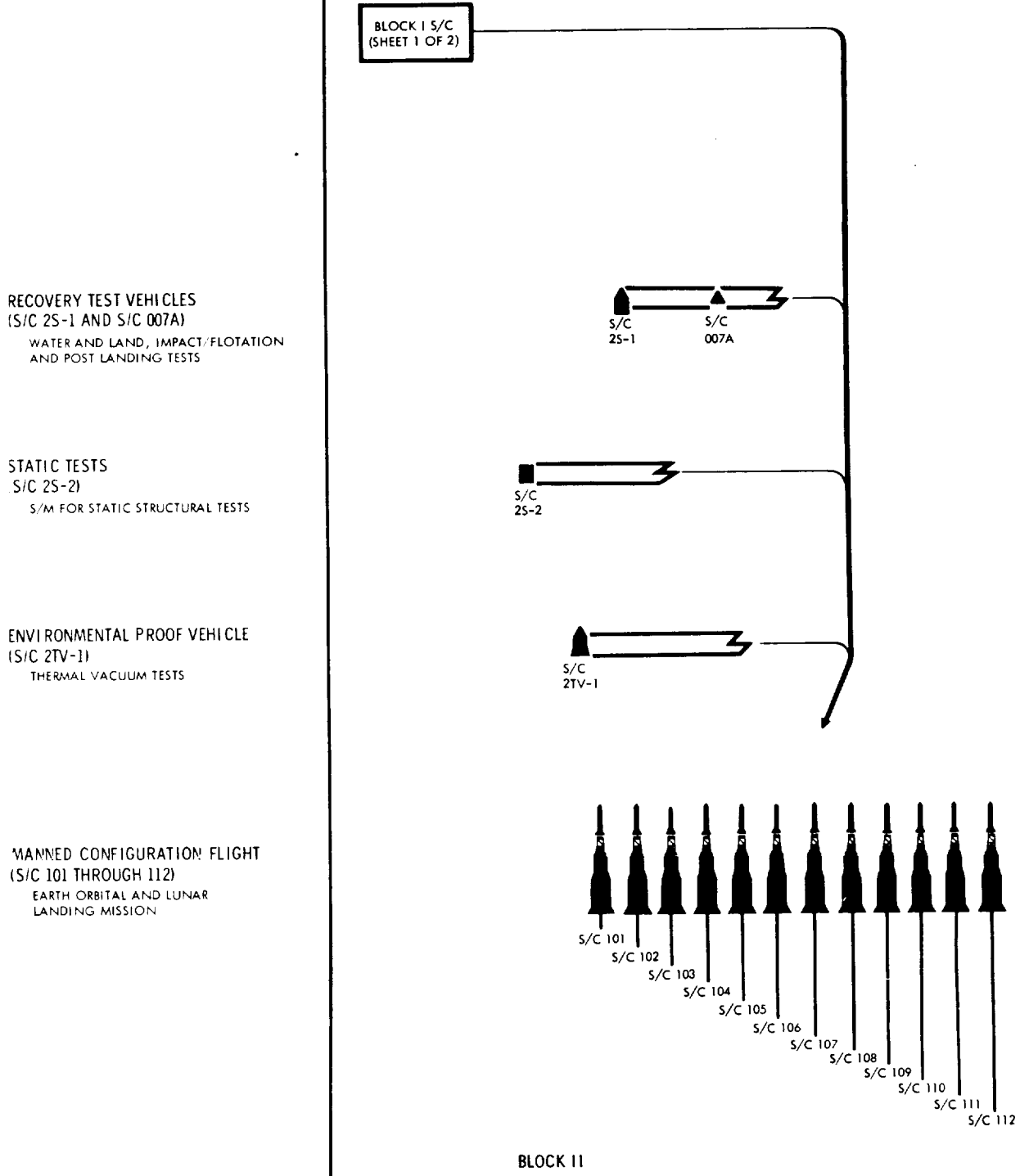


Figure 7-1. Apollo Spacecraft Development Program (Sheet 1 of 2)



SM-2A-B34B

Figure 7-1. Apollo Spacecraft Development Program (Sheet 2 of 2)



SYSTEMS CONFIGURATION LEGEND	NOTE:			DESCRPTIONS	SYSTEMS																																	
	SPACECRAFT	TEST SITES	MISSIONS OR PURPOSE		Command Module Service Module Boat Protection Cover	Structure	SPACECRAFT ADAPTER	SLA Evolution Special	Saturn I / Updated Saturn II Little Joe II	LAUNCH VEHICLES	LAUNCH VEHICLES	Launch Escape Motor Pich Control Motor Abort Motor Abort-Submotor Canard	SERVICE PROPELLSION SYSTEM (SPS)	LES CSM SM SA LEM SLA	SEPARATION SYSTEM	Earth Recovery Aid Recovery Sequencer Emergency Return Vehicle (ERV) SYSTEM (GRN)	STABILIZATION & CONTROL SYSTEM (SCS)	TELEMETRY CONTROL SYSTEM (TECS)	CM ENVIRONMENTAL CONTROL SYSTEM (ECS)	CM ELECTRICAL POWER SYSTEM (EPS)	COMMUNICATIONS SYSTEM	DEEP SPACE (S-BAND) EQUIP.	INSTRUMENTATION SYSTEM	CONTROLS AND DISPLAYS	APOLLO MISSION PROGRAMMER	CREW COUCHES	SUPPORT & RESTRAINT	CREW SYSTEM	ANTHROPOMORPHIC DUMMIES	LUNAR MODULE (LM)								
EARTH RECOVERY AND IMPACT TEST VEHICLES 	S/C 002A	DOWNEY, CALIF.	S/C 002 REFURBISHED FOR LAND IMPACT TESTS	C																																		
	S/C 007	DOWNEY, CALIF. AND MSC	SPACECRAFT FOR ACOUSTIC, WATER IMPACT AND POST LANDING TESTS	SPCCS									S	SSS	SSS	SSS	PCC	S	S	S	S	S	S	S	S	S	S	S	P	S	P	S	S	S	S	S		
ABORT TEST VEHICLES 	S/C 002	WSPM	POWER ON TUMBLING ABORT	CCCC	C			C	CCCCCC			CC	CC	C	C	P			S		P	P																
STRUCTURAL TEST VEHICLES 	S/C 004	DOWNEY, CALIF.	STATIC STRUCTURAL TESTS	SPCCSP			C					S	PPP	P																								
	S/C 004A	DOWNEY, CALIF.	STATIC AND THERMAL STRUCTURAL TESTS	C										P																								
	S/C 006	DOWNEY, CALIF.	CM FOR ELS LOAD TESTS AND LET SEPARATION TESTS	CC										P																								
ENVIRONMENTAL PROOF VEHICLE 	S/C 008	MSC	EVALUATE S/C UNDER SIMULATED MISSION ENVIRONMENTAL CONDITIONS THERMAL VACUUM TESTS	CC	C							S	SS	CPC	C	C	P	C	CC	CC	C	P	C	SP	C	C	C	C										
PROPULSION TEST VEHICLES 	S/C 001	(PSDF) WSPM	COMPATIBILITY VERIFICATION OF S/C SERVICE MODULE PROPULSION SYSTEMS WHEN INTEGRATED WITH S-M SUBSYSTEM	C	C							C	P					SP	C	P	C																	
UNMANNED FLIGHT VEHICLES 	S/C 009	CAPE KENNEDY	SUPER CIRCULAR ENTRY FLIGHT TO QUALIFY S/C PRIOR TO MANNED FLIGHT	CCCC	C		C		CCCC	C	CCC	CCCC			P	C	C	P	P	P	P	P			P	P	P											
	S/C 011	CAPE KENNEDY	SUPER CIRCULAR ENTRY FLIGHT TO DEMONSTRATE OPERATIONAL AND PERFORMANCE OF S/C AND SYSTEMS	CCCC	C		C		CCCC	C	CCC	CCCC	C		P	C	C	CC	CC	C	C	P	C			C	C											
	S/C 017	CAPE KENNEDY	SIMULATED LUNAR RETURN ENTRY	CCCC	C		C		CCCC	C	CCCC	CCCC	P	P	C	C	CC	CC	P	P	P	P			P	P	P	P										P
	S/C 020	CAPE KENNEDY	SIMULATED LUNAR RETURN ENTRY	CCCC	C		C		CCCC	C	CCCC	CCCC	P	P	C	CC	CC	CC	P	P	P	P			P	P	P	P										
MANNED CONFIGURATION VEHICLES FLIGHT 	S/C 012	CAPE KENNEDY	EARTH ORBITAL FLIGHT & SEA RECOVERY TO EVALUATE IN-FLIGHT OPERATIONS	CCCC	C		C		CCCC	C	CCC	CCCC	C	C	C	C	CC	CC	C	C	C	C	P	C	C	C	C						M2	C	C	C	C	
	S/C 014	CAPE KENNEDY	EARTH ORBITAL FLIGHT TO EVALUATE IN-FLIGHT CSM OPERATIONS	CCCC	C		C		CCCC	C	CCC	CCCC	C	C	C	C	CC	CC	C	C	C	C	P	C	C	C	C						M2	C	C	C	C	

Figure 7-3. Block I Spacecraft Vehicle Systems Configuration for Spacecraft Development

SM-2A-578G

7-8. Boilerplate and spacecraft vehicle systems configuration for spacecraft development of Block I and Block II vehicles is shown in figures 7-2 through 7-4. Letters are used to designate the following: a complete system (C), a partial system (P), R&D instrumentation equipment only (R), a simulated or inert system (S), a special system (SP), and different configurations of the Apollo mission program (M1, M2, or M3). A blank space in any column indicates the described system is not installed.

#### 7-9. BLOCKS I AND II.

7-10. A block concept is used for spacecraft development to separate the vehicles into different phases, such as research and development (Block I) and production vehicles for earth orbital and lunar missions (Block II). Paragraphs 7-11 through 7-14 give a breakdown of Blocks I and II and their functions.

#### NOTE

Block II information is based on preliminary data only.

7-11. Block I encompasses the entire boilerplate program, and spacecraft 001, 002, 002A, 004, 004A, 006, 007, 008, 009, 011, 012, 014, 017, and 020.

7-12. The boilerplate portion of Block I provide:

- a. Early support of systems development for land impact, water impact, and parachute recovery prequalification tests
- b. Systems qualification to support spacecraft programs including pad abort, high-altitude abort, and house spacecraft No. 1 (boilerplate 14) which contains all systems
- c. Marshall Space Flight Center support including Saturn I development and micro-meteoroid detection
- d. Space-flight capabilities development and coordination of manufacturing, testing operations, engineering, and NASA functions.

7-13. The spacecraft portion of Block I provides:

- a. Command module and service module development for manned earth orbital missions
- b. Demonstration of operational capabilities of systems including all types of aborts, land recovery, water recovery, uprated Saturn I and Saturn V operation (and compatibility), and operation during earth orbits (unmanned)
- c. Qualified teams development for checkout, launch, manned space flight network, recovery, and flight analysis.

#### NOTE

S/C 007 will be refurbished and designated 007A for Block II postlanding tests.

7-14. Block II encompasses spacecraft 2S-1, 007A, 2S-2, 2TV-1, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, and 112, and provides:

- a. Incorporation of lunar module provisions
- b. Improvement of center-of-gravity in command module
- c. Evaluation and incorporation of system changes with respect to lunar mission and reliability impact.



SYSTEMS CONFIGURATION LEGEND			NOTE	DESCRIPTION	Spacecraft or Mission		System/Component																					
SPACECRAFT NUMBER	TEST SITE	MISSIONS OR PURPOSE			Spacecraft Module	Service Module	SLA	Service Module	Launch Vehicle	Launch Escape Motor	Launch Escape System	Service Module	SEPARATION SYSTEM	SEQUENCE CONTROLS	RECOVERY SYSTEMS (RE)	GUIDANCE & NAVIGATION SYSTEM (GEN)	STABILIZATION & CONTROL SYSTEM (SC)	REACTION CONTROL SYSTEM (RCS)	ENVIRONMENTAL CONTROL SYSTEM (ECS)	ELECTRICAL POWER SYSTEM (EPS)	COMMUNICATIONS SYSTEM	INSTRUMENTATION SYSTEM	CONTROLS AND DISPLAYS	EMERGENCY DETECTION SYSTEM	CREW EQUIPMENT	LEMAR MODULE	LEM DOKING SYSTEM	
MAJOR GROUND TEST VEHICLES																												
RECOVERY TEST VEHICLES			25-1	DOWNNEY, CALIF.	MODAL, ACOUSTIC, FLOTATION AND IMPACT	C	C					S S S S	S S S S S	S S C	S	S	C	S S	S S	S	S	P	S		C S C	S P		
STATIC TESTS			25-2	DOWNNEY, CALIF.	S-M FOR STAT C TESTS	SP P C C	C					P P P										P	S			P		
ENVIRONMENTAL PROOF VEHICLE			2TV-1	MSC	THERMAL VACUUM TESTS	C	C				S	S S S S	C C C C C	C C C	C	C	S	S C	C C	C S	S	C P P	C	C	C C C	C C		
MANNED FLIGHTS																												
			101	CAPE KENNEDY	ELLIPTICAL EARTH ORBITAL FLIGHT TO EVALUATE RENDEZVOUS AND DOCKING MANEUVERS	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P P	C	C	C	C C		
			102	CAPE KENNEDY	SMALL ELLIPTICAL EARTH ORBITAL FLIGHT TO EVALUATE RENDEZVOUS AND DOCKING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			103	CAPE KENNEDY	LUNAR LANDING RESEARCH AND DEVELOPMENT	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			104	CAPE KENNEDY	LUNAR LANDING TO EVALUATE MAN ON LUNAR SURFACE AND DEMONSTRATE CAPABILITY	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			105	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			106	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			107	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			108	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			109	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			110	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C
			111	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C		
			112	CAPE KENNEDY	LUNAR LANDING	C	C	C	C	C	C	C C C C	C C C C	C C C	C	C	C C C	C C C	C C	C C C	C C C	C P C	C	C	C	C C		

Figure 7-4. Block II Spacecraft Vehicle Systems Configuration for Spacecraft Development

7-15. The primary differences between the systems of Block I and Block II manned spacecraft are listed as follows:

Spacecraft System	Block I	Block II
ELS	Nylon main parachute risers.	Steel cable main parachute risers.
ECS		Redundant coolant loop added. LM pressurization controls added to C/M.
EPS	S/M separation batteries A and B, used to separate C/M-S/M.	No S/M separation batteries – capabilities for C/M-S/M separation added to fuel cells. One flight bus (d-c) added. No frequency meter on MDC.
RCS	No fuel dump capability in C/M.	Rapid fuel dump C/M-RCS.
G&N	Interfaces with SCS.  Long-relief-eyepieces installed by astronauts.  CDUs electro-mechanical.	Completely independent of SCS.  Long-relief-eyepieces incorporated into sextant and telescope.  CDUs all electronic.  AGC size reduced and memory capacity increased.  Reduced size and weight of IMU. Redesigned navigation base.
SCS	Interfaces with G&N.  One FDAI AGCU  Rate gyro assembly	Two FDAIs  Gyro display coupler (GDC) in place of AGCU.  BMAG assembly in place of RGA.
Crew system	No portable life support system.  Three one-man liferafts.  Fluorescent illumination.  No EVT capabilities.	Portable life support system (PLSS).  One three-man liferaft.  Electroluminescent, fluorescent, and incandescent illumination.  Extravehicular transfer (EVT) and tethering capabilities.

Spacecraft System	Block I	Block II
T/C	C-band transponder. One S-band transponder. One S-band power amplifier. No high-gain antenna.  No rendezvous transponder and antenna.	C-band transponder in S/C 101 and 102 Two S-band transponders. Two S-band power amplifiers. High-gain antenna and controls. Additional VHF/AM capabilities. Rendezvous radar transponder and antenna.
Docking system	None	Installed in Block II S/C only.

#### 7-16. BOILERPLATE MISSIONS.

7-17. The boilerplate missions were primarily research and development tests to evaluate the structural integrity of the spacecraft and confirm basic engineering concepts relative to system performance and compatibility. A number of missions were conducted during this phase of the test program. The missions were scheduled to follow a pattern of development starting with basic structure evaluation, followed by systems performance and compatibility confirmation.

7-18. Each mission was dependent upon the previous mission in developing the systems and operations requisite for lunar exploration. Prior to the start of any mission, the boilerplate to be tested was thoroughly checked at the manufacturer test preparation area under the direction of NASA inspectors. After system and structural checkout was approved, the boilerplate was shipped to the test site for further checkout and mating. A launch countdown was started only after the second checkout and mating had been approved. Figure 7-5 depicts a water impact test.

7-19. BLOCK I BOILERPLATE TEST PROGRAM. The following is a list of each boilerplate and relative mission data. Boilerplates and their missions are part of the Block I portion of the Apollo program. The list is intended as a cross-reference for boilerplate objectives. Chronological order of missions and test grouping is not intended or reflected in the arrangement of the list.

Boiler-plate No.	Test Site	Purpose	Mission	Launch Vehicle
BP1	Downey, Calif.	Development and evaluation of crew shock absorption system; evaluation of C/M on land and water, during and after impact.	Drop tests utilizing impact facility at Downey, Calif.	None
BP2	Downey, Calif.	Same as BP1 and development of the uprighting system.	Drop tests and uprighting tests utilizing impact facility at Downey, Calif.	None

## Block I Boilerplate Test Program (Cont)

Boiler-plate No.	Test Site	Purpose	Mission	Launch Vehicle
BP3	El Centro, Calif.	To evaluate parachute recovery system in the air (destroyed).	Parachute recovery via air drop.	Aircraft (drop)
BP6	White Sands Missile Range (WSMR), New Mexico	To determine aerodynamic stability, tower vibration, and spacecraft dynamics during a pad abort; to demonstrate capability of LES to propel C/M to a safe distance from launch area during a pad abort.	Pad abort mission successfully completed 7 November 1963.	Launch escape system motor
BP6A	El Centro, Calif.	BP6 refurbished for parachute recovery system test in the air.	Parachute recovery system evaluation via air drop.	Aircraft (drop)
BP6B	El Centro, Calif.	BP6A refurbished for parachute recovery system tests.	Parachute recovery system evaluation tests.	Aircraft (drop)
BP9	Marshall Space Flight Center (MSFC), Alabama	Dynamic test to be determined by National Aeronautics and Space Administration.	Determination of dynamic structural compatibility of test S/C with Saturn I.	None
BP9A	Kennedy Space Center, Florida	Utilized for launch vehicle qualification and micrometeoroid experiment.	Micrometeoroid experiment. Successfully launched into orbit 30 July 1965.	Saturn I
BP12	WSMR, New Mexico	To determine aerodynamic stability characteristics of Apollo escape configuration during transonic abort from Little Joe II. To demonstrate capability of LES to propel C/M to safe distance from launch vehicle during an abort at high-dynamic pressure. To demonstrate structural integrity of launch escape tower and operational characteristics during a transonic abort, and demonstrate spacecraft-Little Joe II compatibility.	Transonic abort mission successfully completed 13 May 1964.	Little Joe II

## Block I Boilerplate Test Program (Cont)

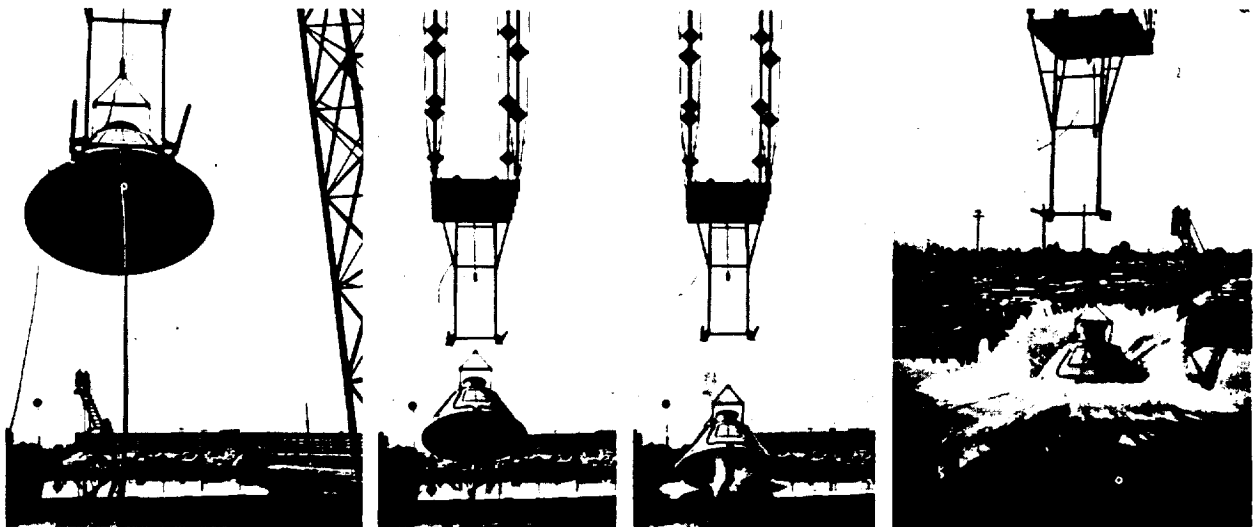
Boiler-plate No.	Test Site	Purpose	Mission	Launch Vehicle
BP12A	Downey, Calif.	BP12 refurbished to evaluate C/M during hard rollover water landing condition.	Water impact test utilizing impact facility at Downey, Calif.	None
BP13	Kennedy Space Center, Florida	To qualify Saturn I launch vehicle, demonstrate physical compatibility of launch vehicle and spacecraft under preflight and flight conditions, and determine launch and exit environmental parameters to verify design criteria.	Launch environment mission successfully completed 28 May 1964 to 31 May 1964.	Saturn I
BP14	Downey, Calif.	Developmental tool (house spacecraft No. 1) for use in developing spacecraft systems and preliminary checks in integrated systems compatibility.	Research and developmental tool for systems evaluation (static vehicle).	None
BP15	Kennedy Space Center, Florida	Second boilerplate flown for environmental data. The purpose of this vehicle and BP13 are similar.	Launch exit environment (orbital flight trajectory) mission successfully completed 18 September 1964 to 22 September 1964.	Saturn I
BP16	Kennedy Space Center, Florida	To be utilized for launch vehicle qualification and micrometeoroid experiment.	Micrometeoroid experiment. Successfully launched into orbit 16 February 1965.	Saturn I
BP19	El Centro, Calif.	To evaluate parachute recovery system in the air.	Parachute recovery system evaluation through means of command module air drop.	Aircraft (drop)
BP22	WSMR, New Mexico	To verify LES, ELS, and canard system during high-altitude abort.	Qualify LES, ELS sequence timing during abort. Mission completed 19 May 1965.	Little Joe II

## Block I Boilerplate Test Program (Cont)

Boiler-plate No.	Test Site	Purpose	Mission	Launch Vehicle
BP23	WSMR, New Mexico	Verification of LES and ELS during high-Q abort.	Demonstration of launch escape vehicle structural integrity and recovery of C/M following high-Q abort. Successfully completed mission 8 December 1964.	Little Joe II
BP23A	WSMR, New Mexico	To qualify LES, ELS sequence timing, canard system, dual drogue parachutes, and boost protective cover during pad abort test. BP23 C/M refurbished for pad abort test.	C/M for pad abort evaluation. Mission completed 29 June 1965.	Launch escape system motor.
BP25	Houston, Texas	To demonstrate pickup and handling techniques as required by National Aeronautics and Space Administration.	Demonstration of equipment and handling capability for command module at a site (simulated) recovery as a design for pickup equipment.	None
BP26	Kennedy Space Center, Florida	To be utilized for launch vehicle qualification and micrometeoroid experiment.	Micrometeoroid experiment using NASA-installed equipment. Successfully launched into orbit 25 May 1965.	Saturn I
BP27	MSFC, Alabama	Second dynamic test. Objectives for this ground test will be determined by National Aeronautics and Space Administration.	Determination of dynamic structural compatibility of test S/C with uprated Saturn I and Saturn V launch vehicles.	Uprated Saturn I and Saturn V (Captive test firing)

Block I Boilerplate Test Program (Cont)

Boiler-plate No.	Test Site	Purpose	Mission	Launch Vehicle
BP28	Downey, Calif.	Test vehicle will be impacted (land and water) a number of times in order to evaluate loads imposed on structure due to landing impact and acceleration, accelerations and onset rates imposed on crew by the crew couch attenuation system, stability, and dynamics of the vehicle.	Definition of landing problems by determination and evaluation of loads imposed on structure due to landing impact, and acceleration and onset rates imposed on crew by crew couch attenuation system.	None
BP29	MSC Houston, Texas	To determine flotation characteristics of command module and to qualify Block I uprighting system.	Full-scale flotation and recovery tests for simulated entry and abort conditions.	None



A PENDULUM FOR APOLLO—An impact test facility, from which NASA's unmanned Apollo test command modules are swung and dropped on land or water, is seen in operation at Downey, Calif. The Apollo command module is suspended below the steel platform and the huge "arm" swings the capsule, releasing it at controlled angles and speeds to simulate impact which later manned Apollo spacecraft will undergo upon return to earth.

SM-2A-488A

Figure 7-5. Structural Reliability Test

## 7-20. SPACECRAFT MISSIONS.

7-21. Spacecraft missions, conducted with production spacecraft, are of a multipurpose nature. The initial missions were conducted to verify production spacecraft structural integrity, and systems operation and compatibility. After the spacecraft structure and systems test missions were completed, a series of unmanned missions were conducted to confirm spacecraft-launch vehicle compatibility and evaluate prelaunch, launch, mission, and post-mission operations. Manned spacecraft missions will be conducted to improve performance and confirm capability between man and spacecraft.

7-22. Each spacecraft mission is dependent upon the success of the previous mission, as an overall program of progressive, manned, space penetration is planned to afford the flight crew maximum familiarity with production spacecraft maneuvers and docking techniques with the LM. Manned missions will penetrate deeper into space as the program progresses. Manned space-flight network techniques will be employed during all earth orbital missions. The system compatibility with Apollo spacecraft will be determined during this phase of the test program. The knowledge gained by the flight crew and engineering personnel during this phase will be analyzed for use during manned lunar surface exploration.

7-23. BLOCK I SPACECRAFT TEST PROGRAM. The following is a complete list of Apollo spacecraft, their missions, and relative data required to complete the Block I portion of the Apollo program. The list is similar in intent to that of paragraph 7-19; the chronological order of spacecraft missions is not intended or reflected in the arrangement of the list.

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
001	Propulsion System Development Facility (PSDF), White Sands, Missile Range (WSMR), New Mexico	To verify compatibility of spacecraft S/M propulsion system; evaluate S/M service propulsion system and reaction control system during malfunction, normal, and mission profile conditions. To evaluate interface compatibility between all onboard systems during integrated systems test; evaluate performance and compatibility pertaining to ground support equipment, safety rules, operating techniques, and checkout of applicable systems.	Determine spacecraft structural vibration and acoustic characteristics during all phases of SPS operation, and performance of electrical power system and cryogenic storage subsystem during service propulsion and reaction control systems operation.	None (See figure 7-6.)
002	WSMR, New Mexico	To demonstrate structural integrity of production C/M under high dynamic pressure at transonic speed. To determine operational characteristics during power on tumbling abort.	Abort at high dynamic pressures in transonic speed range. Mission successfully completed 20 Jan 1966	Little Joe II



## Block I Spacecraft Test Program (Cont)

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
002A	Downey, Calif.	S/C 002 refurbished for land impact tests to verify structural integrity of C/M and assure acceptable crew accelerations during land impact.	Land impact tests utilizing impact facility at Downey, Calif.	None
004	Downey, Calif.	S/C for verification of structural integrity and intramodular compatibility of combined module structures under critical loadings.	Static tests.	None
004A	Downey, Calif.	Verification of structural integrity and intramodular compatibility of combined module structures under critical loading.	Static and thermal structural tests.	None
006	Downey, Calif.	C/M ELS load tests and C/M-LET separation tests.	Systems evaluation.	None
007	Downey, Calif. and MSC	This spacecraft will serve a dual purpose: module transmissibility and water impact and flotation tests. Module transmissibility test will determine free-fall lateral bending modes, and longitudinal and shell modes, utilizing two spacecraft configurations. Configuration A will incorporate launch escape tower and C/M; configuration B will incorporate C/M and S/M. Water impact and flotation tests will utilize C/M only. Purpose of water impact test is to verify structural integrity of C/M and crew support system dynamics under shock conditions at water impact. Flotation tests will demonstrate C/M flotation and water-tight integrity in varying sea conditions as well as crew survival in a closed module, and crew egress in varying sea conditions.	Acoustic, water impact, and post-landing tests.	None
008	MSC, Houston, Texas and Downey, Calif.	Spacecraft 008 will undergo both manned and unmanned deep-space environmental control tests. The first of these tests will be conducted at Downey, Calif. After	Thermal vacuum tests.	None

## Block I Spacecraft Test Program (Cont)

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
		operational checkout of installed systems, spacecraft will be shipped to MSC facility at Houston, Texas, for evaluation and verification of complete spacecraft design under launch simulation, orbital mission simulation, thermal investigation, system failure increments, emergency operations, module separation, entry separation, and recovery aids checkout.		
009	Kennedy Space Center, Florida	To evaluate heat shield ablator performance, RCS and SPS operations, SCS operation, open loop EDS and partial EPS operation. To determine loading separation characteristics and communications performance. To demonstrate operation of recovery system, launch vehicle and spacecraft compatibility. A mission programmer, model M1, controlled S/C in-flight operations.	Supercircular high-heat rate entry flight.  Mission successfully completed 26 Feb 1966	Uprated Saturn I
011	Kennedy Space Center, Florida	An unmanned flight to evaluate heat shield ablator performance, EDS performance, and SPS propellant retention device. Determine SLA structural loading, separation characteristics, performance of G&N, SCS, ECS, EPS, RCS, and telecommunications. To demonstrate launch vehicle and S/C compatibility, structural integrity, C/M entry, multiple SPS restarts, and recovery. S/C was controlled by model M3 mission programmer.	A supercircular high-heat load entry flight.  Mission successfully completed 25 Aug 1966	Uprated Saturn I

## Block I Spacecraft Test Program (Cont)

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
012	Kennedy Space Center, Florida	A manned configured flight to evaluate crew-S/C compatibility, crew tasks and subsystems performance, manual, and backup modes of subsystem separations. To demonstrate closed loop EDS.	An open-end orbital flight for CSM subsystem performance.	Upgraded Saturn I
014	Kennedy Space Center, Florida	A manned configured flight to evaluate in-flight CSM performance. To determine radiation levels and to demonstrate closed loop lifting entry.	Elliptical orbital flight for CSM operation.	Upgraded Saturn I
017	Kennedy Space Center, Florida	An unmanned flight to evaluate mission programmer performance, ECS entry performance, heat shield performance, countdown operations, Saturn V performance, MSFN ability, SCS entry performance, G&C during entry, and G&C boost monitor. To determine open-loop EDS performance, boost environment, structural loading, SPS performance, radiation levels ECS, and EPS operation. To demonstrate structural performance, G&C effectiveness, sea recovery compatibility, and parachute recovery.	Structural integrity and simulated lunar return high-heat rate entry.	Saturn V
020	Kennedy Space Center, Florida	An unmanned flight to evaluate heat shield performance, countdown, launch vehicle repeatability, MSFN ability, LM propulsion performance, and LM G&C stability. To determine open-loop EDS performance, ECS entry performance, LM G&C control, and LM subsystem performance. To demonstrate LM performance, SPS performance, LM fluid systems, LM separation, and sea recovery.	Simulated lunar return high-heat load entry and LM propulsion.	Saturn V

7-24. BLOCK II SPACECRAFT TEST PROGRAM. The following is a complete list of Apollo spacecraft, their missions, and relative preliminary data required for the Block II portion of the Apollo program.

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
2S-1	Downey, Calif.	Water and land impact tests to verify structural integrity of C/M and assure acceptable crew accelerations during land impact.	Water and land impact tests utilizing impact facility at Downey, Calif.	None
007A	Downey, Calif.	S/C 007 refurbished for Block II postlanding tests.	Recovery test vehicle.	None
2S-2	Downey, Calif.	To verify structural integrity of CSM	CSM for static structural tests.	None
2TV-1	MSC, Houston, Texas	To evaluate S/C under simulated mission environmental conditions.	Environmental proof (thermal vacuum) tests.	None
101	Kennedy Space Center, Florida	To evaluate rendezvous maneuvers, rendezvous radar transponder, CSM guidance and control, and RCS plume effects. To determine LM propulsion effects. To demonstrate G&C entry, LM ECS operation, transposition and docking, LM $\Delta V$ to CSM, landing gear deployment, crew transfer, and one-man LM operation.	Systems evaluation open-end elliptical manned earth orbital flight.  Dual launch S/C 101 AS207, LM2 AS 208	Upgraded Saturn I
102	Kennedy Space Center, Florida	To evaluate SCS, LM, and CSM in deep space. To determine LM restart effects, SPS effectiveness, plume effects, and heat shield performance. To demonstrate one man operation of CSM and manual entry.	Manned, small elliptical, open-end earth orbital flight.	Saturn V

## Block II Spacecraft Test Program (Cont)

Spacecraft No.	Test Site	Purpose	Mission	Launch Vehicle
103	Kennedy Space Center, Florida	Research and development to evaluate LM and CSM operations, man on lunar surface, and to demonstrate LM capability.	Manned lunar landing flight.	Saturn V
104	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
105	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
106	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
107	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
108	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
109	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
110	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
111	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V
112	Kennedy Space Center, Florida	Lunar landing.	Manned lunar landing flight.	Saturn V

## 7-25. TEST FIXTURES.

7-26. Three service propulsion engine test fixtures will be used to test the service module service propulsion systems. A test fixture (figure 7-6) is a structure used for system predevelopment and developmental tests leading to design of a spacecraft article. The fixtures are designated F-1, F-2, and F-3.

7-27. The F-1 test fixture functions to provide a test bed for the service propulsion engine vendor-acceptance, reliability, and qualification tests. The fixture will be used to evaluate the engine for safe operation and performance, to evaluate service propulsion engine basic design parameters, perform early evaluation of propellant system interaction effects, and to evaluate overall compatibility of the propulsion system components and subsystems.

7-28. The F-2 test fixture is a boilerplate structure that simulates the service module service propulsion system. This fixture will be used at PSDF, WSMR, New Mexico, to evaluate the service propulsion system under normal-design limit, and mission flight conditions through hot-propulsion static ground tests. The fixture will be used to permit continuance of the service propulsion system test program during periods when the propulsion spacecraft is out of service for modification, maintenance, and malfunction simulation.

7-29. The F-3 test fixture will be used at AEDC for vendor-acceptance and reliability tests. The F-3 fixture will also be used for engineering system development and static checkout tests by Space and Information Systems Division of North American Aviation, Inc.

## 7-30. GROUND SUPPORT EQUIPMENT.

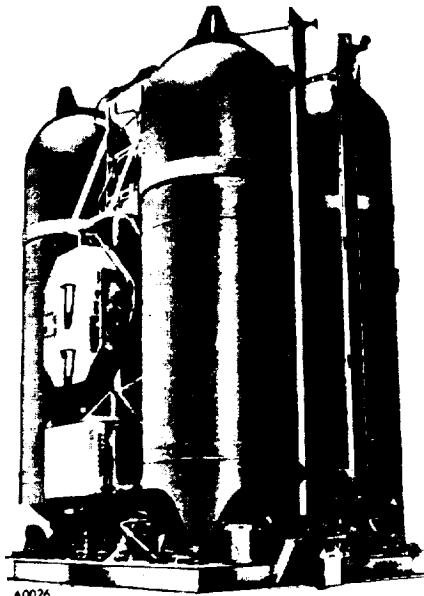
7-31. Ground support equipment (GSE), required for Apollo spacecraft, is separated into four categories: checkout, auxiliary, servicing, and handling. The purpose of GSE is to provide the Apollo program with a GSE system that will establish a level of confidence in the onboard spacecraft systems and will ensure mission success within prescribed reliability factors.

7-32. CHECKOUT EQUIPMENT. Checkout equipment consists of acceptance checkout equipment (ACE), special test units (STU), bench maintenance equipment (BME), boilerplate and associate checkout equipment, and cabling systems.

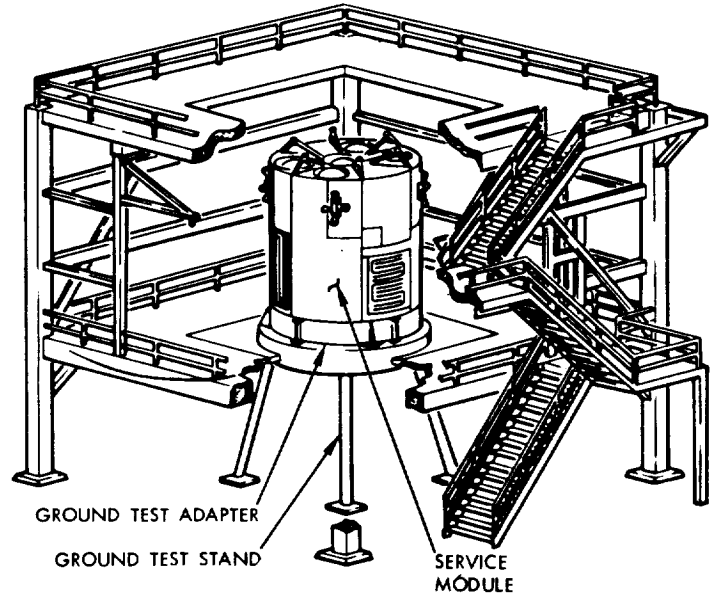
7-33. Acceptance checkout equipment consists of permanently installed equipment located in control and computer rooms and carry-on (portable) equipment located near or onboard the spacecraft. Carry-on equipment is removed from the S/C prior to launch. ACE is computer-controlled equipment which provides the capability to check out spacecraft systems and to isolate malfunctions to a removable module. ACE also controls spacecraft systems servicing equipment.

7-34. Special test units provide the equipment to support the development of spacecraft systems and ACE systems. STU consists of manual checkout equipment and is required to operate and monitor the functional performance of the spacecraft systems.

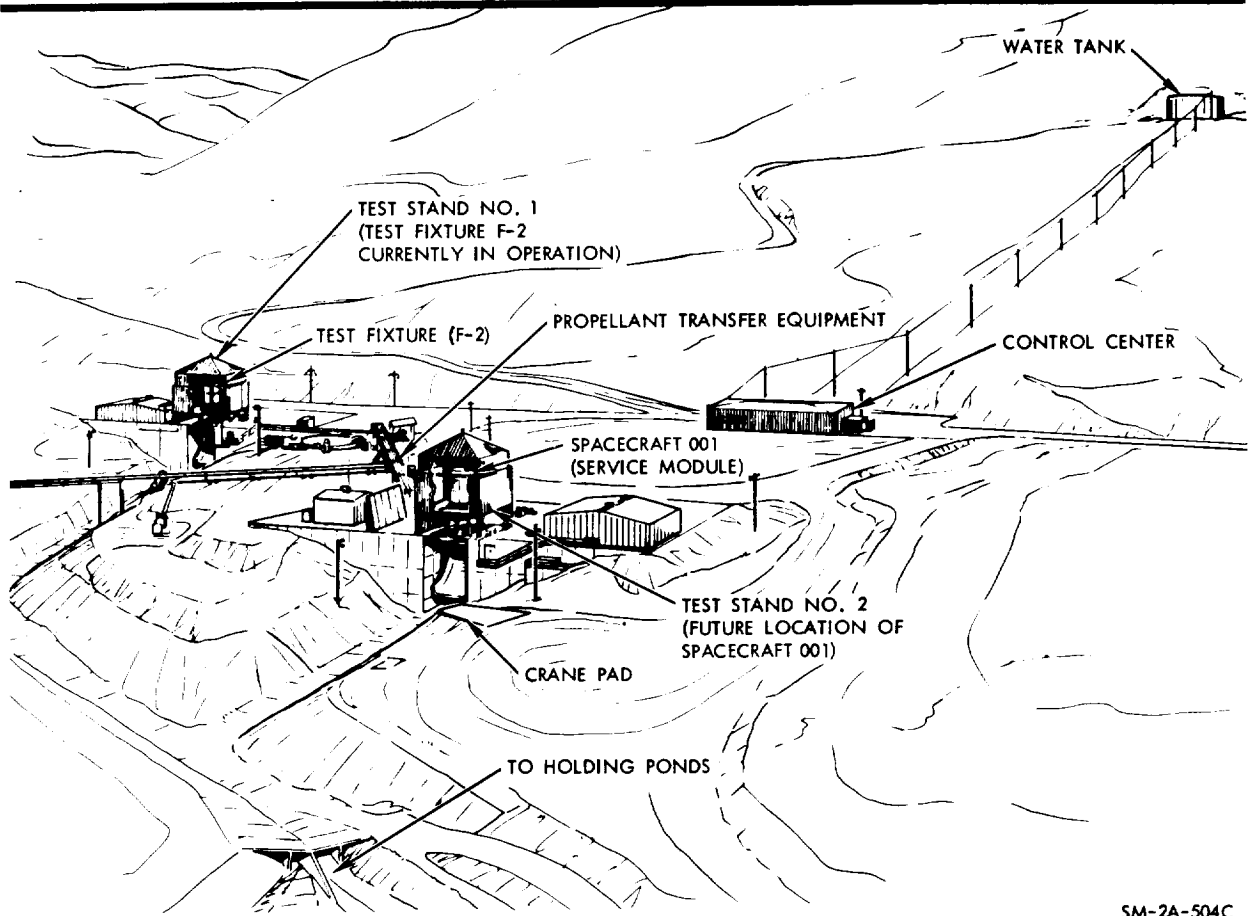
7-35. Bench maintenance equipment is provided to perform verification and recertification, confirm defects, isolate malfunctions, perform repair verifications, perform calibration, and make adjustments on spacecraft systems, subsystems, and some components (to the lowest replaceable unit).



TEST FIXTURE (F-2)



SPACECRAFT 001



PSDF TEST STAND AREA, WSMR, NEW MEXICO

SM-2A-504C

Figure 7-6. Test Fixture (F-2) and Spacecraft 001 at Test Site

7-36. Boilerplate and associate checkout equipment consists of equipment that cannot be classified as ACE, STU, or BME. Boilerplate checkout equipment, such as the Apollo R&D instrumentation console and the onboard record checkout unit, are used to check out some boilerplates. Associate checkout equipment, such as the R-F checkout unit, supports the spacecraft systems when ACE or STU checkout equipment is being used, and equipment that cannot be isolated to one particular spacecraft system, such as the mobile recorder and spacecraft ground power supply and power distribution panel.

7-37. Cabling systems include that equipment necessary to provide electrical interconnection between various spacecraft vehicles, ground equipment, and test facilities, as required to provide an integrated electrical checkout station.

7-38. AUXILIARY EQUIPMENT. Auxiliary equipment consists of accessory equipment and special devices, such as substitute units, alignment equipment, and protective closures, which are not a part of the checkout, servicing, and handling equipment.

7-39. Substitute units, such as the launch escape tower substitute unit, service module substitute unit, and command module substitute unit, provide the intermodule interface required to support an interface compatibility checkout of the electrically unmated command module or service module.

7-40. Alignment equipment, such as the optical alignment set and the command module optical alignment support, provide the test fixtures required to accomplish alignment tasks.

7-41. Protective closures, both hard and soft, provide covering for flight equipment during transportation and storage.

7-42. SERVICING EQUIPMENT. Servicing equipment consists of fluid handling equipment necessary to support the spacecraft systems during ground operation, and fluid handling equipment necessary to permit the onboard loading of all liquids and gases required to operate the spacecraft systems. Servicing equipment provides additional capabilities such as flushing, purging, conditioning, vapor disposal necessary to support the basic servicing function, and decontaminating the spacecraft systems as required after detanking.

7-43. HANDLING EQUIPMENT. Handling equipment provides for lifting, transportation, weight and balance, alignment, access, protection, and support of the service module, command module, and launch escape assembly.



7-44. MISSIONS COMPLETED.

7-45. The following missions have been successfully completed.

## 7-46. BOILERPLATE 6.

7-47. Boilerplate 6, an unmanned, pad abort test vehicle, using the launch escape and pitch control motors as a launch vehicle, successfully completed its mission at the White Sands Missile Range, New Mexico, 7 November 1963. (See figure 7-7.) An abort command caused the launch escape and pitch control motors to ignite, lifting the command module from the launch pad adapter. At an approximate altitude of 5000 feet, the launch escape assembly and forward heat shield were separated from the C/M, and the tower jettison motor ignited, propelling the launch escape assembly and forward heat shield clear of the C/M trajectory. The earth landing system was initiated to accomplish drogue parachute deployment, and release and deployment of three pilot parachutes which, in turn, deployed the three main parachutes, slowing the C/M to a safe landing speed (approximately 25 feet per second). Boilerplate 6 is being refurbished for further parachute recovery system tests and will be designated boilerplate 6A.

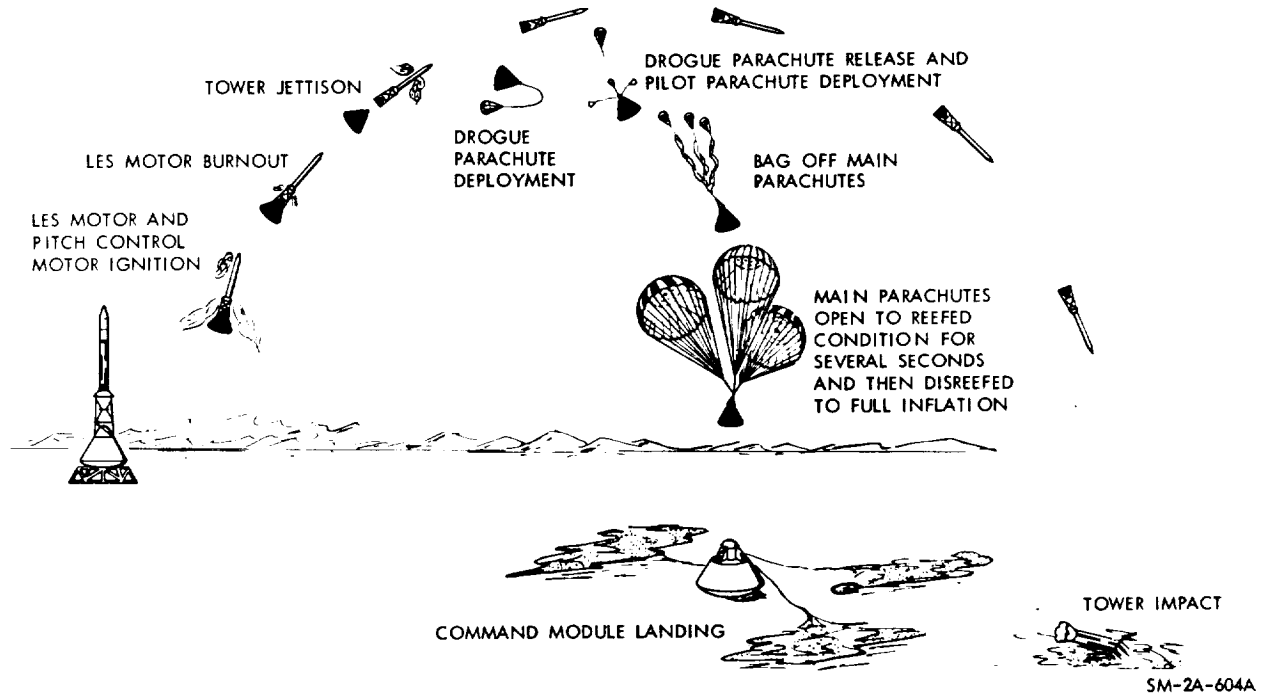


Figure 7-7. Boilerplate 6 Mission Profile

7-48. BOILERPLATE 12.

7-49. Boilerplate 12, an unmanned, transonic abort test vehicle, using a Little Joe II booster as a launch vehicle, successfully completed its mission at WSMR, New Mexico, 13 May 1964. (See figure 7-8.) This was the first full-scale test flight of the launch escape system in the transonic speed range. The Little Joe II boosted the boilerplate command-service modules to an approximate altitude of 21,000 feet, where an abort command caused separation of the C/M from the S/M and ignition of the launch escape and pitch control motors. The launch escape assembly propelled the command module away from the S/M and launch vehicle to an approximate altitude of 28,000 feet. The tower was separated from the C/M and the tower jettison motor ignited, carrying the launch escape assembly and forward compartment heat shield away from the trajectory of the C/M. The earth landing system was then initiated to accomplish drogue parachute deployment and release, and deployment of three pilot parachutes which, in turn, deployed the three main parachutes. One main parachute did not inflate fully and was separated from the C/M; however, the boilerplate 12 command module landed upright and undamaged.

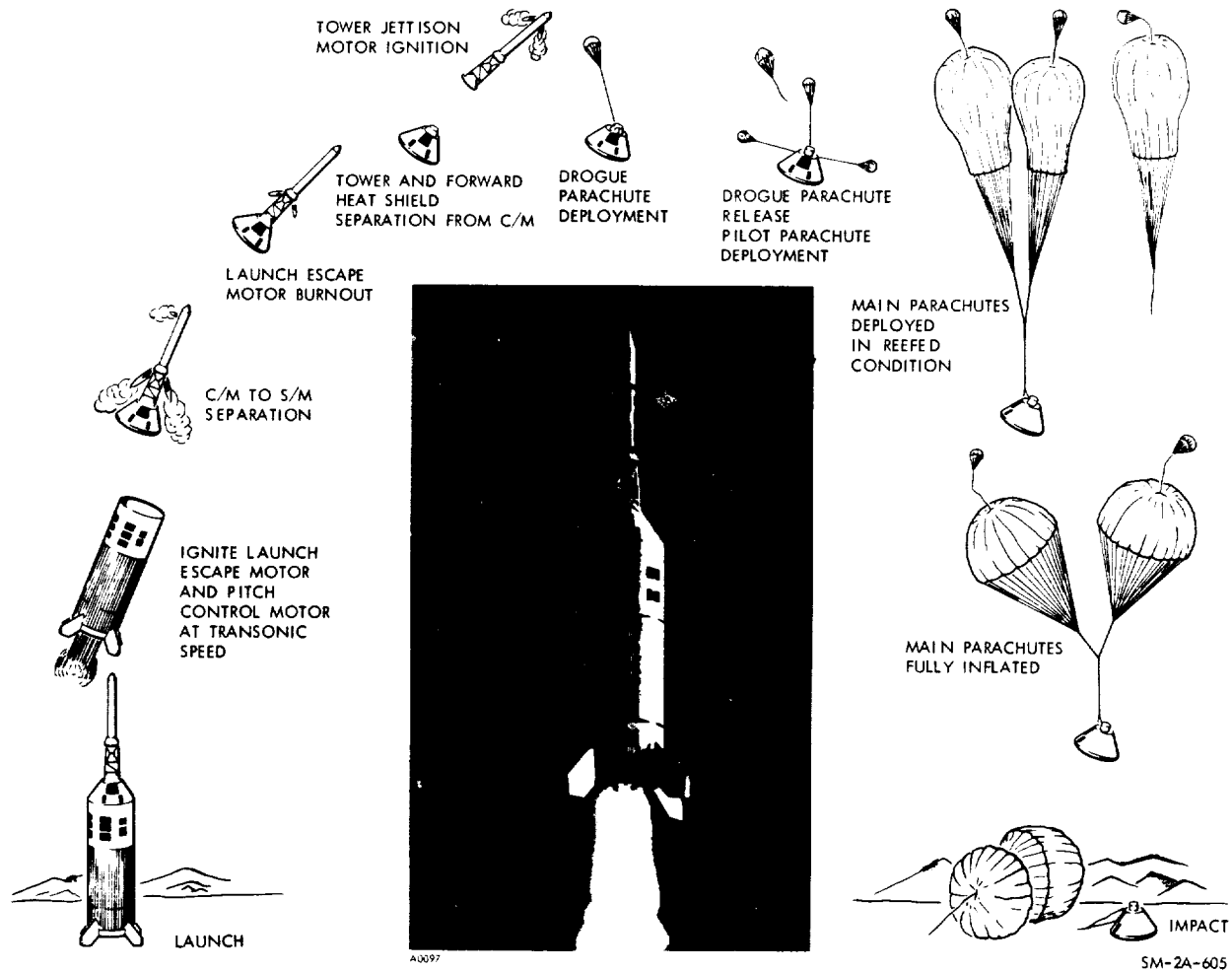


Figure 7-8. Boilerplate 12 Mission Profile

7-50. BOILERPLATE 13.

7-51. Boilerplate 13, an unmanned, launch environment test vehicle, using a Saturn I as a launch vehicle, was successfully launched into orbit from Kennedy Space Center, Florida, 28 May 1964. (See figure 7-9.) This was the first test flight to qualify the Saturn I launch vehicle and to demonstrate the compatibility of the spacecraft and launch vehicle. All test objectives were met; design parameters and conclusions about the flight, based on ground research, were as predicted. Orbits of the CSM and second-stage booster ranged from 110 to 140 miles above the earth surface and continued until 31 May 1964. Upon entry into earth atmosphere, the test vehicle disintegrated, as no provisions were made for recovery.

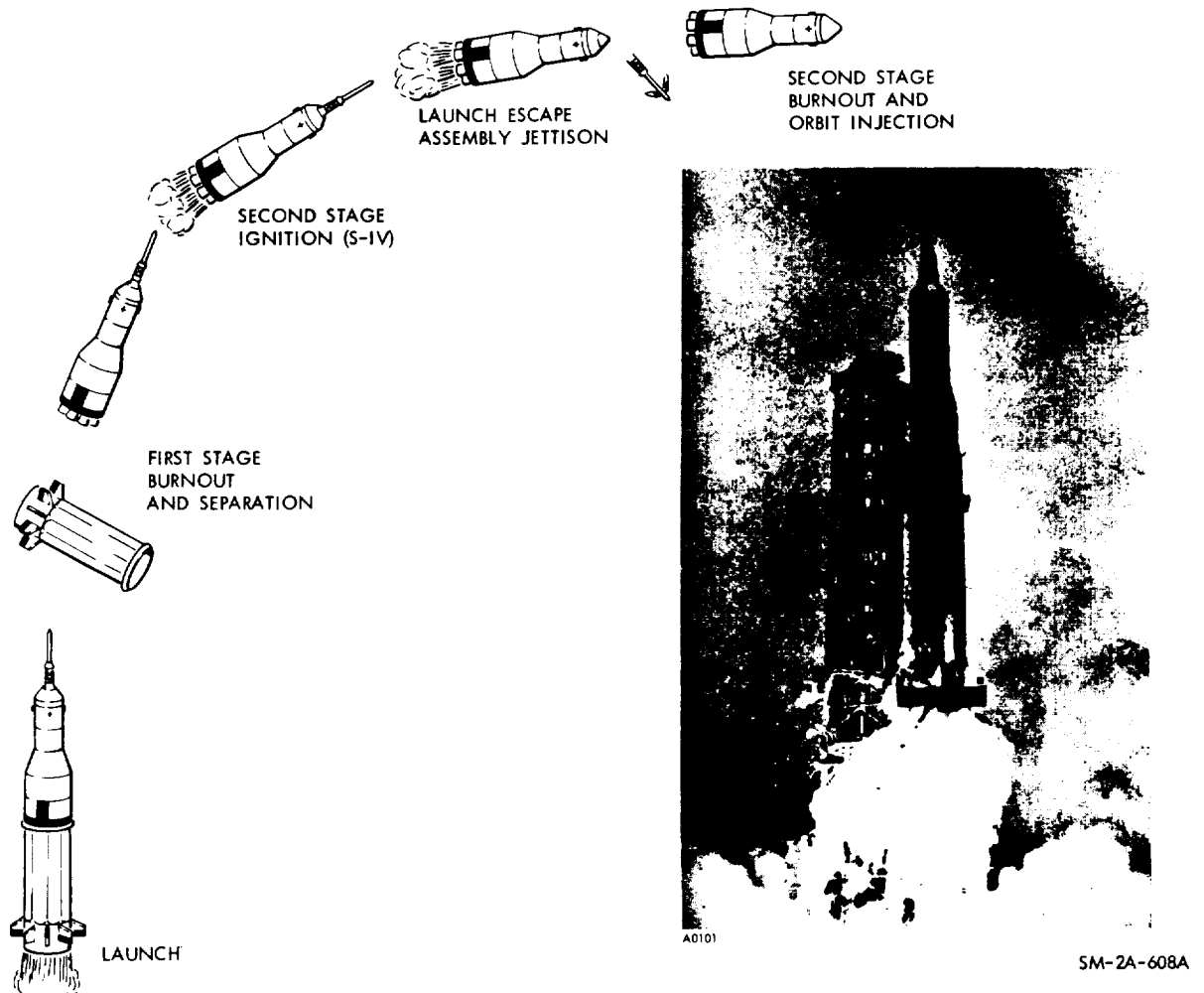


Figure 7-9. Boilerplate 13 Mission Profile

7-52. BOILERPLATE 15.

7-53. Boilerplate 15, an unmanned, launch environment test vehicle, using a Saturn I as a launch vehicle, was successfully launched into orbit from Kennedy Space Center, Florida, 18 September 1964. (See figure 7-10.) This was the second successful test flight to qualify the Saturn I launch vehicle and to demonstrate compatibility of the spacecraft and launch vehicle. An alternate mode of jettisoning the launch escape assembly was also demonstrated. Orbits of the CSM and second-stage booster ranged from 115 to 141 miles above the earth's surface and continued until 22 September 1964. No provisions were made for recovering the test vehicle upon entry into the atmosphere of the earth.

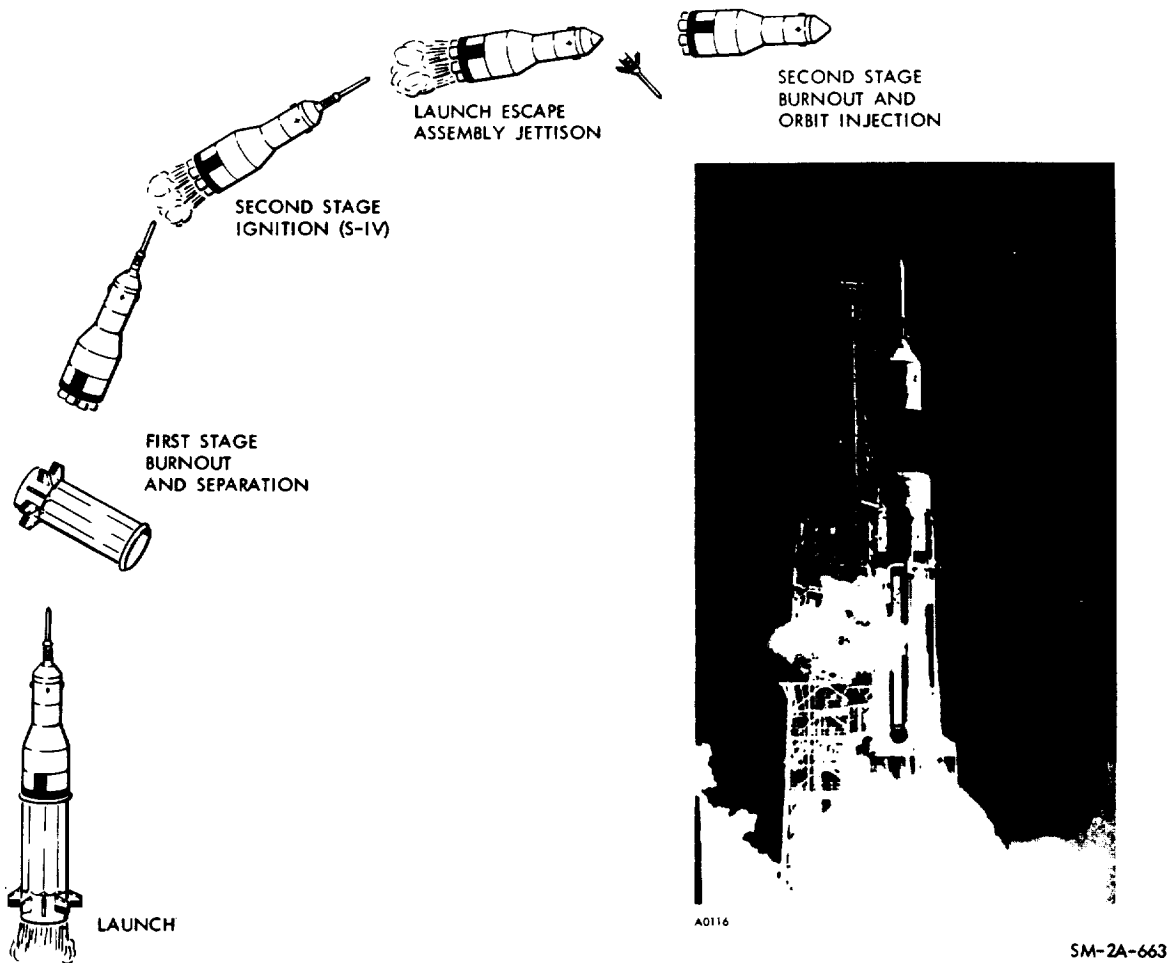


Figure 7-10. Boilerplate 15 Mission Profile

## 7-54. BOILERPLATE 23.

7-55. Boilerplate 23, an unmanned, abort test vehicle, using a Little Joe II booster as a launch vehicle, successfully completed its mission at WSMR, New Mexico, 8 December 1964. (See figure 7-11.) At approximately 32,000 feet a radio command signalled the launch vehicle control system to produce a pitch-up maneuver, simulating an abort condition. An abort command was initiated at an approximate altitude of 35,000 feet. Upon receipt of the abort signal, the C/M-S/M separated, and the launch escape and pitch control rocket motors ignited, to carry the C/M away from its launch vehicle. Eleven seconds after abort was initiated, the canards deployed, turning the C/M around and stabilizing it in a blunt-end forward attitude. At approximately 25,000 feet, the launch escape assembly separated from the C/M and the tower jettison motor ignited, carrying the launch escape assembly, boost protective cover, and forward heat shield away from the C/M. The earth landing system was initiated, accomplishing: drogue parachute (2) deployment in a reefed condition; drogue parachutes disreefed (at approximately 11,000 feet) slowing the speed and oscillation of the C/M for main parachute deployment, drogue parachute release, pilot parachute (3) deployment which, deployed the three main parachutes in a reefed condition; main parachutes disreefed lowering C/M to ground at a safe landing speed (approximately 25 feet per second). Boilerplate 23 is being refurbished for further C/M pad abort tests and will be designated boilerplate 23A.

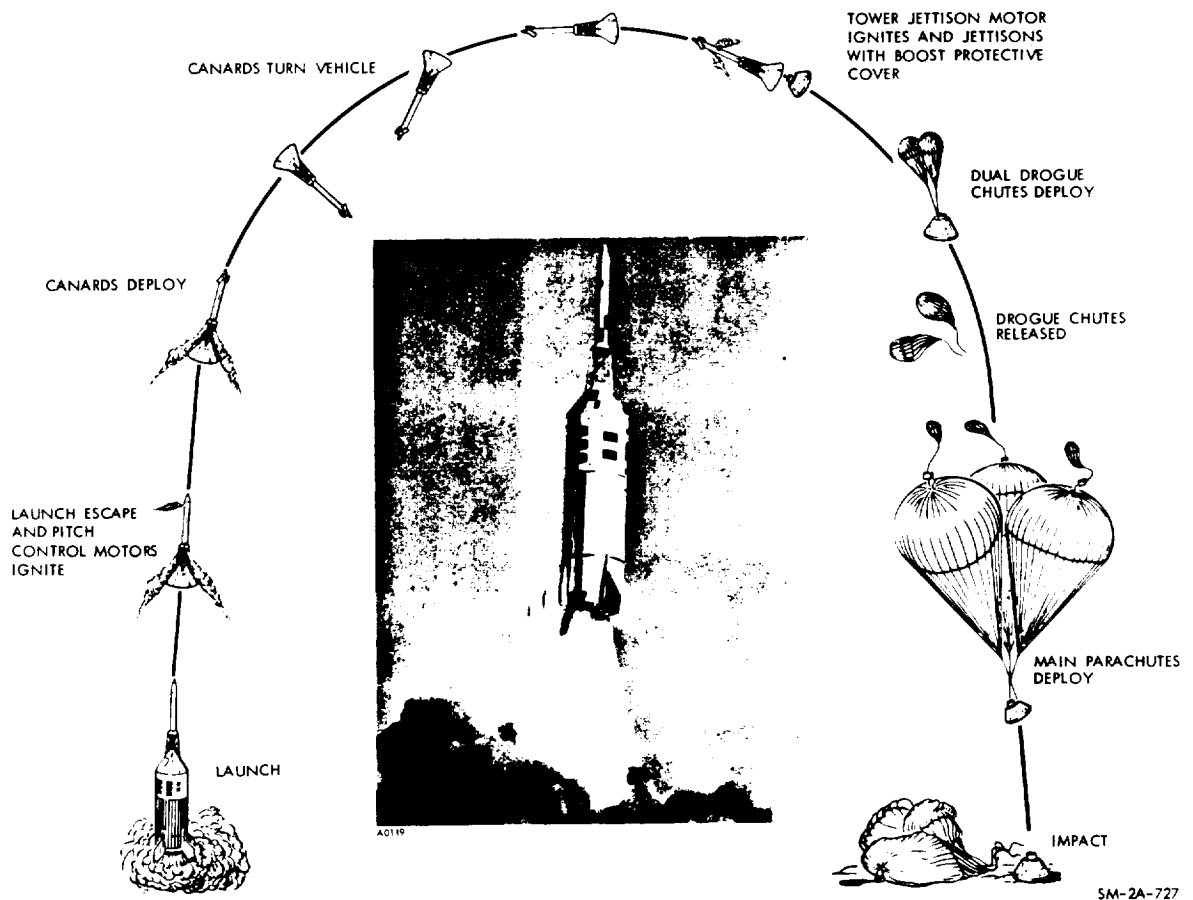


Figure 7-11. Boilerplate 23 Mission Profile

7-56. BOILERPLATE 16.

7-57. Boilerplate 16, an unmanned, micrometeoroid experiment test vehicle, using a Saturn I as a launch vehicle, was successfully launched into orbit from Kennedy Space Center, Florida, 16 February 1965. (See figure 7-12.) Once the orbit was attained, the CSM was jettisoned from the second stage (S-IV) by using the LES, and two large (NASA-installed) panels, unfolded. The panels and associated electronics, installed in the S-IV, are used to detect micrometeoroid particles and transmit the information to ground stations. The orbit of the test vehicle ranges from 308 to 462 miles above the earth. No provisions have been made for recovering the test vehicle upon entry into the atmosphere of the earth.

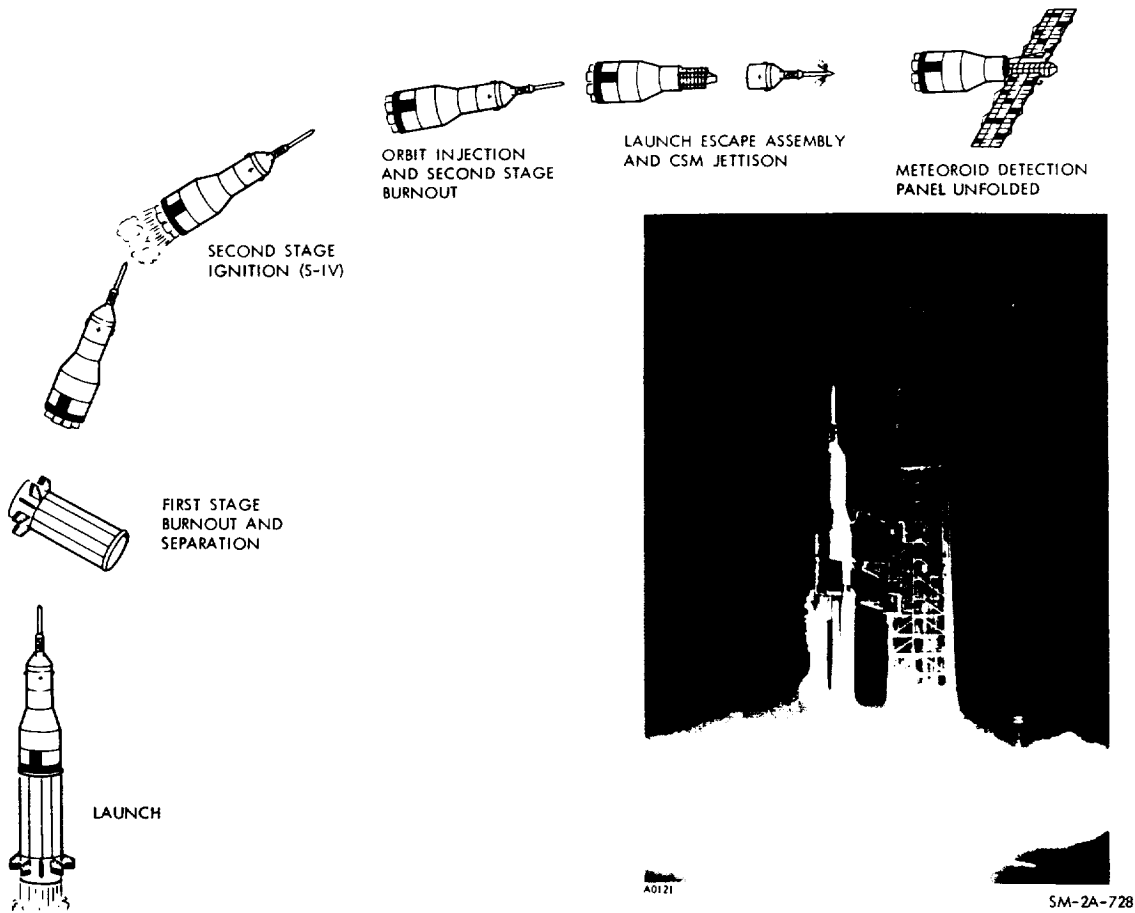


Figure 7-12. Boilerplate 16 Mission Profile

7-58. BOILERPLATE 22.

7-59. Boilerplate 22, an unmanned abort test vehicle using a Little Joe II booster as a launch vehicle, was partially successful in completing its mission at WSMR, New Mexico, 19 May 1965. (See figure 7-13). Although a high-altitude abort was planned, the boost vehicle malfunctioned causing a premature low-altitude abort; however, the Apollo systems functioned perfectly. An abort command was initiated due to the malfunctioning boost vehicle. Upon receipt of the abort signal, the C/M-S/M separated, and the launch escape and pitch control rocket motors ignited carrying the C/M away from the launch vehicle debris. The earth landing system was initiated lowering the C/M safely to the ground.

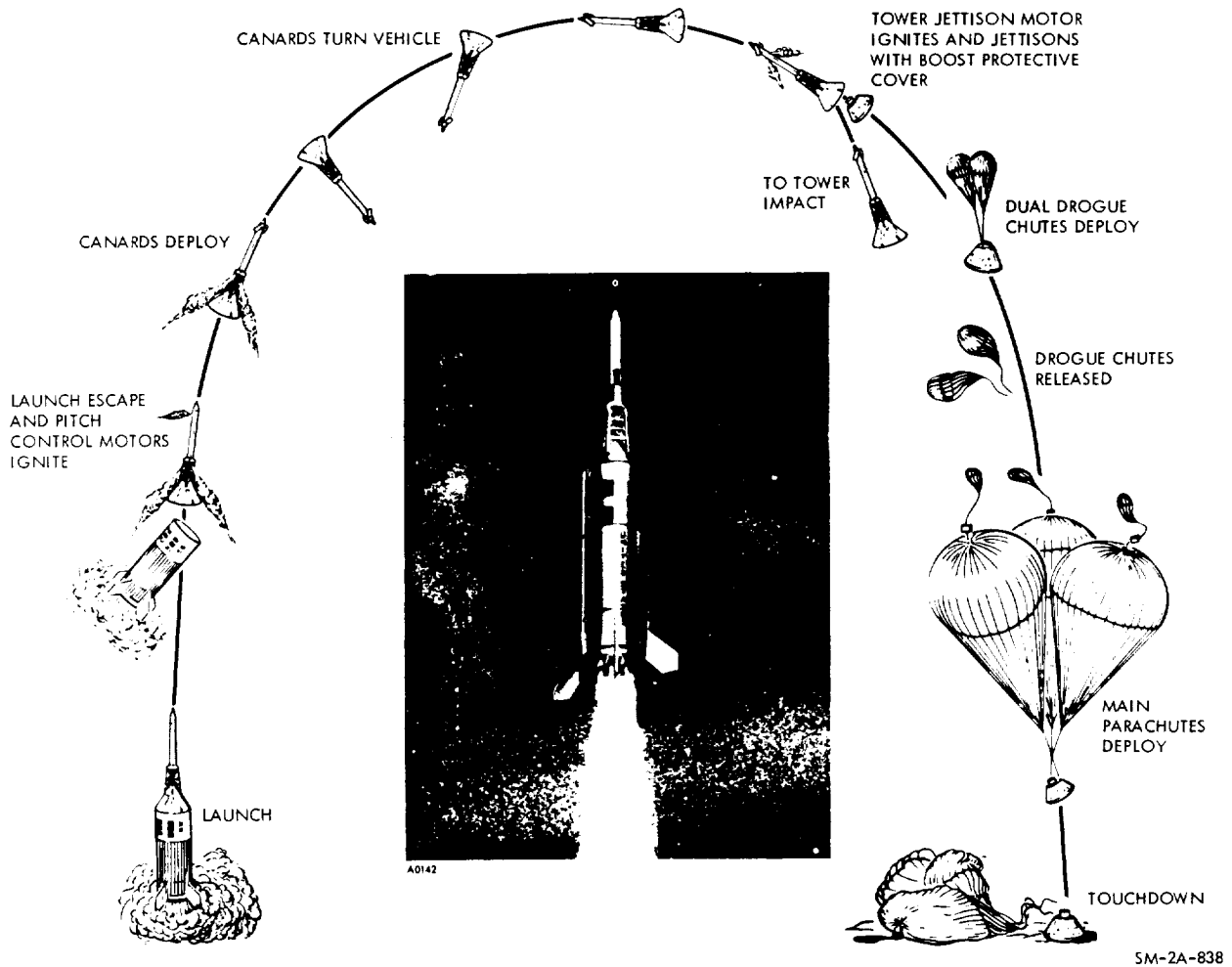


Figure 7-13. Boilerplate 22 Mission Profile

7-60. BOILERPLATE 26.

7-61. Boilerplate 26, the second unmanned micrometeoroid experiment test vehicle, was successfully launched into orbit from Kennedy Space Center, Florida, 25 May 1965. The launch vehicle used was a Saturn I. Using the LES, the CSM was jettisoned from the second stage (S-IV) upon reaching the planned orbit. (See figure 7-14.) Two large (NASA-installed) panels installed in the S-IV, unfolded, to be used with associated electronics to detect micrometeoroid particles and transmit the information to ground stations. No provisions have been made for recovering the test vehicle upon entry into the atmosphere of the earth.

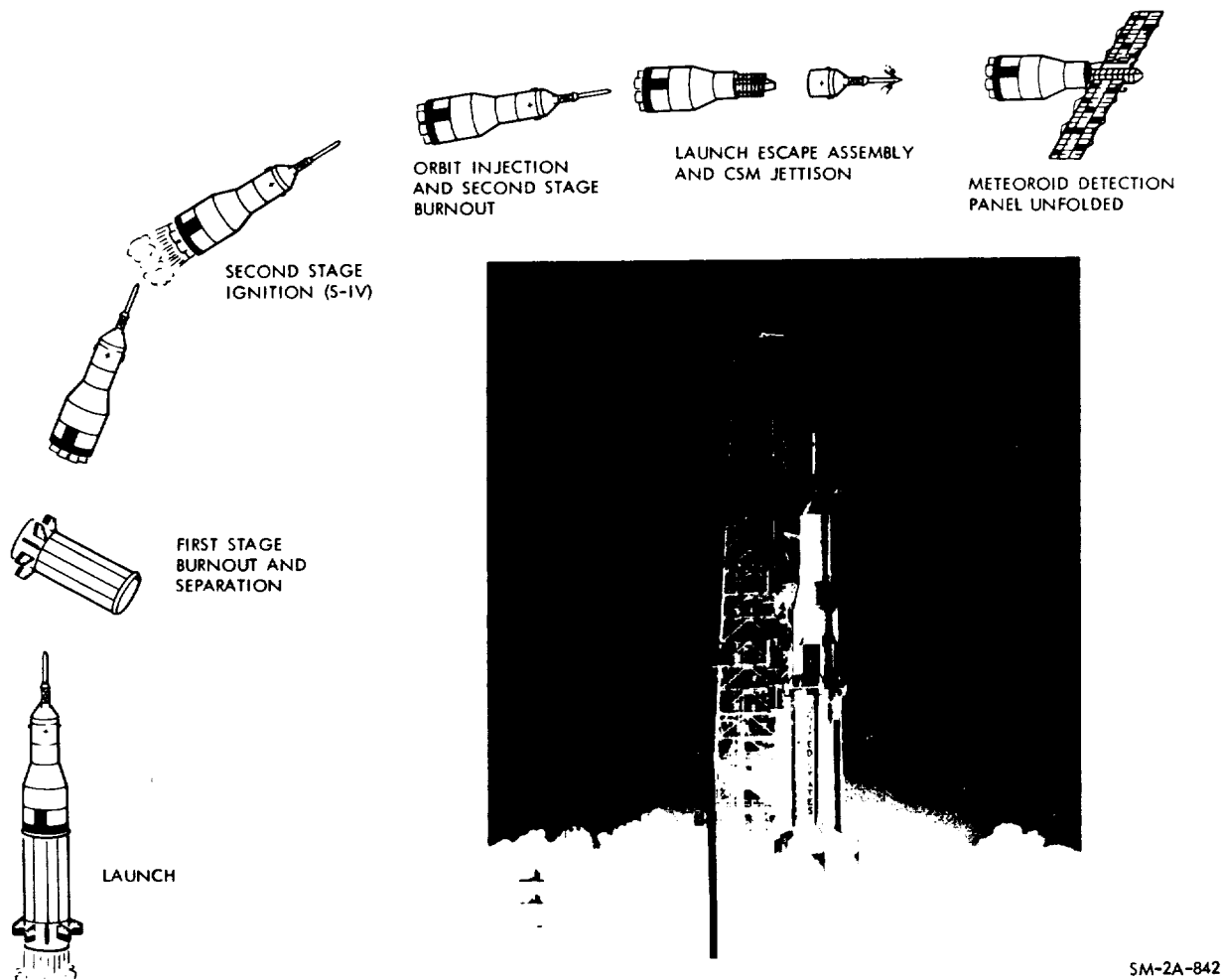
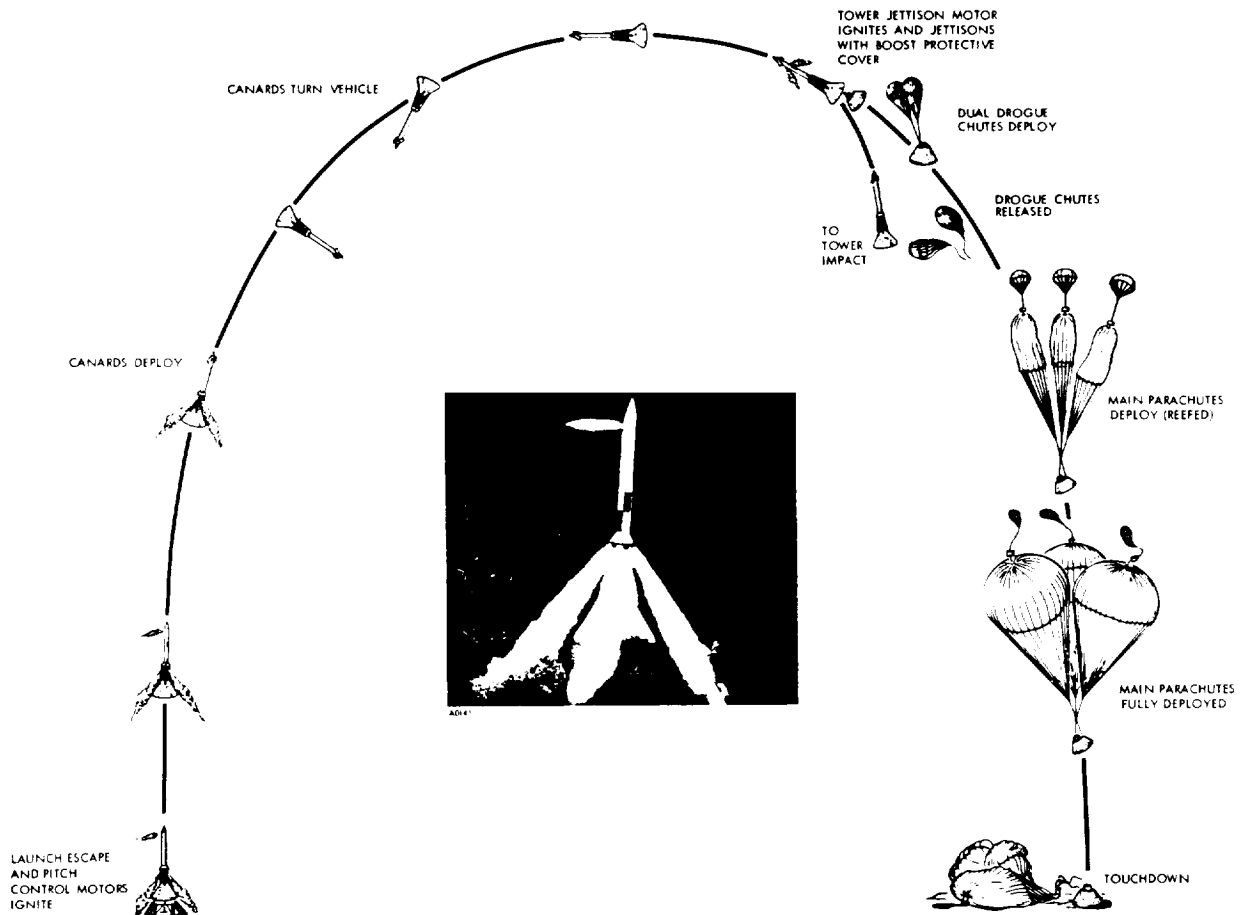


Figure 7-14. Boilerplate 26 Mission Profile



7-62. BOILERPLATE 23A.

7-63. Boilerplate 23A, another pad abort test vehicle, successfully completed its mission at the White Sands Missile Range, New Mexico, 29 June 1965. (See figure 7-15.) This was the second test of the launch escape systems ability to lift the C/M off the pad. The test simulated an emergency abort which might occur while the C/M was still on the launch pad atop a Saturn launch vehicle. An abort command was initiated causing the launch escape and pitch control motors to ignite, the C/M to separate from the S/M, and lifting the C/M from the launch pad adapter. Improvements incorporated in boilerplate 23A which were not included on the first pad abort test vehicle were: canard surfaces, boost protective cover, a jettisonable forward compartment heat shield, and reefed dual drogue parachutes. All systems worked as predicted and the C/M was lowered to the ground safely.

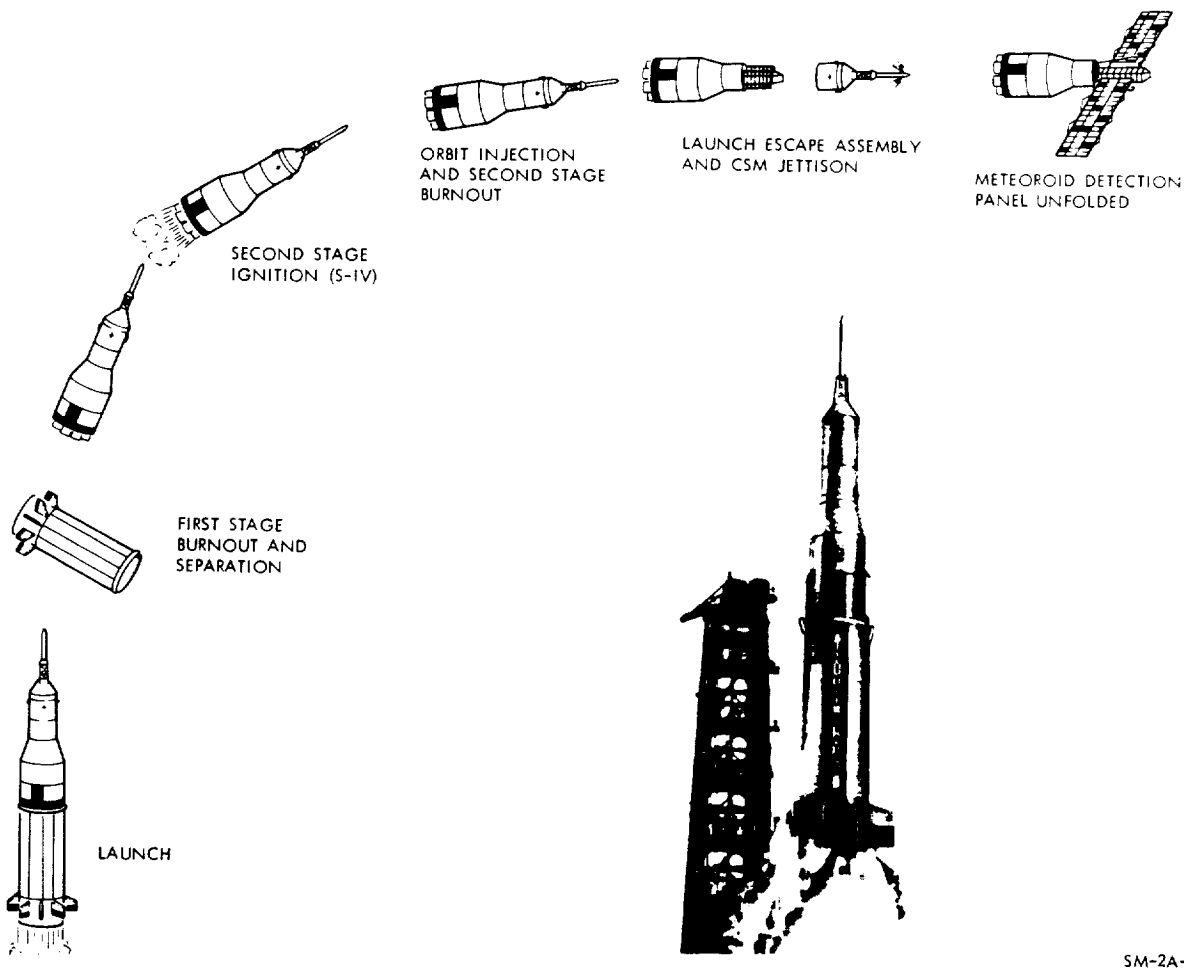


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Figure 7-15. Boilerplate 23A Mission Profile

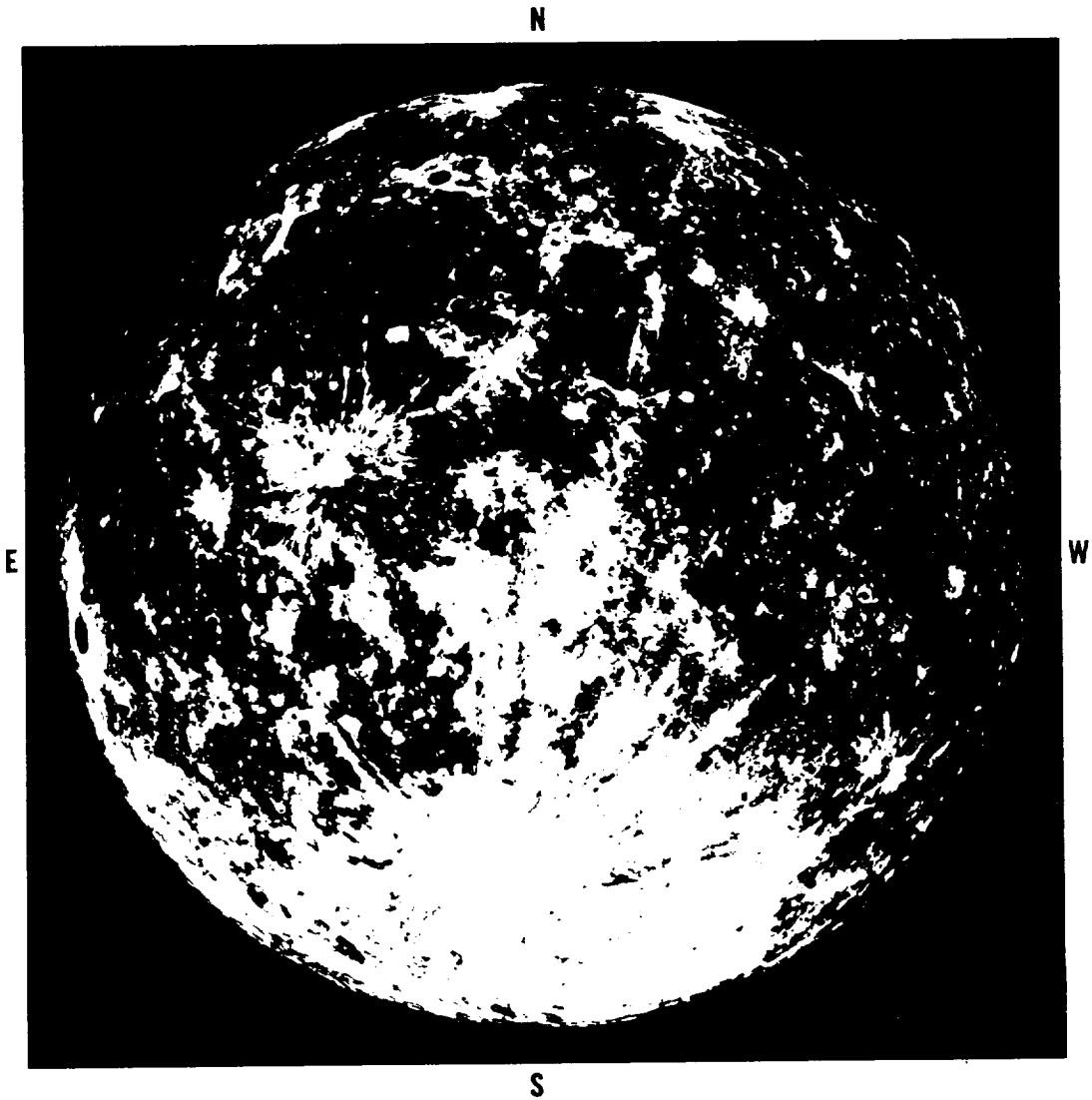
7-64. BOILERPLATE 9A.

7-65. Placing the third micrometeoroid experiment test vehicle successfully into orbit, was accomplished 30 July 1965, from Kennedy Space Center, Florida. Boilerplate 9A was used as a cover for the folded test panels, and a Saturn I with an S-IV second stage was used as the launch vehicle. (See figure 7-16.) After reaching its orbit, the CSM was jettisoned using the LES, and the large (NASA-installed) panels unfolded from the second stage (S-IV), the same as the two previous micrometeoroid test vehicles. Micro-meteoroid particles are detected when they strike the panels, and the information is transmitted to ground stations by way of electronics installed in the S-IV. The test vehicle will not be recovered upon entry into the atmosphere of the earth.



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Figure 7-16. Boilerplate 9A Mission Profile



### LUNAR DATA

DISTANCE FROM EARTH - 253,000 MILES (MAX.)

DIAMETER                      2160 MILES

TEMPERATURE

SUN AT ZENITH      214°F (101°C)

NIGHT    APPROX.   -250°F (-157°C)

SM-2A-878



## LUNAR LANDING MISSION

### 8-1. GENERAL.

8-2. The culmination of the Apollo program will be the lunar landing mission. This mission will produce the first extraterrestrial-manned exploration of the moon. This section contains a sequential presentation of the major events of the lunar landing mission. Text and illustrations within this section (figures 8-1 through 8-23) provide general information concerning the operations involved in the lunar landing mission. Text and corresponding illustrations are connected by the use of common titles.

### 8-3. KENNEDY SPACE CENTER.

8-4. The lunar landing mission will originate from the Kennedy Space Center (KSC). Facilities have been constructed at KSC to handle space-exploration vehicles and associated equipment. These special facilities provide capability to handle the large vehicles and components within precise parameters. Figure 8-1 shows launch pad B of complex 39 in the foreground, the remote blockhouse to the left, the 500-foot-plus vehicle assembly building (VAB) in the background, and the interconnecting crawlerway.

8-5. The component assemblies of the Apollo spacecraft and the Saturn V launch vehicle will be transported to KSC for final assembly tests. The spacecraft and launch vehicle will be assembled (stacked) on the launch umbilical tower (LUT) platform in the vehicle assembly building. The launch umbilical tower platform is mounted on the crawler-transporter. After assembly is completed, interface and systems tests will be made.

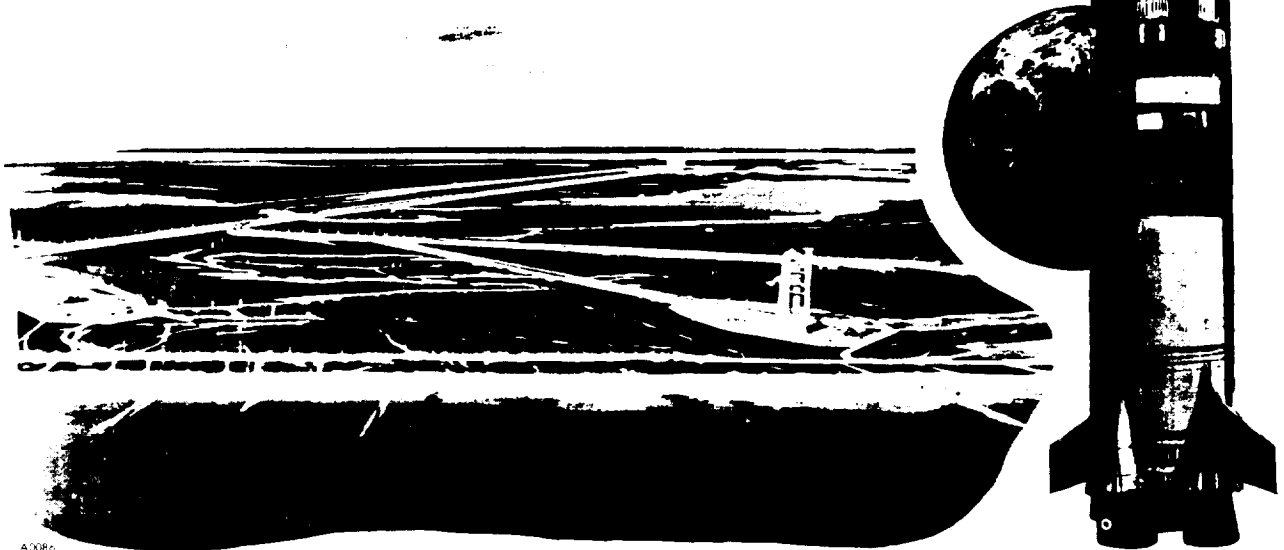
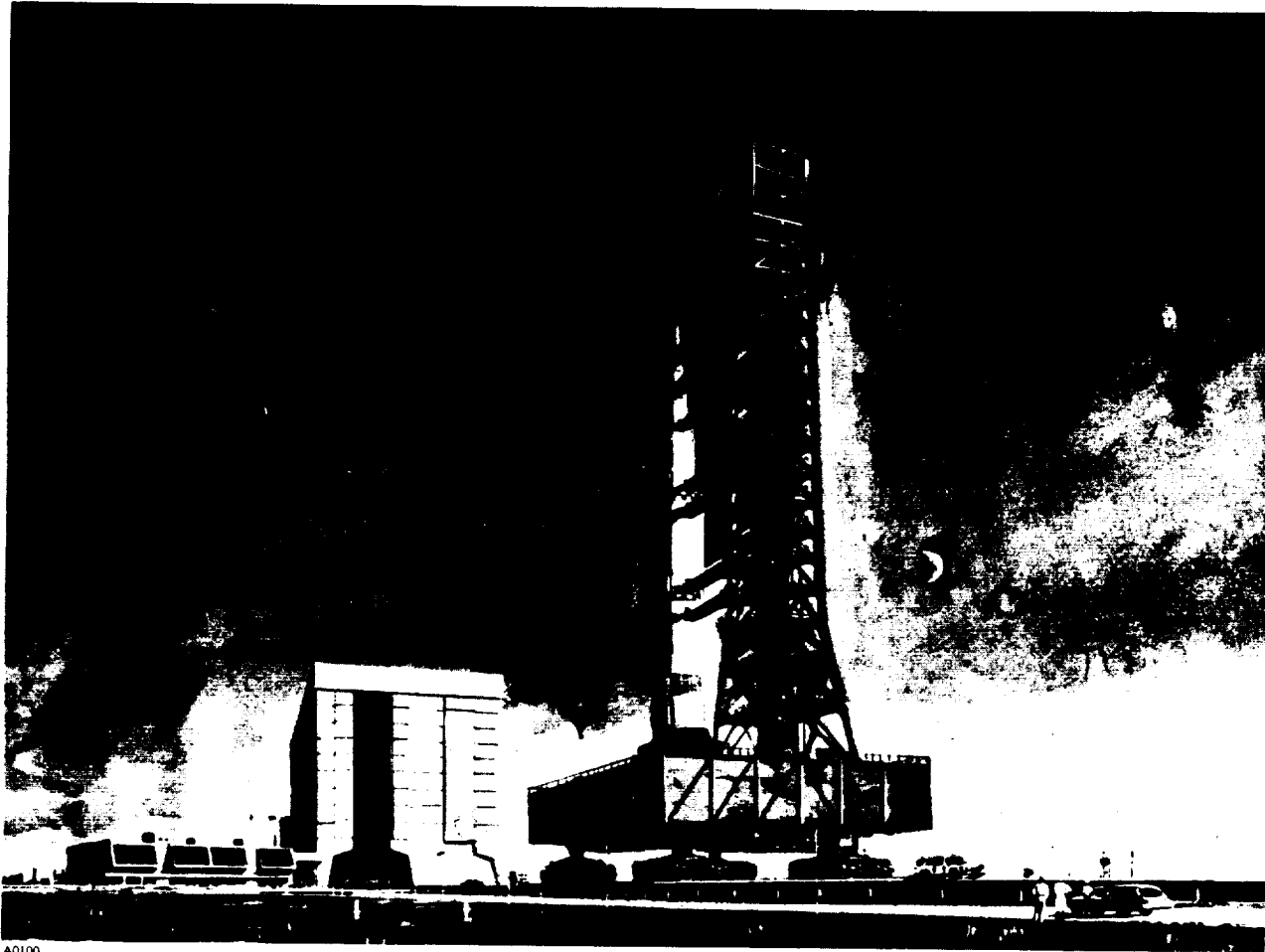


Figure 8-1. Kennedy Space Center (KSC)



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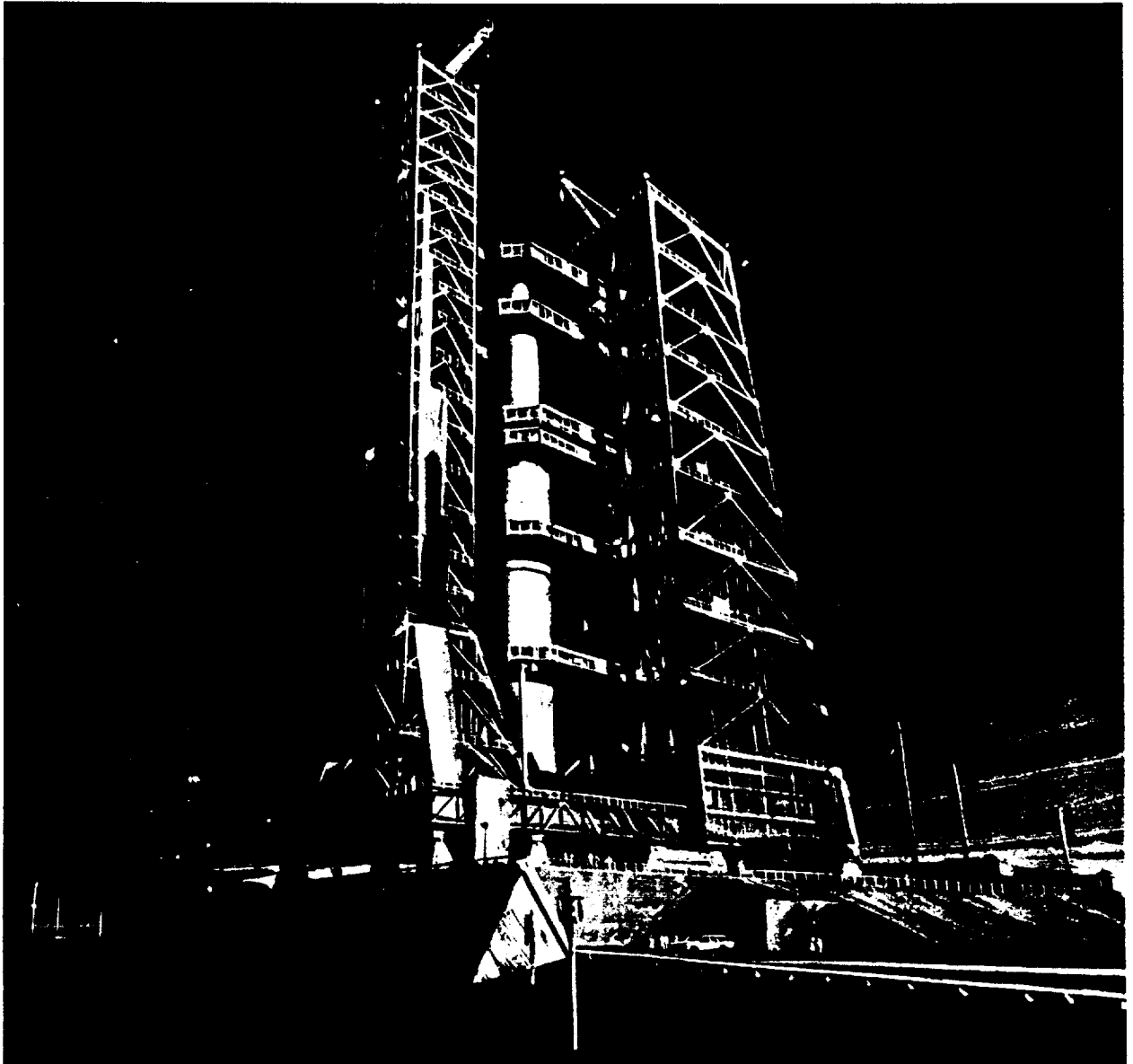
Figure 8-2. Transportation to Launch Pad

#### 8-6. TRANSPORTATION TO LAUNCH PAD.

8.7 After operations are concluded in the vehicle assembly building, the assembled LUT, spacecraft, and launch vehicle will be transported to launch complex 39. Transportation of the launch umbilical tower, spacecraft, and launch vehicle will be provided by the crawler-transporter. The crawler-transporter will carry this load 3.5 miles to launch pad A and 4.7 miles to launch pad B on a specially constructed crawlerway. The crawlerway is a pair of parallel roadways which can support a load in excess of 18-million pounds. The crawler-transporter will proceed at a rate of approximately 1 mile per hour.

### 8-8. LAUNCH PAD.

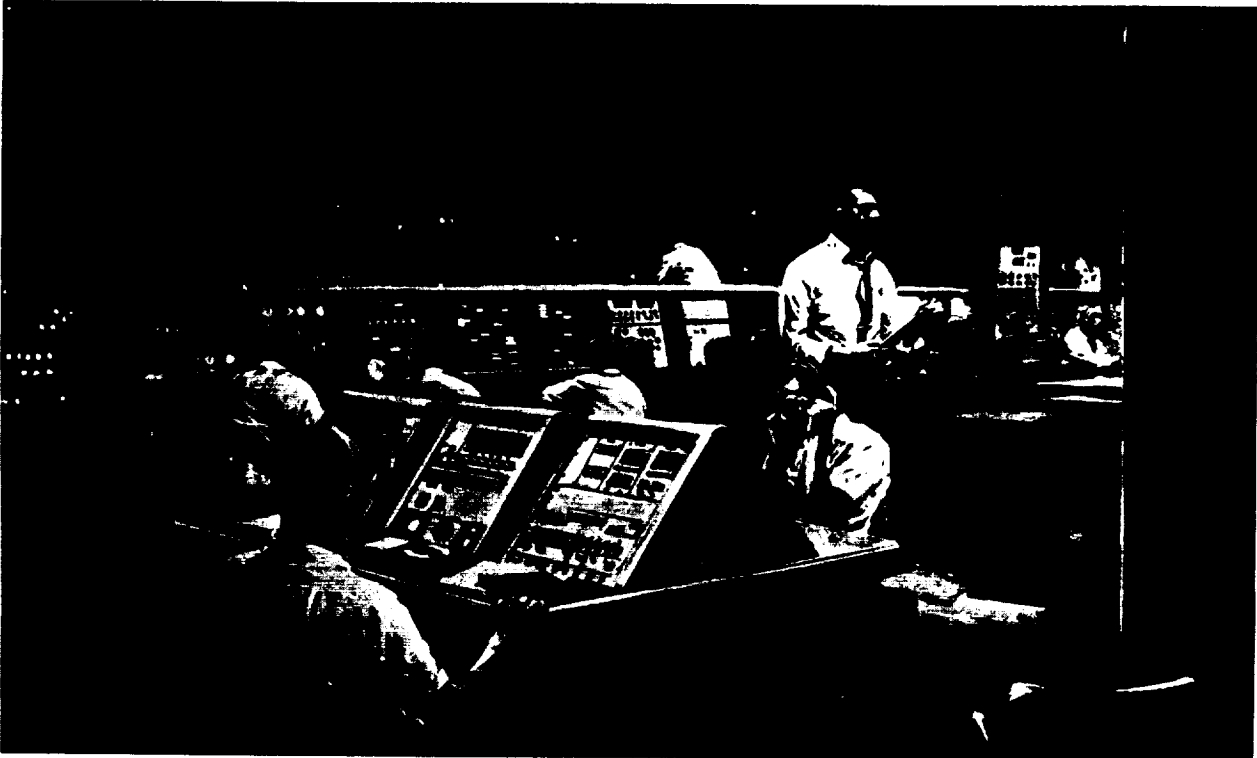
8-9. Upon arrival at the launch pad, the crawler-transporter will lower the launch umbilical tower, platform, spacecraft, and launch vehicle onto steel foundations. The crawler-transporter will move a mobile service structure onto the pad next to the spacecraft. The MSS provides facilities for pyrotechnic arming and fueling operations. When the MSS is no longer needed, the crawler-transporter and the MSS will be removed from the launch area.



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Figure 8-3. Launch Pad



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Figure 8-4. Countdown



#### 8-10. COUNTDOWN.

8-11. The final prelaunch countdown sequence begins upon final positioning of the launch umbilical tower, spacecraft, and launch vehicle on the launch pad. Ordnance components required on the spacecraft are armed, utilizing the MSS. Appropriate protective devices are installed at the time of ordnance installation to prevent inadvertent operational arming and firing of the pyrotechnics, and to provide maximum safety for the spacecraft checkout crew and launch area ground personnel.

8-12. The prelaunch countdown follows a programed sequence which is directed by, and under the control of, the launch control director. This sequence establishes the order of required operational checkout of the spacecraft systems and of the servicing and loading of consumable gases, fuels, and supplies.

8-13. The countdown sequence consists essentially of the activation, or simulated activation, and verification checks of the spacecraft operational systems as follows:

- Removal of ground support equipment (GSE)
- Leak checks
- Battery activation
- Final arming of ordnance devices
- Removal of ordnance shorting devices
- Loading of fuels: helium, liquid hydrogen, and liquid oxygen
- Fuel cell activation
- Entry of mission flight crew into command module
- Closing of command module crew hatch
- Installation of boost protective cover hatch access cover
- Command module crew cabin leak check
- Purging the command module cabin with 100-percent oxygen
- Final confidence checks of the spacecraft systems by the crew
- Final arming of the launch escape system
- Ground-to-spacecraft umbilical disconnect.

8-14. Upon completion of final checks, the ground-to-spacecraft umbilical cables are disconnected and the launch tower support arms are retracted. Final decision and approval to launch is verified by the launch control center and the spacecraft crew.

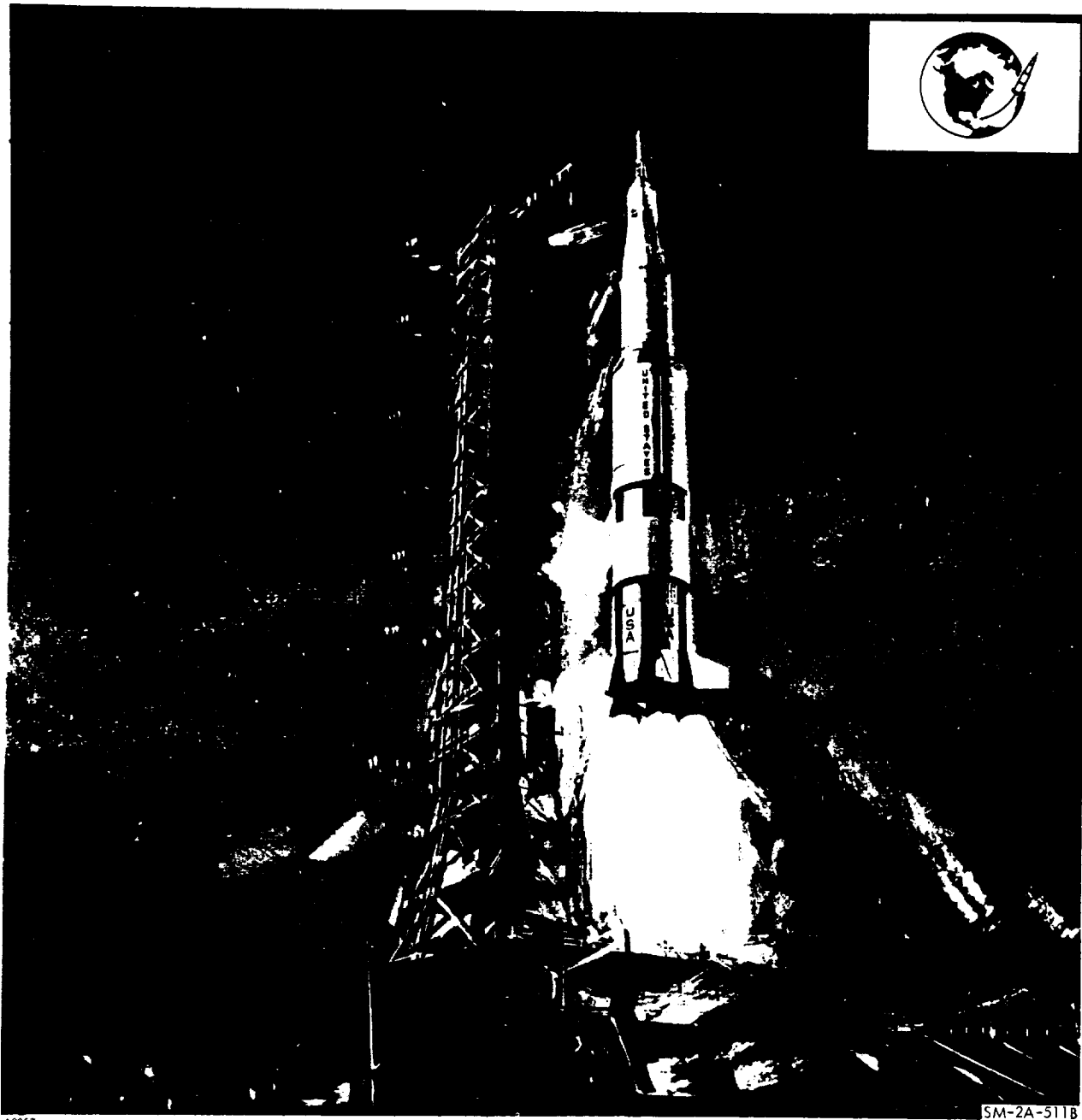


Figure 8-5. Lift-Off

8-15. LIFT-OFF.

8-16. Upon launch, the Saturn V first-stage (S-IC) engines are ignited by the launch control center. The center engine ignites first, followed by the ignition of the four outer engines. The launch pad hold-down devices release after initial operational thrust is sufficient. The launch control center and the spacecraft crew will continuously monitor the initial operational ascent attitude parameters.

## 8-17. FIRST-STAGE SEPARATION.

8-18. The launch vehicle guidance system initiates roll of the spacecraft to the required launch azimuth. The first-stage pitch programmer initiates the required pitchover of the spacecraft. Voice communication between the crew and manned space-flight network (MSFN) is maintained through the critical maximum dynamic flight conditions and throughout the ascent phase. The cutoff of the first-stage engines is followed by ignition of the second-stage ullage rockets. The first-stage retrorocket then separates the first stage from the second stage.

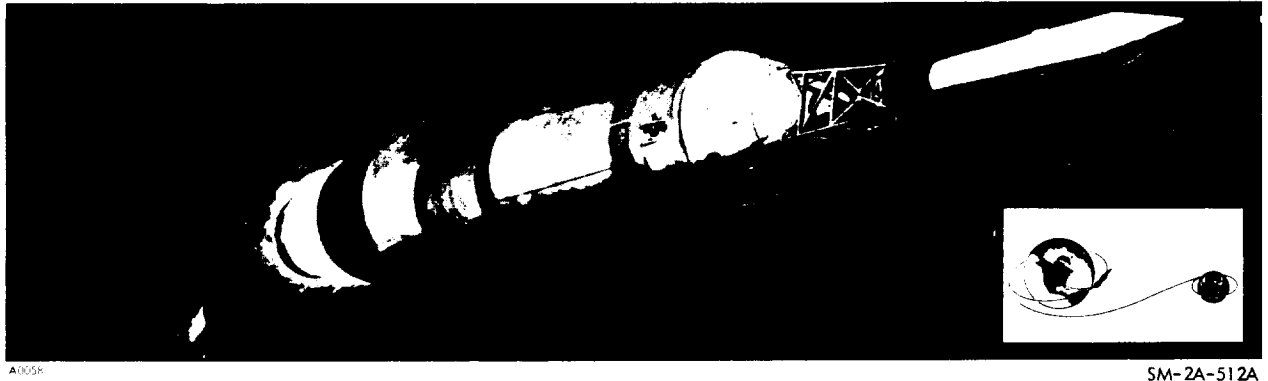


Figure 8-6. First-Stage Separation

## 8-19. SECOND-STAGE EVENTS.

8-20. Second-stage (S-II) engine ignition occurs nominally two seconds after cutoff of the first-stage engines at approximately 200,000 feet. The flight trajectory of the spacecraft is controlled by the third stage (S-IVB) inertial guidance system. The launch escape system is operationally jettisoned at approximately 320,000 feet altitude. The second-stage engines are cut off at an altitude of approximately 600,000 feet. The sequential ignition of the third-stage (S-IVB) ullage rockets, second-stage retrorockets, and third-stage engines effects separation of the second stage. The third-stage engines provide the thrust required to place the spacecraft in earth orbit. The third-stage guidance control system cuts off the third-stage engines after the programmed orbit conditions have been attained.

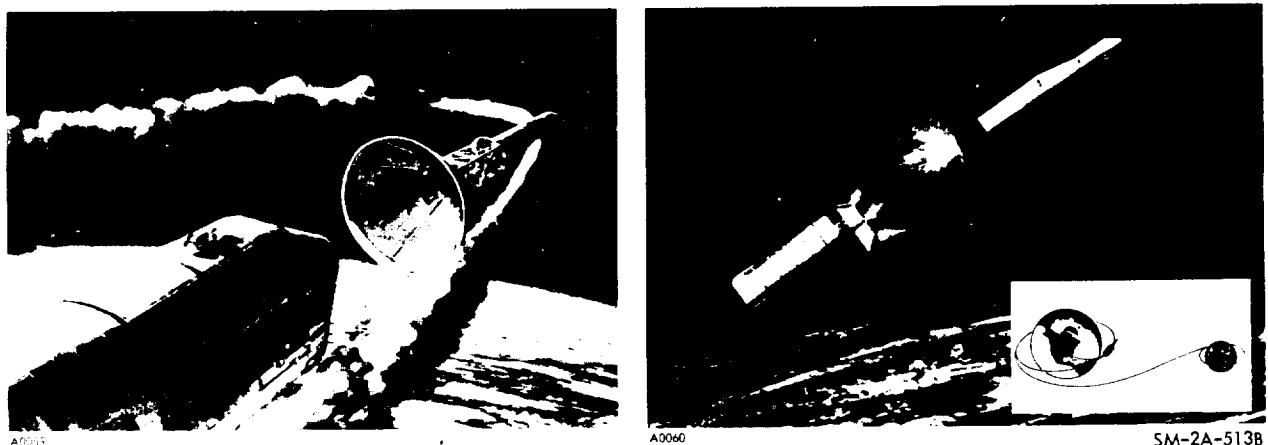


Figure 8-7. Second-Stage Events



Figure 8-8. Earth Orbit

#### 8-21. EARTH ORBIT.

8-22. The spacecraft and third stage are to orbit the earth, no more than three times, at an approximate altitude of 100 nautical miles. During this period, the orbital parameters are determined by manned space-flight network; then verified by landmark navigational sightings and the spacecraft crew. This determines the required velocity increment and trajectory for translunar injection.

8-23. The crew will perform a biomedical and safety equipment check. Sequence checks will be made of the environmental control system, communications and instrumentation system, service propulsion system, service module reaction control system, electrical power system, guidance and navigation system, stabilization and control system, and crew equipment system.

8-24. Translunar injection parameters are determined onboard the spacecraft by sequential landmark navigational sightings (using the scanning telescope) and by the Apollo guidance computer. Trajectory and star-tracking data computations are made by the Apollo guidance computer. The inertial measurement unit is fine-aligned for the translunar injection monitor, using the Apollo guidance computer. The center-of-gravity offset angles are set into the service propulsion system gimbal position display. The  $\Delta V$  program, time, and direction vector are set into the Apollo guidance computer. The stabilization and control system is prepared for the  $\Delta V$  maneuver, including minimum deadband hold control and monitor mode. Finally, the third-stage reaction control system is prepared for the  $\Delta V$  translunar injection.

8-25. Verification of "go" conditions for translunar injection will be confirmed by the spacecraft crew and the MSFN. The third-stage countdown and ignition sequence is performed with the spacecraft in the required translunar injection attitude.



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Figure 8-9. Translunar Injection

#### 8-26. TRANSLUNAR INJECTION.

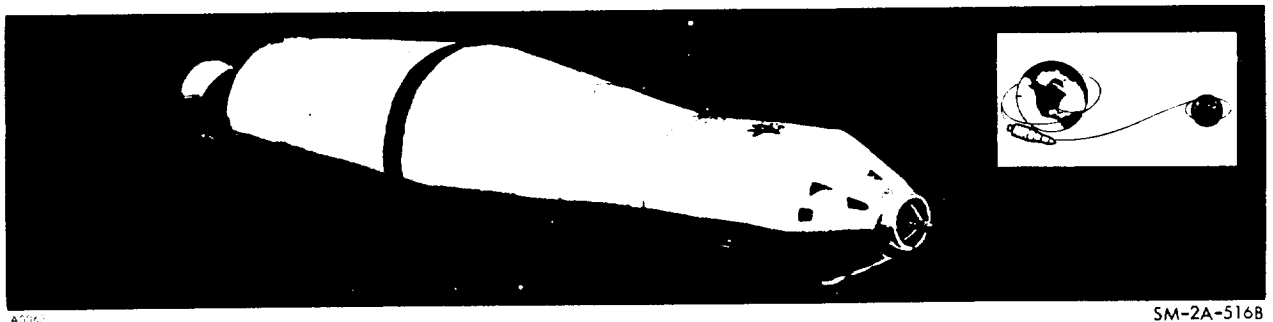
8-27. The translunar injection phase begins with the third-stage ullage rocket ignition. The third-stage propulsion system is operated to provide sufficient thrust to place the spacecraft in a translunar "free-return" trajectory in accordance with the  $\Delta V$  magnitude, time duration, and thrust vector previously established and operationally programmed onboard the spacecraft by the crew, and confirmed by the MSFN.

8-28. The third-stage instrument unit provides operational guidance control for the translunar injection with the Apollo guidance and navigation system capable of backup control, if necessary. The third-stage engines operate for the predetermined time, nominally 5 minutes. The crew monitors the emergency detection system and spacecraft attitude control displays. The spacecraft guidance and navigation system monitors the programmed injection maneuver.

#### 8-29. INITIAL TRANSLUNAR COAST.

8-30. Following translunar injection, the MSFN will determine the spacecraft trajectory and verify it with an onboard determination performed by the crew. The operational controls are then set for an initial coast phase. An onboard systems check is then made of all crew equipment, electrical power system, environmental control system, service module reaction control system, and the service propulsion system. The status of these systems is communicated to MSFN.

8-31. The spacecraft body-mounted attitude gyros are aligned, using the third-stage stable platform as a reference, and the flight director attitude indicator is set preparatory to initiating transposition of the lunar module. Confirmation of conditions for initiating transposition of the lunar module is made with MSFN.



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Figure 8-10. Initial Translunar Coast

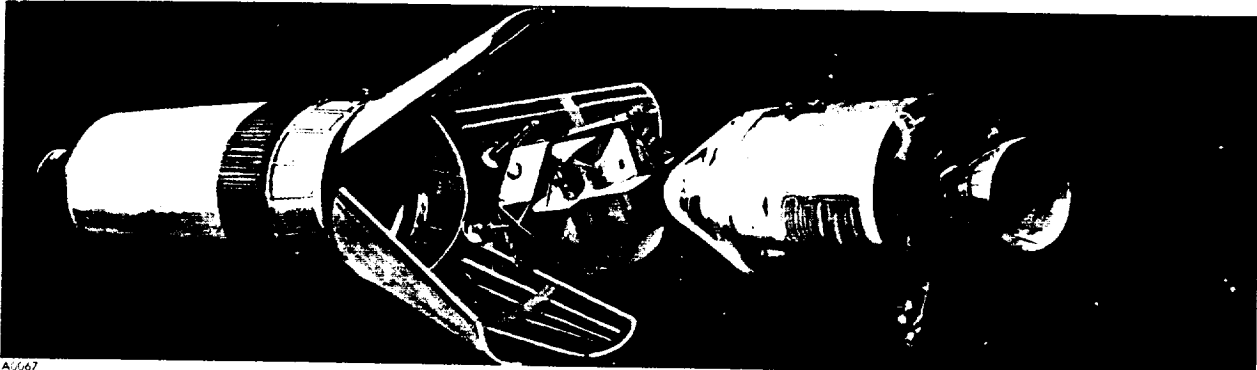
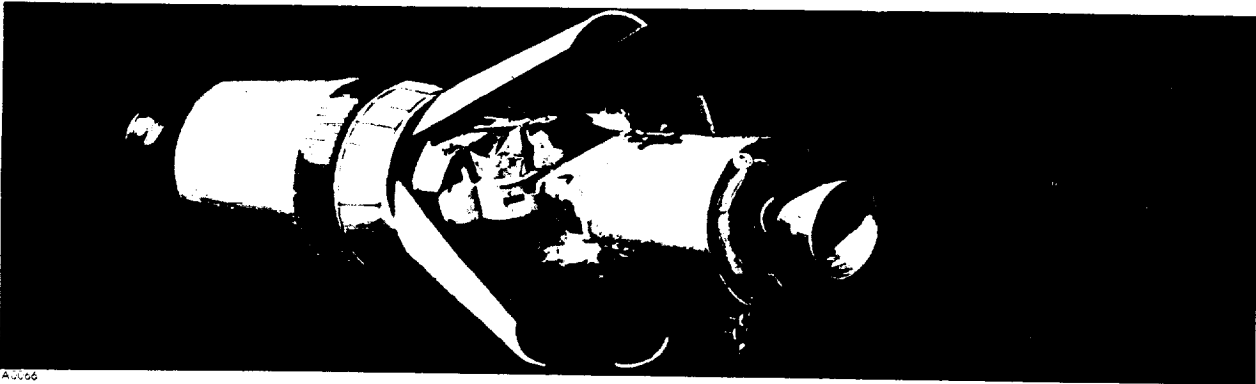
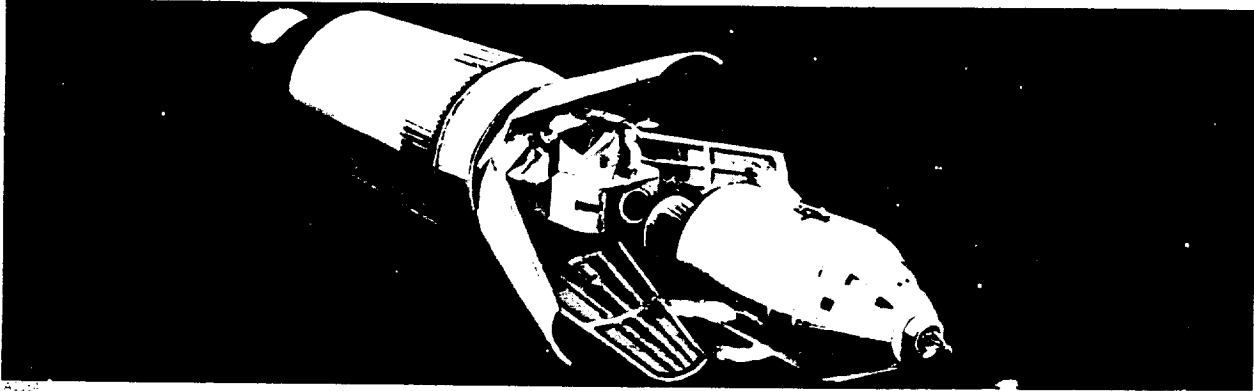


Figure 8-11. Spacecraft Transposition and Docking

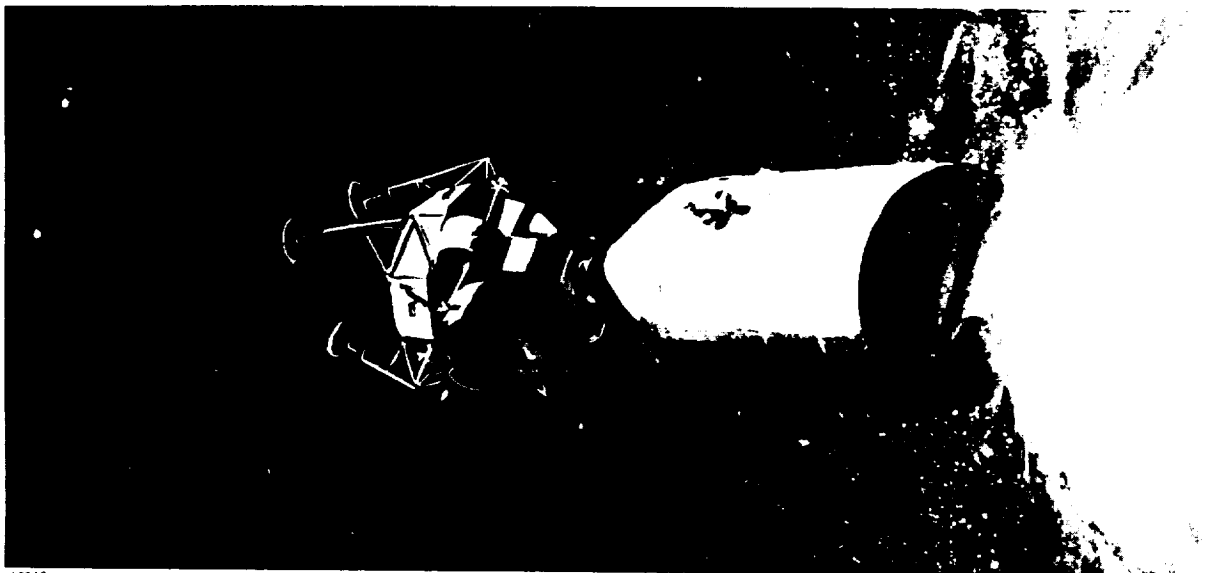
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### 8-32. SPACECRAFT TRANSPOSITION AND DOCKING.

8-33. Transposition and docking of the spacecraft consists essentially of separating and translating the command/service module from the spacecraft-LM-adaptor (SLA), third stage, pitching the command/service module 180 degrees, and translating the command/service module back to the lunar module to join the lunar module to the command module. The S-IVB guidance system stabilizes the SLA and third stage, during the transposition operations which precede docking. Upon completion of docking, the third stage is jettisoned. The entire maneuver will normally be completed within one hour after trans-lunar injection. Necessary precautions will be observed by the crew during the time the spacecraft passes through the Van Allen belts.

8-34. The spacecraft will be oriented within communication constraints to provide the most desirable background lighting conditions for the transposition of the spacecraft. The third stage is stabilized in an attitude-hold mode. The adaptor is pyrotechnically separated from the command/service module, which is then translated approximately 50 feet ahead of the lunar module and third stage, using the service module reaction control system engines. The command/service module is then rotated 180 degrees in pitch, using the service module reaction control engines. The docking attitude of the command/service module for the SLA, third stage will be established and maintained, using the service module reaction control system engines.

8-35. The command/service module will be translated toward the SLA, third stage, with minimum closing velocity, so that the command/service module docking probe engages within the drogue mechanism on the lunar module. A mechanical latching assembly secures the lunar module to the command/service module. The command/service module, with the lunar module attached, then separates and translates away from the third stage.



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Figure 8-12. Final Translunar Coast

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8-36. FINAL TRANSLUNAR COAST.

8-37. The final translunar coast phase begins with the ignition of the service module reaction control system to separate the spacecraft from the third stage, and ends just prior to lunar orbit insertion. The primary operations occurring during this phase consist of spacecraft systems checkout, trajectory verifications, and preparation for lunar orbit insertion. Midcourse  $\Delta V$  corrections, navigational sightings, and inertial measurement-unit alignments are to be made.

8-38. The spacecraft guidance and navigation system computes the trajectory of the spacecraft (in conjunction with navigational sightings). The delta increment required is determined by MSFN, and confirmation of the trajectory and velocity increment values is made with the Apollo guidance computer. Midcourse incremental velocity corrections will be made when required.

8-39. The attitude of the spacecraft will be constrained at times because of operational temperature control restrictions. At least one astronaut will be in his space suit at all times. A crew work-rest cycle will be established and followed during this phase. The capability to initiate an abort at any time during this space will be provided.

8-40. In preparation for lunar orbit insertion, the spacecraft attitude, lunar orbit insertion velocity increment, and the time to initiate the service propulsion system thrust required to achieve the desired orbit around the moon are determined by trajectory data from MSFN and from the guidance and navigation system.



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Figure 8-13. Lunar Orbit Insertion

#### 8-41. LUNAR ORBIT INSERTION.

8-42. This phase begins with the spacecraft properly oriented for lunar orbit insertion and ends with the cutoff of the service propulsion system as the spacecraft is inserted into a lunar orbit.

8-43. Navigation sightings will be made using the Apollo guidance computer, inertial measurement unit, and scanning telescope. The MSFN determines the lunar orbit insertion trajectory and star catalog data,  $\Delta V$  correction parameters, and the lunar orbit insertion parameters. These determinations are confirmed using the Apollo guidance computer. The reaction control system ignition provides a translation impulse and roll-control operation. The guidance and navigation system initiates and controls the programmed insertion maneuvers and service propulsion system.

8-44. The retrograde impulse required to establish the lunar orbit occurs near the minimum altitude of the lunar approach trajectory. The point of this altitude is almost directly behind the moon with respect to the earth. The total velocity increment required to achieve the desired orbit around the moon, including any necessary plane changes, is applied during this phase.

8-45. The initial lunar orbit coast phase begins with cutoff of the service propulsion engine as the spacecraft is inserted into lunar orbit and ends with activation of the lunar module reaction control system to effect separation from the spacecraft.

8-46. Following lunar orbit insertion, the crew will transmit trajectory data and information to MSFN. The orbit ephemeris about the moon will be determined as accurately as possible, using the spacecraft guidance system and MSFN. A confirming checkout of the lunar module guidance system is also made prior to separation from the spacecraft.

8-47. The CSM systems will be capable of operation at their nominal design performance level for a mission of approximately 11 days. A single crewmember can control the spacecraft in lunar orbit for several days. Communication capability will be provided between the CSM, manned space-flight network, and the lunar module when separated and within line-of-sight. The CSM and lunar module separation and docking operations will not be restricted by natural illumination conditions.

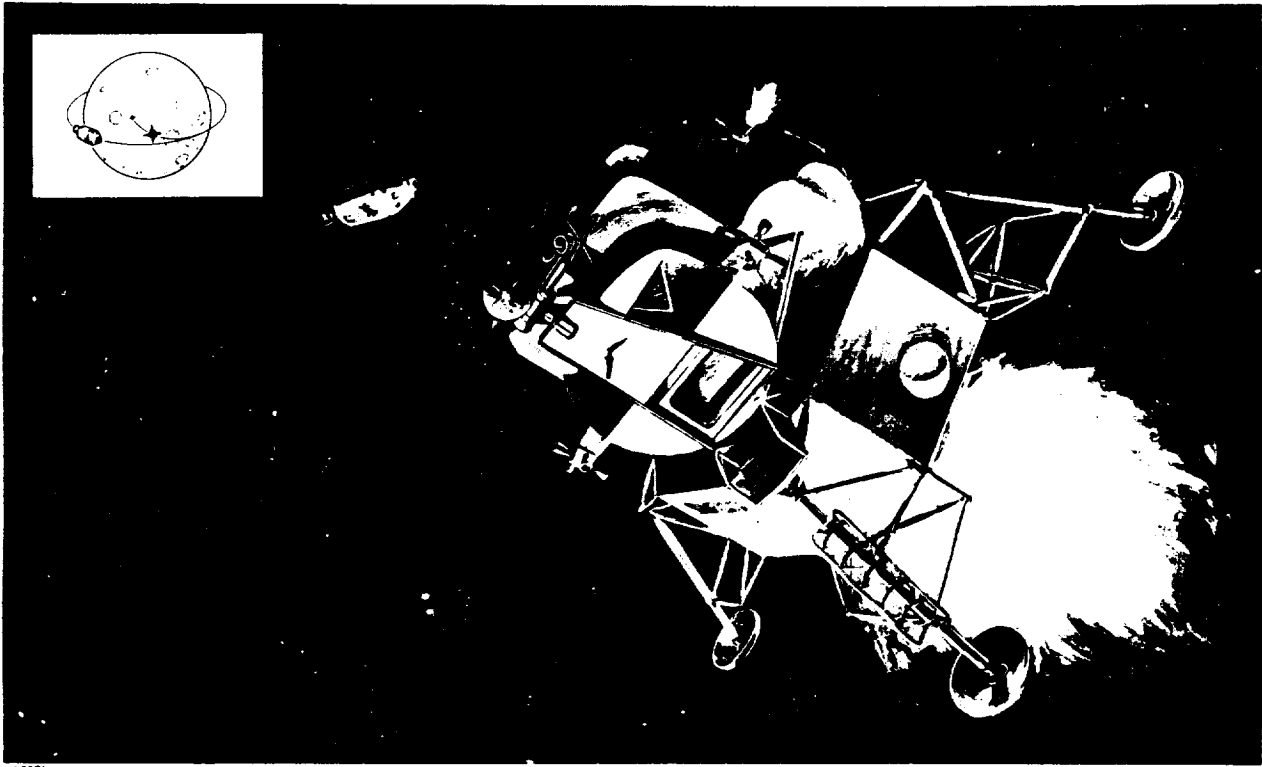
8-48. Observations and calculations will be made of the preselected landing site from the CSM, to determine if the area location is satisfactory or if an alternate landing area should be selected. Detailed surveillance of the landing area is to be made from the lunar module prior to landing.

8-49. Lunar orbit trajectory verification requires fine-alignment of the inertial measurement unit, and a related series of navigational sightings will be made of known lunar surface areas and reference stars, using the scanning telescope, sextant, and Apollo guidance computer. Parameters for lunar orbit and transearth injection will be determined by MSFN and confirmed by the Apollo guidance computer; but the LM descent trajectory will be calculated using the LM guidance, navigation, and control system.

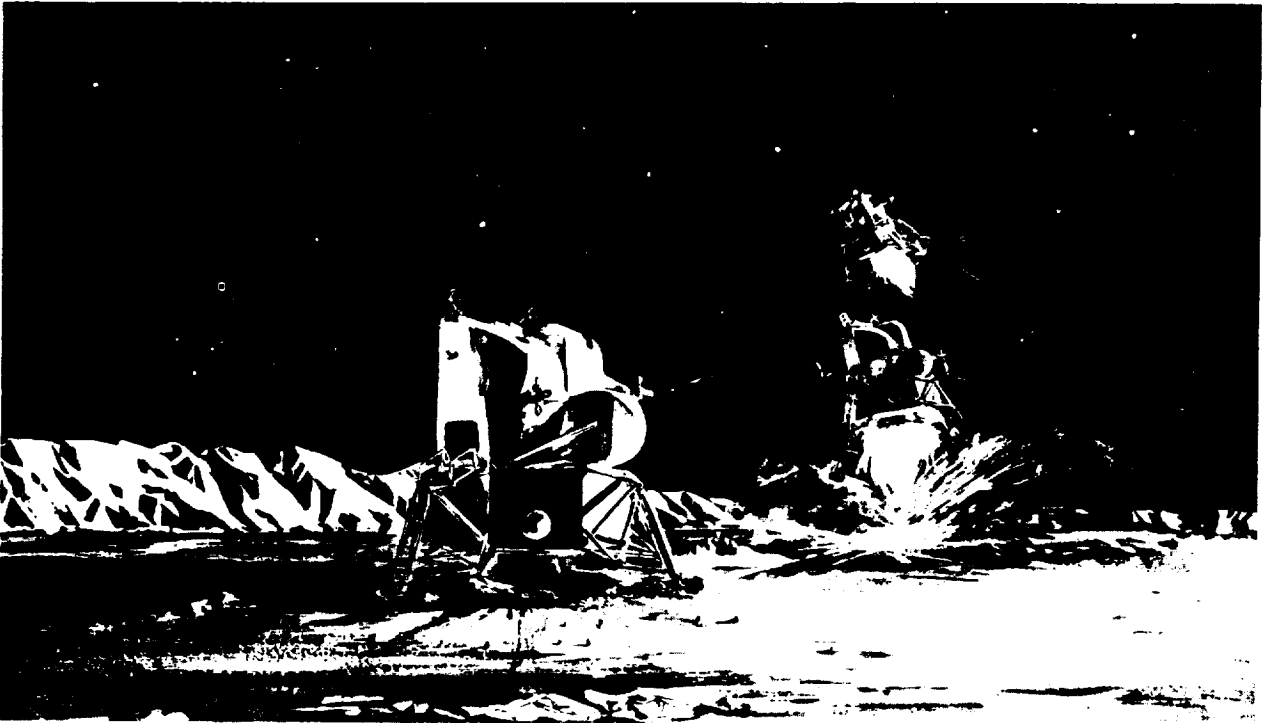
8-50. Upon final confirmation of these parameters, the commander and the pilot will transfer from the CSM to the lunar module. The lunar module electrical power system, environmental control system, communication system, guidance, navigation, and control system, reaction control system, and ascent and descent engine systems will be checked out and the landing gear extended. A check will be made of emergency procedures and corresponding spacecraft systems. The operational capability of the air lock will be verified. Initial operational information will be synchronized between the CSM and lunar module.

8-51. The CSM will be aligned and held in the required attitude for separation. The lunar module guidance computer will be programmed for the transfer trajectory when the CSM orbit is determined accurately. The orbit will not be disturbed, unless an emergency requirement prevails, or until the docking phase is complete. Emergency or additional data may require that the CSM lunar orbit be updated as necessary by the remaining crewmember.

8-52. Actual separation of the lunar module from the CSM is effected by a propulsion thrust from the lunar module reaction control system. After a specified time, an equivalent impulse is applied in the opposite direction so that the relative velocity between the lunar module and the CSM will be zero during the final checkout of the lunar module. Final checkout is accomplished with the lunar module in free flight, but relatively close to the CSM in case immediate docking is required.



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Figure 8-14. Lunar Landing

8-53. LUNAR LANDING.

8-54. The lunar landing operations phase begins with initial lunar module separation from the CSM and ends with touchdown on the surface of the moon.

8-55. The essential lunar module operations which occur are attitude control, incremental velocity control, and time to fire, computed by the lunar module guidance, navigation, and control system and verified by the CSM guidance and navigation system. Lunar module insertion into a descent orbit is accomplished by reaction control system ullage acceleration and ignition of the descent engine with the thrust level and burn-time automatically controlled by the lunar module guidance navigation, and control system. The lunar module separates from the CSM during this maneuver, and communication with manned space-flight network at time of insertion cannot be accomplished, since it occurs on the far side of the moon.

8-56. Descent trajectory determination will be made using data from the LM rendezvous radar tracking the CSM. The lunar module will coast in a descent transfer orbit following descent engine cutoff, and close observation of the proposed lunar landing site will be made for final approval. The descent engine will be re-ignited prior to reaching the low point in the orbit and sustained thrust initiated for the descent maneuver. The thrust and attitude are controlled by the guidance, navigation and control system by comparison of the actual and planned landing tracks.

8-57. The translational and radial velocities will be reduced to small values and the descent engine cut off at a specified altitude above the lunar surface. The commander will control the descent within present limits. Terminal descent and touchdown will be made by manual control and use of the landing radar. Confirmation of initial lunar touchdown will be made by the lunar module crew to the CSM and to MSFN.

8-58. The crewman in the CSM will maintain visual observation of the lunar landing operation as long as possible. All three crewmen will be in their space suits.

8-59. LUNAR SURFACE OPERATIONS.

8-60. The lunar surface operations phase begins with lunar touchdown and ends with launching of the lunar module from the moon.

8-61. Initial tasks to be performed by the two astronauts following touchdown include review and determination of the lunar ascent sequence and of the parameters required. A complete check of the lunar module systems and structure will be made. Necessary maintenance will be determined and performed to assure the operational ascent capability of the lunar module. The systems will be put into a lunar-stay mode and a systems monitoring procedure established. The lunar module will be effectively secured as necessary, and the landing and launch stage disconnect mechanisms activated.

8-62. The lunar landing must be made on the earth-side of the moon to permit and establish communication with MSFN and the lunar orbiting CSM from the surface of the moon. Voice and signal communication will be verified prior to beginning egress and lunar exploration activity. A post-touchdown status report will be made to the CSM before line-of-sight communication is lost as the spacecraft orbits below the lunar horizon. The position and attitude of the lunar module on the moon will be established and reported.

8-63. The lunar module is capable of operating normally on the lunar surface during any phase of the lunar day-night cycle. The lunar module, designed to be left unoccupied with the cabin unpressurized on the lunar surface, will be capable of performing its operations independently of earth-based information or control.

8-64. Although the nominal lunar stay-time may be from 4 to 35 hours, depending on the planned scientific exploration program, the capability to launch at any time in an emergency situation shall be established. Portable life support systems will provide the capability for 24 man-hours of separation from the lunar module. Maximum continuous separation will be 4 hours (3 hours of normal operation plus 1 hour for contingencies). The astronauts shall alternately share the lunar surface exploration within the above mentioned PLSS limits until the exploration is concluded.



Figure 8-15. Lunar Surface Operations

8-65. One of the two astronauts will descend to the lunar surface to perform scientific exploration and observation and will stay within sight of the crewmember remaining behind. The scientific exploration activity may include gathering selected samples from the lunar surface and atmosphere, measurement of lunar surface and atmospheric phenomena, and the securing of scientific instruments on the lunar surface for signal transmission and telescopic observation from earth. Video transmission from the lunar surface may be accomplished by means of portable television equipment. Provision will be made for return of approximately 80 pounds of samples from the lunar surface.

8-66. Following completion of the lunar surface exploration activity, preparation for ascent will begin. The two astronauts will return to the LM and secure themselves in the LM cabin. Launch and rendezvous plans will be confirmed with the crewman in the CSM and with MSFN. The spacecraft tracking and rendezvous data determination sequence will be initiated. The lunar module operational systems required for lunar ascent, the ascent and descent stage separation, and the inertial measurement unit alignment will be checked out.

8-67. CSM SOLO LUNAR ORBIT OPERATIONS.

8-68. During separation of the lunar module from the CSM for lunar operations, the crewmember in the CSM will perform a series of backup operations in support of the lunar activity.

8-69. The CSM crewmember will initially monitor the separation sequence and initiate optical tracking of the LM. A communication link between the CSM, lunar module, and MSFN will be established. The spacecraft will monitor the LM orbit injection sequence and maintain cognizance of essential operational parameters.

8-70. In addition, periodic operational checks will be made of the CSM systems, the inertial measurement unit alignment procedure performed, and the lunar orbit parameters periodically updated and confirmed with MSFN.

8-71. The lunar landing sequence may be monitored by optical tracking and essential operational data will be transmitted to MSFN. The location of the lunar landing site will be determined. Visual observations will be made of the lunar surface operations and periodic line-of-site communication with the crew maintained as required.

8-72. CSM confirmation of the LM ascent and rendezvous parameters will be established. Radar tracking of the ascent trajectory will be established to permit determination of the operational maneuvers to effect rendezvous. The spacecraft guidance and navigation system determines these essential parameters.

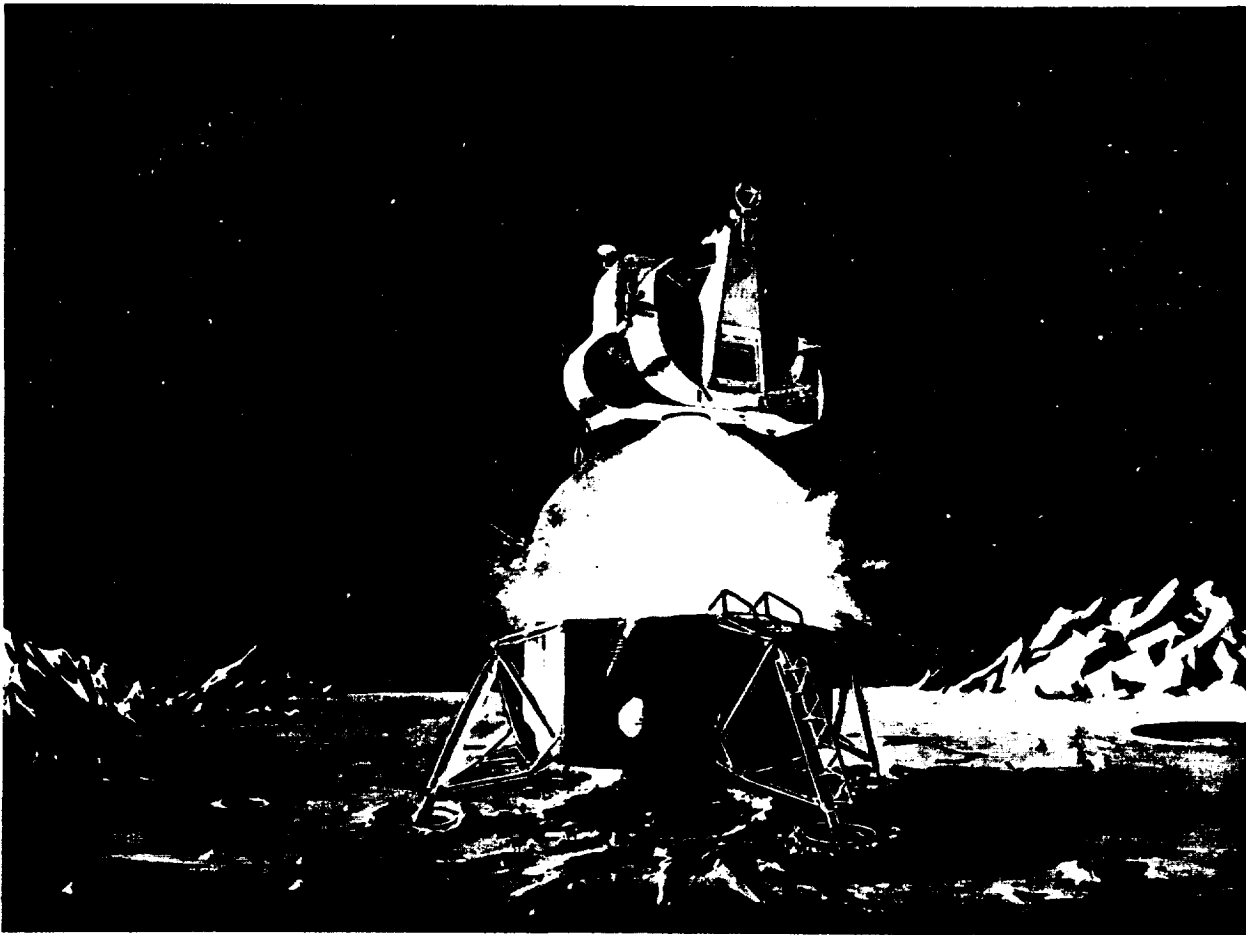
8-73. For rendezvous and docking, the CSM normally will be stabilized in a passive mode. However, the CSM will have the capability of controlling the terminal attitude and translation required for rendezvous and docking. The CSM solo operation ends after completion of docking, when the crew transfers from the LM to the CSM.

8-74. LUNAR ASCENT.

8-75. Confirmation of "go" conditions for lunar launch is made with the CSM and MSFN. The ascent engine will be ignited and launch from the lunar surface accomplished.

8-76. The lunar module ascent trajectory places it in a position approximately 50,000 feet above the lunar surface, at a velocity such that the resultant orbit about the moon has a clear minimum altitude of approximately 50,000 feet and a nominal intercept with the orbiting CSM. The launch trajectory of the lunar module is controlled through its guidance, navigation, and control system. The lunar module rendezvous radar tracks the CSM during the ascent to provide inputs to the guidance, navigation, and control system. The lunar module reaction control system executes the required roll, attitude, and pitch maneuvers to place it in the required orbit.

8-77. Following the cutoff of the ascent engine, the radar will continue to track the CSM. The CSM guidance and navigation system will compute the orbit of the lunar module and the crew will determine if any  $\Delta V$  corrections are required to effect rendezvous. The final coast trajectory parameters, range, rate, and attitude angles will be determined and rendezvous operations will be initiated.



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Figure 8-16. Lunar Ascent



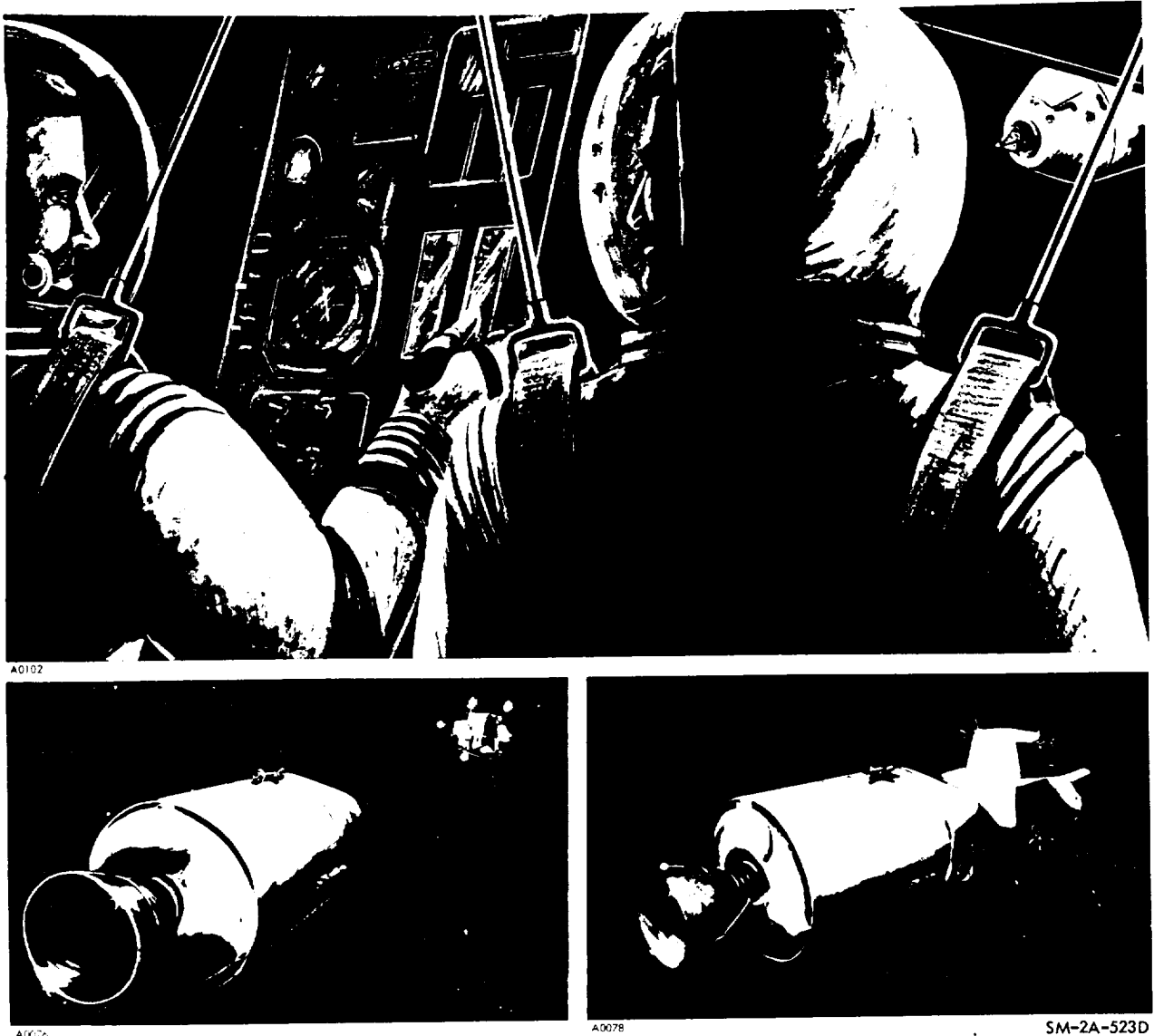


Figure 8-17. Rendezvous

8-78. RENDEZVOUS.

8-79. The rendezvous operations begin during the LM ascent phase. The ascent trajectory may require up to three midcourse corrections to reach a target course with the CSM. These corrections will be made with either the LM ascent engine or the reaction control system. The final rendezvous maneuvers will include three terminal homing thrusts from the LM reaction control system to reduce the relative velocity to a minimum.

8-80. The LM crew will manually control the lunar module within a range of approximately 500 feet from the CSM, with a relative velocity of 5 feet per second, or less. Both the CSM and the LM are capable of performing the final rendezvous and docking maneuvers required. The CSM is normally stabilized in passive mode with the lunar module operationally active to effect rendezvous.

8-81. The final rendezvous maneuvers of the LM to effect contact with the CSM, are performed using the reaction control engines. Docking alignment and closing velocity will be verified and necessary manual operational control established to effect engagement of the drogue and probe. Following verification of the drogue and probe engagement the latching sequence will be performed. Completion of final docking will be verified by both the LM and CSM crewmembers. The postdocking status of the system will be determined and, when the docking maneuver is completed, information will be transmitted to manned space-flight network.

8-82. Following engagement of the drogue and probe, and four semiautomatic latches (initial docking), an LM crewmember will remove the LM upper hatch and secure the LM to the CSM by locking eight manual latches and four semiautomatic latches provided (final docking). (See figure 3-22.) After the drogue and probe are removed and stowed in the LM, the pressures are allowed to equalize and the C/M access hatch is removed.

8-83. Following completion of final docking, the LM systems will be secured. The LM crew will then transfer the lunar scientific equipment and samples to the command module and store them. The two crewmembers will enter the command module and secure the access hatch between the command module and the lunar module.

8-84. A system status check will be made of the spacecraft operational systems and the status for separation from the LM will be communicated to MSFN. The sequence for separation will then be initiated. The LM will be pyrotechnically released from the CSM and the service module reaction control engines activated to translate the CSM away from the lunar module.

8-85. Following this separation, the CSM will be operationally maneuvered for the inertial measurement unit alignment. After fine-alignment of the inertial measurement unit, a series of three navigational sightings will be made to establish the transearth injection parameters. The transearth injection trajectory is computed by the Apollo guidance computer and subsequently confirmed with MSFN. The final transearth injection operational parameters, service module reaction control system ullage acceleration, required service propulsion system firing time, incremental velocity, thrust vector, and transearth injection attitude are determined and confirmed by MSFN.

#### 8-86. TRANSEARTH INJECTION AND COAST.

8-87. The transearth injection phase covers the period of time the service propulsion system burns when injecting the CSM into a transearth trajectory.

8-88. For each lunar orbit there exists one opportunity for transearth injection. Injection occurs behind the moon, with respect to the earth, nominally one orbit after completion of rendezvous with the lunar module. The service propulsion system ullage acceleration is manually initiated to begin the earth injection sequence. The injection velocity increment for the predetermined transit time to earth is initiated with the service propulsion system thrust controlled by the guidance and navigation system.

8-89. The transearth coast phase begins with service propulsion system engine cutoff following transearth injection and ends at the entry interface altitude of 400,000 feet.

8-90. The transearth injection will be operationally performed to place the spacecraft in a return trajectory toward the earth, and will require a minimum of operational maneuvers and corrections. A  $\Delta V$  budget sufficient to provide a total velocity correction of 300 feet per second during the transearth coast phase is provided. Nominally, three transearth velocity corrections may be made: one near the moon, the second approximately near the midpoint of the return trajectory, and the third  $\Delta V$  increment near the earth.

9-91. The primary operations which occur consist of periodic systems checks, trajectory verification, determination of the  $\Delta V$  corrections required, preparation for jettison of the service module, service module jettison from the command module, and preparations for earth entry.

8-92. The midcourse corrections are determined by means of sequential trajectory verifications. The MSFN computes variations from the required trajectory parameters; and determines velocity changes (if necessary), thrust vectors, and firing time. This data is confirmed with the Apollo guidance computer. The  $\Delta V$  is operationally implemented and the verification of the velocity correction is subsequently determined after each midcourse correction.

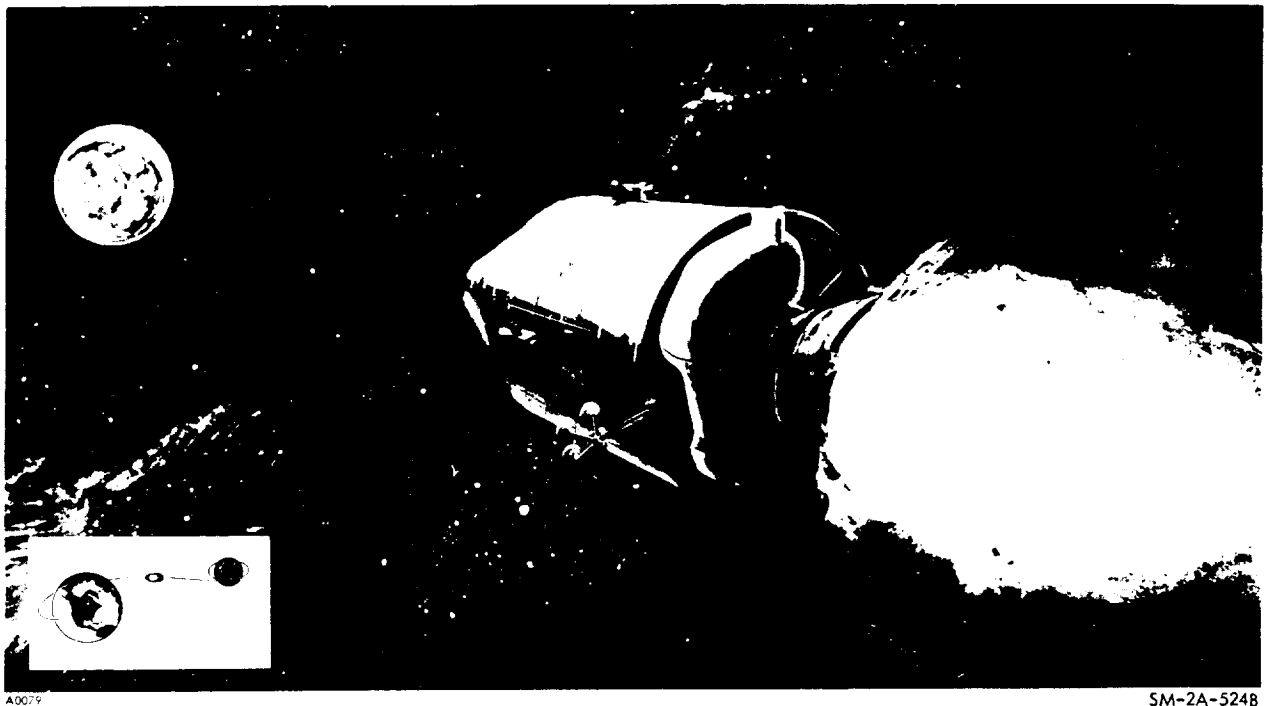
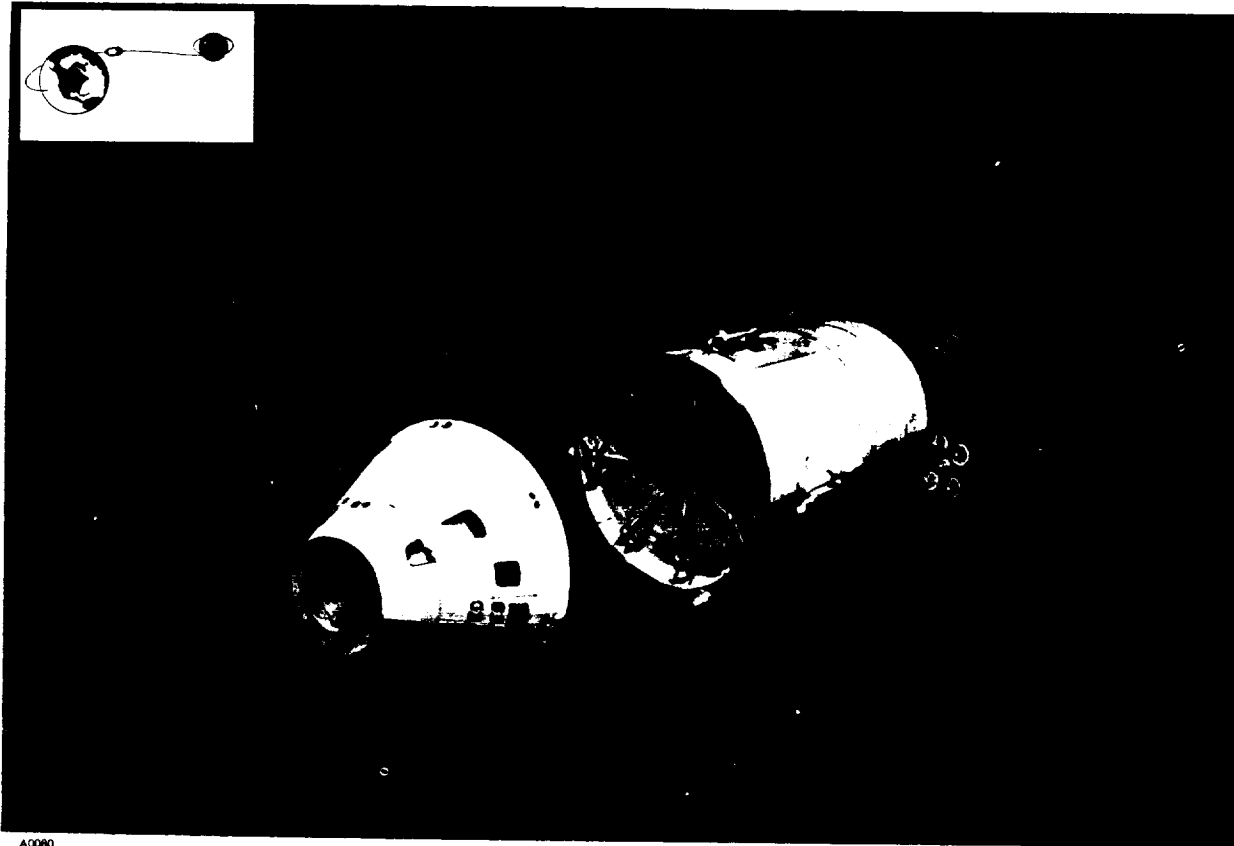


Figure 8-18. Transearth Injection and Coast



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Figure 8-19. Service Module Jettison

### 8-93. SERVICE MODULE JETTISON.

8-94. Following the last midcourse correction, preparatory activity will be initiated for jettisoning the service module. The near-earth entry corridor and pre-entry parameters for separation of the service module from the command module will be determined by MSFN and confirmed by the Apollo guidance computer. The final systems check will be performed and the spacecraft oriented for service module jettison. The command module entry batteries will be activated, and the service module operationally jettisoned by pyrotechnic separation of the adapter and subsequent translational thrust by the service module reaction control engines to effect space separation of the command module and service module. The command module is then oriented into an MSFN-confirmed entry attitude by the command module reaction control engines.

8-95. A status check will be made of the systems after service module separation. Final operational checks will be made of the systems for entry. Confirmation of the entry parameters will be made with MSFN. The entry monitor control and display will be operationally activated, entry alignment of the inertial measurement unit made, and utilization of the flight director attitude indicator and Apollo guidance computer implemented.

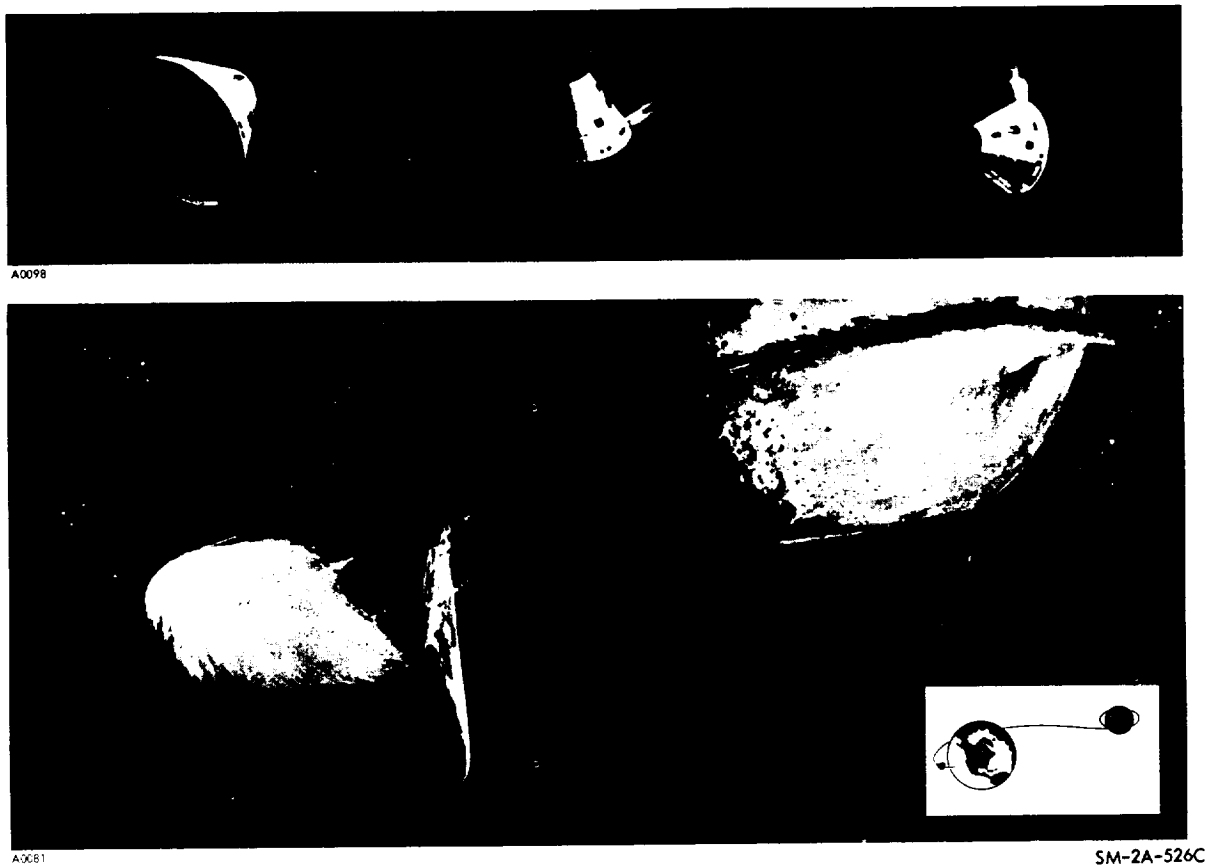


Figure 8-20. Earth Entry

8-96. EARTH ENTRY.

8-97. The earth entry phase begins at an altitude of 400,000 feet and ends upon activation of the earth landing system.

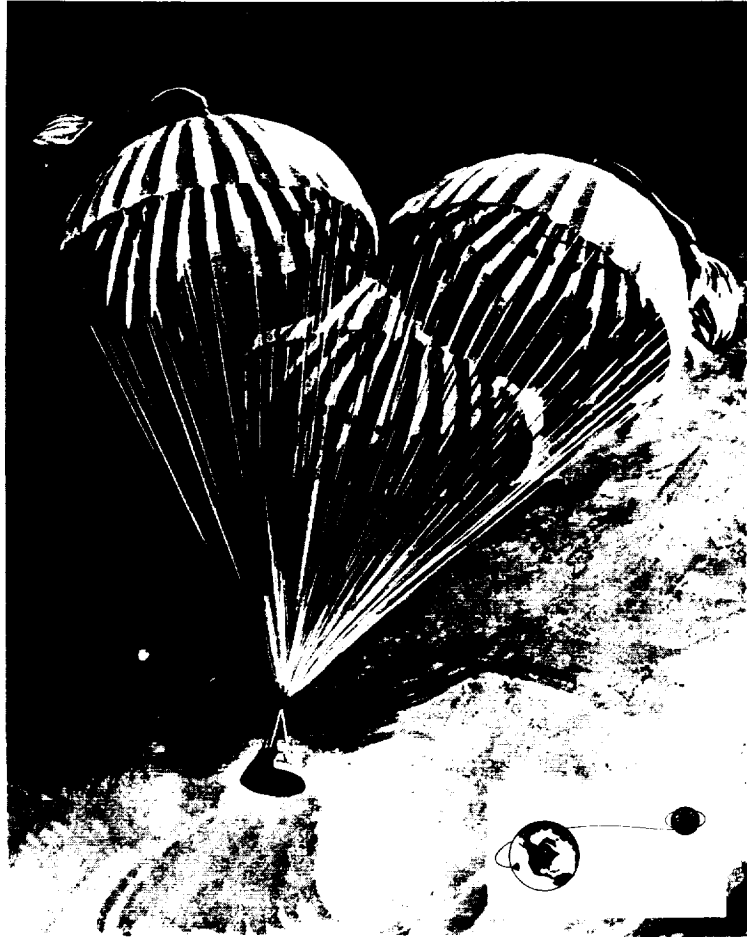
8-98. The operational control of the entry is dependent on the range required from the 400,000-foot entry point to the landing area. For short-entry ranges, no skip-out maneuver is required. For entry ranges approaching the upper limit, a skip-out maneuver is required to attain the greater distance. In either case, the lift maneuver is controlled by rolling the command module using the reaction control engines. Operational control is normally maintained through the guidance and navigation system with the commander providing a backup capability using the entry monitor display.

8-99. Entry into the earth atmosphere is sensed by a 0.05G signal indication. The entry attitude is determined on the flight director attitude indicator, and the entry monitor control display is observed. The Apollo guidance computer computes the range to "go" and provides navigation from the 0.05G point and time.

8-100. The range control maneuver is initiated by reaction control engines roll control and necessary pitch and yaw damping. The entry monitor display indicates the  $\Delta V$  and G-level, and the survival display requirements. The guidance and navigation system executes the required reaction control system roll commands.



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Figure 8-21. Earth Landing

### 8-101. EARTH LANDING.

8-102. The earth landing phase begins when the earth landing system is operationally armed at an altitude of 100,000 feet and ends with touchdown. The earth landing system automatic sequencer pyrotechnically ejects the forward heat shield at approximately 24,000 feet. Two seconds later, the two drogue parachutes are mortar-deployed in a reefed condition. The reefing lines are pyrotechnically severed and the drogue parachutes open fully in approximately 8 seconds to orient the C/M apex upward during descent to 10,000 feet. Three pilot parachutes are automatically mortar-deployed at 10,000 feet, and the drogue parachutes are pyrotechnically disconnected. The pilot parachutes in turn, deploy the three main parachutes to a line-stretch, reefed condition. The reefing lines are pyrotechnically severed and the main parachutes open fully in approximately 8 seconds. The main parachutes lower the command module to touchdown and impact at a terminal descent velocity, assuring an impact G-level consistent with the safety of the crew. The main parachute attach lines are pyrotechnically severed upon touchdown.

8-103. During the final part of the main parachute descent, the recovery communication systems are activated and transmit a location signal for reception by the operational recovery forces.



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Figure 8-22. Recovery Operations, Primary Landing

8-104. RECOVERY OPERATIONS.

8-105. The recovery operations phase begins with touchdown and ends with the recovery of the crew and retrieval of the command module. The HF communication system is deployed and begins transmitting a repeating location signal for reception by the recovery task forces deployed in the area of predicted touchdown. Voice communication capability is also provided by the H-F communications system.

8-106. If touchdown occurs in water (primary landing), fluorescent dye goes into solution, coloring the water a bright, fluorescent, yellow-green over an extended area and lasting approximately 12 hours. The dye should be visible to recovery force aircraft or ships for a considerable distance. A flashing beacon light is also provided for use at night.

8-107. Immediately following a water landing, after the main parachutes are pyrotechnically cut from the command module, the crew will assess the flotation status and

capability of the command module. If the command module is in the inverted (stable II) flotation attitude, the crew will activate the uprighting system. When the command module achieves an upright (stable I) flotation attitude, the crew will remain in the command module or, if necessary, will leave in the inflatable liferaft provided for the three crewmembers. Steps will be taken, as necessary, to effectively secure the command module for optimum flotation stability and subsequent retrieval. The capability is to be provided for helicopter pickup of the command module, using the recovery pickup loop, or a nearby ship may pick up the command module. The three crewmembers may be picked up by helicopter, ship, or boat. Land ground forces may pick up the command module if the land touchdown point is in an accessible area.

8-108. The flotation design will provide a survivable flotation capability for a minimum of 48 hours, under design sea conditions. A water landing provides fewer touchdown hazards and a correspondingly greater safety for the crew.



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Figure 8-23. Recovery Operations, Backup Landing



## APOLLO SUPPORT MANUALS

### A-1. GENERAL.

A-2. Apollo support manuals consist of published data packages to support the Apollo program. The manuals are categorized into general series and defined by specific letter/number combinations as follows:

- SM1A-1                      Index of Apollo Support Manuals and Procedures
- SM2A-02                    Apollo Spacecraft Familiarization Manual
- SM2A-03-(S/C No.)      Preliminary Apollo Operations Handbook, Command and Service Module
- SM2A-03A-(S/C No.)    Preliminary Apollo Operations Handbook, Command and Service Module (Confidential Supplement to SM2A-03)
- SM2A-08-(S/C No.)      Apollo Recovery and Postlanding Operations Handbook
- SM3A-200                  Apollo Ground Support Equipment Catalog
- SM6A-(Series No.)      Apollo Training Equipment Maintenance Handbooks
  - 22                          Electrical Power System Trainer
  - 23                          Environmental Control System Trainer
  - 24                          Stabilization Control System Trainer
  - 25                          Sequential Flow System Trainer
  - 26                          Propulsion System Trainer
  - 41-1 and -2              Mission Simulators Maintenance and Operations Manual
- SM6T-2-02                Apollo Mission Simulator Instructor Handbook

### A-3. INDEX OF APOLLO SUPPORT MANUALS AND PROCEDURES.

A-4. Index SM1A-1 is published periodically and provides a listing of all Apollo Support Manuals and Procedures in publication.

A-5. APOLLO SPACECRAFT FAMILIARIZATION MANUAL.

A-6. The familiarization manual (SM2A-02) presents a general, overall description of the Apollo program. Coverage includes physical configuration, functional operation, the test program, and the missions of the equipment utilized within the scope of the Apollo program. General terms are used in the descriptive text with sufficient detail to ensure comprehension.

A-7. PRELIMINARY APOLLO OPERATIONS HANDBOOK, COMMAND AND SERVICE MODULE.

A-8. A preliminary Apollo operations handbook (SM2A-03 and -03A) is a preliminary version of the Apollo Operations Handbook designed as a single source of spacecraft data and operational procedures. The handbook provides detailed spacecraft operating instructions and procedures for use by the crew during all phases of the latest, manned Block I mission. This involves normal, alternate, backup, malfunction, and contingency procedures, crew procedures, and checklists. CSM and LM interface instructions and procedures applicable to the command module are included, with information on spacecraft controls and displays, systems data, crew personal equipment, in-flight experiments, and scientific equipment.

A-9. APOLLO RECOVERY AND POSTLANDING OPERATIONS HANDBOOK.

A-10. The Apollo recovery and postlanding operations handbook (SM2A-08-S/C No.) provides detailed information for retrieval of the recoverable portion of the spacecraft. Descriptive text and illustrations specify procedures and provide the information necessary to perform recovery and postlanding operations of each manned and unmanned command module scheduled for recovery.

A-11. APOLLO GROUND SUPPORT EQUIPMENT CATALOG.

A-12. An Apollo ground support equipment catalog (SM3A-200) is provided to identify and illustrate items of specific auxiliary, checkout, handling, and servicing equipment associated with Project Apollo.

A-13. APOLLO TRAINING EQUIPMENT MAINTENANCE HANDBOOKS.

A-14. An Apollo training equipment maintenance handbook (SM6A-series) is provided for the maintenance of the systems trainers and mission simulators.

A-15. APOLLO MISSION SIMULATOR INSTRUCTOR HANDBOOK.

A-16. An instructor's handbook (SM6T2-02) is provided for the mission simulators. The handbook provides the necessary information for training astronauts on the Apollo mission simulators.

## GLOSSARY OF ABBREVIATIONS, SYMBOLS, AND TERMS

This glossary lists terminology found in Apollo documentation and engineering drawings. Frequently used common terms, which are industry standard, have been omitted for brevity. This glossary will be updated to reflect the latest changes during each revision of the manual.

## ABBREVIATIONS

AAO	Astronauts Activities Office	AERO-A	AERO - Aerodynamics analysis
ABD	Airborne Ballistics Division (NASA)	AERO-D	AERO - Dynamics analysis
AC	Audio center	AERO-DIR	AERO - Director
ACA	Associate contractor administration	AERO-E	AERO - Experimental aerodynamics
ACE	Acceptance checkout equipment	AERO-F	AERO - Flight evaluation
ACED	AC Electronics Division	AERO-G	AERO - Aerophysics and astrophysics
ACF	American Car and Foundry	AERO-P	AERO - Future projects
ACM	Audio center module	AERO-PCA	AERO - Program coordination and administration
ACME	Attitude control and maneuvering electronics	AERO-PS	AERO - Projects staff
A&CO	Assembly and checkout	AERO-TS	AERO - Technical and scientific staff
ACR	Associate contractor	AF	Audio frequency
ACRC	Audio center - receiver	AFCS	Automatic flight control system
ACS	Attitude control and stabilization	AFETR	Air Force eastern test range
ACSB	Apollo crew systems branch	AGAA	Attitude gyro accelerometer assembly
ACTM	Audio center - transmitter	AGANI	Apollo guidance and navigation information
ACV	AC volts	AGAP	Attitude gyro accelerometer package (superseded by AGAA)
AD	Apollo development	AGC	Apollo Guidance Computer (used by MIT)
A/D	Analog-to-digital	AGC	Aerjet General Corporation
ADA	Angular differentiating accelerometer	AGCS	Automatic Ground Control Station (NASA)
ADC	Analog-to-digital converter	AGCU	Attitude gyro coupling unit
ADF	Automatic direction finding (equip.)		
ADP	Automatic data processing		
AEB	Aft equipment bay		
AEDC	Arnold Engineering Development Center		
AERO	Aeroballistics (MSFC)		

## SM2A-02

AGE	Apollo Guidance and Navigation Equipment (used by MIT)	APHFFF	Ames Prototype Hypersonic Free Flight Facility
AGE	Aerospace ground equipment	APK	Accelerometer package
AIAA	American Institute of Aeronautics & Astronautics	APO	Apollo project office
AIDE	Aerospace installation diagnostic equipment	APP	Access point PACE
AII	Apollo implementing instructions (NAA, S&ID)	APTT	Apollo Part Task Trainer
ALFA	Air lubricated free attitude	APU	Auxiliary power unit
ALIAS	Algebraic logic investigations of Apollo systems	AQ	Apollo qualification
AM	Amplitude modulation	ARA	Auxiliary recovery antenna
AMG	Angle of middle gimbal	ARC	Ames Research Center (NASA) (Moffet Field, Calif.)
AMMP	Apollo master measurements program	ARE	Apollo reliability engineering
AMOO	Aerospace Medical Operations Office (MSC)	AREE	Apollo reliability engineering electronics
AMPTF	Apollo Mission Planning Task Force	ARIS	Advanced range instrumentation ships
AMR	Atlantic Missile Range (Superseded by ETR)	ARM	Apollo Requirements Manual
AMRO	Atlantic Missile Range Operations (MSC)	ARS	Attitude reference system
AMS	Acoustic measurement system	ASCS	Automatic stabilization and control system
AMS	Apollo mission simulator	ASDD	Apollo signal definition document
AMW	Angular momentum wheel	ASDTP	Apollo Spacecraft Development Test Plan
AOH-CSM	Apollo Operations Handbook-CSM	ASF TS	Auxiliary systems function test stand
AOH-LM	Apollo Operations Handbook-LM	AS/GPD	Attitude set and gimbal position display
AORA	Atlantic Ocean Recovery Area	ASI	Apollo systems integration
AOS	Atlantic Ocean ship	ASM	Apollo Systems Manual
AP	Access point	ASP	Apollo spacecraft project
AP	Accelerometer package	ASPI	Apollo supplemental procedural information
APC	Procurement and Contracts Division (MSC)	ASPO	Apollo Spacecraft Project Office
APCA	Procurement Apollo	ASTR	Astronics (MSFC)
APCAL	Procurement Apollo lunar module	ASTR-A	ASTR - Advanced studies
APCAN	Procurement Apollo navigation and guidance	ASTR-ADM	ASTR - Administrative
APCAS	Procurement Apollo spacecraft	ASTR-E	ASTR - Electrical systems integration
APCAT	Procurement Apollo test and instrumentation	ASTR-F	ASTR - Flight dynamics
APCR	Apollo program control room	ASTR-G	ASTR - Gyro and stabilizer
APD	Advanced program development	ASTR-I	ASTR - Instrumentation development
		ASTR-M	ASTR - Electromechanical engineering
		ASTR-N	ASTR - Guidance and control systems

ASTR-P	ASTR - Pilot manufacturing development	CBC	Complete blood count
ASTR-PC	ASTR - Program coordination	CBX	C-band transponder
ASTR-R	ASTR - Applied research	cc	Cubic centimeter
ASTR-TSA	ASTR - Advanced research and technology	CCTV	Closed-circuit television
ASTR-TSJ	ASTR - Saturn	CCW	Counterclockwise
ASTR-TSR	ASTR - Reliability	C/D	Countdown
ATC	Assistant test conductor	C&D	Communication and data
ATO	Apollo Test and Operations	CDC	Computer Development Center (NASA)
AT&O	Apollo Test and Operations (ATO is preferred)	CDCM	Coupling display manual control - IMU
ATR	Apollo test requirement	CDCO	Coupling display manual control - optics
ATS	Atlantic tracking ship	CDOH	Coupling display optical hand controller
AUTO	Automatic	CDR	Critical design review
A-V	Audio-visual	CDRD	Computations and Data Reduction Division (MSC)
AVC	Automatic volume control	CDSC	Coupling display SCT manual control
AVSS	Apollo Vehicle Systems Section (NASA)	C&DSS	Communications and data subsystems
AWI	Accommodation weight investigation	CDU	Coupling display unit
BAC	Boeing Aircraft Company	CDU	Coupling data unit
BATT	Battery	CDUM	Coupling display unit - IMU
BCD	Binary coded decimal	CDUO	Coupling display unit - optics
BCO	Booster engine cutoff	CEPS	Command module electrical power system
BDA	Bermuda (remote site)	C/F	Center frequency
BECO	Booster engine cutoff	CFAE	Contractor-furnished airborne equipment
BER	Bit error rate	CFD	Cumulative frequency distribution
BG	Background	CFE	Contractor-furnished equipment
BLWR	Blower	CFDF	Crew flight data file
BM	Bench maintenance	CFM	Cubic feet per minute
B/M	Bench maintenance (BM is preferred)	cg	Center of gravity
BMAG	Body-mounted attitude gyro	CGSS	Cryogenic gas storage system
BME	Bench maintenance equipment	CH <sub>4</sub>	Methane
BMG	Body-mounted (attitude) gyro (BMAG is preferred)	CHGE	Charger
BOA	Broad ocean area	C&I	Communication and Instrumentation
BOD	Beneficial occupancy data	CIF	Central Information Facility (AMR)
BP	Blood pressure	CIR&SEP	H <sub>2</sub> Circulation, water separation centrifuge, and glycol circulation
BP	Boilerplate	CIS	Communication and instrumentation system
BPC	Boost protective cover		
BPS	Bits per second		
BSI	Booster situation indicator		
B/U	Backup		
COAS	Crewman optical alignment sight		
C/B	Circuit breaker		
CBA	C-band transponder antenna		

C&IS	Communication and instrumentation system (CIS is preferred)	DBM	Decibels with respect to one milliwatt
CL	Closed-loop	DBW	Decibels with respect to one watt
CLM	Circumlunar mission	D&C	Displays and controls
C/M	Command module	DCA	Design change authorization
CMM	Communications and Telemetry (used by MIT)	DCCU	Decommutator conditioning unit (PACE)
CO	Carbon monoxide	DCIB	Data communication input buffer
C/O	Checkout	DCOS	Data communication output selector
C/O	Cutoff	DCS	Design control specification
CO <sub>2</sub>	Carbon dioxide	DCU	Display and control unit
COMP	Compressor	DCV	DC volts
CP	Control panel	DDP	Data distribution panel
CP	Control Programmer	DDS	Data display system
CPE	Chief project engineer	DE	Display electronics
CPEO	CPE Engineering Order	DEA	Display electronics assemblies
CPO	Central Planning Office (MSFC)	DECA	Display/AGAP electronic control assembly
cps	Cycles per second	DEI	Design engineering inspection
CPS	Critical path schedule	DF	Direction finding
CRT	Cathode-ray tube	D/F	Direction finder
CRYO	Cryogenics	DFS	Dynamic flight simulator
CS	Communication system	DIM	Design information manual
CSD	Computer systems director	DISC	Discharge
CSD	Crew System Division (MSC)	DISPLAY/AGAA ECA	Display and attitude gyro, accelerometer assembly-electronic control assembly
CSM	Command and service module	DM	Design manual
CSS	Crew safety system	DNR	Downrange
CSS	Cryogenic storage system	DOD	Department of Defense
CST	Combined systems test	DOF	Degree of freedom
CSTU	Combined systems test unit	DOF	Direction of flight
CTE	Central timing equipment	DOVAP	Doppler velocity and position
CTL	Component Test Laboratory (NASA)	DP	Design proof
CTN	Canton Island (remote site)	DPC	Data processing center
CTU	Central timing unit	DPDT	Double-pole double-throw
CUE	Command uplink electronics (ACE)	DPST	Double-pole single-throw
CW	Clockwise	DRM	Drawing requirements manual
CW	Continuous wave	DSB	Double sideband
CWG	Constant-wear garment	DSE	Data storage equipment
CYI	Canary Islands	DSIF	Deep-space instrumentation facility
DA	Dip angle	DSKY	Display and keyboard
DA	Double amplitude	DTCS	Digital test command system (ACE)
DAC	Digital-to-analog converter		
DAE	Data acquisition equipment		
DART	Director and response tester		
DAS	Data acquisition system		
db	Decibel		

DTS	Data transmission system	ELS	Earth landing system
DTVC	Digital transmission and verification converter (ACE)	E/M	Escape motor
DVD	Delta velocity display	EMD	Entry monitor display
DVO	Delta velocity on/off	EMG	Electromyograph, electromyography, electromyogram
DVU	Delta velocity ullage	EMI	Electromagnetic interference
EBW	Explosive bridgewire	EMS	Entry monitor system
ECA	Electronic control assembly	ENVR	Environmental
ECA	Engineering change analysis	EO	Earth orbit
ECAR	Electronic control assembly - roll	EO	Engineering order
ECD	Engineering control drawing	E&O	Engineering and operations (building)
ECD	Entry corridor display	EOD	Explosive ordnance disposal
ECET	Electronic control assembly - engine thrust	EOL	Earth orbit launch
ECG	Electrocardiograph, electrocardiography, electrocardiogram	EOM	Earth orbital mission
ECK	Emergency communications key	EOR	Earth orbital rendezvous
ECN	Engineering change notice	EPDS	Electrical power distribution system
ECO	Engine cutoff	EPS	Electrical power system
ECO	Engineering Change Order (MSC)	EPSTF	Electrical power system test facility
ECPY	Electronic control assembly - pitch & yaw	EPUT	Events per unit time
ECS	Environmental control system	ERG	Electroretinograph, electroretinography, electroretinogram
ECU	Environmental control unit	ERP	Eye reference point
EDL	Engineering development laboratories (NAA, S&ID)	ERS	Earth recovery system
EDP	Electronic data processing	ERU	Earth rate unit (15 degrees/hour)
EDPM	Electronic data processing machine	ESB	Electrical Systems Branch (MSC)
EDS	Emergency detection system	ESE	Engineering support equipment
EED	Electroexplosive device	ESS	Emergency Survival System (NASA)
EEG	Electroencephalograph, electroencephalography, electroencephalogram	ESS	Entry survival system
EET	Equivalent exposure time	ESTF	Electronic System Test Facility (NASA)
EFSSS	Engine failure sensing and shutdown system	ESV	Emergency shutoff valve
EHF	Extremely high frequency	ET	Escape tower
EI	Electromagnetic interference	E/T	Escape tower
EI	Electronic interface	ETF	Eglin Test Facility
EKG	Electrocardiograph, electrocardiography, electrocardiogram	ETOC	Estimated time of correction
ELCA	Earth landing control area	ETR	Eastern test range
		EVAP	Evaporator
		EVT	Extravehicular transfer
		FACT	Flight acceptance composite test

F AE	Final approach equipment	G&CEP	Guidance and control equipment performance
F AP	Fortran assembly program	GCU	(Attitude) gyro coupling unit (AGCU is preferred)
F AX	Facsimile transmission	GDC	Gyro display coupler
F C	Ferrite core	GETS	Ground equipment test set
F/C	Fuel cell	GFAE	Government-furnished aeronautical equipment
F/C	Flight control	GFE	Government-furnished equipment
FCD	Flight control division	GFP	Government-furnished property
FCH	Flight controller's handbook	GG	Gas generator
FCOB	Flight Crew Operations Branch (NASA)	GH <sub>2</sub>	Gaseous hydrogen
FCOD	Flight Crew Operations Division (MSC)	GHE	Gaseous helium
FCSD	Flight Crew Support Division (MSC)	GHe	Gaseous helium (preferred)
FCT	Flight Crew Trainer (IMCC)	GLY	Glycol
FD	Flight Director (NASA)	GMT	Greenwich Mean Time
FDAI	Flight director attitude indicator	G&N	Guidance and navigation
FDO	Flight dynamics officer	G&NS	Guidance and navigation system
FDRI	Flight director rate indicator	GN <sub>2</sub>	Gaseous nitrogen
FEB	Forward equipment bay	GNC	Guidance and navigation computer
FEO	Field engineering order	GNE	Guidance and navigation electronics
FF	Florida Facility	GO <sub>2</sub>	Gaseous oxygen
FHS	Forward heat shield	GORP	Ground operational requirements plan
FIDO	Flight dynamics officer	GOSS	Ground Operational Support System (superseded by MSFN)
FLSC	Flexible linear-shaped charge	GOX	Gaseous oxygen (superseded by GO <sub>2</sub> )
FM	Frequency modulation	GP	General purpose
FMA	Failure mode analysis	GPD	Gimbal position display
FMD&C	Flight mechanics, dynamics and control	GPI	Gimbal position indicator
FMX	FM transmitter	gpm	Gallons per minute
FO	Florida Operations	GSDS	Goldstone duplicate standard (standard DSIF equipment)
FOD	Flight Operations Division (MSC)	GSE	Ground support equipment
FOF	Flight operations facilities	GSFC	Goddard Space Flight Center (NASA) (Greenbelt, Md.)
FORTTRAN	Formula translation	GSP	Guidance signal processor
FOS	Flight operations support	GSPO	Ground Systems Project Office (MSC)
FP	Fuel pressure	GSP-R	Guidance signal processor - repeater
FPO	Future Projects Office (MSFC)	GSR	Galvanic skin response
FPS	Frames per second	GSSC	General Systems Simulation Center (NASA)
fps	Feet per second	GSSC	Ground Support Simulation Computer (MCC)
FQ	Flight qualification	GTI	Grand Turk Island
FQR	Flight qualification recorder	GTK	Grand Turk
FRDI	Flight research and development instrumentation		
FRF	Flight readiness firing		
FSK	Frequency shift keying		
FTP	Flight test procedure		
GAEC	Grumman Aircraft Engineering Corp.		
GC	Gigacycles (1000 megacycles)		
G&C	Guidance and control		



GTP	General test plan	I/C	Intercom
G vs T	Deceleration units of gravity versus time	ICA	Item change analysis
G vs V	Deceleration units of gravity versus velocity	ICD	Interface control document
GYI	Grand Canary Island (remote site)	ICM	Instrumentation and Communications monitor
GYM	Guaymas, Mexico (remote site)	ID	Inside diameter
H <sub>2</sub>	Hydrogen	IESD	Instrumentation and Electronic Systems Division (MSC)
H/A	Hazardous area	IF	Intermediate frequency
HAA	High altitude abort	I/F	Interface
HAW	Kauai Island, Hawaii (remote site)	IFM	In-flight maintenance
HBW	Hot bridgewire	IFT	In-flight test
HC	Hand control	IFTM	In-flight test and maintenance
He	Helium	IFTS	In-flight test system
H/E	Heat exchanger	IG	Inner gimbal
HF	High frequency	IGA	Inner gimbal axis
H/F	Human factors	IL	Instrumentation Lab (MIT)
HFA	High frequency recovery antenna	IL	Inertial Lab (NASA)
HFX	High frequency transceiver	IL	Internal letter
HGA	High-gain antenna (2 KMC)	ILCC	Integrated launch checkout and control
HGB	Hemoglobin	IMCC	Integrated Mission Control Center (superseded by MCC)
HI	High	IMU	Inertial measurement unit
H <sub>2</sub> O	Water	IND	Indicator
H <sub>2</sub> S	Hydrogen sulfide	INS	Inertial navigation system
HS	Hot short	INV	Inverter
HS	Hydrogen sulfide	IORA	Indian Ocean Recovery Area
H/S	Heat shield	IOS	Indian Ocean ship (tracking)
H-S	Hamilton Standard	I/P	Impact predictor
H-S	Horizon scanner	IR	Infra red
HS/C	House spacecraft	IRG	Inertial rate gyro
HSD	High-speed data	IRIG	Inertial rate integrating gyroscope (used by MIT)
HTRS	Heaters	IRP	Inertial reference package
HW	Hotwire	IS	Instrumentation system
HWT	Hypersonic wind tunnel	I <sub>sp</sub>	Specific impulse
H/X	Heat exchanger	IST	Integrated systems test
IA	Input axis	IU	Instrumentation unit
IAD	Interface analysis document	I/U	Instrumentation unit (IU is preferred)
IAS	Indicated air speed	IUA	Inertial unit assembly
IC	Intercommunication equipment	J/M	Jettison motor
		KC	Kilocycle (1000 cycles per second)
		KMC	Kilomegacycle (gigacycle)
		KNO	Kano, Nigeria (remote site)
		KOH	Potassium hydroxide

KSC	Kennedy Space Center	LN <sub>2</sub>	Liquid nitrogen
KW	Kilowatt	LO	Launch operations
		LO	Low
LAC	Lockheed Aircraft Corporation	L/O	Lift-off
LAET	Limiting actual exposure time	LO <sub>2</sub>	Liquid oxygen
LC	Launch complex	LOC	Launch Operations Center (NASA)(Cocoa Beach, Fla.)
LC-39	Launch complex 39	LOD	Launch operations directorate
LCC	Launch Control Center (MCC)	LOD	Launch Operations Division (NASA)(superseded by LOC)
LCE	Launch complex engineer	LOM	Lunar orbital mission
LCS	Launch control system	LOR	Lunar orbital rendezvous
L/D	Lift-drag ratio	LOS	Line of sight
LDGE	LM dummy guidance equipment	LOS	Loss of signal
LDP	Local data package	LOX	Liquid oxygen (superseded by LO <sub>2</sub> )
LDT	Level detector	LP	Lower panel
LE	Launch escape	LPA	Log periodic antenna
L/E	Launch escape (LE is preferred)	LPC	Lockheed Propulsion Company
LEB	Lower equipment bay	LPGE	LM partial guidance equipment
LEC	Launch escape control	LRC	Langley Research Center (NASA)(Hampton, Va.)
LECA	Launch escape control area	LRC	Lewis Research Center (NASA)(Cleveland, Ohio)
LEM	Launch escape motor	LRD	Launch Recovery Division
LES	Launch escape system	LSB	Lower sideband
LESC	Launch escape system control	LSC	Linear-shaped charge
LET	Launch escape tower	LSD	Low-speed data
LEV	Launch escape vehicle	LSD	Life Systems Division (MSC) {superseded by CSD}
LGC	LM guidance computer	LSD	Launch systems data
LGE	LM guidance equipment	LSS	Life support system
LH	Left-hand	LTA	LM test article
LH <sub>2</sub>	Liquid hydrogen	LTC	Launch vehicle test conductor
LHA	Local hour angle	LTDT	Langley transonic dynamics tunnel
LHE	Liquid helium	LUPWT	Langley unitary plan wind tunnel
LHe	Liquid helium (preferred)	LUT	Launch Umbilical Tower
LHFEB	Left-hand forward equipment bay	LV	Launch vehicle
LHSC	Left-hand side console	LV	Local vertical
LiOH	Lithium hydroxide	L/V	Launch vehicle
LJ	Little Joe	LVO	Launch Vehicle Operations (MSFC)
LL	Low-level	LVOD	Launch Vehicle Operations Division (MSFC)
LLM	Lunar landing mission	LVSG	Launch vehicle study group
LLM	Lunar landing module		
LLOS	Landmark line of sight		
LLV	Lunar landing vehicle		
LM	Landmark		
LM	Lunar module		
L&M	Light and Medium Vehicles Office (MSFC)		
LMSC	Lockheed Missile and Space Company		

MAN	Manual	MN A	Main bus A
MASTIF	Multi-axis spin test inertial facility	MN B	Main bus B
M. C. & W. S.	Master caution and warning system	MNEE	Mission nonessential equipment
MCA	Main console assembly	M&O	Maintenance and operation
MCC	Mission control center	MOC	Master operations control
MCOP	Mission control operations panel	MOCR	Mission Operations Control Room (MCC)
MCR	Master change record	MODS	Manned Orbital Development Station (MSC)
MD	Master dimension	MORL	Manned orbiting research laboratory
MDC	Main display console	MOV	Main oxidizer valve
MDF	Main distribution frame (MCC)	MPTS	Multipurpose tool set
MDF	Mild detonating fuse	MRCR	Measurement requirement change request
MDR	Mission data reduction	MRO	Maintenance, repair, and operation
MDS	Malfunction detection system	M&S	Mapping and surveying
MDS	Master development schedule	MSC	Manned Spacecraft Center (NASA) (Clear Lake, Texas)
MDSS	Mission data support system	MSC-FO	Manned Spacecraft Center - Florida operations
MDT	Mean downtime	MSD	Mission systems data
MEC	Manual emergency controls	MSFC	Marshall Space Flight Center (NASA) (Huntsville, Ala.)
MEE	Mission essential equipment	MSFC-LVO	Marshall Space Flight Center - Launch Vehicle Operations
MERu	Milli-earth rate unit (0.015 degree/hour)	MSFN	Manned Space Flight Network (formerly GOSS)
MESC	Master event sequence controller	MSFP	Manned space flight program
MEV	Million electron volts	MT	Magnetic tape
MFG	Major functional group	MTF	Mississippi Test Facility (NASA)
MFV	Main fuel valve	MTS	Master timing system
MG	Middle gimbal	MTU	Magnetic tape unit
MG	Motor-generator	MTVC	Manual thrust vector control
MGA	Middle gimbal axis	MU	Mockup
MGE	Maintenance ground equipment	M/U	Mockup (MU is preferred)
MI	Minimum impulser	MUC	Muchea, Australia (remote site)
MIG	Metal inert gas	MV	Millivolt
MIL	Miliradian	MVD	Map and visual display (unit)
MILA	Merritt Island Launch Area (superseded by KSC)	MW	Milliwatt
MILPAS	Miscellaneous information listing program Apollo spacecraft	MWP	Maximum working pressure
MIT	Massachusetts Institute of Technology	N <sub>2</sub>	Nitrogen
ML	Mold line	NAA	North American Aviation
MLT	Mission life test	NAACD	NAA, Columbus Division
M/M	Maximum and minimum	NAARD	NAA, Rocketdyne Division
MMH	Monomethylhydrazine (fuel)	NAASD	NAA, Space Division
MMHg	Millimeters of mercury		
MMU	Midcourse measurement unit		

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NASA	National Aeronautics and Space Administration	ODM	One-day mission
N/B	Narrow band	O/F	Orbital flight
NC	Nose cone	O/F	Oxidizer-to-fuel ratio
N/C	Normally closed	OFB	Operational Facilities Branch (NASA)
N&G	Navigation and guidance (G&N is preferred)	OFO	Office of Flight Operations (NASA)
NH <sub>4</sub>	Ammonium	OG	Outer gimbal
N <sub>2</sub> H <sub>4</sub>	Hydrazine (fuel)	OGA	Outer gimbal axis
NM	Nautical mile	OIB	Operations Integration Branch (NASA)
NMO	Normal manual operation	OIS	Operational instrumentation system (MCC)
N/O	Normally open	OL	Overload
NOS ESS	Nonessential	OL	Open-loop
N <sub>2</sub> O <sub>4</sub>	Nitrogen tetroxide (oxidizer)	OMSF	Office of Manned Space Flight (NASA)
NPC	NASA procurement circular	OMU	Optical measuring unit
NPDS	Nuclear particle detection system	OOA	Open ocean area
NPSH	Net positive suction head	OPS	Operations Director (NASA)
NRD	National Range Division	OR	Operations requirements document (range user)
NRZ	Nonreturn to zero	OSS	Office of Space Sciences
NSC	Navigational star catalog	OTDA	Office of Tracking and Data Acquisition
NSIF	Near Space Instrumentation Facility	OTP	Operational test procedure
NSM	Network status monitor	OTU	Operating test unit
NST	Network support team	OVERS	Orbital vehicle re-entry simulator
NTO	Nitrogen tetroxide (oxidizer)	OXID	Oxidizer
NVB	Navigational base	ΔP	Pressure change (differential)
O <sub>2</sub>	Oxygen	PA	Precision angle (used by MIT)
OA	Output axis	PA	Power amplifier
OA	Ominiantenna	PA	Pad abort (used by NASA)
OAM	Office of Aerospace Medicine (NASA)	P/A	Pressure actuated
OAO	Orbital astronomical observatory	ACE	Automatic checkout equipment
O&C	Operation and checkout	PAFB	Patrick Air Force Base
OCC	Operational control center	PAM	Pulse-amplitude modulation
OCDU	Optics coupling display unit (G&N)	PATH	Performance analysis and test histories
O&C/O	Operation and checkout (O&C is preferred)	P&C	Procurement and Contracts (MSFC)
OD	Operations directive	P/C	Pitch control
OD	Outside diameter (overall diameter)	PCCP	Preliminary contract change proposal
ODDA	Office of Deputy Director for Administration (MSFC)	PCD	Procurement control document
ODDRD	Office of Deputy Director for Research and Development (MSFC)	PCM	Pitch control motor

PCM	Pulse-code modulation	PP	Partial pressure
PCME	Pulse-code modulation event	PPE	Premodulation processor equipment
PCPL	Proposed change point line	PPM	Parts per million
PDA	Precision drive axis	PPS	Pulse per second
PDD	Premodulation processor - deep-space data	PPS	Primary propulsion system
PDU	Pressure distribution unit	PR	Pulse rate
PDV	Premodulation processor - deep-space voice	PRA	Precession axis
PE	Positive expulsion	PRESS	Pressure
PE	Project engineer	PRF	Pulse repetition frequency
PEP	Peak envelope power	PRM	Pulse-rate modulation
PERT	Program evaluation and review technique	PRN	Pseudo-random noise
PF	Preflight	PSA	Power and servo assembly
PFL	Propulsion Field Laboratory (Rocketdyne)	PSA	Power servo amplifier
PFM	Pulse-frequency modulation	PSD	Phase sensitive demodulator
PFRT	Preliminary Flight Rating Test	PSDF	Propulsion System Development Facility
PGA	Pressure garment assembly	psia	Pounds per square inch absolute
PGNCS	Primary guidance navigation control system	psig	Pounds per square inch gage
pH	Alkalinity to acidity content (hydrogen ion concentration)	PSK	Phase shift keyed
PIAPACS	Psychophysical information acquisition processing and control system	PSO	Pad safety officer (superseded by PSS)
PIGA	Pendulous integrating gyroscopic accelerometer	PSP	Program support plan
PAO	Public Affairs Office NASA	PSS	Pad safety supervisor
PIP	Pulsed integrating pendulous (accelerometer)	PTPS	Propellant transfer pressurization system
PIPA	Pulsed integrating pendulous accelerometer	PTT	Push-to-talk
PIRD	Project instrumentation requirement document	PTV	Parachute test vehicle
PIV	Peak inverse voltage	PU	Propellant utilization
PL	Postlanding	PU	Propulsion Unit (NASA)
PLSS	Portable life support system	PUGS	Propellant utilization gauging system
PMP	Premodulation processor	P&VE	Propulsion and Vehicle Engineering (MSFC)
PMR	Pacific Missile Range	P&VE-ADM	P&VE - Administrative
PND	Premodulation processor - near earth data	P&VE-DIR	P&VE - Director
POD	Preflight Operations Division (MSC)	P&VE-E	P&VE - Vehicle engineering
POI	Program of Instruction (NASA)	P&VE-F	P&VE - Advanced flight systems
POL	Petroleum oil and lubricants	P&VE-M	P&VE - Engineering materials
POS	Pacific Ocean ship	P&VE-N	P&VE - Nuclear vehicle projects
		P&VE-O	P&VE - Engine management
		P&VE-P	P&VE - Propulsion and mechanics
		P&VE-PC	P&VE - Program coordination
		P&VE-REL	P&VE - Reliability

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P&VE-S	P&VE - Structures	RGP	Rate gyro package (superseded by RGA)
P&VE-TS	P&VE - Technical and scientific staff	RGS	Radio guidance system
P&VE-V	P&VE - Vehicle systems integration	RH	Relative humidity
P&W	Pratt & Whitney	RH	Right-hand
P&WA	Pratt & Whitney Aircraft	RHFEB	Right-hand forward equipment bay
PYRO	Pyrotechnic	RHSC	Right-hand side console
QA	Quality assurance	RJS	Reaction jet system
QAD	Quality Assurance Division (MSFC)	RO	Reliability Office (MSFC)
QAM	Quality assurance manual	RP-1	Rocket propellant No. 1 (kerosene)
QC	Quality control	RPD	Research Projects Division (MSFC)
QD	Quick-disconnect	RR	Respiration rate
QRS	Qualification review sheet	RRS	Restraint release system
QUAL	Quality Assurance Division (MSFC)	RR/T	Rendezvous Radar/ Transponder
QVT	Quality verification testing	R/S	Range safety
RA	Radar altimeter	RSC	Range safety control
RAD	Radiation absorbed dose	RSC	Range safety command
RAE	Range, azimuth, and elevation	RSCIE	Remote station communication interface equipment
RAPO	Resident Apollo Project Office (NASA)	RSO	Range safety officer
RASPO	Resident Apollo Spacecraft Project Office (MSC)	RSS	Reactants supply system
RB	Radar beacon	RTC	Real Time Computer (MCC)
R/B	Radar beacon (RB is preferred)	RTCC	Real Time Computer Complex (MCC)
RBA	Recovery beacon antenna (VHF)	RTTV	Real time television
RBE	Radiation biological effectiveness	RZ	Return to zero
R/C	Radio command	R&Z	Range and zero
R/C	Radio control	S	ASPO (Apollo Spacecraft Project Office)
RCC	Range control center	S-	Saturn stage (prefix)
RCC	Recovery control center	SA	RASPO - Atlantic Missile Range
RCC	Rough combustion cutoff	SA	Shaft angle (used by MIT)
RCS	Reaction control system	SA	Saturn/Apollo
RD	Radiation detection	SACTO	Sacramento test operations
R&D	Research and development	SAE	Shaft angle encoder
RDMU	Range-drift measuring unit	SAL	San Salvador Island (tracking station)
R/E	Re-entry	SAL	Supersonic Aerophysics Laboratory
REG	Regulator	SAR	RASPO - Atlantic Missile Range (superseded by SA)
rem	Roentgen equivalent man	SARAH	Search and range homing
RES	Restraint system		
RF	Radio frequency		
RFI	Radio frequency interference		
RG	Rate gyroscope		
RGA	Rate gyro assembly		

SAT	Saturn Systems Office (MSFC)	SCVE	Spacecraft vicinity equipment
SBUE	Switch - Backup entry	SDA	Shaft drive axis
SBX	S-band transponder	SDF	Single degree of freedom
S&C	Stabilization and control	SDG	Strap down gyro
SC	ASPO - CSM (command and service modules)	SDL	Standard distribution list
SC	Signal conditioner (SCR is preferred)	SDP	Site data processor
S/C	Spacecraft	SECS	Sequential events control system
SCA	Sequence control area	SED	Space Environment Division (MSC)
SCA	Simulation Control Area (MCC)	SEDD	Systems Evaluation and Development Division
SCAT	Space communication and tracking	SEDR	Service engineering department report
SCATS	Simulation, checkout, and training system (MCC)	SEF	Space Environmental Facility (NASA)
SCC	Simulation control center	SEP	Standard electronic package
SCD	Specification control drawing	SEPS	Service module electrical power system
SCE	Signal conditioning equipment	SET	Spacecraft elapsed time
SCF	Sequence compatibility firing	SF	Static-firing
SCGSS	Super-critical gas storage system	SFX	Sound effects
SCIN	Scimitar notch (T/C)	SG	ASPO - G&C (guidance and control)
SCIP	Self-contained instrument package	SGA	RASPO LM - GAEC Bethpage (superseded by SLR)
SCM	ASPO - CSM (superseded by SC)	SGC	ASPO - G&C (superseded by SG)
SCO	Subcarrier oscillator	SGE	ASPO - G&C engineering
S/CO	Spacecraft observer	SGP	ASPO - G&C administration
SCP	ASPO - CSM administration	SGR	RASPO - G&C MIT, Boston
SCPA	SCS control panel	SHA	Sidereal hour angle
SCR	Subcontractor	SHF	Super high frequency
SCR	Silicon controlled rectifier	SI	ASPO - system integration
SCR	Signal conditioner	SI	Systems integration
SCR	RASPO CSM - NAA, Downey	S/I	Systems integration (SI is preferred)
SCRA	RASPO CSM - NAA, Downey - administration	S-I	Saturn I first stage
SCRE	RASPO CSM - NAA, Downey - engineering	SIA	Systems integration area
SCRR	RASPO CSM - NAA, Downey - reliability	S-IB	Saturn IB first stage
SCS	Stabilization and control system	S-IC	Saturn V first stage
SCT	Scanning telescope	SID	Space and Information Systems Division (NAA)
SCT	ASPO - CSM systems test	S&ID	Space and Information Systems Division (NAA)
SCTE	Spacecraft central timing equipment	S-II	Saturn V second stage

SITE	Spacecraft instrumentation test equipment	SPAF	Simulation processor and formatter (MCC)
S-IV	Saturn I second stage	SPDT	Single-pole double-throw
S-IVB	Saturn IB second stage and Saturn V third stage	SPP	ASPO - program plans and control (superseded by SP)
S-IVB G	Launch vehicle guidance system	SPS	Service propulsion system
SL	Star line	SPST	Single-pole single-throw
SL	ASPO - LM (lunar module)	SRD	Spacecraft Research Division (MSC) (superseded by STD)
SLA	Spacecraft LM adapter	SRO	Superintendent of range operations
S/L	Space laboratory	SRS	Simulated remote station (MCC)
SLE	ASPO - LM engineering	SS	ASPO - spacecraft
SLM	ASPO - LM (superseded by SL)	S/S	Samples per second
SLM	Spacecraft laboratory module	S/S	Subsystem
STLOS	Star line-of-sight	SSA	Space suit assembly
SLP	ASPO - LM administration	SSB	Single sideband
SLR	RASPO LM - GAEC Bethpage	SSC	Sensor signal conditioner
SLT	ASPO - LM systems test	SSD	Space Systems Division (USAF)
SLV	Space launch vehicle	SSDF	Space Science Development Facility (NAA)
S/M	Service module	SSE	Spacecraft simulation equipment
SMD	System measuring device	SSI	ASPO - systems integration (superseded by SI)
SMJC	Service module jettison controller	SSM	Spacecraft systems monitor
S/N	Signal-to-noise ratio	SSO	Saturn Systems Office (MSFC)
S/N	Serial number	SSR	Support Staff Rooms (NASA)
SNA	RASPO NAA, Downey (superseded by SCR)	SSS	Simulation study series
SNAE	RASPO NAA, Downey engineering (superseded by SCRE)	SST	Simulated Structural Test (NASA)
SNR	Signal-to-noise ratio	SST	Spacecraft Systems test
S/O	Switchover	ST	Shock tunnel
SOC	Simulation operation computer (MCC)	STC	Spacecraft test conductor
SOFAR	Sound fixing and ranging	STD	Spacecraft Technology Division (MSC)
SOM	Suborbital mission	STMU	Special test and maintenance unit
SOP	Standard operating procedure	STS	System trouble survey
SP	ASPO - project integration	STU	Static Test Unit (NASA)
SP	Static pressure	STU	Special test unit
SPA	S-band power amplifier		
ACE	Automatic checkout equipment		



STU	Systems test unit	TRDA	Three-axis rotational control - direct A
SVE	Space Vehicle Electronics (DAC) (superseded by Astrionics Branch)	TRDB	Three-axis rotational control - direct B
SW	Sea water	TRNA	Three-axis rotational control - normal A
SW	RASPO - White Sands Missile Range	TRNB	Three-axis rotational control - normal B
SWT	Supersonic wind tunnel	TTE	Time to event
SXT	Space sextent	TTESP	Test time-event sequencer plan
SYS	System	TTY	Teletype
TACO	Test and checkout station	TV	Television
T/B	Talk back	TVC	Thrust vector control
TBD	To be determined	TVCS	Thrust vector control system
TC	Test conductor	TWT	Transonic wind tunnel
TC	Transfer control	TWX	Teletype wire transmission
TC	Transitional control	UA	Urinalysis
T/C	Telecommunications	UDL	Up-data link
T/C	Thrust chamber	UDMH	Unsymmetrical dimethyl hydrazine (fuel)
TCA	Thrust chamber assembly	UHF	Ultra high frequency
TCA	Transfer control A register	USB	Upper sideband
TCB	Technical Coordination Bulletin (MSFC)	USBE	Unified S-band equipment
TCOA	Translational control A	$\Delta V$	Velocity change (differential)
TCOB	Translational control B	VAB	Vehicle assembly building
TCSC	Trainer control and simulation computer	VAC	Volts ac
TD	Technical Directive (MSFC)	$\Delta V D$	Velocity change display
TDA	Trunnion drive axis	VDD	Visual display data
TDR	Technical data report	VEDS	Vehicle Emergency Detection System (NASA)
TE	Transearch	VGP	Vehicle ground point
TEC	Transearch coast	VHAA	Very high altitude abort
TFE	Time from event	VHF	Very high frequency
TJM	Tower jettison motor	VLF	Vehicle launch facility
TK HTRS	Tank heaters	VLF	Very low frequency
TLC	Translunar coast	VOX	Voice-operated relay
TLI	Translunar injection	VRB	VHF recovery beacon
TLS	Telescope	VSC	Vibration safety cutoff
TM	Telemetry	VTF	Vehicle test facility
TMG	Thermal micrometeoroid garment	VTS	Vehicle test stand
T/M	Telemeter	W/G	Water-glycol
TP	Test point	W-G	Water-glycol
TPA	Test point ACE		
TPS	Thermal protection system		
TR	Test request		
T/R	Transmit/receive		

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WGAI	Working Group Agenda Item (MSFC)	WSMR	White Sands Missile Range
WHS	White Sands, New Mexico (remote site)	XCVR	Transceiver
WIS	Wallops Island Station (NASA) (Wallops, Va.)	XDUCER	Transducer
W/M	Words per minute	XEQ	Execute (ACE)
WMS	Waste management system	XMAS	Extended Mission Apollo Simulation (100 days) (NASA)
WODWNY	Western Office, Downey	XMTR	Transmitter
WOM	Woomera, Australia (remote site)	Z	Astronaut Activities Office
WOO	Western Operations Office (NASA)	ZI	Zone of Interior (continental USA)
WPM	Words per minute	ZZB	Zanzibar, Tanganyika (remote site)

SYMBOLS

$\Delta P$	Delta P	$\Delta V$	Delta V
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TERMS

ABLATIVE MATERIAL	During entry of spacecraft into the earth's atmosphere at hypersonic speeds, aids in the dissipation of kinetic energy and prevents excessive heating of the main structure.	APOLLO	A term generally used to describe the NASA manned lunar landing program but specifically used to describe the effort devoted to the development test and operation of the space vehicle for long duration, earth orbit, circumlunar, and lunar landing flights.
ABORT	Premature and abrupt termination of a mission because of existing or imminent degradation of mission success probability.	APOLLO SPACE-CRAFT	The vehicle required to perform the Apollo mission after separation of the final launch stage. It consists of the command module (C/M),
APOGEE	A point on the orbit of a body which is at the greatest distance from the center of the earth.		