

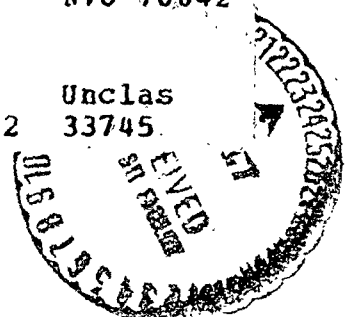
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APOLLO  
SPACECRAFT FAMILIARIZATION

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## SECTION I

## INTRODUCTION

1-1. The familiarization manual provides a general description of each of the significant types of spacecraft and a typical boilerplate. Each of the major ground test items is described with the exception of the engineering simulators and evaluators. A description of the Apollo mission and the mission objectives is included. The lunar excursion module is covered in gross terms. The individual command and service module systems are described in general terms with sufficient detail to convey a clear understanding of the system as a whole. A general description of the functional and operational procedures related to the significant spacecraft and the typical boilerplate beginning with delivery to the launch facility and ending with recovery operations is included. There is a reference index of all support procedures and handbooks. These handbooks serve as an orientation-indoctrination type document and as a reference document containing information relative to all systems and major components.

1-2. THE APOLLO SPACECRAFT FAMILIARIZATION MANUAL.

1-3. Section I contains the introduction to the manual. Section II describes the Apollo spacecraft in the lunar landing configuration which includes the lunar excursion module. Section III comprises a description of the spacecraft systems at the level mentioned in paragraph 1-1. Section IV covers the spacecraft test program. Section V describes a typical abort test flight. Section VI is concerned with the manned orbital qualification phase which is centered around a manned earth-orbital flight. Section VII describes the Apollo lunar mission which will achieve the ultimate goal of the program. Appendix A is the reference index mentioned in paragraph 1-1.

1-4. THE APOLLO SPACECRAFT.

1-5. Section II describes the Apollo spacecraft in the lunar excursion module (LEM) configuration. The description is entirely physical in nature and covers the entire spacecraft. The facilities are mentioned and located by means of text and illustration. The ground support equipment (GSE) required in the Apollo program is a major item in both number of units and variety of uses. The GSE is described by division into the principal functional groups and by operation of major units to provide examples of GSE utility.

1-6. OPERATIONAL SYSTEMS.

1-7. Section III describes each of the 11 primary spacecraft systems at the level specified in paragraph 1-1. The descriptions are individual, but mention is made of system interoperation as it occurs.

1-8. SPACECRAFT TEST PROGRAM.

1-9. Section IV covers the spacecraft test program with regard to the most important ground test items. These items are indicative of the major aims of the program which is to fully support spacecraft flight.

1-10. ABORT TEST PHASE.

1-11. Section V describes in comparative detail boilerplate test flights. The purpose of all abort tests is to demonstrate life-saving techniques and equipment as they apply to spacecraft crews and, therefore, the abort tests are of prime importance.

1-12. MANNED ORBITAL QUALIFICATION PHASE.

1-13. Section VI describes in comparative detail a manned earth-orbital mission. The mission can last as long as two weeks and is a significant milestone in the entire Apollo program.

1-14. LUNAR MISSION PHASE.

1-15. Section VII describes in comparative detail a lunar mission which is the ultimate goal of the Apollo program. The lunar mission described includes a lunar landing and return to the spacecraft.

1-16. THE APPENDIX.

1-17. The appendix is a reference index of all support procedures and handbooks. It is specifically required by the documentation requirements for the familiarization handbook.

1-18. INTRODUCTION SUMMARY.

1-19. The familiarization handbook presents a general description of the ultimate spacecraft and spacecraft primary systems, the overall supporting test program, and the Apollo lunar landing mission.



## SECTION II

## THE APOLLO SPACECRAFT

2-1. This section contains a description of the Apollo spacecraft (figure 2-1) in both physical and functional aspects. The configuration described in the following paragraphs is the manned spacecraft.

2-2. THE APOLLO SPACECRAFT.

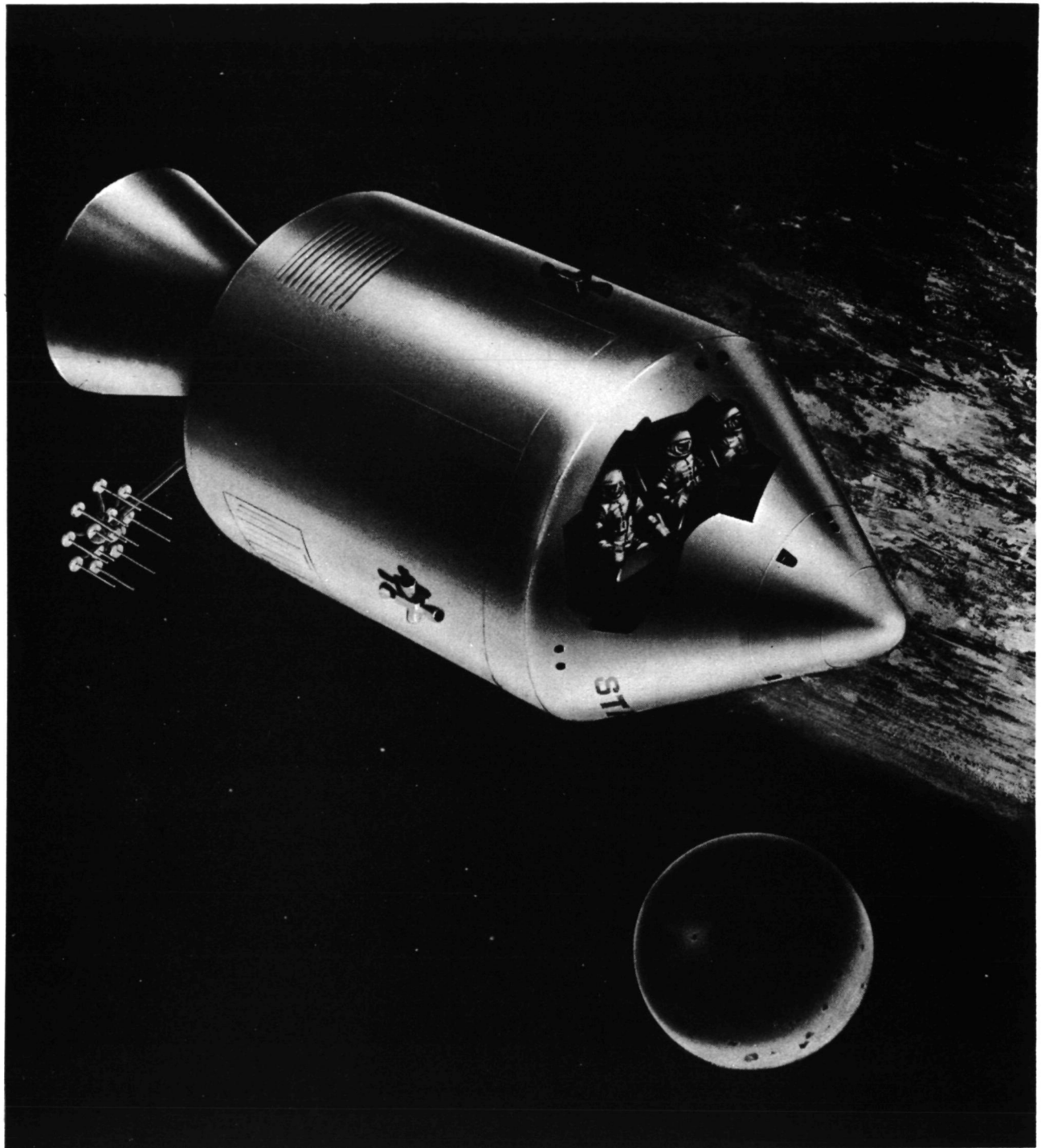
2-3. The Apollo spacecraft is a three-man vehicle with sufficient means to fulfill the goals of the Apollo program. The means include propulsion and control systems, life support equipment, and installations to ensure a safe return to earth.

2-4. PURPOSE.

2-5. The purpose of the Apollo spacecraft is to develop the technology of manned space flight to the degree that will enable man to travel safely to the moon, land, explore, and return to earth. Each Apollo mission will serve to qualify the objectives of subsequent missions. The basic categories of lunar missions are circumlunar, lunar-orbital, and lunar-landing. Circumlunar and lunar-orbital missions serve to further develop and operationally test the space vehicle. Closeup reconnaissance of the lunar surface will be made to determine suitable areas for landing and for scientific and technological purposes. The lunar-landing mission will place man on the moon.

2-6. PHYSICAL DESCRIPTION.

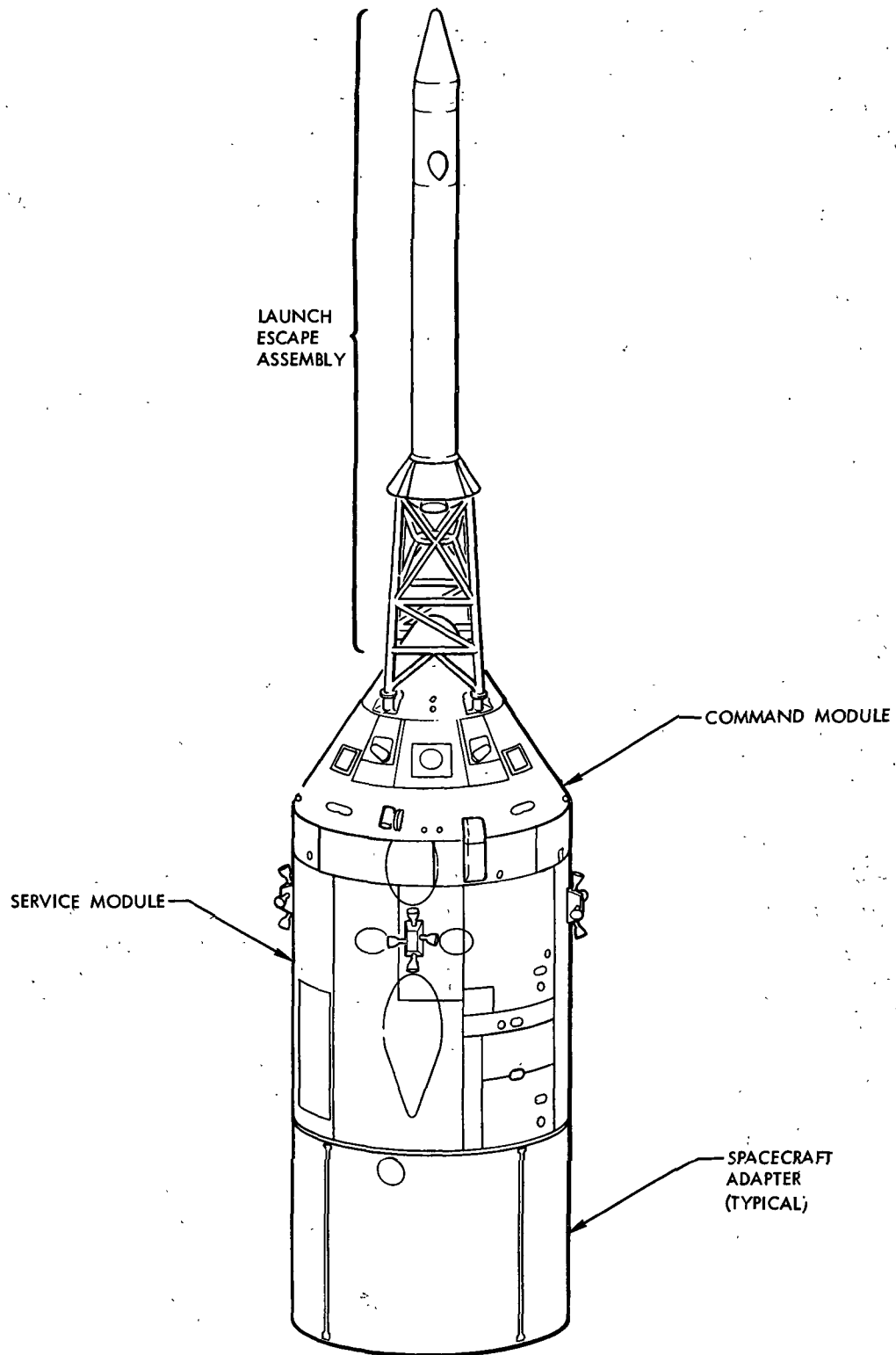
2-7. The spacecraft consists of the launch escape assembly, the command module, the service module, and the spacecraft adapter. The external appearance of the spacecraft is shown in figure 2-2. Weights and dimensions of these major spacecraft components are listed in table 2-1. The basic structures of these modules and assemblies are referred to as the structural system. The operational equipment contained within the structure is divided into 11 formal systems. Each of these systems consists either of a group of functionally related hydraulic, pneumatic, mechanical, or electronic equipment or is an arbitrary combination of supplementary equipment. The 11 equipment systems are descriptively named as follows: (1) environmental control, (2) crew, (3) launch escape, (4) guidance and navigation, (5) stabilization and control, (6) reaction control, (7) service propulsion, (8) communications and instrumentation, (9) electrical power, (10) earth landing, (11) in-flight test.



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Figure 2-1. The Apollo Spacecraft



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Figure 2-2. Spacecraft Structures

Table 2-1. Weights and Dimensions

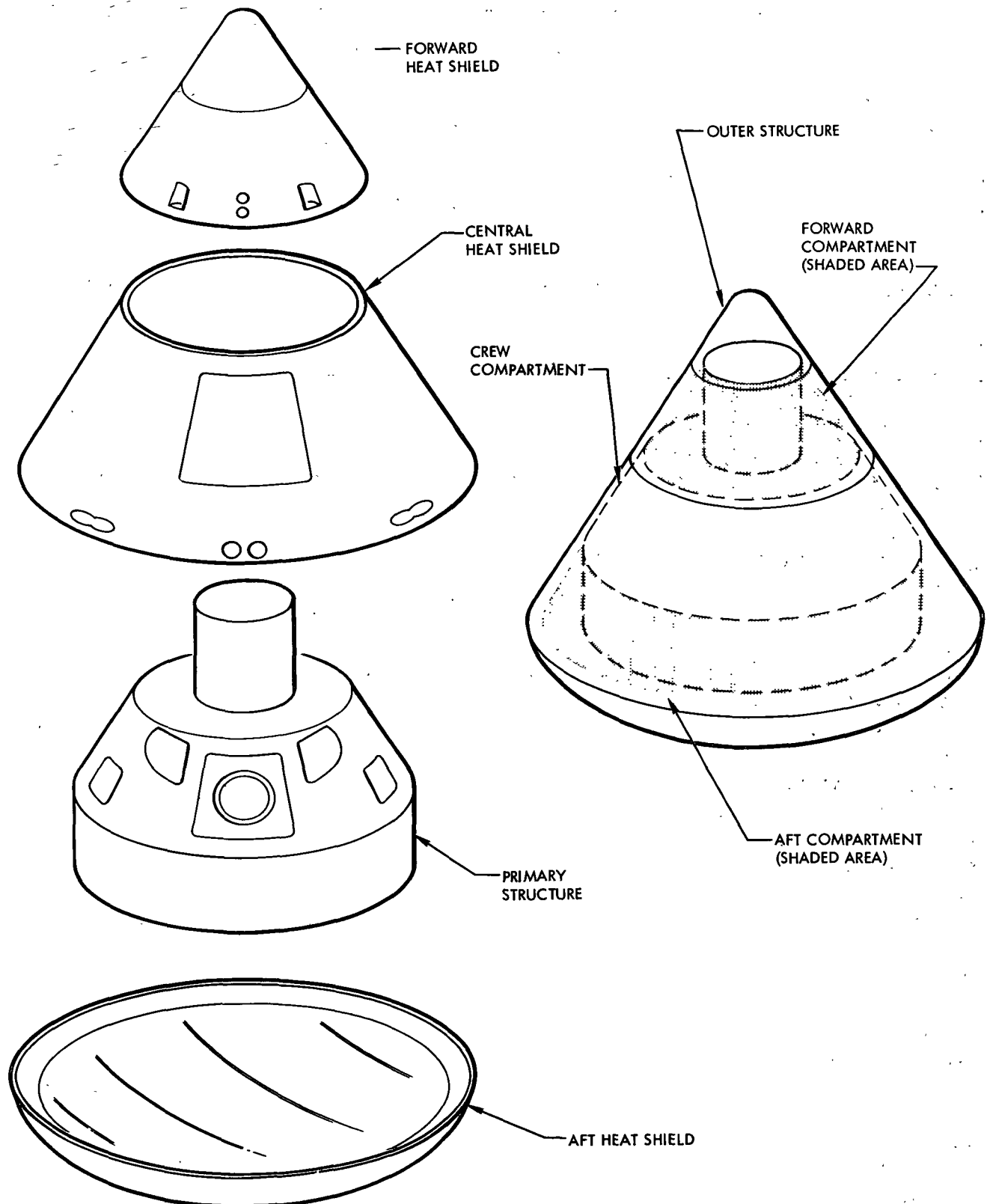
Structural	Overall Dimensions	Nominal Loaded Weight (pounds)
Launch escape assembly	Length: 35 feet (approx) Width: 4 feet (approx)	7,000 (approx)
Command module	Length: 11 feet (approx) Diameter: 13 feet (approx)	10,000 (approx)
Service module	Length: 13 feet (approx) Diameter: 13 feet (approx)	50,000 (approx)
Spacecraft standard adapter (typical Saturn I dimensions)	Length: 10 feet (approx) Diameter: 13 feet (approx)	700 (approx)
Lunar excursion module	Length: 30 feet (approx) Diameter: 22 feet (approx)	30,000 (approx)

## 2-8. LAUNCH ESCAPE ASSEMBLY.

2-9. The launch escape assembly comprises the major portion of the launch escape system which is described in section III. Components of the launch escape assembly provide the means of propelling the command module to a safe altitude and position in the event of an off-pad or suborbital abort. The launch escape assembly consists of three rocket motors (launch escape, tower jettison, and pitch control), structural housings, and a tower which transmits loads between the command module and launch escape assembly components. Explosive bolts at the base of each of the four tower legs secure the assembly to the command module. Upon completion of a successful launch the assembly is jettisoned from the remainder of the spacecraft. In addition to the launch escape system components mentioned above, the launch escape assembly houses motion sensing and motor performance sensing instrumentation.

## 2-10. COMMAND MODULE.

2-11. The conical command module is the major unit of the Apollo spacecraft. It is a recoverable module that remains essentially unchanged for all missions. It consists of a primary structure and three outer structures as shown in figure 2-3. The outer structures are the heat shields. The illustration shows only the essential structural elements. The command module has three distinct sections called the forward compartment, the aft compartment, and the crew compartment. The forward and aft compartments are formed by the spaces resulting from placing the irregularly shaped primary structure inside the conical structure formed by the combined heat shields. Structural members and insulation



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Figure 2-3. Command Module Structure

material join the primary structure to the heat shields. The forward and aft heat shields are continuous structures coated with ablative material. A circular thrust ring on the inner face of the aft shield transmits loads from the service module to the command module. The central heat shield consists of a series of externally applied segments which are mechanically fastened to the primary structure. Removable panels provide exterior access to the aft compartment equipment.

2-12. **FORWARD COMPARTMENT.** The forward compartment is the area encompassed by the forward portion of the crew compartment and the forward heat shield. The center portion of this compartment is occupied by the forward egress hatch. The perimeter space is divided into four equal areas which contain the recovery equipment, two reaction control engines, and heat shield jettisoning mechanisms. Three of these areas also contain the three main landing parachutes and the three pilot chutes with mortars. The fourth area, which is centered on the -Z axis, contains the drogue chute and mortar, the two earth landing sequencers, and the two reaction control engines. The forward heat shield release mechanism and four thruster-ejectors used to eject the forward heat shield during the landing sequence are also located in the forward compartment.

2-13. **CREW COMPARTMENT.** The crew compartment is a pressurized cabin for the three-man crew when the command module is operated in conjunction with the service module. The compartment contains the spacecraft controls, display panels, observation windows, access hatches, equipment bays, and crew facilities as illustrated in figure 2-4.

2-14. **Crew Compartment Structure.** The crew compartment is the pressurized interior of the primary structure which is fabricated from bonded aluminum honeycomb into a pressure-tight unit. The floor of the compartment is reinforced by a series of beams which are integral to the inner facing sheets. The module structure and equipment within the crew compartment have been arranged to minimize the effects of radiation. The aft area of the crew compartment is shielded from radiation by the service module.

2-15. **Crew Compartment Facilities.** The crew compartment contains all the necessary equipment for the support of the crew and operational equipment for the control and recovery of the spacecraft. The crew support equipment consists of temperature and atmosphere controls, food and water, sanitation facilities for collection of waste materials, medical instrumentation for physiological measurements, pressure suits, and emergency equipment for crew survival after landing. The command module operational equipment consists of components, controls, and indicators for all the operational systems. The compartment also contains windows, access hatches, and equipment bays. The name, location, and contents of each equipment bay are listed in table 2-2. The side access hatch door contains a window and is composed of two parts. The inner part opens inward and the outer

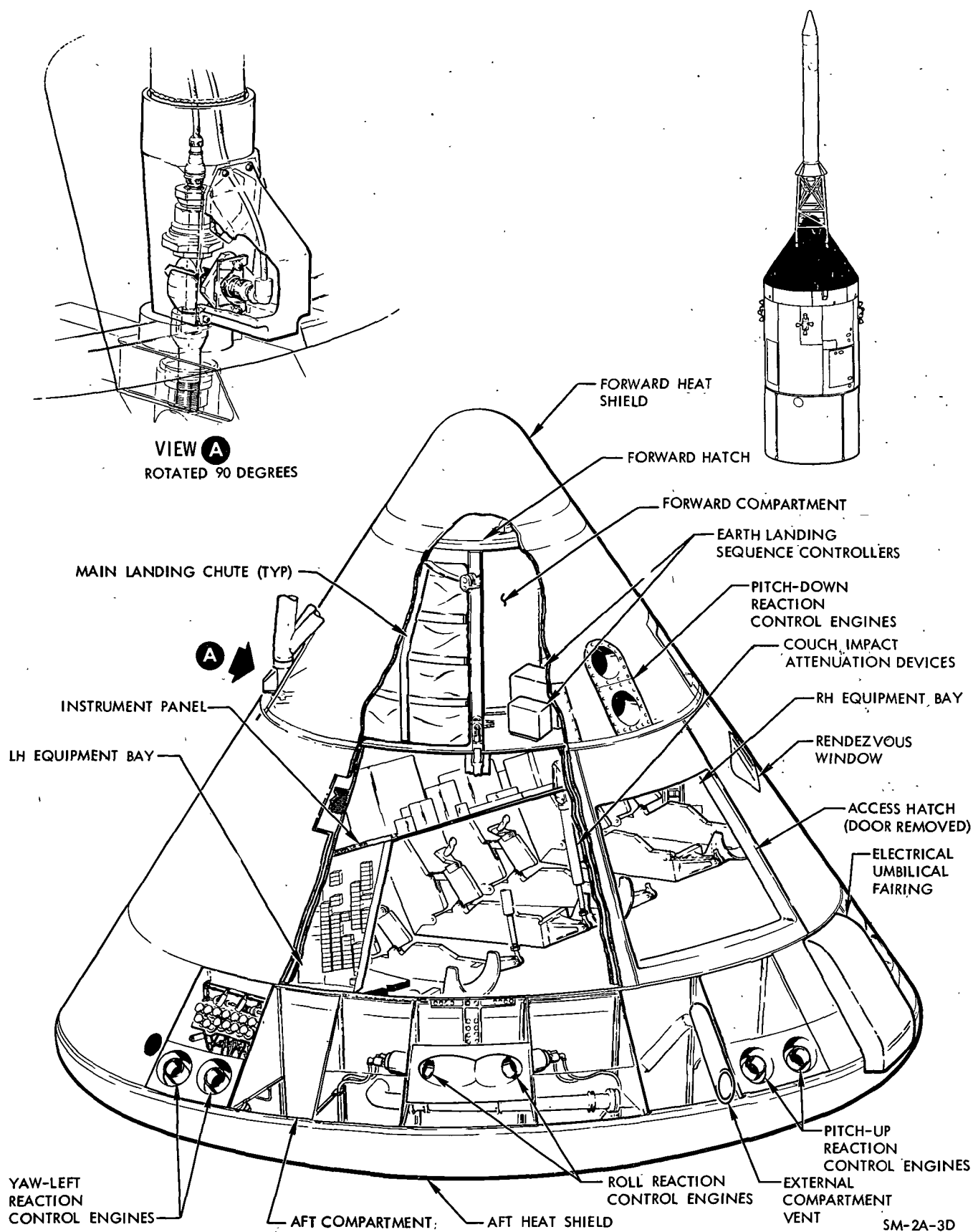


Figure 2-4. Command Module Facilities

part opens outward. There is a rendezvous window and a side window located on each side of the hatch. The crew compartment is equipped with three couches for the crew. The center couch may be removed and stowed to increase living space and allow easier access to provisions and equipment stowed in the bays. Detailed coverage of these facilities is provided in section III.

Table 2-2. Crew Compartment Equipment Bays

Name	Location	Contents
Aft equipment bay	Directly above the heads of the crew when they are in a reclining position	<p>Storage space for two spacesuits (flat) while in shirtsleeve environment</p> <p>Portable life-support system space while in shirtsleeve environment</p> <p>Portable life-support system space while in ascent or entry phase</p> <p>Portable life-support system carbon dioxide absorber</p> <p>Fecal canister</p> <p>Tools and umbilicals locker</p> <p>Spacesuit assembly spares (2) compartment</p> <p>Two electronics spares compartments</p> <p>Storage space for one spacesuit (folded) while in shirtsleeve environment</p> <p>Storage space for three helmets while in shirtsleeve environment</p> <p>Four environmental control system lockers</p>



Table 2-2. Crew Compartment Equipment Bays (Cont)

Name	Location	Contents
Right hand equipment bay	Right of the crew when they are in a reclining position	<p>Eight carbon dioxide absorber cartridge lockers holding a total of 34 cartridges</p> <p>In-flight test system panel</p> <p>Scientific equipment locker</p> <p>Electrical power compartment</p> <p>Electrical power equipment locker</p> <p>Waste storage compartment</p> <p>Vacuum cleaner locker</p> <p>Waste management compartment</p> <p>Personal hygiene supply locker</p> <p>Sanitary supply locker</p> <p>Medical supply locker</p> <p>Two emergency oxygen supply outlets</p> <p>Individual survival kit storage</p> <p>Press suit receptacle</p>
Left hand equipment bay	Left of the crew when they are in a reclining position	<p>Freon system</p> <p>Cabin pressure relief valve</p> <p>Re-entry oxygen supply</p> <p>Pressure suit receptacle</p> <p>Two carbon dioxide odor absorber-filters</p>

Table 2-2. Crew Compartment Equipment Bays (Cont)

Name	Location	Contents
Lower equipment bay	Directly beneath the feet of the crew when they are in a reclining position	<p>Environmental control system control panel</p> <p>Thermal radiation overalls (2) storage locker</p> <p>Clothing lockers (2)</p> <p>Portable life-support system emergency oxygen supply</p> <p>Pressure suit receptacles (2)</p> <p>Cabin air recirculation fan</p> <p>Food reconstitution device</p> <p>Optical equipment locker</p> <p>Map and data viewer</p> <p>Sextant and telescope shroud</p> <p>Guidance and navigation control panel</p> <p>Power servo assembly</p> <p>Clock and event timer panel</p> <p>Control display unit</p> <p>Control display unit mode control panel</p> <p>Gyro and accelerometer package</p> <p>Computer control panel</p> <p>Medical supply compartments (2)</p> <p>Data storage equipment locker</p>

Table 2-2. Crew Compartment Equipment Bays (Cont)

Name	Location	Contents
		<p>Signal conditioning and patching panel</p> <p>Food compartments (2)</p> <p>Scientific or flight qualification equipment compartment</p> <p>Computer</p> <p>Display attitude gyro, accelerometer package electronic control assembly compartment</p> <p>Pulse-code-modulation (PCM) unit compartments (2)</p> <p>Data wiring compartment</p> <p>Map and manual set compartment</p> <p>Workshelf</p> <p>Yaw channel electronic control assembly compartment</p> <p>Roll channel electronic control assembly compartment</p> <p>Pitch channel electronic control assembly compartment</p> <p>Auxiliary compartment for stabilization and control components</p> <p>Radiation detection equipment</p> <p>Flight qualification telemetry compartment</p> <p>VHF multiplexer</p> <p>Premodulation processor</p>

Table 2-2. Crew Compartment Equipment Bays (Cont)

Name	Location	Contents
		Unified S-band equipment and spares  S-band power amplifier  Up data link  C-band transponder  VHF/AM transceiver  VHF recovery beacon  VHF/FM transmitter  HF transceiver  Audio center compartment  Central timing equipment locker  Junction box  Portable life-support system battery charger control  Inverter (2)  Batteries (3)  Pyrotechnic batteries (2)  VHF/UHF diplexer  S-band antenna selector switch  Battery charger  Motor switches (3)  AC power box

2-16. **AFT COMPARTMENT.** The aft compartment is the area encompassed by the lower portion of the central heat shield, the aft heat shield, and lower portion of the primary structure. This compartment contains 10 of the 12 reaction control engines, impact attenuation devices, and storage tanks for water, fuel, oxidizer, and gaseous helium.

2-17. **SERVICE MODULE.**

2-18. The service module (figure 2-5) is attached to the command module for all phases of the operation except earth landing. It is jettisoned prior to entering the earth atmosphere. This module houses the service propulsion system and major portions of environmental control, electrical power, and reaction control systems. These installations do not require maintenance or operation by the crew during flight. The service propulsion system engine nozzle extends into the spacecraft adapter, when the spacecraft is mated to the launch vehicle.

2-19. **SERVICE MODULE STRUCTURE.** The service module structure is a structure formed by six panels of aluminum honeycomb shell. The interior area between the forward and aft bulkheads is divided into sectors and a center section by six radial beams or webs. The structure contains and supports the equipment installations and transmits booster and mission propulsion loads to the command module. The radial beams have forward extensions or trusses tipped with pads which support the command module. Three of the trusses have compression pads and the other three have shear pads. The trusses with shear pads also have tension ties which pass through the command module aft heat shield and are attached to the inner structure. A redundant system of flexible linear-shaped explosive charges are attached to the center flat portion of the tension ties. This system is the means by which the command and service modules are separated in flight. A fairing completely encloses the gap between the modules caused by the separation system.

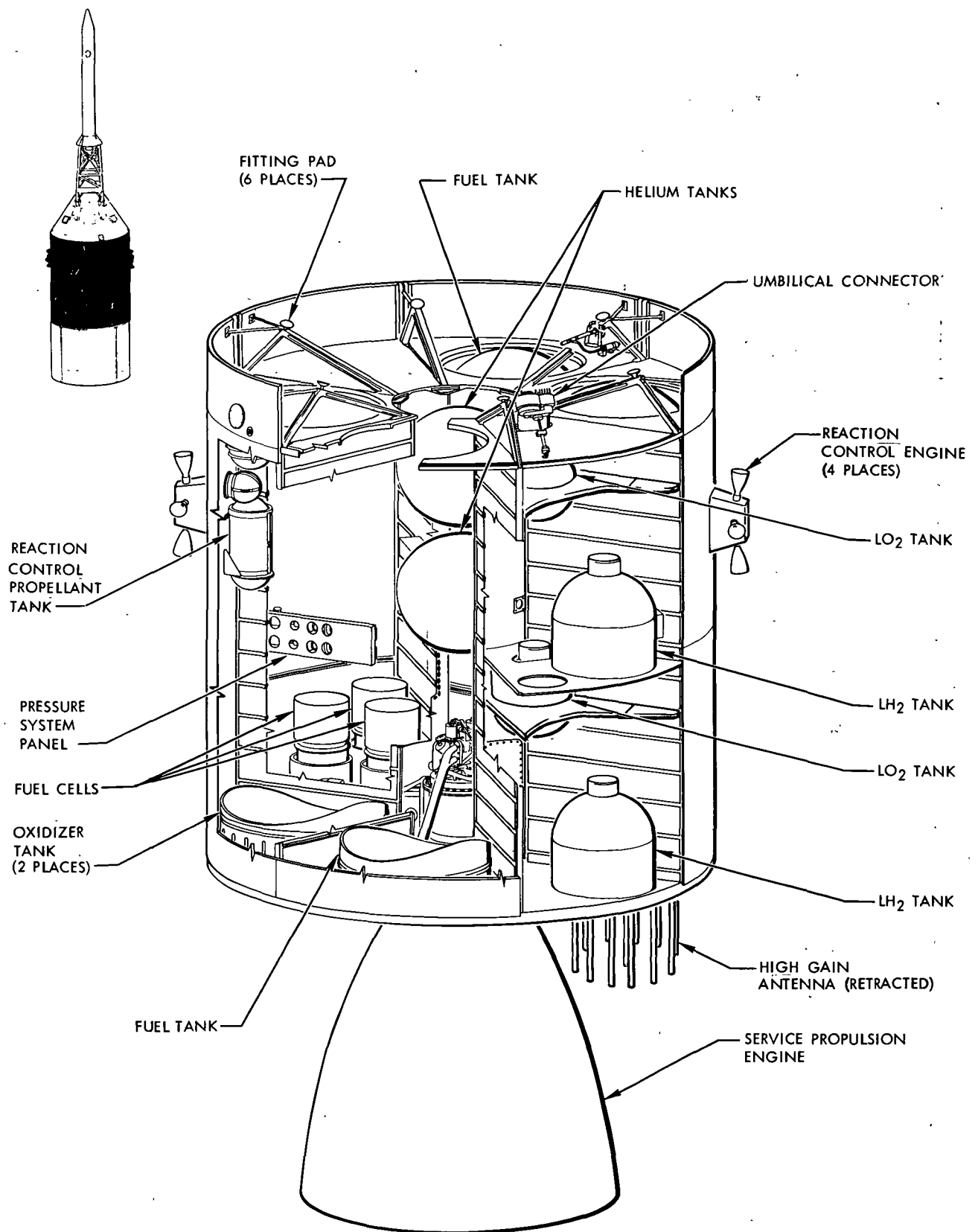
2-20. **SERVICE MODULE FACILITIES.** The specific equipment contained in each of the sectors and the center section is listed in table 2-3. External equipment such as the reaction control engines and flush-mounted equipment such as the radiators are included. Internal equipment is accessible through doors in the module shell.

Table 2-3. Service Module Compartments

Name	Contents
Sector I (upper right)	Electrical power system space radiator Liquid oxygen tanks (2) Liquid hydrogen tanks (2) High-gain antenna (stowed under)

Table 2-3. Service Module Compartments (Cont)

Name	Contents
Sector II (mid right)	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 valves (2)
Sector III (lower right)	Service propulsion system fuel tank Reaction control system engine cluster (+Z axis) Reaction control system helium tank Reaction control system fuel tank Reaction control system oxidizer tank
Sector IV (lower left)	Electrical power system space radiator Fuel cells (3) Helium distribution system Reaction control system control unit Electrical power system power control relay box
Sector V (mid left)	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
Sector VI (upper left)	Space radiator selection valves (2) Glycol shutoff valves (2) 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
Center Section	Service propulsion system helium tanks (2) Service propulsion system engine



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Figure 2-5. Service Module

## 2-21. SPACECRAFT ADAPTER.

2-22. The spacecraft adapter is used to connect the service module to the launch vehicle. It encloses the thrust chamber of the service propulsion engine and the high-gain antenna prior to separation. It also encloses the lunar excursion module (LEM) during the early stages of a lunar mission. There is more than one adapter configuration due to the various requirements of Apollo missions. The adapter capable of housing the LEM is briefly described in paragraphs 2-23 and 7-7. Adapters vary in length and location of access doors according to launch vehicle configurations. The earth-orbital type adapter illustrated in figure 2-6 is a hollow cylinder composed of four panels joined by means of linear-shaped explosive charges. An umbilical cable between the adapter and the service module connects circuits that provide launch vehicle propulsion, control, and abort information to the spacecraft.

## 2-23. LUNAR EXCURSION MODULE.

2-24. The lunar excursion module (LEM) carries a crew of two and will separate from the spacecraft, land on the moon, and lift off to rendezvous with the lunar-orbiting spacecraft. The module is enclosed and supported by the LEM adapter which is a structural fairing between the service module and the S-IVB booster. The adapter contains the LEM during all mission phases prior to the transposition to the apex of the command module. The communications and instrumentation system is adequate for all possible LEM events and contingencies.

## 2-25. APOLLO GROUND SUPPORT EQUIPMENT.

2-26. Ground support equipment (GSE) is the nonairborne equipment necessary for operational and maintenance tasks and is grouped into four classifications according to principal use. The Apollo program contains a great number of individual items of GSE due to the various configurations and the many operations that must be performed between the times of manufacture and of launch. The four classifications are described in the following paragraphs.

2-27. AUXILIARY GSE. Auxiliary equipment is designed to assist major equipment function, supplement major equipment, or aid personnel in utilizing major equipment. The group includes a number of simulators for the spacecraft, a few of which are capable of simulating an entire module during test operations. There are protective covers and seals for portions of the spacecraft subject to damage from exposure to the weather. The auxiliary GSE also performs cleaning and air conditioning functions. Optical alignment sets and dummy launch escape system motors facilitate assembly and testing.

2-28. CHECKOUT GSE. Checkout equipment is used to verify functional integrity and flight readiness of the spacecraft systems, to isolate major malfunctions, and to control and monitor the operation of the spacecraft systems. This group consists of bench maintenance equipment, spacecraft combined



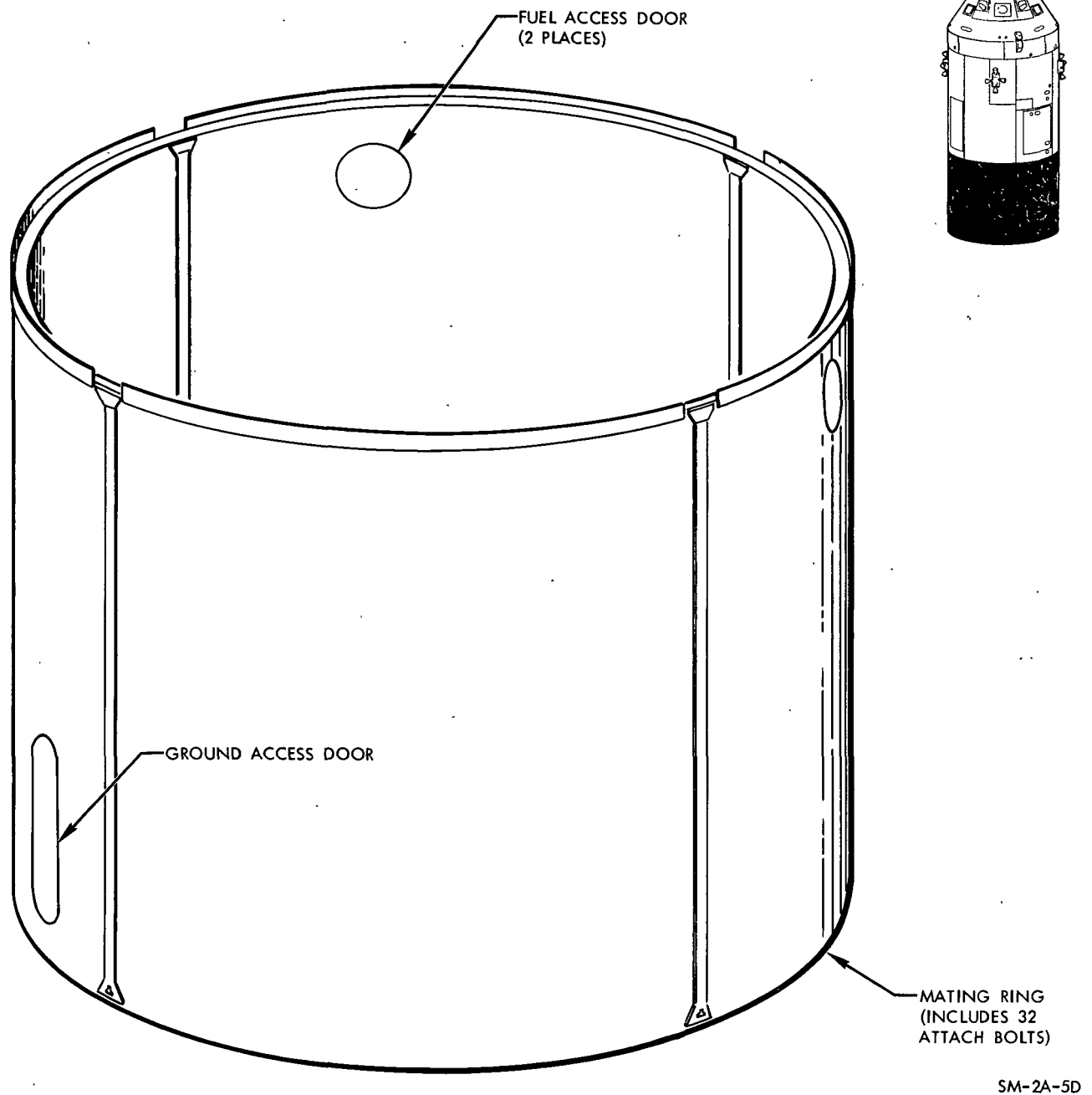


Figure 2-6. Spacecraft Adapter

system test units, and prelaunch automatic checkout equipment (PACE). Bench maintenance equipment is used to perform checkouts at all levels up to and including a complete system. A spacecraft special test unit is used for local/manual checkout of the command and service modules. The unit supports such functions as the command and service module vehicle checkout of both combined and integrated systems. PACE is used for remote and automated checkout of the spacecraft. It is computer-directed and operates from a remote control room. PACE is supported by three types of equipment: built-in, carry-on, and ground. The built-in equipment is installed in the spacecraft. The carry-on equipment is placed aboard and removed before launch.

2-29. HANDLING GSE. Handling equipment is used to handle, position, or transport the spacecraft and the supporting GSE. The equipment includes a number of slings, each of which is specially constructed to hold a particular assembly during installation or removal from the spacecraft. There are also workstands of various heights to provide personnel with convenient access to the spacecraft sections when it stands in a vertical position. Several storage tanks for cryogenic liquids require slings and stands which are also included in the handling GSE group as are dollies required for transportation of large assemblies

2-30. SERVICING GSE. Servicing equipment is used for transfer of such media as liquids, gases, solids, and electrical power between the spacecraft, other units of GSE, and facility locations. This group includes a number of units especially constructed for the purpose of loading the spacecraft with all the required liquids with a minimum of hazard or leakage. There are also mobile containers to serve requirements for rapid tanking of the spacecraft or of portions under test.

## SECTION III

### OPERATIONAL SYSTEMS

3-1. In this section the 11 operational systems of the spacecraft are described in general terms but with sufficient detail to convey an understanding of the systems as a whole. Each system is mechanically, electrically, or functionally interfaced with one or more of the other systems. (See figure 3-1.) This section also covers spacecraft controls and indicators which are related to all operational systems.

#### 3-2. ENVIRONMENTAL CONTROL SYSTEM.

3-3. The function of the environmental control system is to provide a shirt-sleeve environment in the crew compartment, a conditioned atmosphere for pressure suit operation under normal and emergency conditions, and thermal control of the electronic equipment in the command and service modules. The environmental control system is capable of accomplishing these functions for a three-man space flight of as long as two weeks duration. A 72-hour water supply after landing is available as a result of system flight operation.

3-4. The environmental control system conditions the atmosphere of the command module by removing debris and carbon dioxide, supplying oxygen, and controlling temperature and humidity. The system also provides automatic control of the flow, pressure, temperature, and composition of the gas in the pressure suits. Potable water generated by the electrical power fuel cells in the service module is piped into the command module for crew consumption. The main supply of oxygen for the command module is stored in the service module. Since the service module is jettisoned prior to entry, a surge tank in the command module provides oxygen during entry and landing phases. The crew may override automatic operation and assume manual control of the environmental control system at any time.

#### 3-5. CREW SYSTEM.

3-6. The crew system consists of the equipment and supplies that fulfill the needs peculiar to the presence of human beings aboard the spacecraft. The crew system provides a certain amount of physical protection from radiation, acceleration, impact, weightlessness, and depressurization, and includes provisions and facilities necessary for survival in case of abnormal or emergency conditions. The crew system also includes the provisions and facilities necessary for the routine functions of eating, drinking, sleeping, shaving, bodily cleansing, and elimination of waste.

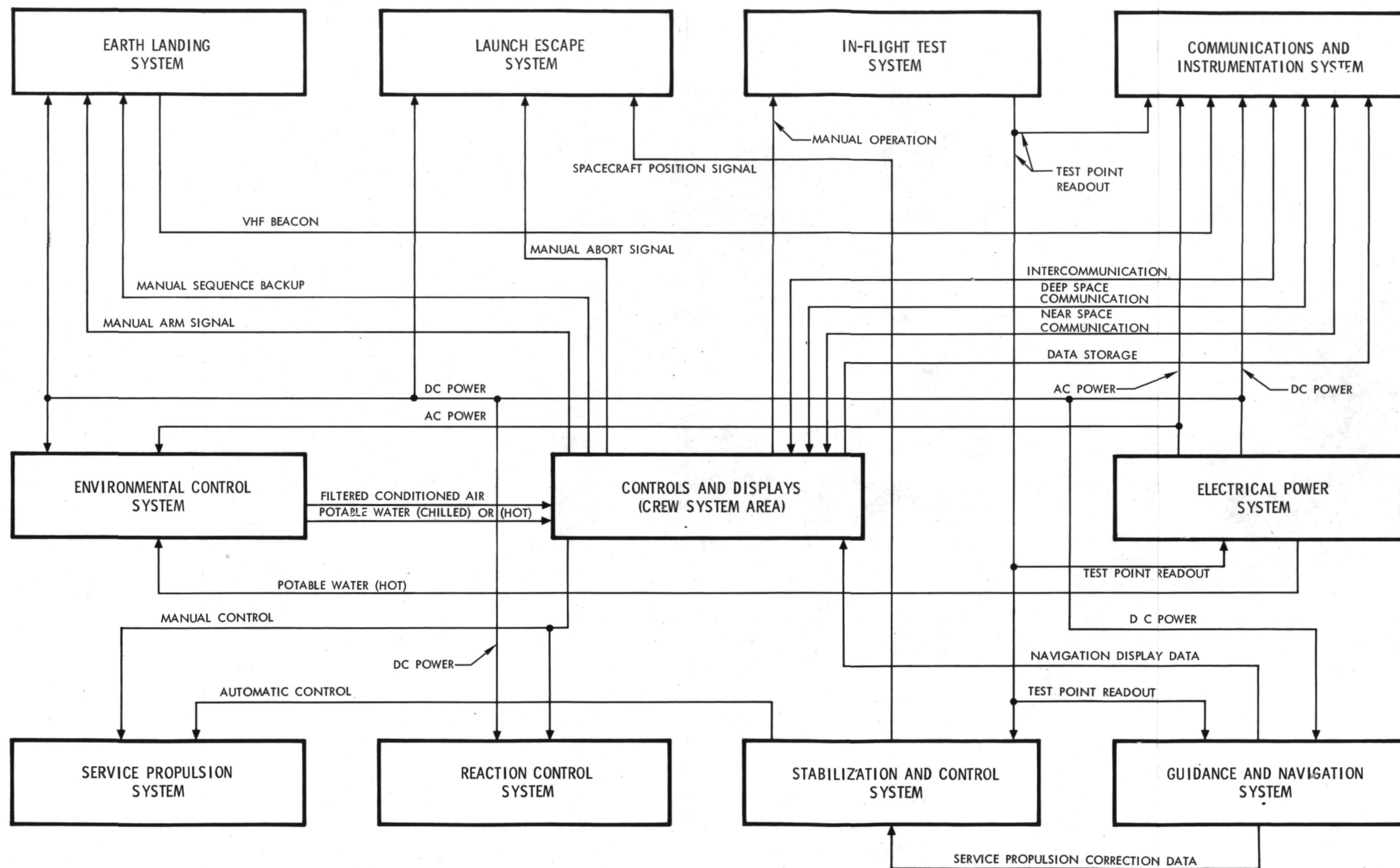


Figure 3-1. Spacecraft Systems Functional Block Diagram

### 3-7. PERSONAL EQUIPMENT.

3-8. Each crew member is equipped with a constant wear garment with accessories, a pressure suit with a backpack (portable life-support system), restraint harness, and communication headset. The constant wear garment is worn under the pressure suit and during cabin "shirtsleeve environment" conditions. It consists of a one-piece tailored coverall, soft-soled shoes, and a constant-wear hat. An umbilical line from the environmental control system provides atmospheric control to the spacesuit for use during a crew compartment decompression emergency. The backpack is used with the pressure suit during extra-vehicular activities. Personal communications are provided by the use of headsets within the constant-wear hat or the spacesuit helmet.

### 3-9. COUCHES AND RESTRAINTS.

3-10. The command module is equipped with three couches and restraining devices. The restraining devices are for use during launch and entry phases or abnormal flight conditions. The basic support for all three couches is a fixed frame suspended from shock attenuators. The couches are equipped with adjustable headrests, backrests, and armrests. The couches also have angular adjustments in the vicinity of the hip and of the knee. The couch seat is approximately 24 inches wide with a slight lateral curvature to accommodate a man in a pressurized suit. The couch is covered with a lining to improve load distribution and absorb shock at the time of landing impact. The lining is composed of three layers of trilock covered with a nylon or dacron netting. The thickness of the lining is approximately 1/2 inch. The left-hand and center couches are equipped with parallel-connected flight controls. These controls are located on the armrests of the two couches so as to be accessible to both occupants. Controls for the rotational maneuvers around the spacecraft axes are on the right armrests of the couches, and the controls for the translational maneuvers along the axes are on the left armrests. The center couch may be removed and stowed to increase living space and allow easier access to provisions and equipment stored in equipment bays.

### 3-11. SLEEPING PROVISIONS.

3-12. For sleeping and for increased living space the center couch is removed and repositioned on the floor beneath the left couch. An inflatable, adjustable cover, attached along three edges of the couch and the wall, isolates the area. A two-way stretch, open-mesh coverlet is drawn over the occupant to hold him in place against an inflated mattress. The isolation cover can be used to close out cabin light and reduce noise level. A pressure suit receptacle is located within the sleeping area.

### 3-13. FOOD AND WATER FACILITIES.

3-14. Food provided for the crew is freeze-dehydrated and vacuum-sealed in trilaminate mylar-seran-polyethylene bags with a capacity of 12.5 cubic inches. Approximately 400 of these tubes weighing a total of 75 pounds may be stored. This food is reconstituted by adding hot water and kneading until mixed. Feeding is accomplished by squeezing this mixture into the mouth.

3-15. The fuel cell reaction product (water vapor with a temperature of up to 500°F) is routed through a condensor and water separator where it is condensed, cooled, and delivered to the environmental system. This system is capable of providing 19 pounds (9 quarts) of water each day to the cabin storage tank for metabolic and personal hygiene requirements. Drinking is accomplished by the use of the crewman water delivery assembly which is a valve-controlled tube inserted into the mouth.

### 3-16. WASTE MANAGEMENT CONTROL.

3-17. Waste management control consists of collecting, sterilizing, and storing human fecal matter, urine, and personal hygiene wastes. The fecal matter is collected in polyethylene bags, disinfected with a solution of calcium chloride, and stored. The urine is stored for a maximum of 6 hours. The storage unit is periodically emptied by automatic means.

### 3-18. POSTLANDING SURVIVAL PROVISIONS.

3-19. A seven-day supply of food and water is allocated for survival. The spacecraft also carries a three-man life raft, location aids, and other survival equipment.

### 3-20. LAUNCH ESCAPE SYSTEM.

3-21. The launch escape system provides the means of propelling the command module to a safe altitude and position in the event of an off-pad or suborbital altitude abort. The launch escape system consists of three rocket motors (launch escape, tower jettison, and pitch control motors), a four-legged tower that transmits loads between the command module and the launch escape assembly, and sequence controllers. The tower structure is attached to the command module by four explosive bolts. The sequence controllers in the command module and on the structural skirt control operation of the system by transmitting signals that ignite the motors and actuate the separation mechanisms.

3-22. If an early stage abort is necessitated by troubles in the launch vehicle systems, a signal from the sequence controller initiates separation of the command module from the service module with subsequent ignition of the launch escape and pitch control motors. These motors provide the thrust for lateral translation and lift of the command module to the required altitude for effective

operation of the earth landing system. In a launch pad abort situation, the launch escape system propels the command module to an altitude of approximately 5000 feet and a lateral distance of approximately 4000 feet depending on wind conditions. Upon completion of either a successful launch or an abort, the launch escape assembly is jettisoned from the command module. The sequence controller controls the jettisoning by transmitting signals that fire the explosive bolts and ignite the jettison motor. After separation from the assembly in an abort situation, the forward heat shield is ejected and the drogue chute is deployed followed by the deployment of the main parachutes to provide a safe landing for the crew. (Refer to earth landing system coverage in paragraph 3-66.)

### 3-23. GUIDANCE AND NAVIGATION SYSTEM.

3-24. The guidance and navigation system is a semiautomatic assembly that is directed and operated by the crew. It supplies display and control signals to the astronauts, the stabilization and control system, the service propulsion, and the reaction control system. The major components of the guidance and navigation system are the inertial measurement unit, the guidance computer, the coupling display, the power and servo amplifier, the scanning telescope, and the sextant. The components are fully supported by controls and displays. The guidance computer is operated independently of the system to perform the calculations involved in spacecraft navigation. The computer acts upon an input of navigational sighting data to furnish such flight parameters as orbit deviation, points of injection and ejection, flight trajectory deviation and correction, and point of entry.

3-25. The guidance and navigation system establishes and maintains a primary inertial reference, with respect to a number of coordinate axes including those of the earth and the moon. The reference can be shut down and re-established in flight at any time. The system has several modes of operation, one of which is the monitoring of the spacecraft attitude. The indications are transmitted to the stabilization and control system for display. The system also generates attitude control signals upon crew command. The signals originated in this mode order the spacecraft to remain in a specified attitude or to maneuver to a new one. The stabilization and control system relays these signals to the appropriate thrust jets of the service module reaction control subsystem and provides the displays indicative of attitude and attitude change. The manual controls in the spacecraft can interrupt or override the control mode at any time. The guidance and navigation system supplies control and display signals to provide large thrust vector increments from the service propulsion system or small velocity vector increments from the service module reaction control subsystem. Earth entry is programmed and directed by the guidance and navigation system, controlled and displayed by the stabilization and control system, and carried out by the engines of the command module reaction control subsystem. This phase concludes with the initial step in the operation of the earth landing system.

### 3-26. STABILIZATION AND CONTROL SYSTEM.

3-27. The stabilization and control system is a manual and semiautomatic system that is directed and operated by the crew. It provides display and control signals that are required by the crew, the guidance and navigation system, the reaction control system, and the service propulsion system. The specific functions of this system are as follows:

- a. Rate damping after launch escape assembly jettison so that a successful high-altitude abort re-entry may be accomplished if necessary
- b. Angular orientation and stabilization of the spacecraft about three axes under crew command, guidance and navigation system, or the system inertial reference which is known as the secondary inertial reference
- c. Translational control during rendezvous and docking
- d. Thrust vector control during midcourse corrections
- e. System displays to the crew.

The major components of the stabilization and control system are the gyro, accelerometer, and five electronic control assemblies. They are amply supported by displays and controls.

3-28. The stabilization and control system provides attitude control during flight when the guidance and navigation system is not functioning. The system secondary inertial reference is with respect to a number of coordinate axes and may be shut down and re-established in flight as desired. The system can function to hold the spacecraft at a specified attitude when the guidance and navigation system is not functioning. The manual controls in the system permit rotational and translational maneuvers and minimum rotational impulse control. The spacecraft may be set in a free-drift flight by means of disabling switches. The system directs pitch and yaw attitude control signals to the respective gimbals during service propulsion engine firing. The roll attitude control signals continue to go to the service module reaction control subsystem. The stabilization and control system operates in entry maneuvers if required. It supplies manual rotational and automatic pitch and yaw rate damping controls, and monitors attitude rates.

### 3-29. REACTION CONTROL SYSTEM.

3-30. The reaction control system is comprised of two completely independent reaction control subsystems. They are the command module and the service module reaction control subsystems. These subsystems are similar in that both are pressure-fed, utilize hypergolic propellants, and contain total redundancy of all components. The primary purposes of the subsystem are to provide attitude control and stabilization for the module.



3-31. Specific uses of the command module reaction control subsystem are to accomplish roll maneuvers and to provide three-axis control of the module after separation from the service module for the purpose of entry orientation. A specific use of the service module reaction control subsystem is to provide minor velocity increments for correction of the earth orbit after spacecraft insertion by the launch vehicle. Both subsystems operate in response to control signals from the stabilization and control system or a secondary electrical circuit connected to manual override controls.

3-32. The command module reaction control subsystem consists of two independent, equally capable, and identical networks. Each of these networks consists of six reaction control engines, fuel and oxidizer tanks, a helium tank, and the associated components. The components include propellant lines, regulators, valves, filters, burst discs, and fittings. Four of the valves are used for emergency dumping of fuel and oxidizer. They are squib-actuated and operate upon crew command. Two of the six reaction control engines provide control about each of the three major spacecraft axes. All components of this subsystem are located in the aft compartment with the exception of the two positive pitch (pitch down) engines, which are located in the forward compartment. The corresponding engines of the two networks are mounted in pairs. The pitch control engines are placed on the -Z side of the module. Both positive pitch engines lie in the XZ plane and their longitudinal axes are parallel to the Z axis. The negative pitch (pitch up) engines are placed 3.5 degrees left and right of the XZ plane and are canted 47 degrees forward from the YZ plane. The negative yaw (yaw left) engines are located on the -Y side and the positive yaw (yaw right) are located on the +Y side. Both pairs of yaw control engines are placed 3.5 degrees left and right of the XY plane and have the same cant as the negative pitch engines. The two pairs of roll control engines are placed so that one pair is midway between the negative pitch engines and each pair of yaw control engines.

3-33. The service module reaction control subsystem consists of four independent, equally capable, and identical networks. Each of these networks consists of four reaction control engines, fuel and oxidizer tanks, a helium tank, and the associated components. The components include propellant lines, regulators, flow meters, valves, filters, and fittings. These are all located in the service module. The reaction control engines for each network are mounted in packages of four. Two of the engines in each package are for roll control. The other two are for pitch or yaw control depending upon the location of the package. The four packages are mounted on the exterior of the module near the forward end and are offset 7 degrees from the +Z, -Z, +Y, and -Y axes. The tankage and control components associated with each package are mounted directly behind it in the interior of the module.

### 3-34. SERVICE PROPULSION SYSTEM.

3-35. The service propulsion system provides impulse for large velocity changes of the spacecraft after booster separation. The system operates in response to electrical signals generated by the stabilization and control system or by manual override controls. This system provides velocity increments required for orbital corrections during earth-orbital missions.

3-36. The service propulsion system consists of a rocket engine, pressure and propellant tankage, and associated components. The components include hydraulic lines, valves, filters, regulators, and fittings. The entire system is located in the service module. The engine is pressure-fed and produces a single value of thrust when in operation. It has no throttle control but has gimbaling provisions. It is located at the aft end of the center section. The gaseous helium supply used for pressurization is contained in two spherical tanks mounted forward of the engine in the center section. The propellant supply is contained in four long, rounded-end, skirted, cylindrical tanks. Two contain fuel and the other two contain oxidizer. The fuel tanks are located in the upper left and lower sectors, and the oxidizer tanks are located in the mid-left and mid-right sectors.

### 3-37. COMMUNICATIONS AND INSTRUMENTATION SYSTEM.

3-38. The two major functional divisions of the communications and instrumentation system are the communications subsystem and the instrumentation subsystem. The communications subsystem provides transmission of voice, television, telemetry, and tracking and ranging information from the spacecraft to the GOSS stations. The subsystem also receives voice communications from the ground and processes ranging and tracking signal reception for transmission back to earth. There are facilities for intercommunication between spacecraft crewmen and for communication between the spacecraft and the LEM throughout all phases of a lunar landing mission. The instrumentation subsystem monitors spacecraft system operations and provides appropriate displays. Provision is made to store data on board for delayed transmission or for future analysis.

3-39. The communications and instrumentation system consists of the following equipment subsystems:

- a. RF Equipment Group
- b. Antenna Equipment Group
- c. Intercommunication Equipment Group and Controls
- d. Data Acquisition Equipment Group
- e. Data Handling Equipment Group

- f. Data Storage Equipment Group
- g. Spacecraft Central Timing Equipment Group
- h. Control and Display Equipment Group.

### 3-40. RF EQUIPMENT GROUP.

3-41. The RF equipment group consists of a VHF FM transmitter, a VHF AM transceiver, a unified S-band transponder, a C-band transponder, a VHF recovery beacon, an HF transceiver, and an up-data link. The group provides near-earth, deep-space, and spacecraft-LEM communication. The range of near-earth communication is from the surface of the earth up to 8,000 nautical miles above it.

3-42. VHF FM TRANSMITTER. The function of the VHF FM transmitter is to transmit telemetry during near-earth phases of a mission. It has an output of 10 watts and operates within a frequency range of 215 to 260 megacycles.

3-43. VHF AM TRANSCEIVER. The function of the VHF AM transceiver is to provide two-way communication between the spacecraft and the ground stations during near-earth phases of a mission, between the spacecraft and one or more astronauts located externally, between the spacecraft and the LEM, and between the command module and the recovery group prior to earth impact. The transceiver transmits on a frequency of 296.8 megacycles and receives on a frequency of either 296.8 or 259.7 megacycles. It has a power output of 5 watts.

3-44. UNIFIED S-BAND TRANSPONDER. The function of the unified S-band transponder is to provide all deep-space communication, all television transmission, and all deep-space two-way Doppler tracking and ranging. The transponder transmits on a frequency of either 2282.5 or 2287.5 megacycles and receives on a frequency of 2106.2 megacycles. The receiver portion is a double conversion superheterodyne unit. The amplifier section of the transponder furnishes two power outputs. A reduced output of 5 watts or a full output of 20 watts is available.

3-45. C-BAND TRANSPONDER. The function of the C-band transponder is to provide two-way Doppler tracking and ranging during near-earth phases. The equipment transmits at a frequency of 5765 megacycles and receives at a frequency of 5690 megacycles. Transmitter peak power is 2500 watts.

3-46. VHF RECOVERY BEACON. The function of the VHF recovery beacon is to provide line-of-sight direction finding capabilities which aid in locating the spacecraft during the recovery phase of a mission. The beacon is a radio transmitter device which operates at a frequency of 243 megacycles and has a power output of 3 watts.

3-47. HF TRANSCEIVER. The function of the HF transceiver is to provide beyond line-of-sight direction finding and communication capabilities to aid in locating the spacecraft during the recovery phase of a mission. The transceiver operates on single-side-band or compatible AM for voice communication and on CW for key operation of the transmitter. The frequency is a single, preassigned one within the 8 to 16 megacycle range. The transmitter output is 20 watts peak-envelope-power on single-side-band and 5 watts average-carrier-power on AM.

3-48. UP-DATA LINK. The up-data link is a UHF FM receiver which operates on a frequency of 405 to 450 megacycles. The function of the link is to receive data from the ground during flight. The data is supplied to the computer in the guidance and navigation system, thereby facilitating space navigation. The navigation equations stored in the computer memory are constantly revised from data received from the ground. It is connected to both the VHF and the high-gain antennas for use in both the near-earth and the deep-space regions of space.

### 3-49. ANTENNA EQUIPMENT GROUP.

3-50. The antenna equipment group contains two VHF/UHF broad band antennas, a C-band antenna, a high-gain antenna, and two HF/VHF recovery antennas. The two broad band antennas are scimitar-shaped and are located inside the strakes. They are the wave radiating elements for the VHF FM transmitter, the VHF AM transceiver, the UHF up-data link, and the S-band transponder when it is operated at low power output. The C-band antenna is used in conjunction with the C-band transponder. The antenna consists of four segments equally spaced around the side of the command module exterior. The high-gain antenna is used with the S-band transponder during deep-space flight and is deployed from the rear of the service module. The recovery antennas are of the whip type and are deployed from the forward compartment of the command module. The antennas are used for both VHF recovery beacon and HF transceiver operation.

### 3-51. INTERCOM EQUIPMENT GROUP AND CONTROLS.

3-52. The intercom equipment group and controls consist of audio control units, microphones, and headsets at each of the three flight stations. The control units contain microphone and headset amplifiers, and voice-operated relay circuits. VOX or push-to-talk switches can be used at each station for transmission. Volume control is automatically as well as manually controlled.

### 3-53. DATA ACQUISITION EQUIPMENT GROUP.

3-54. The data acquisition equipment group consists of sensor, photographic, and television units. There is also a clock for timing various spacecraft operations. The sensors monitor the pressures and temperatures encountered in flight. The photographic equipment provides 16 mm motion picture camera and 35 mm still camera coverage. The spacecraft contains a real-time television system. The real-time system transmits a direct video signal via the unified

S-band transponder to earth monitoring observers. Through this system, crew and spacecraft flight operations can be observed continuously during all missions including lunar surface explorations. The scanning telescope of the guidance and navigation system has a relatively broad field and is used for visual observations.

### 3-55. DATA HANDLING EQUIPMENT GROUP.

3-56. The data handling equipment group contains signal conditioning, data distribution panel, and pulse-code-modulation (PCM) telemetry units. The signal conditioning portion consists of d-c amplifiers, their associated hardware and cabling, and a signal conditioning unit. The amplifiers transform the low-level signals from the sensors to a 0- to 5-volt d-c range which is the basic instrumentation subsystem analog voltage. The unit functions as the main signal path junction point. It controls appropriate calibration circuitry and provides required reference potentials. The data distribution panel gathers the data from the various sensors and routes it to the test, telemeter, or recording circuitry. The PCM telemetry system processes spacecraft data into signals for transmission to ground monitoring stations. This data from analog sensors is commutated and digitized into coded PCM pulses. The transmission is accomplished by the VHF FM transmitter during near-earth phases and the S-band transponder in deep space. The components of the telemetry system consist of an analog commutator, amplifier, analog-to-digital converter, digital commutator, storage and coder, and programmer.

### 3-57. DATA STORAGE EQUIPMENT GROUP.

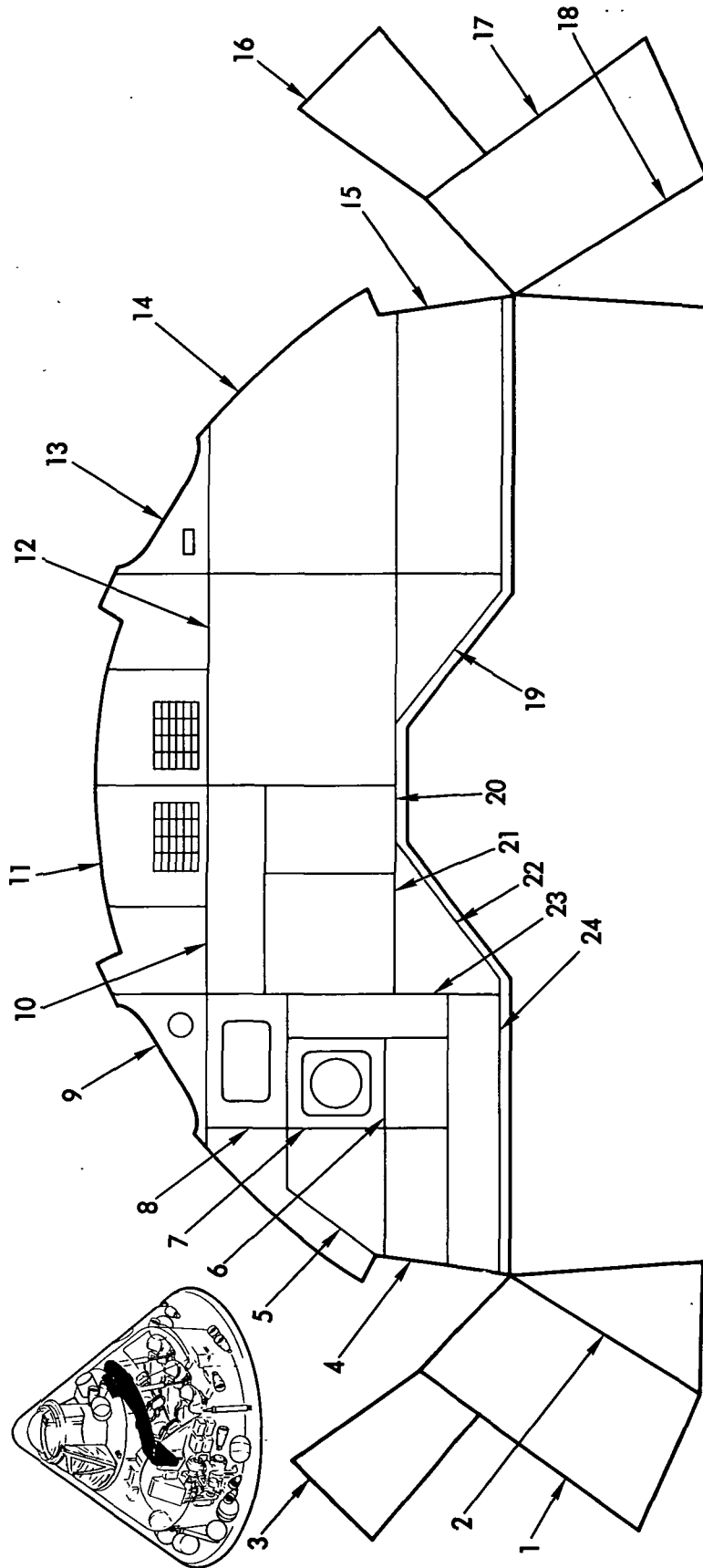
3-58. A magnetic tape recorder stores data from mission commencement to completion. The recorder receives signals directly from the telemetry system for all measurements. The tape is used by data reduction facilities to evaluate all pertinent data after mission completion.

### 3-59. SPACECRAFT CENTRAL TIMING EQUIPMENT GROUP.

3-60. The clock in the central timing group is used in guidance, telemetry, calibration, and in tape recorder operation. It displays time in Greenwich Mean Time, time-to-event, and time-after-event.

### 3-61. CONTROL AND DISPLAY EQUIPMENT GROUP.

3-62. All controls and displays are located in the crew compartment of the command module. Spacecraft displays and indicators provide the means of making periodic observations concerning operating parameters, performance of systems, and equipment status. The controls provide the means of energizing systems, checking systems, selecting specific subsystems, and controlling system outputs. Spacecraft systems controls and indicators are shown in figure 3-2.



- |   |   |
|---|---|
| 1. STABILIZATION AND CONTROL SYSTEM POWER CONTROLS AND SYSTEMS CIRCUIT BREAKERS   | 13. OXYGEN WARNING INDICATOR  |
| 2. MISSION SEQUENCE CONTROLS  | 14. ELECTRICAL POWER SYSTEM FUEL CELL CONTROLS AND INDICATORS                     |
| 3. AUDIO AND LIGHTING CONTROLS  | 15. COMMUNICATIONS CONTROLS AND SERVICE PROPULSION SYSTEM CONTROLS AND INDICATORS |
| 4. ATTITUDE SET AND GIMBAL POSITION DISPLAY   | 16. AUDIO AND LIGHTING CONTROLS   |
| 5. EMERGENCY DETECTION INDICATORS AND GIMBAL DRIVE CONTROLS   | 17. BUS SWITCHING CONTROLS AND SYSTEMS CIRCUIT BREAKERS                           |
| 6. Δ V DISPLAY  | 18. BUS SWITCHING CONTROLS  |
| 7. FLIGHT DIRECTOR ATTITUDE INDICATOR   | 19. ANTENNA CONTROLS  |
| 8. ENTRY MONITOR DISPLAY  | 20. REACTION CONTROL SYSTEM CONTROLS AND INDICATORS                               |
| 9. BAROMETRIC INDICATOR   | 21. GUIDANCE AND NAVIGATION SYSTEM COMPUTER CONTROLS                              |
| 10. REACTION CONTROL SYSTEM INDICATORS, GREENWICH MEAN TIME INDICATOR, AND STATIC PORT VALVE  | 22. CREW SAFETY CONTROLS  |
| 11. MASTER CAUTION INDICATORS (2 PLACES)  | 23. EMERGENCY DETECTION SUBSYSTEM AND SEQUENCER DISPLAY                           |
| 12. RADIATION INDICATORS, AUDIO CONTROLS, CRYOGENIC CONTROLS AND INDICATORS, AND ENVIRONMENTAL CONTROL SYSTEM CONTROLS AND INDICATORS | 24. STABILIZATION AND CONTROL SYSTEM CONTROLS AND MODE SELECT                     |

SM-2A-8C

Figure 3-2. Systems Control and Display Panel

### 3-63. ELECTRICAL POWER SYSTEM.

3-64. The major function of the electrical power system is to provide the a-c and d-c electrical power required by the various spacecraft systems during flight and postlanding phases of missions. Secondary functions of this system are to distribute electrical power received from ground support equipment during pre-launch phases of operation and to supply potable water to the environmental control system. Three hydrogen-oxygen fuel cells, which are the primary sources of power in the spacecraft, produce water as a by-product of power generation. This water is piped to the environmental control system for handling and distribution. In addition to containing the fuel cells which provide the d-c power that is the primary source in the spacecraft, the electrical power system contains the facilities that control, regulate, store, distribute, and convert this power from dc to ac. The circuitry which ignites the pyrotechnic devices is completely independent of the remainder of the system.

3-65. The electrical power system consists of the fuel cells and accessories, storage batteries, pyrotechnic batteries, charger, inverters, and associated controls and displays. The three fuel cell modules and associated reactant and pressurization tankage heat exchangers, piping, and valves are located in the lower left sector of the service module. The fuel cell radiators are located on the service module skin in the upper right and lower left sectors. The three storage batteries, the battery charger, and the three inverters are located in the lower equipment bay of the crew compartment. The two pyrotechnic batteries are located in the lower equipment bay. The batteries are of the zinc-silver oxide type.

### 3-66. EARTH LANDING SYSTEM.

3-67. The purpose of the earth landing system is to provide the crew and the command module a safe landing on ground or water after either a suborbital abort or a normal entry into the earth atmosphere from orbital flight or a lunar mission. This system also provides recovery aids.

3-68. The earth landing system consists of the parachute subsystem, the forward compartment heat shield separation subsystem, the recovery aids, and the necessary displays and controls. The parachute subsystem is comprised of FIST-type, nylon ribbon drogue chute, 13.7 feet in diameter; three ring-sail, 1.1 ounce rip-stop nylon main chutes, 88.1 feet in diameter; three ringslot pilot chutes, 10.0 feet in diameter; deployment bags; bridles; suspension lines; an inertia switch (unmanned flights only); a sequence controller; and mortars and the hardware necessary to attach the main parachutes to the command module. The main parachutes are packed individually in deployment bags and stowed one to section in three of the four equipment areas in the forward compartment. The drogue parachute is packed separately in the mortar in the fourth section of the forward

compartment. The recovery aids consist of a SOFAR bomb, fluorescein dye markers, and a flashing light beacon. These items are packed beside the drogue chute in the forward equipment bay, except the dye markers, which are located in the aft compartment.

### 3-69. IN-FLIGHT TEST SYSTEM.

3-70. The in-flight test system is used to isolate equipment failures to those units that are accessible and also repairable or adjustable. The system is inoperative until it is activated at the discretion of the crew. The system undergoing test may be in either an operating or a nonoperating status. The test system monitors a voltage from a potential total of 2241 inputs. Voltmeter measurement and telemetry transmission occur simultaneously. Of the inputs, 225 are of the analog type and the remainder are signals available at GSE access connectors located within the command module. Identification of the 225 conditioned analog signals is by means of lighting of a placarded indicator. The other inputs are identified by connecting circuitry which permits assignment of a unique binary number to each.

3-71. The principal assemblies that comprise the in-flight test system are as follows:

- a. Voltage comparator
- b. Switch and readout
- c. Test and control
- d. Power supply and reference
- e. Stimulus test.

3-72. VOLTAGE COMPARATOR ASSEMBLY. The voltage comparator assembly consists of 225 voltage comparator subassemblies. The comparator assembly compares the input signals from the spacecraft systems with reference voltages. It generates out-of-limit signals if the input signals are out of tolerance. The out-of-limit signals light the indicator lamps in the switch and readout assembly.

3-73. SWITCH AND READOUT ASSEMBLY. The switch and readout assembly performs the following functions:

- a. Supplies visual out-of-limits indications associated with each voltage comparator.
- b. Provides a voltmeter.
- c. Provides switching circuits for the selection of input signals to be measured by the voltmeter.



- d. Provides switching circuits for the routing of analog signals for telemetry transmission when they are being measured by the voltmeter.
- e. Permits the positive identification of any input signal at the time that the signal is being measured by the voltmeter. The identification is transmitted by the telemetry equipment.
- f. Transfers stimulus signals from the stimulus test assembly to the spacecraft systems under test.
- g. Permits individual out-of-limit indications to be disabled by the spacecraft crew.

#### NOTE

Rotary switches are the typical means employed for manual switching.

3-74. TEST AND CONTROL ASSEMBLY. The test and control assembly performs the functions of applying power to the system and of selecting the individual test. The functional controls are located on the front panel of the in-flight test system. The main power switch and a master out-of-limits indicator are mounted on the control and display panel. (Refer to paragraph 3-62.) The main power switch applies or cuts off full power to the in-flight test system. The master out-of-limits lamp lights whenever one or more of the lamps on the system panel is activated by an out-of-limits signal.

3-75. POWER SUPPLY AND REFERENCE ASSEMBLY. The power supply and reference assembly is the sole source of power for the in-flight test system. A nominal voltage of 28 volts dc is applied from the spacecraft power system, and the test system is designed to operate with a low power requirement under full operating conditions. The maximum power demand is intended not to be over 45 watts.

3-76. STIMULUS TEST ASSEMBLY. The stimulus test assembly provides test signals to the spacecraft systems upon command through the switch and readout assembly. All comparators associated with test signals which are dependent upon a stimulus will be interlocked with the stimulus transfer switch. When the stimulus is applied, the comparator output gates will be enabled and an out-of-limits signal is allowed if it is present. During periods when the stimulus is not applied, the associated inhibit gates will block the passage of an out-of-limits signal.

## SECTION IV

## THE SPACECRAFT TEST PROGRAM

4-1. The spacecraft test program consists of groups or series of tests which are performed upon simulated spacecrafts or sections of spacecrafts. Typical objectives of these tests are the evaluation of structural integrity, the analysis of performance characteristics of operational systems, and the development of operational procedures. The configurations described in this section are ground-located and ground-operated.

4-2. PROGRAM TEST VEHICLES.

4-3. Four test configurations are described physically and functionally in the following paragraphs. Two of the test vehicles comprise the house spacecraft program. One is boilerplate 14 which is House Spacecraft No. 1, and the other is Spacecraft 006 which is House Spacecraft No. 2. The propulsion system test program utilizes two test vehicles which are designated Text Fixture F-2 and Spacecraft 001.

4-4. HOUSE SPACECRAFT.

4-5. A house spacecraft is a test platform which accommodates an integrated systems test buildup. House spacecraft operation will accelerate checkout and ensure systems compatibility when the production model spacecraft enters into preflight checkout procedures. The house spacecraft evaluates the engineering design of the complete spacecraft and associated ground support equipment (GSE) during actual ground checkout conditions.

4-6. PHYSICAL DESCRIPTION. House Spacecraft No. 1 is essentially a skeletal structure with removable skin. It consists of a launch escape assembly, command module, service module, adapter, and ground adapter. The ground adapter is a standard GSE item. House Spacecraft No. 2 is typical of a manned spacecraft in the latest available flight configuration. It contains complete system installations and the command module is equipped with a heat shield. The propulsion devices are simulated, expended, or rejected equipment. The vehicle includes full instrumentation and a capacity number of test points as a support to the objectives of the test program. Instrumented anthropomorphic dummies are employed for the purpose of crew simulation.

4-7. Both house spacecrafts are located indoors. The supporting facilities include a controlled environmental test area, a service equipment room, control rooms, a maintenance and repair area, a telemetry station, a recording station, handling equipment, and system preparation areas. The Apollo GSE assigned to the house spacecraft will be augmented by prelaunch automatic checkout equipment (PACE) as soon as availability permits.

4-8. FUNCTIONAL DESCRIPTION. House Spacecraft No. 1 functions as a test platform for experimental systems. The removable skin feature was incorporated to facilitate installation and removal of systems with a minimum expense of time and effort. House Spacecraft No. 2 functions as a testing and developmental tool for prototype systems which have originated in an experimental state on House Spacecraft No. 1.

4-9. HOUSE SPACECRAFT OPERATIONS. House Spacecraft No. 1 is operated for the development of systems and as a preliminary check in integrated systems compatibility. Systems become integrated when the command and service modules are electrically and mechanically mated. House Spacecraft No. 1 develops integrated systems to prototype status, evaluates the interaction of systems, establishes preliminary operational procedures, and evaluates ground equipment design and operation with spacecraft. The systems installations are experimental and are made in advance of the manufacture of prototypes. The systems are located in their proper geometric relations to each other to determine actual operating characteristics. On-site modification assessments within working systems are performed, leading to early evaluation of developmental systems.

4-10. House Spacecraft No. 2 is operated to verify systems performance and compatibility in and between major modules, and associated ground support equipment. It evaluates in-flight maintenance capability and operational procedures for vehicle and mission, develops integrated checkout procedures and operational procedures, confirms development design changes prior to inclusion in actual flight systems, and verifies performance according to design specifications including reliability. The systems installations are prototypes. The spacecraft is also operated to accomplish vibration and acoustic tests, resolve interface problems, and perform malfunction mode analysis. House Spacecraft No. 1 operations will gradually approximate those of House Spacecraft No. 2 as the prototype systems increase in number.

4-11. OPERATION LIMITATIONS. Fuels, pyrotechnics, cryogenic fluids, and live rocket motors are not used in house spacecraft operations. The environment, as described in paragraph 4-7, precludes firing and the use of hazardous materials. House Spacecraft No. 1 is incapable of command module crew compartment pressurization tests because of the removable-skin configuration.

#### 4-12. THE F-2 TEST FIXTURE.

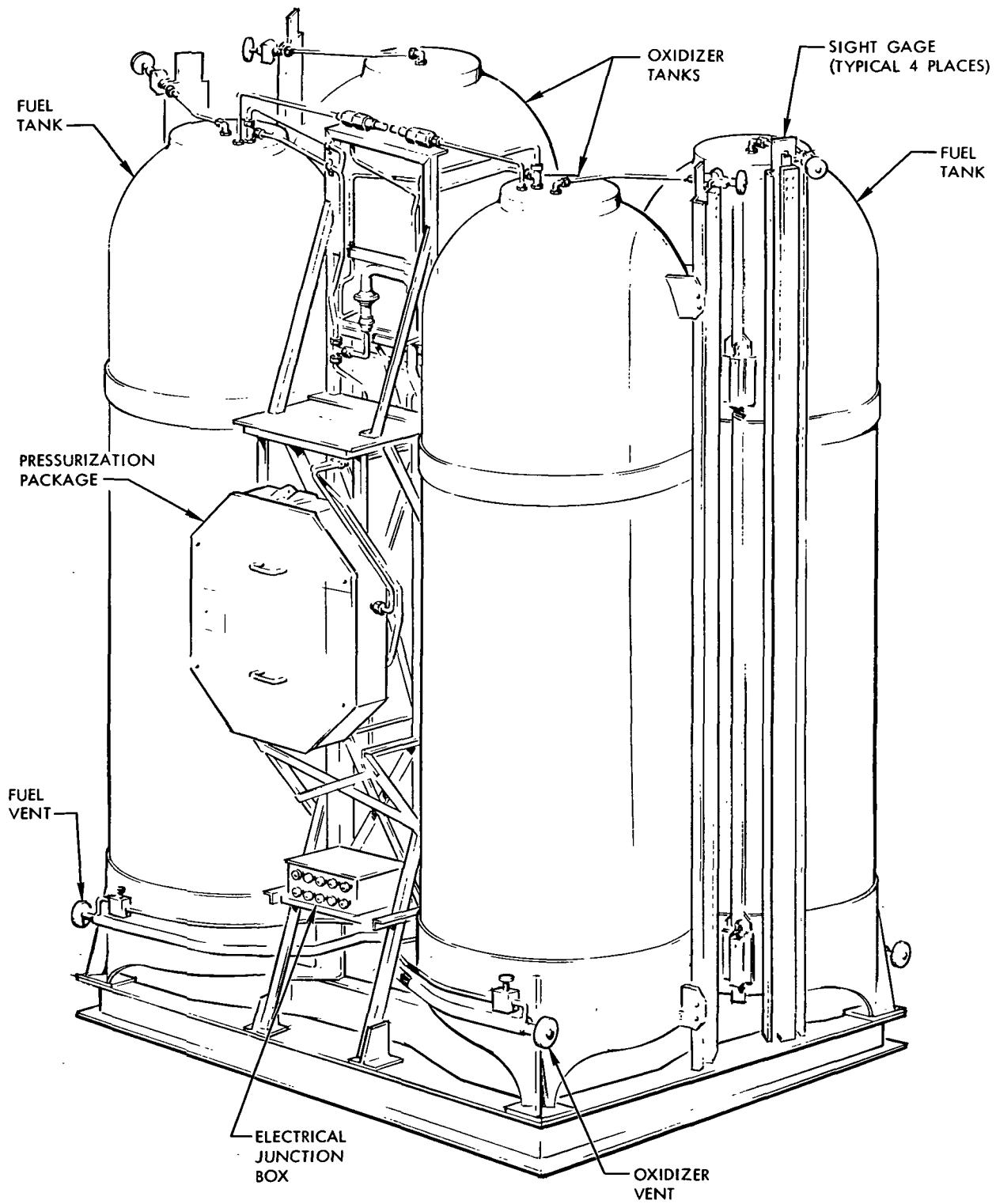
4-13. The F-2 test fixture (figure 4-1) is one of three employed in the Apollo program for the purpose of developing the service propulsion system propellant subsystem. The F-2 is the primary developmental tool of the propellant subsystem.

4-14. PHYSICAL DESCRIPTION. The F-2 test fixture simulates the dimensions of the spacecraft service propulsion system. The propulsion system basically consists of propellant and pressurant containers, an engine, and a pressure-fed transfer subsystem. The test fixture consists of corrosion-resistant tanks, a propellant feed subsystem, and a preliminary flight-rated engine mounted in a structural steel frame. Spacecraft hardware is used in assembly whenever available. The fixture is located on the propulsion development site at WSMR.

4-15. The propellants are contained in four cylindrical tanks with hemispheric ends. Two of them contain fuel and have a total capacity of 15,738 pounds. The other two contain oxidizer and have a total capacity of 31,620 pounds. The outlet port of one fuel tank is connected to the inlet port of the other fuel tank. This series-type connection is identical for the oxidizer tanks. The propellants are earth-storable hypergolic liquids. The fuel is a 50-50 blend of unsymmetrical-dimethylhydrazine (UDMH) and hydrazine ( $N_2H_4$ ), and the oxidizer is nitrogen tetroxide ( $N_2O_4$ ). The pressurant is contained in eight cylindrical tanks having a total helium capacity of 98 pounds pressurized to 4500 psig. The propellant feed system applies a 175-psia pressure to the propellant tanks. The propulsion engine develops a nominal 21,900 pounds of thrust in a space-simulating vacuum. The engine has a specific impulse of 315 seconds. The engine gimbal mechanism has an excursion of  $\pm 8.5$  degrees in the Z axis and  $\pm 6.0$  degrees in the Y axis. The space configuration expansion bell is omitted from the test fixture engine and the nozzle expansion ratio is consequently changed from 60:1 to the test site operation value of 6:1.

4-16. F-2 TEST FIXTURE SITE. The F-2 test fixture is located within the propulsion system test facility at WSMR. It is mounted on one of two test stands. The facility is situated in a comparatively remote section of WSMR due to the hazardous nature of the operations. Each test stand has a ground control station and a control center located at a safe distance from both stands and is the central operating point for the facility. There are underground bunker and cableway installations. Gas, liquid, and propellant storage tanks are situated within adequately spaced protective enclosures.

4-17. FUNCTIONAL DESCRIPTION. The F-2 test fixture undergoes a number of tests at the time of installation which must be completed with satisfactory results before tests upon the service propulsion system can be started. The fixture is subjected to functional checkout, leak test, and instrumentation preparation before installation on the firing stand at the test site. Installation is followed by compatibility testing between the fixture, the facility, and GSE.



SM-2A-310

Figure 4-1. F-2 Test Fixture

Instrumentation and control calibrations are performed. Propellant handling tests and system functional operation tests are completed following system checkout and familiarization tests.

4-18. The F-2 test fixture function primarily to evaluate and certify the safe operation of, the compatibility between, and the performance of the service propulsion pressurization, propellant, and engine subsystems. It also evaluates and certifies the safe operation and performance of the service propulsion system checkout, operating, and servicing GSE. Procedures for servicing, checkout, maintenance, and operation of the system are evaluated and developed. The following paragraphs briefly describe tests that are typical of test fixture operation.

4-19. OPERATIONAL TESTS. The tests described in the following paragraphs cover a complete evaluation of the service propulsion system as performed by the F-2 test fixture. Subsequent tests will include verification, improved systems design, and problem analysis in support to Spacecraft 001 and the Apollo flight program. The test fixture functions primarily to evaluate and certify the safe operation, compatibility between, and performance of the service propulsion system checkout, operating, and servicing ground support equipment. Procedures for servicing, checkout, maintenance, and operation of the system are evaluated and developed.

4-20. NONFIRING SYSTEM OPERATION. This comprises a group of tests performed during the initial prefiring checkout period. The specific tests are as follows:

- a. A leak test of all fluid systems using gaseous nitrogen
- b. A leak test of all helium systems using helium
- c. A proof-pressure test of all fluid systems up to 150 percent of working pressure using gaseous nitrogen or demineralized water
- d. A functional checkout of valves, components, and control systems to verify proper operation and correct installation of control circuitry
- e. A loading and unloading of the propellants performed at least five times.

4-21. NORMAL PERFORMANCE OPERATION. This operation evaluates service propulsion performance during normal system conditions. The tests provide data for the evaluation of system performance during start, shutdown, restart, steady-state, and intermittent cycling, which includes gimbal performance. Base-line data will be established for subsequent limit condition evaluations. The tests consist of the following:

- a. A series of five firings of 5-second duration as required to establish overall test system validity.

b. Five firings of 10- to 20-second duration to establish basic start, stop, and steady-state performance.

c. Five firings of 15- to 20-second duration with shutdown intervals of 1- to 2-second duration to determine the restart characteristics.

d. One 90-second firing for steady-state performance data.

e. Twenty random-time firings which total 200 seconds of firing. The shutdown intervals will total 400 seconds.

f. Two 30-second firings with the engine gimballed by manual control to effect full-thrust vectoring in the Z and Y axes.

g. Five firings in quick succession. Each firing has a duration of 20 seconds and a shutdown interval of 2 seconds.

4-22. SIMULATED MALFUNCTION OPERATION. This operation evaluates service propulsion system performance during simulated malfunction conditions. The simulated conditions are as follows:

a. A low voltage application to the solenoids of the injector valve servos

b. The closing of one bank of the dual injector valve system as in a "fail-close" condition

c. The use of other than normal propellant tank ullage pressures

d. The use of oxidizer to fuel ratios of other than the normal 2:1

e. A combination of maximum and minimum propellant temperatures and different oxidizer to fuel ratios.

4-23. The specific test performed under the condition described in paragraph 4-22, step a, is five firings of 10-second duration each with 20 seconds elapsing between firings; the engine is fixed in the null position and the value of the applied voltage is 20 volts dc.

4-24. The specific tests performed under the condition described in paragraph 4-22, step b, are as follows:

a. Ten firings varying from 2 to 10 seconds in duration with the engine fixed in the null position.

b. Five firings of 30-second duration each with shutdowns totaling 30 seconds. The engine is gimballed manually in the Z and Y axes during each firing.

4-25. The specific tests performed under the condition described in paragraph 4-22, step c, are as follows:

- a. Five starts of firings of 10-second duration at low ullage pressure. The intervals between starts are 3 minutes long to allow restoration of tank pressure.
- b. Three firings of 90-second duration each. The firings start at normal ullage pressure and decrease at a linear rate to a predetermined injector inlet pressure.
- c. Three firings of 30-second duration each. The intervals between firings are 3 minutes long to allow ullage pressure to return to 215 psia. The engine is fixed in the null position.
- d. Five firings of short duration. The intervals between firings are 3 minutes long to allow ullage pressure to return to almost the tank relief pressure, which is 240 psia.

4-26. The specific tests performed under the condition described in paragraph 4-22, step d, are as follows:

- a. Five short firings of 5-second duration with 10 seconds elapsing between firings and concluding with a firing lasting for 20 seconds. The oxidizer to fuel ratio is 1.8:1 and the engine is fixed in the null position.
- b. Step a is repeated using the oxidizer to fuel ratio of 2.2:1.

4-27. The specific tests performed under the conditions described in paragraph 4-22, step e, are as follows:

- a. Three 5-second firings followed by a 20-second run and then three more 5-second firings. The propellant temperature is 135°F, and the oxidizer to fuel ratio is the normal 2:1.
- b. Three 10-second firings with a propellant temperature of 135°F and an oxidizer to fuel ratio of 2.2:1.
- c. Three 10-second firings with a propellant temperature of 135°F and an oxidizer to fuel ratio of 1.8:1.
- d. Three 5-second firings followed by a 20-second run with a propellant temperature of 40°F and an oxidizer to fuel ratio of 2:1.
- e. Three 10-second firings with a propellant temperature of 40°F and an oxidizer to fuel ratio of 2.2:1.
- f. Three 10-second firings with a propellant temperature of 40°F and an oxidizer to fuel ratio of 1.8:1.



4-28. MISSION PROFILE OPERATION. This operation consists of a series of tests which simulate lunar mission firing sequences and durations. The service module propulsion engine is subjected to a firing which totals 720 seconds in duration. The sequence begins with a firing lasting for 60 seconds. This is followed by a programmed series of firings which simulate midcourse corrections, lunar orbital capture, orbital adjustments, lunar orbital separation and return, and midcourse correction.

4-29. F-2 TEST FIXTURE CAPABILITY. The F-2 test fixture is used for analysis of malfunctions and problems encountered during propulsion system tests and during actual spacecraft flight missions. It develops and proves out spacecraft modifications.

4-30. PROPULSION SYSTEM TEST FACILITY GSE. The ground support equipment is comprised of special test units. The main functions of the test fixture GSE are as follows:

a. The propellant servicing group shall be capable of checkout, controlling and monitoring the fuel and oxidizer loading and draining sequence, temperatures, and pressures for the service and command modules.

b. The reaction control servicing group shall have the same capabilities as the equipment in the propellant servicing group.

c. The engine firing group shall be capable of controlling and monitoring automatic, manual, and emergency firings of the command and service module reaction control engines and the service propulsion engine.

d. The gimbal control group shall be capable of controlling and monitoring the gimbal angle of the service propulsion engine. All GSE shall be capable of any additional manually controlled and monitored testing required to qualify the propulsion system.

4-31. F-2 TEST FIXTURE OPERATION LIMITATIONS. All operations performed with the F-2 test fixture take place at an altitude near sea level. There are some deviations from the conditions relative to an Apollo mission. They include earth climatic variations of temperature and humidity, exposure to dust and sand, test fixture rigidity which affects system vibration, earth gravity, and firing without the engine expansion nozzle in place.

4-32. SPACECRAFT 001.

4-33. Spacecraft 001 is one of a group of airframes which will eventually include an airframe performing a manned earth-orbital or lunar mission. Spacecraft 001 is the propulsion test spacecraft. It will verify the conformance of the combined propellant-rocket engine propulsion systems with design specifications and will evaluate the interactions of the related spacecraft systems during propulsion operations. This airframe will be supported by the F-2 test fixture.

4-34. TEST OBJECTIVES. Static firing tests will be performed on the service propulsion system, service module reaction control, and command module reaction control subsystems in their flight configurations. Static firings will be conducted to investigate start-stop transients, systems response, and repeatability for normal and malfunction mode operations. Tests will be performed with high and low propellant delivery pressures and oxidizer-fuel ratios, both above and below nominal. Mission profile tests will be conducted in simulation of suborbital high-altitude abort, earth-orbital, circumlunar, lunar-orbital, and translunar orbital missions. Data will be obtained to provide a comprehensive evaluation of the propulsion and related on-board systems performance. The compatibility of the spacecraft systems associated with control and monitoring of the propulsion systems, ground support equipment, and launch site service systems will be evaluated.

4-35. The static firing tests of the command and service modules require six different test control configurations employed in sequence. This sequence provides an operational confidence buildup necessary to safely meet the program objectives and test schedules. The test control configurations are as follows:

- a. Remove control of service module from control room for the purpose of evaluating the systems to confirm operations and compatibility.
- b. Remote control of command module from control room. The module is attached to a fixed test stand adjacent to the service module stand. The two stands are separated by a protective wall. This configuration permits unmanned command module reaction control subsystem tests and reduces potential hazards.
- c. Remote control of the interconnected modules from the control room. The modules are mounted on the stands mentioned in the previous paragraph for the purpose of unmanned command module operation. The object is to perform integrated systems tests to confirm compatibility of systems operations.
- d. Manned operation of the command module, including service module operation. The spacecraft controls are operated and monitored within the command module and programmed through simulated flight modes.

4-36. PHYSICAL DESCRIPTION. Spacecraft 001 is a prototype spacecraft containing systems of flight configuration. The flight configuration is modified by the omission of the propulsion engine expansion nozzle and the installation of sea level nozzles during some of the reaction control system tests. The major parts of the spacecraft are a command module, a service module, and a special test adapter. The principal systems installations include service propulsion, reaction control, stabilization and control, guidance and navigation, and electrical power. They are supported by controls and displays.

4-37. FUNCTIONAL DESCRIPTION. Spacecraft 001 performs the following evaluations:

- a. Service module propulsion systems
- b. Command module reaction control subsystem
- c. Integrated systems performance and compatibility during hot propulsion system operations
- d. Electrical power system
- e. Spacecraft structural integrity during propulsion operations
- f. Spacecraft and ground support equipment checkout, servicing, and maintenance procedures
- g. Spacecraft and ground support equipment operating and problem investigation procedures
- h. Procedures leading to the establishment of techniques for flight vehicle acceptance static firings.

4-38. PRIMARY SYSTEM TEST. The primary systems to be tested in Spacecraft 001 are the service propulsion, reaction control, and electrical power systems.

4-39. SYSTEM INTERACTION TEST. The systems subjected to interaction testing during the propulsion test program are as follows:

- a. Stabilization and control - available full time for propulsion control investigation under actual firings
- b. Guidance and navigation - installed as required for integrated systems demonstrations during hot propulsion operation
- c. Communications and instrumentation - telemetry portion installed as required for integrated systems demonstrations during hot propulsion operation
- d. In-flight test - installed for integrated systems demonstration during hot propulsion operation.

Applicable controls and displays are installed to support operations of all installed systems. They will also determine system interaction.

4-40. SUPPORTING SYSTEM. The environmental control system is installed in both the command and the service modules during the propulsion program. It is required in the command module to support equipment operation and human occupancy when the command module is closed during service module firings. It is required in the service module to support the mated closed command module operation and the cryogenic assembly.

4-41. SPACECRAFT 001 INSTALLATION. The Spacecraft 001 command and service modules each undergo a series of individual tests before being mated at the test site. The service module is available for test before the completion of the command module. The spacecraft is installed at the other test stand opposite to the F-2 test fixture in the propulsion test site.

4-42. SERVICE MODULE. The service module and the associated GSE receive a thorough test preparation and a number of cold tests before delivery to the test site. The module is also instrumented and checked out prior to shipment. A receiving inspection is performed after delivery. The module is installed upon the propulsion test site test stand for final preparation, compatibility tests, and instrumentation calibration with the facility. Propellant and engine subsystem leak test, purge, and servicing techniques and procedures are investigated. Remote control simulated service module firings are conducted for procedure and test control verification.

4-43. COMMAND MODULE. The command module is made ready for delivery and installation using the same steps that are specified for the service module. Initial tests at the site consist of reaction control subsystem firing operations by means of manual remote control.

4-44. SPACECRAFT 001 TEST OPERATIONS. The tests described in the following paragraphs cover the propulsion ground test evaluations required to certify the spacecraft systems for the flight requirements of the manned suborbital flight.

4-45. Service Module and GSE Systems Operations (Nonfiring). This group includes significant engineering tests for the evaluation of the service module and GSE systems to be performed during the initial prefiring checkout period. The specific activities consist of service propulsion system fueling and defueling tests to evaluate the propellant servicing equipment and the GSE compatibility with the service module. The reaction control system also undergoes fueling and defueling tests to evaluate propellant servicing and system compatibility.

4-46. Service Propulsion System Normal Performance. This operation consists of a number of tests which evaluate the service propulsion system performance with normal operating conditions. The characteristics to be investigated are engine start, shutdown, restart, steady-state, and gimbal performance. The tests are as follows:

a. A series of 1- to 3-second firings to verify the test setup. These tests will demonstrate control and monitor capability and instrumentation performance.

b. Five runs of 10- to 20-second duration. This is for the purpose of establishing basic start, stop, and steady-state performance.

c. Five runs of 15- to 20-second duration in quick succession. The shutdown time between runs is from 1 to 2 seconds. The object is to evaluate the restart characteristics.

d. One 90-second firing in order to evaluate the steady-state performance.

e. Fifty starts with firing times and shutoff intervals of various durations. The total elapsed time is 500 seconds and the purpose is the evaluation of system transients.

f. One 30-second duration firing with the engine being gimbaled through full throw in both axes to evaluate gimbal function and steady state performance.

g. A series of engine firings representing a lunar profile.

4-47. Service Module Reaction Control System Normal Performance. This operation is performed to evaluate the service module reaction control subsystem normal performance characteristics. Integrated compatibility is verified in the three different control modes, manual, emergency, and automatic. The tests consist of the following:

a. Firing checkout runs are made to verify satisfactory operations of all subsystem engines.

b. Evaluation of the performance of all engines by individual firings in the manual control mode. Each run is of short duration and is a steady-state operation.

c. Evaluation of the operation characteristics when performing individual engine firings under emergency control. The runs are steady-state type and are of short duration.

d. Evaluation of the operation characteristics when performing individual tests in the automatic control mode. The firings are of short duration and vary in pulse widths.

e. Firing of each of the four independent engine groups which comprise the subsystem. The firing simulates a complete lunar mission duty cycle.

f. Four runs with two engines operating simultaneously for the purpose of evaluating propellant system dynamics. The runs are of varying pulse width, of short duration, and are performed in an automatic control mode.

g. Two runs with four engines operating consecutively in two different combinations. Subsystem operation with engines firing consecutively is demonstrated to ensure that adverse hydraulic hammering of the propellant system will not be experienced. The runs are of varying pulse width, of short duration, and are performed in an automatic control mode.

4-48. Service Propulsion Design Limit and Malfunction Mode Performance Evaluation. This operation evaluates the service propulsion system functional operation and performance for limit design operating conditions and malfunction modes. The tests consist of the following:

- a. Ten firings of 1- to 10-second duration to evaluate performance with one bank of fuel and oxidizer injector valves in a "fail-close" condition.
- b. One firing of a 30-second duration to evaluate performance with one bank of injector valves in a "fail-close" condition and the engine gimballed through the X and Y axes.
- c. Three firings of 10-second duration each with the propellant inlet pressures initially set at 215 psia. The pressure is allowed to decay to normal operating pressure level in order to evaluate start characteristics at higher than normal pressure.
- d. A series of engine starts with the oxidizer and fuel tank ullage pressure adjusted to various levels to evaluate system performance at high pressure. Initial inlet pressure of 215 psia is used, and subsequent firing are performed at decreased pressure levels in 5-psi increments. The final level is an established value.
- e. A series of fifteen 10-second firings with fuel pressures held at 215 psia and with the oxidizer pressure decreased in 5-psi increments to 140 psia to evaluate variable pressure performance.
- f. A series of fifteen 10-second firings with the oxidizer pressure maintained at 215 psia and the fuel pressure decreased in 5-psi increments to 140 psia to evaluate variable pressure performance.
- g. Three 90-second firings performed in increments starting with the propellant pressures initially set at normal levels and decaying linearly to an established value. The object is the investigation of start, steady-state, and shutdown performance.
- h. Ten 10-second firings with propellant pressures below normal to evaluate low-pressure start performance.
- i. Five 20-second steady-state runs with oxidizer to fuel ratio set at 2.5:1 to evaluate start and steady-state performance.

j. Five 20-second steady-state runs with oxidizer to fuel ratio set at 1.5:1 to evaluate start and steady-state performance.

k. Five short firings with 20 volts dc applied to the injector valve solenoids to investigate the effects on valve operation.

4-49. Service Module Reaction Control Subsystem Design Limit Condition Performance. This operation is conducted to evaluate the service module reaction control subsystem performance with operating levels other than normal. The tests consist of the following:

a. A series of five runs with the propellant pressurization system at the cracking pressure of the system relief valves. The pitch and roll control engines are operated both automatically and manually. The runs are short in duration and are both steady-state and varying-pulse type.

b. A series of ten runs with the propellant pressurization system adjusted to simulate low pressure conditions. The pitch and roll control engines are operated both automatically and manually. The runs are short in duration and are both steady-state and varying-pulse type.

4-50. Command Module and Ground Support Equipment Systems Operation (Nonfiring). This operation includes significant engineering tests for evaluation of command module and GSE systems. It is performed during the initial pre-firing checkout period. One group of tests consists of fueling and defueling activities to evaluate the command module reaction control subsystem propellant servicing equipment.

4-51. Command Module Reaction Control Subsystem Normal Performance. The purpose of this operation is to evaluate the command module reaction control subsystem normal performance characteristics. The tests are intended to verify subsystem integrated compatibility, which includes manual, emergency, and automatic operation. The nozzles on one of the two networks have sea level type replacements to eliminate nozzle flow instability. This results in more realistic system data. The other network retains flight nozzles to formulate checkout procedures for use at launch sites. The tests are as follows:

a. A group of firing checkout runs to verify satisfactory operation of the propulsion and stabilization and control systems. The firings are short in duration and of the pulse type. They are performed in manual, automatic, and emergency control modes. The runs are conducted from the blockhouse.

b. Four runs are performed by individually firing engines in the manual control mode. Both networks are included. The runs are of short duration and are steady-state type.

c. Two runs to evaluate steady-state performance with the use of emergency control. Individual engine firings are conducted. The runs are 5 seconds in duration.

d. Six runs involving the entire subsystem to demonstrate performance with automatic control at varying pulse widths. The runs are of short duration and involve individual engine firings.

e. A series of runs made to demonstrate system performance during simultaneous operation of two and three engines utilizing the automatic control mode. The yaw, pitch, and roll control engines of one network are operated in runs of short duration and of the varying-pulse type.

f. A complete lunar mission duty cycle employing the stabilization and control system.

4-52. Command Module Reaction Control Subsystem Design Limit Tests. This operation comprises a series of tests using the stabilization and control system in manual and automatic firing modes. One network is tuned to operate at conditions beyond the normal range. Six engines are operated consecutively to demonstrate the capability of the propellant feed system. The tests consist of the following:

a. Two runs with six engines firing consecutively to verify that adverse hydraulic hammering in the propellant system will not be experienced. The runs are of short duration and of the varying-pulse type. The automatic control mode is used.

b. Three runs in which maximum propellant pressure conditions are evaluated to simulate a pressure regulator failure condition. The fuel and oxidizer tanks are pressurized with GSE-supplied nitrogen to provide design limit inlet pressure conditions. Engines are fired individually, and both manual and automatic control modes are used. The runs are of short duration and of the varying-pulse type.

c. Five runs in which minimum propellant pressure conditions are evaluated to simulate a pressurization system failure condition. The GSE nitrogen system is utilized to provide the desired conditions. Both automatic and manual control modes are used. The runs are of short duration and of the varying-pulse type.

4-53. Command Module - Service Module Compatibility Tests. Initial tests are performed with the command and service modules interconnected electrically and remotely controlled from the blockhouse. These tests provide data to confirm the compatibility of the interrelated systems. A number of dry firings are conducted to ensure satisfactory operation of all systems. The operation continues with hot propulsion activities. The integrated propulsion system control tests are implemented by either a tape or electronic programmer system. This supplies



error signals to the stabilization and control system in lieu of inertial element signals. The command module is occupied at the conclusion of the remote control test group. The service module is directly controlled from the adjoining module. Controls and displays in the command module are evaluated through a series of hot firings of the reaction control system and the service propulsion system.

4-54. Fuel Cell Prerun and Operational Tests. This operation is a group of tests performed to develop preoperational procedures, to develop methods of servicing the fuel cell system with supercritical reactants, and to evaluate fuel cell operations with and without the environment of propulsion firings. The operation comprises the following steps:

a. Servicing tests are performed to evaluate and establish servicing methods and to determine GSE compatibility. Procedures for the preparation of the fuel cell for power operation are evaluated. A determination of power requirements and time required to heat the fuel cell module is made.

b. The electrical power system is evaluated with the three modules operating and utilizing a normal power profile with modified time durations.

c. The electrical power system is evaluated with three modules operating and utilizing peak power loads with modified time durations.

d. The emergency operation of the system is evaluated by shutting down two modules.

e. Tests are performed to evaluate fuel cell performance when subjected to an environment of heat, shock, vibration, and acoustic noise resulting from service propulsion system and reaction control system firings.

f. The power transfer characteristics and electrical power system compatibility with other systems are evaluated by switching from ground to vehicle power. Tests include use of onboard power during combined systems hot propulsion tests.

4-55. Command Module - Service Module Mission Duty Cycles. Remote controlled and manned spacecraft mission duty cycles are performed to qualify the propulsion and associated control systems for a manned suborbital flight. These tests include simulated suborbital flight profiles along with emergency profiles such as mission aborts.

4-56. Service Module Firings with Off-Limit Propellant Temperature and Mixture Ratios. This operation is for the purpose of evaluating service propulsion system operation in a manned earth-orbital flight during a series of firings with off-limit propellant feed conditions. The tests consist of the following:

a. Engine firings performed with high and low propellant temperatures. Three 10- to 20-second runs are made with a temperature of 135°F. The runs are repeated with a temperature of 40°F.

b. Tests performed with a combination of conditions that consist of high temperature and off-limit mixture ratio, and low temperature and off-limit mixture ratio. The runs consist of ten 1- to 10-second firings each. The following propellant temperature and mixture ratios prevail: (1) 135°F and 2.2:1, (2) 135°F and 1.8:1, (3) 40°F and 2.2:1, and (4) 40°F and 1.8:1. The preceding conditions require a total of four runs.

4-57. Spacecraft Mission Duty Cycles. The operation consists of a number of mission profiles which are performed to support the qualification of the command module and the service module for a manned earth-orbital mission. The stabilization and control system programs the simulated missions. The environmental control system supplies cooling for the equipment. The fuel cells are operated to supply electrical power, and the water generated is monitored for life systems evaluation. The telemetry and in-flight test systems may be utilized during the simulated missions to determine any degradation due to propulsion operations and interactions with other systems.

## SECTION V

## THE ABORT TEST PHASE

5-1. The abort test phase demonstrates the ability of the Apollo command module to safely escape from a launch vehicle by means of the launch escape system. The launch escape system is potentially operative while on the launch pad and during the first stages of flight to a short interval after second stage booster ignition. The three simulated emergencies of greatest significance in the abort test phase are launch pad abort (boilerplate 6), high dynamic pressure abort (boilerplate 12), and high altitude abort (boilerplate 22). This section contains a description of these three tests.

5-2. ABORT TEST BOILERPLATES.

5-3. Three of the boilerplates in the Apollo program are the test vehicles which demonstrate the ability of the command module to escape from a booster under the flight conditions imposed in the individual test.

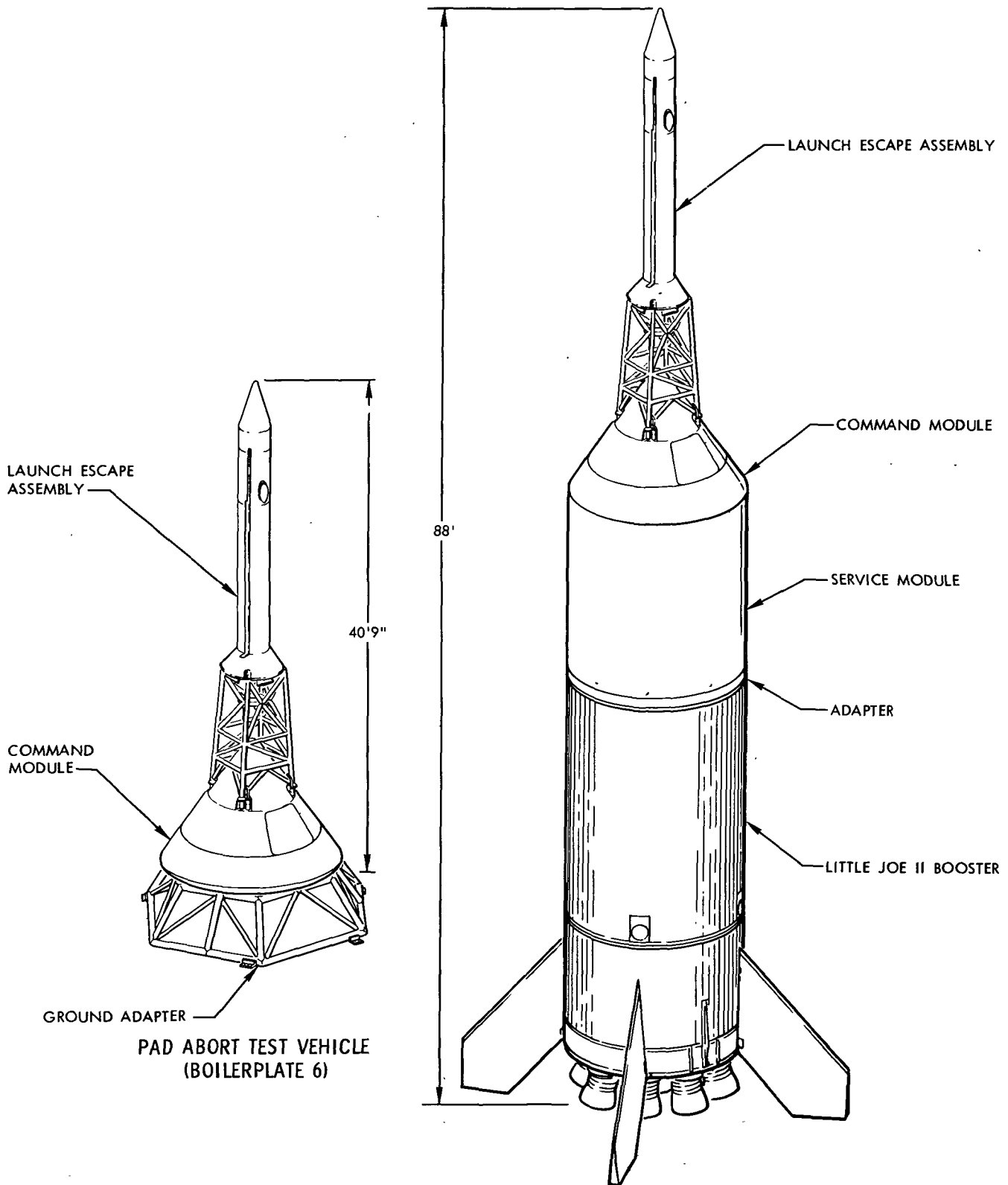
5-4. DESCRIPTION.

5-5. The launch pad abort boilerplate consists of a command module and a launch escape assembly. The launch escape assembly also serves as the launch vehicle. The high dynamic pressure and high altitude abort boilerplates consist of a command module, a service module, and a launch escape assembly. The launch vehicle is a Little Joe II booster which is mated to the service module by means of an adapter. The configurations are illustrated in figure 5-1.

5-6. LAUNCH ESCAPE ASSEMBLY. The launch escape assembly is a prototype of the assembly used on the manned spacecraft. The major components are the launch escape, pitch control, and jettison motors and the four-legged tower. The assembly is complete and updated as closely as possible to the latest configuration in keeping with the purpose of the test flights.

5-7. COMMAND MODULE. The boilerplate command module is a simulation of the manned spacecraft module. It is equipped with such systems and portions of systems as are necessary to carry out each flight operation.

5-8. Command Module Structure. The command module structure simulates the manned module in external size and shape, structural soundness, mass, and center of gravity. The structure is equipped with an access hatch, an aft heat shield, and attach fittings for the purpose of facilitating ground handling.



SM-2A-314A

Figure 5-1. Abort Test Vehicles

5-9. Command Module Equipment. The command module contains the launch escape sequence controller which, together with the launch escape assembly, comprises the launch escape system. The forward compartment has a complete prototype earth landing system whose operation will demonstrate the recovery of the command module. The communications and instrumentation system installation is partial but sufficient for the flight test. It is energized by the boilerplate electrical power system, which is composed of three batteries and the necessary circuitry. The major components of the system are telemetry subsystems, transponders, an on-board data recorder, and a network of pressure and temperature transducers. A simplified environmental control system is provided for the purpose of cooling several items of equipment during the short time that the module is airborne.

5-10. SERVICE MODULE. The boilerplate service module is a structural simulation of the manned spacecraft module and it contains no systems. A bulkhead is installed within the module to produce the air resistance factor that occurs with a normal systems installation. The service module serves to demonstrate the command module-service module separation subsystem and to supply flight data regarding the module structure integrity.

5-11. ADAPTER. The boilerplate adapter is cylindrical in shape and is the same diameter as the boilerplate. It is comparatively short in length and is the means of joining the booster to the service module. Bolts are used at both ends of the adapter in the launch pad assembly.

5-12. LAUNCH VEHICLES. The launch vehicle for the pad abort test is the launch escape system. The launch vehicle for the other tests is the Little Joe II booster. The booster is a fin-stabilized airframe which uses solid fuel rocket motors as the source of propulsion power. The fins are fixed and are equally spaced around the booster base. The airframe structure is cylindrical with a truncated-form corrugated skin. The rocket motors comprise one sustaining and six booster motors. The booster is mounted upon a launcher which supports it in a vertical position so that the fins are clear of the launch pad surface. The pad abort test vehicle is mounted upon a ground adapter at the launch pad.

5-13. ABORT TEST GSE. The abort test GSE is divided into four groups according to principal function. They are monitor and control, checkout, substitution, and bench maintenance. The basic functional operation of the GSE is composed of three elements which are application of stimuli to system under test, acquisition and measurement of system response, and evaluation of system performance. The monitor and control console is comprised of all necessary equipment with the capability to command, monitor, and provide system response displays of a system or integral group of systems during the preparation and actual firing of the spacecraft. The checkout consoles contain all the necessary equipment to perform combined system or integrated systems checks. The substitution consoles consist of all the necessary equipment required for the simulation of conditions to be imposed upon a spacecraft system, a GSE interface, or both. The simulation may be of normal operational conditions or of some arbitrary

application of a set of conditions. The bench maintenance consoles comprise all the necessary equipment needed to isolate a malfunctioning system, subsystem, or component. This equipment facilitates complete interface simulation of electrical and mechanical functions and also calibrates and aligns assemblies up to the equivalent of a complete system.

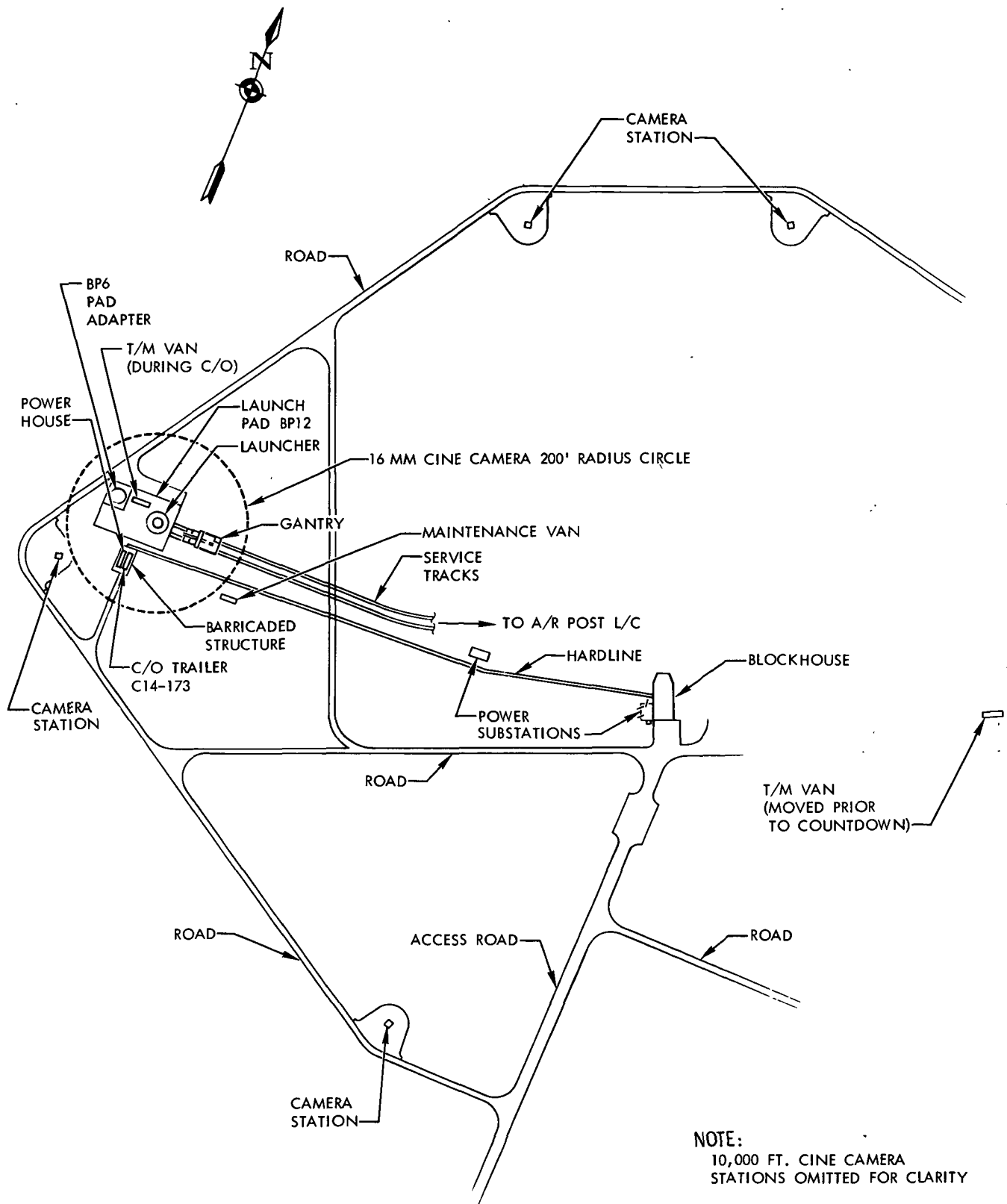
5-14. **LAUNCH SITE.** The boilerplate launch site at WSMR is an area selected for use in pad abort tests. (See figure 5-2.) It consists of a launch pad and several supporting facilities. A distance of 1100 feet separates the pad from the blockhouse used to direct flight operations. An underground terminal room is located beneath the pad for the purpose of housing signal conditioning equipment. The connecting cabling is laid beneath the surface of the ground to a safe distance away from the launch pad. The receiving area for nonhazardous test vehicle components is located in one section of a high-bay type industrial building near the boilerplate launch site. The site includes a hazardous assembly building in a comparatively remote area. The building stands on a special type of foundation and is equipped with an overhead crane and air conditioning. The building is primarily intended for installation of pyrotechnic devices with a minimum of danger to other range installations. A gantry crane, mounted on a track, facilitates pad operations.

#### 5-15. **FLIGHT OPERATIONS.**

5-16. Boilerplate flight operations at WSMR consist generally of receiving the various components and storing, testing, and assembling them into conveniently sized assemblies for transportation to the launch pad. Final assembly, including mating of the launch vehicle, is followed by preflight alignments and checkouts. Countdown and launch take place, and the final operation is the recovery of as much of the vehicle as is possible.

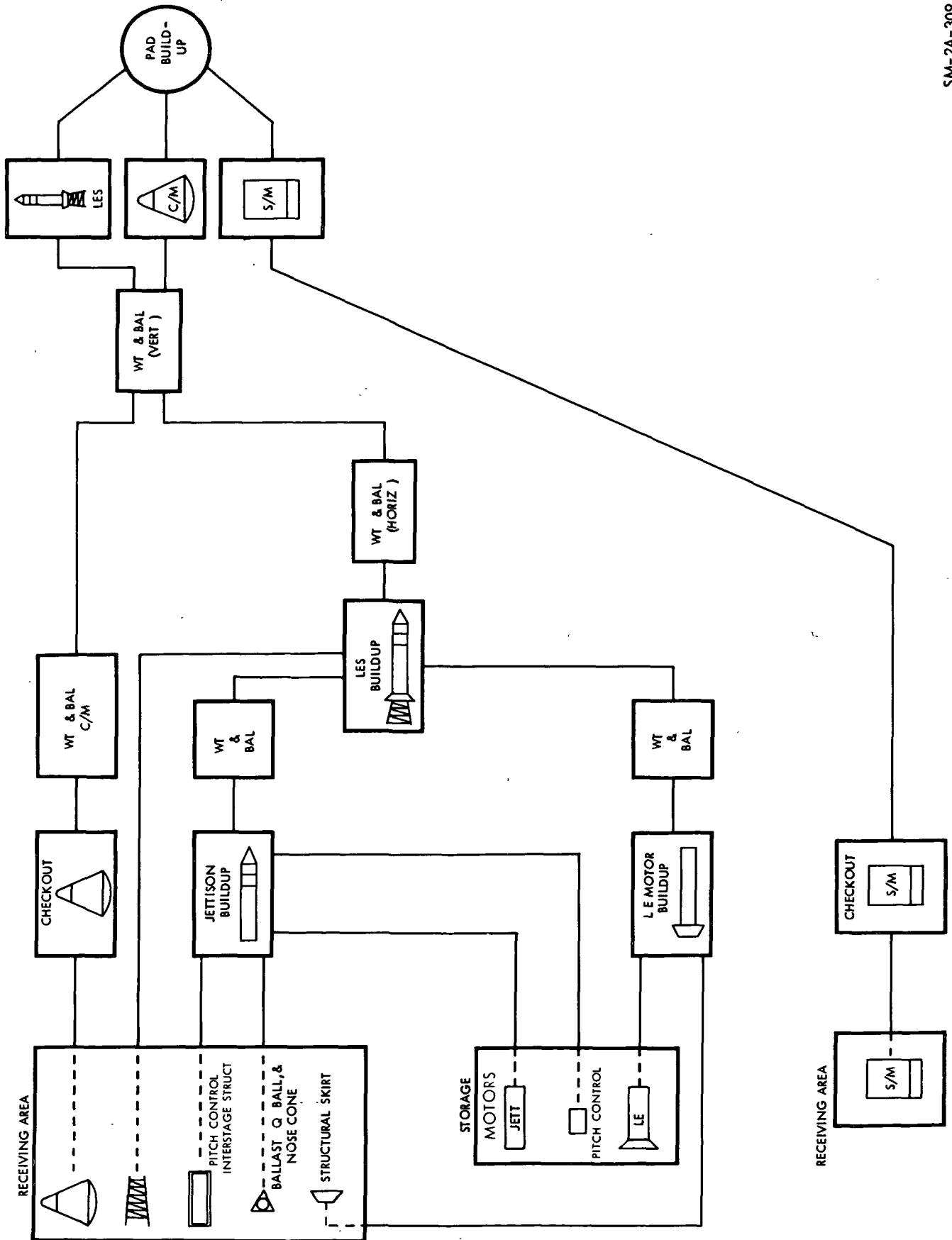
5-17. **PRELAUNCH OPERATIONS.** (See figure 5-3.) All of the test vehicle system components are shipped by truck to the receiving area within the administration building with the exception of those containing pyrotechnic material. These are stored in a separate location as a safety precaution. The components in the receiving area are checked out, integrated, and assembled into their respective systems. The systems, except the launch escape system structure, are installed in the command module. The command module and the launch escape system structure are transported separately to the hazardous assembly building for pyrotechnic device installations and weight and balance tests. The command module and launch escape assembly are then transported to the launch pad for final assembly which also includes the service module and the booster. The service module is sent directly to the pad from the receiving area.

5-18. **Receiving.** The components of the boilerplates are delivered to the receiving area by truck. The pyrotechnic devices are immediately routed to the ordnance facility as a safety measure. The parachutes are sent to the parachute facility for storage. The remaining components which are nonhazardous are inspected for possible damage incurred in transit and stored until needed.



SM-2A-253

Figure 5-2. Abort Test Launch Site



SM-2A-309

Figure 5-3. WSMR Abort Vehicle Assembly Flow Chart



5-19. Operations and Checkout. Preliminary assembly and checkout of non-hazardous components is done in the receiving area. Assembly is for the purpose of verifying mechanical fit and for ease in transporting about the abort test site. The service module, being just a structure in this configuration, is sent directly to the launch pad. The majority of prelaunch operations and checkout takes place in the hazardous assembly building because live pyrotechnic devices are involved. Assembly of the launch escape system, including instrumentation installation, is performed, and parachutes and pyrotechnics are installed in the command module. Weight and balance tests are performed, and vehicle alignment procedures take place with the use of optical devices. The dimensions of this building permit vertical assembly of the launch escape assembly and the command module. They are demated at the conclusion of the tests and transported separately to the launch pad. The pyrotechnic devices and the parachutes are returned to their respective facilities for storage.

5-20. Ordnance. The ordnance facility is primarily a place of storage for components with explosive potential. It is necessarily at a distance from the other site installations. Such devices as launch escape system rocket motors, explosive bridgewires, deployment mortars, and explosive bolts are stored here and released only for actual use at the hazardous assembly building and the launch pad.

5-21. Parachute. The parachute storage facility is equipped to maintain the parachute subassemblies at the same level as personnel parachutes. The parachute packages are carefully inspected at regular intervals and are stored so as to guard against damage or deterioration in any form. They are released to the other facilities only for actual use.

5-22. Weight and Balance. Weight and balance tests are performed upon the launch escape assembly in the horizontal position, the command module in the horizontal and the vertical position, and the combined assembly module in the vertical position. The results of these tests establish the center of gravity of the assembly, and the launch escape motor thrust vector angle can be determined with respect to the vehicle.

5-23. LAUNCH PAD. The operations at the launch pad prior to flight consist of precountdown activities and countdown. These operations are supported by handling and servicing GSE, preparation of tracking and photographic equipment, and weather observations which will indicate favorable conditions for launch and flight.

5-24. Precountdown Operations. The command module, without pyrotechnic and parachute installations, and the launch escape assembly are mated in a vertical position upon arrival at the launch pad. Calibration of launch escape instrumentation and safety verification of systems are conducted. Checkout equipment compatibility and system operation verification is ensured before the installation of pyrotechnics. The command module and launch escape assembly are demated,

and the parachutes and pyrotechnics are installed. The test vehicle is reassembled, and a final integrated systems test is performed to establish launch readiness. The gantry crane is used in the final vehicle assembly. The service module is mated to the booster upon the launch pad when they are included in the assembly; the command module and launch escape assembly combination is mated to the service module. The booster is checked for launch readiness, and the complete vehicle is qualified for countdown.

5-25. Countdown. The launch countdown operation includes a practice launch operation requiring full personnel and ground equipment support. The status of all systems is monitored continuously from the start of countdown to the removal of the umbilical connections. The time required for countdown is approximately 4 hours.

5-26. FLIGHT. The abort test flights commence with the launching of the boilerplates by means of the launch escape system or the Little Joe II booster. The abort is initiated at the altitude established for the individual test. Initiation in the pad abort test occurs upon the ground. Abort initiation occurs at approximately 20,000 feet above sea level in the high dynamic pressure flight and at approximately 180,000 feet in the high altitude abort test. The launch escape system separates the command module from the remainder of the vehicle and propels it away from the flight trajectory. The escape assembly is then jettisoned, and the module descends to earth by means of the earth landing system.

5-27. Flight Events. Launch begins with simultaneous ignition of all booster motors or of the launch escape motor by means of a signal from the blockhouse. The abort sequence commences at the predetermined altitude. The command module is separated, and the launch escape system transports it clear of the launch pad or the launch vehicle. The launch escape assembly is then jettisoned and ejected from the vicinity of the command module to enter into a free-fall trajectory to earth. The forward heat shield is blown away from the apex of the command module, and the drogue parachute is deployed. The drogue chute and the strakes orient the module into a blunt-end forward attitude. The drogue chute is released, and the three pilot chutes are deployed. These chutes deploy the main chutes, which are in a reefed condition for a short time. This condition reduces the opening shock. The chutes then become fully inflated and establish a controlled rate of descent. The module lands with a greatly reduced potential of impact, and the main chutes are released.

5-28. Sequence of Events. The abort sequence of the flight is initiated by a timer which is activated at the instant of booster ignition or of pad abort launch command. Initiating of the abort sequence instantly arms the tower jettison motor, fires the launch escape and pitch control motors, and activates the command module-service module separation subsystem in the flights where the service module is part of the assembly. The command module is propelled

clear by the combined thrust of the two motors and will coast to a higher altitude after motor burnout. The next step is jettison motor ignition and escape tower separation, which occur simultaneously. The earth landing sequence controller is then activated, and it directs the timing and order of the steps that take place during the operation of the earth landing system.

5-29. POSTFLIGHT OPERATIONS. The postflight operations include recovery of the command module, service module, and launch escape assembly. All pyrotechnic devices are checked to see if they are expended. Live devices are disarmed or disposed of by special personnel. The airborne tape recorder is removed and the telemetry power supply turned off. All flight data is collected for evaluation, and the recovered flight components are returned to the work area for examination and laboratory tests.

## SECTION VI

## MANNED ORBITAL QUALIFICATION PHASE

6-1. This section describes the manned orbital qualification phase of the Apollo program. There is a physical description of the spacecraft, launch vehicle, ground support equipment, and launch site. Flight operations are described from the arrival of the components at the launch site to postflight operations. This includes assembly, checkout at various facilities, final assembly on the launch pad, final checkout, countdown, launch, flight, and analysis of all results after recovery.

6-2. EARTH-ORBITAL SPACECRAFT.

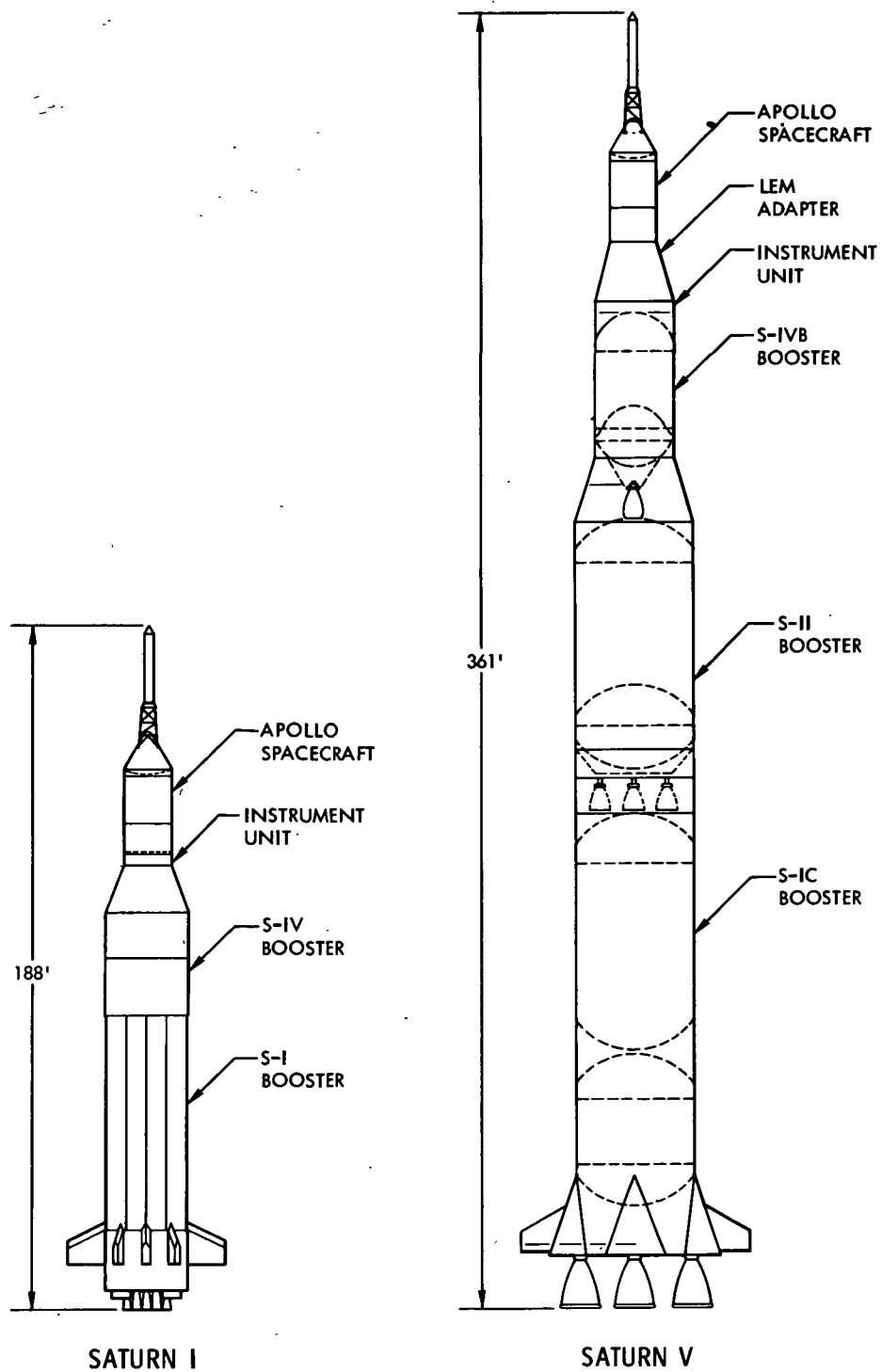
6-3. An Apollo spacecraft will perform a manned orbital flight around the earth. The Apollo spacecraft can endure such a flight for a period of up to two weeks. This flight provides a means for analysis and verification of technical concepts and equipment, as well as the qualification of operational systems. Experimental investigations and studies of physiological and psychological reactions and capabilities of the crew in space can be made. Ground and flight operational techniques and supplementary equipment necessary for extended space flights are developed.

6-4. PHYSICAL DESCRIPTION.

6-5. The space vehicle consists of a spacecraft and the Saturn I launch vehicle as illustrated in figure 6-1. The two are mated by means of an instrument unit. The Saturn I consists of two stages which are the S-I and the S-IV boosters. The launch and supporting operations take place at AMR.

6-6. THE SPACECRAFT. The spacecraft for the manned earth-orbital mission is complete and equipped with the latest system configurations. The configuration consists of the launch escape assembly, command module, service module, and adapter. These are of standard dimensions except for the adapter, which is of a length peculiar to this configuration.

6-7. THE LAUNCH VEHICLE. The S-I booster and S-IV booster comprise the Saturn I launch vehicle. The two stages are connected by an interstage, and an instrument unit is located between the launch vehicle and the spacecraft. The propellants are liquid oxygen and RP-1 for the first stage and liquid oxygen and liquid hydrogen for the second stage. Each booster is built in similar tandem tank configurations housed in a cylindrical shell. Stage control is handled by



SM-2A-312

Figure 6-1. Lunar Mission and Earth-Orbital Space Vehicles

the instrument unit. Interface relationship is monitored by the flight crew with provision for abort in the event of a stage system malfunction. Vehicle attitude is accomplished by gimbal-mounted engines on both stages. A separate roll control system is used in the single engine units of the second stage.

6-8. S-I Booster. The first stage, or S-I, booster is a large base vehicle. It is equipped with four aerodynamic fins mounted on four semiconical outboard engine fairings and is powered by eight H-1 liquid propellant engines. Eight retro rockets are positioned in pairs on each outboard engine fairing around the bottom skirt. The S-I bolts directly to the S-IV aft interstage mating ring and separates from the S-IV upon depletion of fuel. The retro rockets furnish the first-plane separation thrust.

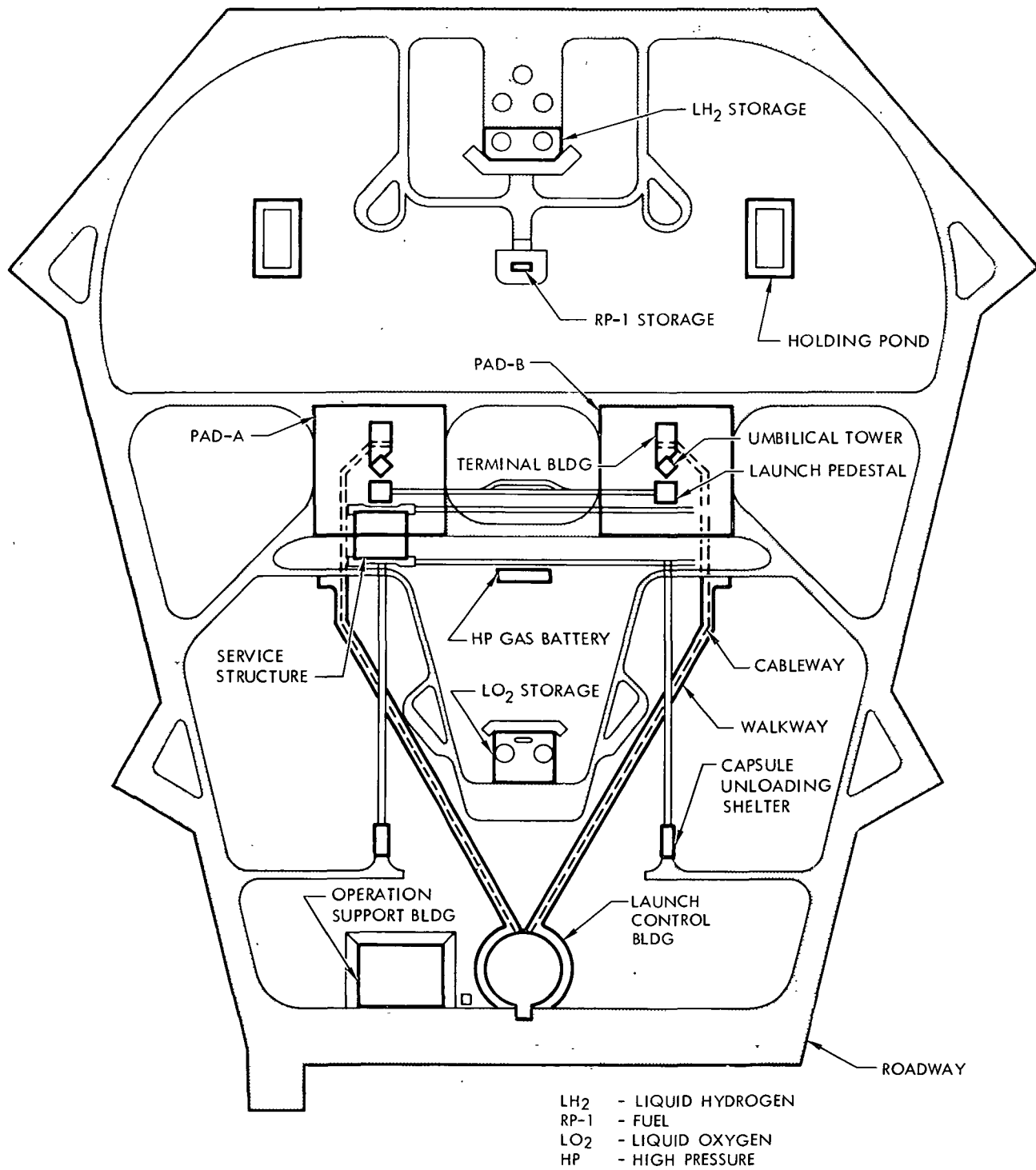
6-9. S-IV Booster. The second stage, or S-IV, booster has a conical-shaped aft interstage assembly to permit fairing-in and attaching the S-IV to the S-I. The S-IV is powered by six PW liquid propellant engines. The booster is capable of a total of three programmed engine shutdowns and restarts during the flight phase. The S-IV bolts directly to the S-I forward skirt mating ring and separates from the S-I above the forward end of the interstage. Four retro rockets are mounted partially submerged on the S-IV aft interstage fairing. The rockets and the interstage remain with the S-I upon separation.

6-10. INSTRUMENT UNIT. The instrument unit is located between the spacecraft and the launch vehicle. The unit is the same diameter as the spacecraft and is approximately 4 feet long. It contains guidance instrumentation, including a computer, controls, magnetic amplifiers, signal processors and resolvers, and the programming that is necessary to control each of the two stages in flight.

6-11. GROUND SUPPORT EQUIPMENT (GSE). A full complement of GSE is required in the manned earth-orbital phase. The flight configuration is nearly as complete as that required for the lunar missions and, consequently, requires almost as much supporting equipment.

6-12. LAUNCH SITE. The earth-orbital mission launch site (figure 6-2) contains a launch pad of adequate dimensions and equipment to accommodate the space vehicle. There is a number of buildings in the immediate vicinity for the purpose of performing one or more functions connected with prelaunch operations. The launch pad and buildings are interconnected by a roadway system. The roadway is capable of supporting all of the ground transportation equipment connected with this mission. The individual facilities are as follow:

- a. Spacecraft operations and checkout
- b. Radar boresight
- c. Hypergolic
- d. Static firing



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Figure 6-2. Earth-Orbital Space Vehicle Launch Site

- e. Ordnance
- f. Parachute
- g. Environmental control system
- h. Weight and balance
- i. Cryogenic
- j. Launch pad.

#### 6-13. FLIGHT OPERATIONS.

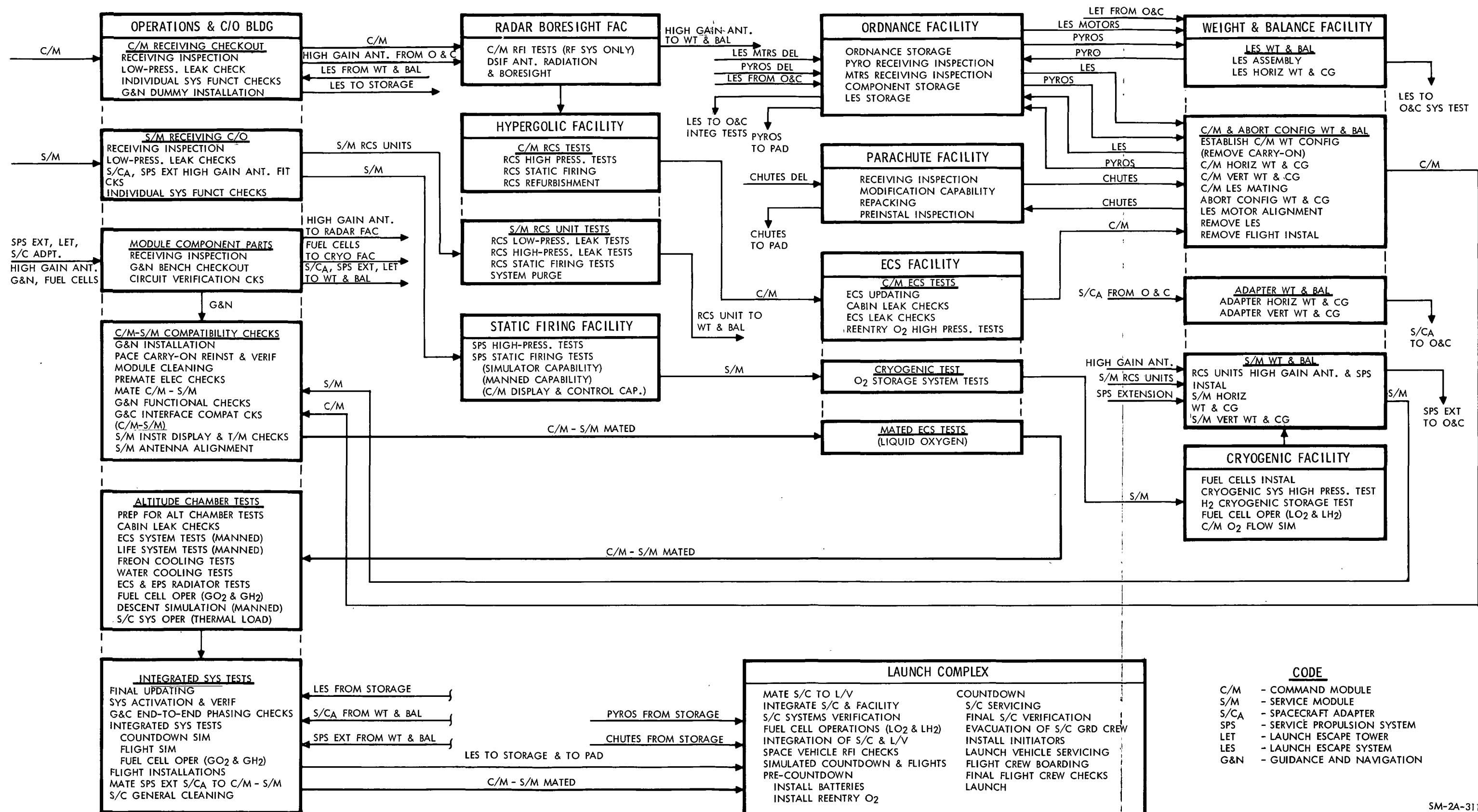
6-14. Flight operations commence with the delivery of the spacecraft and associated equipment to the missile range facilities and continue through post-mission hardware and data evaluation. The following paragraphs cover prelaunch operations and their respective facilities, launch and flight operations, and post-landing recovery operations.

6-15. PRELAUNCH OPERATIONS. The operations and checkout building contains the receiving area for most spacecraft components, facilities for performing compatibility checks and integrated system tests, and an altitude chamber installation. The command module and the service module are received here and routed separately through the other facilities as illustrated in figure 6-3. The guidance and navigation system and PACE carry-on equipment are installed in the command module when it is returned to the operations and checkout building. The service module is mated to the command module after it is returned from the other facilities, and compatibility checks are performed on the mated configuration. These checks comprise tests on the guidance and navigation system and the communications and instrumentation system. The configuration is sent to the altitude chamber after a series of tests in the environmental control system facility. The altitude chamber simulates boost and descent conditions and the crew compartment is checked for leakage. Manned tests are performed on the environmental control and crew system components and the spacecraft radiators are checked. The operability of all spacecraft systems under thermal load is verified, and the mated modules are transferred to the integrated systems test area. Final updating modifications are incorporated, and the equipment is cleaned prior to the integrated systems tests. These tests verify the compatibility and operability of the systems and include flight sequence simulations and mechanical phasing checks. The equipment is then restored to a flight-ready state and transported to the launch pad.

6-16. Receiving. All shipments of spacecraft components arrive at the receiving area in the operations and checkout building. The pyrotechnic devices and launch escape motors are immediately sent to the ordnance facility as a safety measure. The parachute subsystem is routed to the parachute facility



## APOLLO CHECKOUT FLOW



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Figure 6-3. Earth-Orbital Launch Site Operations Flow Chart

because of the special type of handling that is required. The items stored in the receiving area are inspected for damage in transit and for obvious physical discrepancies. The command and service modules may be received separately in the area. Some of the major components stored in the receiving area are the propulsion engine extension, the adapter, and the high-gain antenna.

6-17. Reaction Control. The reaction control tests take place in the hypergolic facility. The command module is sent from receiving by way of the radar bore-sight facility where systems utilizing radio frequency equipment are checked for interaction. The command module reaction control subsystem undergoes high-pressure tests and static firing operations. The command module is transported to the environmental control system facility at the conclusion of these activities. The service module reaction control subsystem units are sent separately from the receiving area and are tested in another part of the hypergolic facility. The units undergo high- and low-pressure leak tests, static firing operations, and subsystem purge before being forwarded to the weight and balance facility.

6-18. Ordnance. All pyrotechnic devices and launch escape motors are immediately sent to the ordnance facility upon arrival at the launch site and are only withdrawn for actual use in either the weight and balance facility or prelaunch activity at the pad. All hazardous components undergo receiving inspection in the ordnance facility instead of in the operations and checkout building receiving area. Pyrotechnic devices and launch escape motors are returned to the ordnance facility at once when not needed for operations.

6-19. Parachute. The parachute subsystem of the earth landing system is delivered directly to the parachute facility for receiving inspection and storage until required for weight and balance tests or prelaunch installation at the launch pad. The facility is equipped to maintain the parachute at the same level as personnel chutes. Parachutes are evaluated for modification capability, repacked, or inspected prior to installation, as necessary. Chutes not in actual use at other facilities are immediately returned to the parachute facility.

6-20. Weight and Balance. Weight and balance tests are carried out in the weight and balance facility in four areas. The areas are designated by the assembly configurations tested in each area. They are launch escape assembly, command module and launch escape assembly, adapter, and service module. The launch escape assembly is complete with pyrotechnic and motor installations and is the subject of horizontal weight and balance determinations. The assembly is sent to the ordnance facility for storage until needed for the command module and assembly combination tests. The command module is received from the environmental control system facility and equipped with a parachute subsystem. The module is positioned in both horizontal and vertical attitudes for weight and balance tests and is then mated to the launch escape assembly. The combination undergoes a weight and balance test and is demated. The assembly is returned to the ordnance facility, and the command module goes back to the operations and checkout building. The adapter and the service module both are checked by

weight and balance procedures in the vertical and horizontal positions. The service module comes fully equipped from the cryogenic facility with the exception of the high-gain antenna, the engine expansion nozzle, and the reaction control subsystem units, which are reinstalled in the weight and balance facility before the tests are commenced. At the conclusion of these tests the service module is returned to the operations and checkout building for mating with the command module. The adapter is also sent to this building for eventual mating. Final alignment of the launch escape motor with respect to the spacecraft axes is contingent on the results of weight and balance tests.

6-21. Static Tests. The service propulsion system undergoes tests as the service module passes through the static firing facility. The system is subjected to high-pressure tests and the system engine is operated in static firing conditions. The service module is then sent to the cryogenic facility by way of one section of the environmental control system facility. The module receives fuel cell installation at the cryogenic facility and undergoes some cryogenic subsystem tests.

6-22. Environmental Checkout. The command module is subjected to environmental control system updating at this point and is subjected to cabin and system leak checks. High-pressure tests are also conducted upon the re-entry oxygen supply subsystem. The service module receives a series of oxygen storage subsystem tests. The mated command and service modules are transported from the operations and checkout building for tests involving liquid oxygen subsystem operation and then sent to the altitude chamber area.

6-23. LAUNCH PAD.

6-24. PRECOUNTDOWN OPERATIONS. The spacecraft components and equipment arrive at the launch pad after being processed through the site facilities. Parachutes and pyrotechnic devices are installed on the modules. The spacecraft is mated to the launch vehicle, and the umbilical cables are connected. Proper integration of the spacecraft to the launch facilities and to the launch vehicle is verified. Operability of all systems is established and then a simulated countdown and launch is performed. The launch escape assembly is installed just prior to countdown.

6-25. COUNTDOWN. Initial countdown operations consist of spacecraft servicing and a final verification of spacecraft equipment. The flight crew then boards the spacecraft and the ground crew is evacuated from the pad. Launch is initiated when the launch vehicle has been serviced and the final flight crew checks have been made.

6-26. FLIGHT. The flight consists of placing the space vehicle in earth orbit using the S-I booster. The launch escape system will separate the tower legs from the command module prior to orbit injection. The objectives include

manned qualification of the launch vehicle, demonstration of the physical and the flight compatibilities of the launch vehicle and manned spacecraft, verification of tracking compatibility, and development of range operational procedures and techniques of the ground tracking systems. The following paragraphs describe the individual flight events.

6-27. Ascent and Orbital Injection. The ascent phase begins with first stage (S-I) propulsion system ignition, which causes space vehicle liftoff. The phase ends with second stage (S-IV) injection of the spacecraft into the earth orbit which is just under 100 nautical miles above the surface of the earth. First stage burnout and separation are immediately followed by second stage ignition at an altitude of approximately 200,000 feet. The launch escape assembly is jettisoned at about the 300,000-foot level. The second stage separates from the spacecraft after injection.

6-28. Earth Orbital Operations. The earth orbital phase begins with second stage separation as the spacecraft is injected into the earth orbit. The phase ends with orbit ejection. Crew operations consist of attitude control maneuvers, systems operation checkouts, maintenance functions, orbital adjustments, and establishment of communications with the Ground Operation Support Systems (GOSS) network.

6-29. Earth Orbital Ejection. The earth orbital ejection phase is a powered flight which places the spacecraft on a deorbital coast trajectory. Retrograde action is initiated by maneuvering the spacecraft to the proper attitude with the reaction control system. The service propulsion system then provides the thrust for deceleration from orbital velocity to the correct coast and entry trajectory.

6-30. Deorbital Coast. The deorbital coast phase starts with cutoff of the service propulsion engine while the spacecraft continues to descend from orbital altitude to an altitude of approximately 400,000 feet. The service module is separated from the command module about 5 minutes before reaching this altitude. The strakes then orient the command module to the proper attitudes for atmospheric entry. The command module reaction control subsystem is used to assist the strakes in the performance of this function.

6-31. Recovery. The recovery phase commences with the jettisoning of the forward heat shield when the command module has descended to an altitude of approximately 25,000 feet. The drogue chute is then deployed by mortar to assist the strakes in stabilizing the module attitude. At an altitude of about 15,000 feet the drogue chute is released and the three pilot chutes are mortar-deployed. The pilot chutes perform their function of deploying the main chutes. The VHF recovery beacon commences operation when it is activated by the crew. The crew has additional location aids which they may employ after landing at their discretion, such as a dye marker, a SOFAR bomb, or an HF transceiver.

6-32. POSTFLIGHT OPERATIONS. Postflight operations consist of transporting the command module to an examination area for inspection and removal of all recorded data. All command module installations are subjected to checkout and laboratory tests. The data from tracking stations and from photographic sources is assembled to assist in a full evaluation of the mission and the planning of future missions.

## SECTION VII

## THE LUNAR MISSION PHASE

7-1. This section contains a description of the lunar mission phase of the Apollo program.

7-2. THE LUNAR MISSION CONFIGURATION.

7-3. The ultimate object of Project Apollo is to land men on the moon for limited observation and exploration in the vicinity of the landing area. This is followed by a safe return to earth. This objective will climax a series of earth-orbital, circumlunar, and lunar-orbital missions. Each of these missions will have specified objectives, but they will be flown primarily for the advancement and qualification of systems for the ultimate lunar landing mission. Unique objectives of the lunar landing mission include:

- a. Lunar excursion module (LEM) landing
- b. Lunar surface exploration
- c. Mission verification
- d. Evaluation of crew reaction on lunar surface
- e. One-man crew command module operation in lunar orbit
- f. Two-manned lunar launch
- g. Lunar orbit rendezvous.

7-4. PHYSICAL DESCRIPTION.

7-5. The space vehicle consists of the lunar mission spacecraft, the lunar excursion module (LEM), and the Saturn V launch vehicle. An instrument unit is used to mate the launch vehicle to the remainder of the space vehicle. There are three stages within the lunar mission launch vehicle. They are the S-IC, the S-II, and the S-IVB boosters. The entire configuration is illustrated in figure 6-1.

7-6. THE SPACECRAFT. The spacecraft for the lunar mission is the ultimate configuration in the Apollo program. The systems are complete and represent the latest operational advancements that development time permits. The configuration consists of the launch escape assembly, command module, service

module, and adapter. These are of standard dimensions except for the adapter, which has a length peculiar to this configuration.

7-7. THE LUNAR EXCURSION MODULE (LEM) AND ADAPTER. The LEM adapter is a structural fairing between the service module and the S-IVB booster. It encloses and supports the LEM during all mission phases prior to the transition to the apex of the command module. The LEM carries a crew of two and will separate from the spacecraft, land on the moon, and lift off to rendezvous with the lunar-orbiting spacecraft. The LEM communications and instrumentation system is adequate for all possible LEM events and contingencies.

7-8. INSTRUMENT UNIT. The instrument unit is located between the spacecraft and the launch vehicle. The unit is the same diameter as the spacecraft and is approximately 4 feet long. It contains guidance instrumentation, including a computer, controls, magnetic amplifiers, signal processors and resolvers, and the programming that is necessary to control each of the three stages in flight.

7-9. THE LAUNCH VEHICLE. The lunar mission launch vehicle is the Saturn V, which is a three-stage configuration. The stages are designated S-IC, S-II, and S-IVB for the first, second, and third stages respectively. The propellants are liquid oxygen and RP-1 for the first stage and liquid hydrogen and liquid oxygen for the second and third stages. Each booster is built in similar tandem tank configurations housed in a cylindrical shell. Stage control is handled by the instrument unit. (Refer to paragraph 7-8.) Interface relationship is monitored by the flight crew with provision for abort in the event of a stage system malfunction. Vehicle attitude is accomplished by gimbal-mounted engines on all three stages. A separate roll control system is used in the single engine units of the third stage.

7-10. S-IC Booster. The first stage, or S-IC, booster is a large base vehicle. It is equipped with four aerodynamic fins mounted on four semiconical outboard engine fairings and is powered by five F-1 liquid propellant engines. Eight retro rocket motors are positioned in pairs on each outboard engine fairing around the bottom skirt. The S-IC bolts directly to the S-II aft interstage mating ring and separates from the S-II upon depletion of fuel. The retro rockets furnish the first-plane separation thrust.

7-11. S-II Booster. The second stage, or S-II, booster is surrounded at the lower end of the aft interstage with eight ullage rocket motors designed to ensure positive axial load factor during engine start and to aid in the S-IC and S-II dual plane separation mode. The S-II is powered by five J-2 liquid propellant engines. The interstage and burned-out ullage rockets are package-ejected within 30 seconds after engine start to increase payload capability. The S-II is bolted directly to the other two stages and is separated from each stage at the proper time sequence by severing the S-II and S-IVB interstages through properly positioned linear-shaped charges.

7-12. S-IVB Booster. The third stage, or S-IVB, booster has a conical-shaped aft interstage assembly to permit fairing-in and attaching the S-IVB to the S-II. The S-IVB is powered by a single J-2 liquid propellant engine. The booster is capable of a total of three programmed engine shutdowns and restarts during the flight phase. The S-IVB bolts directly to the S-II forward skirt mating ring and separates from the S-II above the forward end of the interstage. Four retro rockets are mounted partially submerged on the S-IVB aft interstage fairing. The rockets and the interstage remain with the S-II upon separation.

7-13. LAUNCH SITE. The lunar mission launch site consists of a launch pad of adequate dimensions and equipment to accommodate the Apollo space vehicle. There is a number of buildings in the immediate vicinity for the purpose of performing one or more functions connected with prelaunch operations. The launch pad and buildings are interconnected by a specially constructed reinforced roadway system. The roadway will accommodate a 2500-ton launch-transporter crawler which can move an assembled space vehicle and umbilical tower. The roadway surface is sufficiently smooth and level to minimize vibration and other adverse effects encountered during transportation. The individual facilities are as follows:

- a. Spacecraft operations and checkout
- b. Ordnance
- c. Parachute
- d. Reaction control system
- e. Static firing
- f. Weight and balance checkout
- g. Radar bore sight
- h. Vertical assembly
- i. Launch control center
- j. Launch pad
- k. Mobile arming and service tower.



#### 7-14. FLIGHT OPERATIONS.

7-15. Flight operations commence with the delivery of the spacecraft and associated equipment to the missile range facilities and continue through postmission hardware and data evaluation. The following paragraphs cover prelaunch operations and their respective facilities, launch and flight operations, and postlanding recovery operations.

7-16. PRELAUNCH OPERATIONS. The operations and checkout building contains the receiving area for most spacecraft components, facilities for performing compatibility checks and integrated system tests, and an altitude chamber installation. The command module and the service module are received here and routed separately through the other facilities as illustrated in figure 7-1. Final assembly of the spacecraft takes place in the vertical assembly building which is located in the vicinity of the launch pad. The entire configuration, consisting of the spacecraft and launch vehicle, is transported to the launch pad.

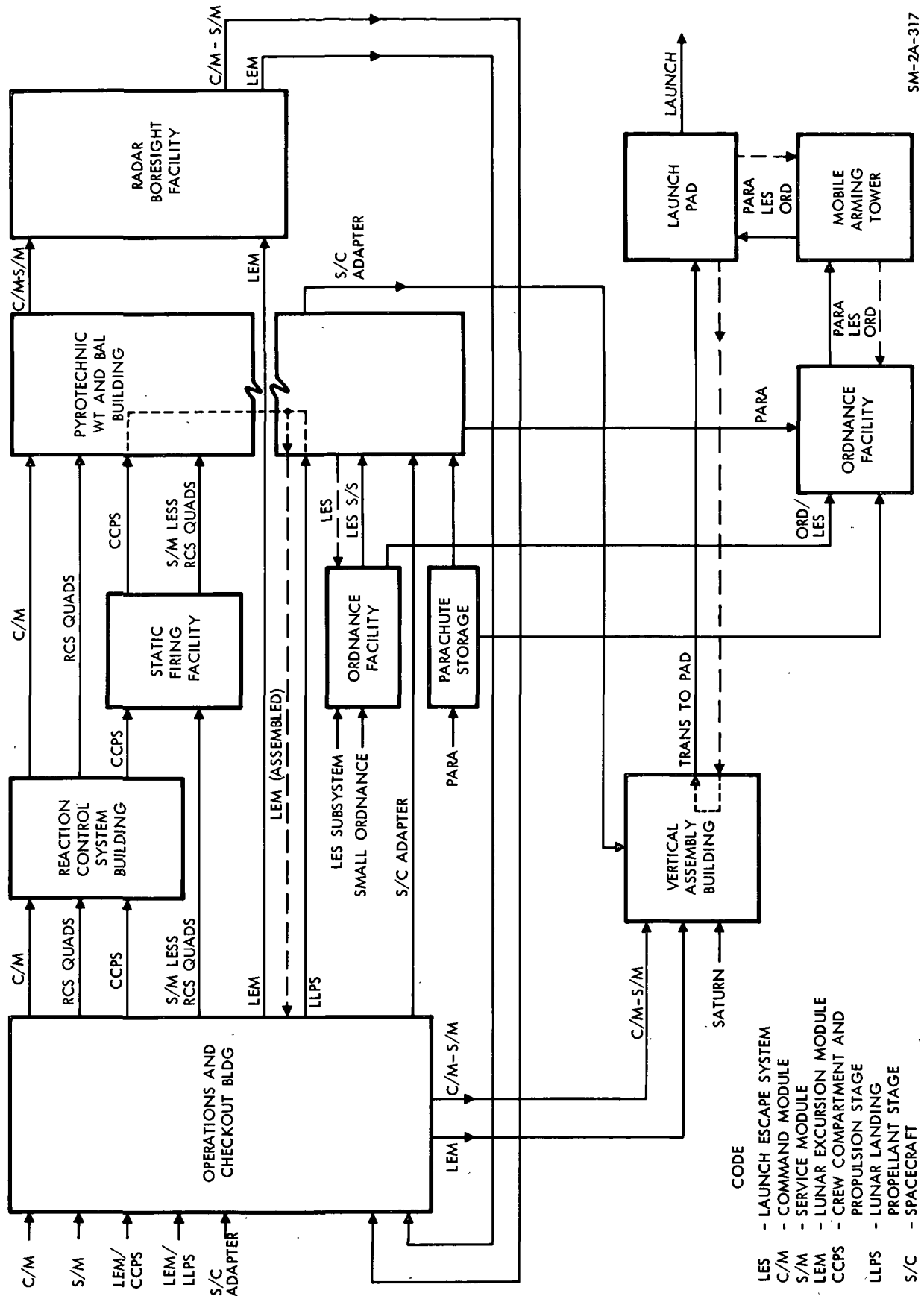
7-17. Receiving. The entire lunar mission spacecraft is delivered to the operations and checkout building for receiving inspection. The hazardous components are immediately routed to the ordnance facility as a safety measure. The remainder of the spacecraft, received separately as the command module, service module, adapter, and lunar excursion module (LEM), is inspected for signs of damage while in transit and for obvious physical discrepancies.

7-18. Reaction Control. Static firing tests of the reaction control system are performed at the reaction control facility. The facility includes a high-bay section which permits tests to be performed upon the assembled spacecraft.

7-19. Ordnance. The spacecraft solid propellant motors, explosive ordnance, pyrotechnic devices, and associated spare parts are sent to the ordnance facility which is located in a comparatively remote area. The facility provides for inspection, modification, subsystem performance checkout, maintenance, and bonded storage.

7-20. Parachute. The parachute packages are sent directly to the parachute facility which provides space and equipment for receiving inspection, modification, parachute packing, and bonded storage.

7-21. Weight and Balance. The weight and balance tests on the command module, service module, and launch escape assembly are performed in the weight and balance facility. The facility provides for physical and electrical mating of the command module and the launch escape assembly and subsequent weight and balance and alignment operations.



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Figure 7-1. Lunar Mission Launch Site Operations Flow Chart

7-22. Static Test. The static firing tests are performed in the static firing facility. This facility is equipped with rocket propulsion test stands, propellant supply systems, hydraulic fluid and gas supply systems, pressurization systems, instrumentation control rooms, and an emergency safety system. The static firing facility performs firing tests upon the service module propulsion system. Provisions are made for testing a spacecraft or individual modules.

7-23. Environmental Checkout. Environmental checkout is performed within the environmental control system facility. There is ample room for assembly and interface systems integration and combined systems checkout. A fluid system test assembly provides for checkout and test of all fluid systems in the spacecraft. The altitude chamber installation is for the purpose of reduced pressure tests on the modules.

7-24. LEM Checkout. The lunar excursion module (LEM) is sent through the applicable facilities described in the preceding paragraphs for a series of tests and checkouts which parallel those performed upon the other modules. The LEM is finally returned to the operations and checkout building and then to the vertical assembly building for mating with the remainder of the space vehicle.

7-25. LAUNCH PAD.

7-26. PRECOUNTDOWN OPERATIONS. The greater part of the precountdown operations takes place in the vertical assembly building. The building is a high-bay structure equipped for the final assembly and checkout of the integrated spacecraft and launch vehicle. There is checkout equipment for verification of the integrated systems. The building contains several bays for simultaneous assembly and checkout and is of sufficient size to completely enclose the space vehicle. The launch control center contains both automatic and manual checkout and launch control equipment and is linked to the launch pad and to the operations and checkout building by means of communications and coaxial cable. The launch pad is fully equipped with such facilities as a flame deflector, propellants supply, electrical power, hydraulic fluid and gas supply, decontamination equipment, coaxial and communications installations, and personnel protective shelters. There is also an umbilical tower which provides physical access to the space vehicle on the pad and crew entry to the command module. The mobile arming and service tower facilitates safe installation of flight ordnance equipment such as is stored in the ordnance facility. The tower also is instrumental in providing physical and electrical mating of the launch escape assembly and command module as well as checkout of the resulting integrated systems.

7-27. COUNTDOWN. Initial countdown operations consist of space vehicle servicing and a final verification of vehicle equipment. The flight crew then boards the spacecraft, and the ground crew is evacuated from the pad. Launch is initiated when servicing is completed and the final flight crew checks have been made.

7-28. FLIGHT. The lunar mission consists of placing the space vehicle in an earth-parking orbit by means of the booster stages. The vehicle remains in this orbit until the moon is in line with the intended flight trajectory. The spacecraft is then injected into the translunar phase and eventually placed into lunar orbit. The lunar excursion module (LEM) separates from the spacecraft and lands on the moon and then returns after a predetermined lapse of time. It rendezvous with the orbiting spacecraft and is then jettisoned after the crew is reunited. The spacecraft is injected into the transearth phase from lunar orbit when the earth is in line with the intended flight trajectory. The flight concludes with entry into the earth atmosphere and landing upon the surface of the earth.

7-29. Ascent and Orbital Injection. The ascent phase begins with first stage (S-1C) propulsion system ignition, which causes space vehicle liftoff. The phase ends with third stage (S-IVB) engine cutoff as the spacecraft and S-IVB are injected into the earth-parking orbit at a distance of 100 nautical miles above the surface of the earth. First stage burnout and separation are immediately followed by second stage ignition at an altitude of approximately 200,000 feet. The launch escape assembly is jettisoned at about the 300,000-foot level. The second stage (S-II) propels the vehicle to an altitude of 600,000 feet before burning out and separating. The third stage (S-IVB) ignites and provides the thrust required to inject the spacecraft into the earth-parking orbital phase of a lunar mission.

7-30. Parking Orbital Operations. The earth-parking orbital phase begins with third stage (S-IVB) engine cutoff as the spacecraft and S-IVB are injected. The distance from the earth at injection into the earth-parking orbit is 100 nautical miles. The phase ends with S-IVB ignition for the purpose of translunar injection. Crew operations during this phase consist of attitude control maneuvers, system operation checkouts, maintenance functions, orbital adjustments, and establishment of communications with the ground station network. Orbital adjustment is accomplished by a comparison of on-board with ground station determinations of flight path. The on-board determination commences by booster stabilization and orientation of the spacecraft followed by a series of telescope and sextant navigational sightings on known landmarks and stars. The sighting data is inserted into the computer of the guidance and navigation system. The resulting computer program will first determine the moving positions and velocity values of the parking orbit and then predict the positions at regular intervals in future orbits.

7-31. Lunar Mission Operations. There are three basic types of lunar missions in the Apollo program. They are known as circumlunar, lunar-orbital, and lunar landing. The phases included in the circumlunar mission include translunar injection from the earth-parking orbit, translunar coast, circumlunar maneuver, and injection into transearth coast. These phases are followed by entry maneuvers. The lunar-orbital mission requires two additional phases, which are injection into lunar orbit from translunar coast and injection into transearth coast from lunar orbit. A lunar landing mission is essentially the same as the lunar-orbital mission

except that the following lunar excursion module (LEM) operations are included: docking, transfer of personnel, separation from spacecraft in lunar orbit, ejection from lunar orbit, lunar landing, lunar launch and injection into orbit, orbital rendezvous and docking with spacecraft, transfer of personnel, and separation from the LEM.

7-32. The translunar injection phase begins with S-IVB ignition and ends with S-IVB engine cutoff. The characteristics of this phase are a small angle of climb, an increase in velocity, and an ascent of an additional 400,000 feet in altitude. The translunar coast phase begins with S-IVB engine cutoff and ends with service module reaction control subsystem acceleration just prior to lunar orbit injection. The phase includes transposition of the LEM, attitude control maneuvers, systems checkout, and four midcourse corrections. The lunar-orbital phase prior to LEM separation begins with service propulsion system cutoff as the spacecraft is injected into lunar orbit and ends with LEM propulsion system ignition. Lunar orbit is at a distance of 80 nautical miles above the surface of the moon. The lunar-orbital phase during LEM landing begins with LEM separation and ends with completion of the rendezvous and docking operation. The lunar-orbital phase subsequent to LEM rendezvous begins with a post docking check and ends with service module reaction control subsystem acceleration. This portion of the phase includes separation from the LEM and a systems check-out. The transearth injection phase begins with service module reaction control subsystem acceleration and ends with service propulsion system cutoff. The transearth coast phase begins with service propulsion cutoff and ends when the command module begins entry into the earth atmosphere at approximately 400,000 feet above the surface. This phase includes a systems checkout, four midcourse corrections powered by the service propulsion system, and service module jettison.

7-33. The guidance and navigation system computer calculates the desired translunar injection point and the program that is required to hit the specified key lunar aiming point. The computer uses the difference between the actual and the reference parking orbit as a basis for computations. During the translunar trajectory, comparisons are made between on-board determinations and ground station determinations for the purpose of detecting deviations. The on-board determinations are initiated by performing a series of telescope and sextant navigational sightings on known landmarks and stars. The navigational sightings are facilitated by spacecraft attitude maneuvers. The sighting data is placed in the computer, and a program commences that smooths out and averages the total input and then computes the current translunar trajectory. The computer calculates the projected miss-distance at the key lunar aiming point of the actual trajectory followed by the required correction that will compensate for it. Comparisons are made with determinations received from ground stations. These procedures are similar for the other phases of a flight to the moon and back to earth.

7-34. Entry Phase. The entry phase begins with atmospheric entry at an altitude of about 400,000 feet and ends with drogue chute deployment at 25,000 feet. This chute deployment is one of the initial steps involved in the operation of the earth landing system. The command module is oriented to the proper attitude for entry by the command module reaction control subsystem and the strakes. The entry steps include attitude stabilization, control maneuvers, a transition to glide, and a glide to the point where parachute descent commences. The result is a reduction in speed to a rate at which parachute deployment occurs safely and with a minimum of opening shock. The point of earth landing is largely predetermined by spacecraft velocity, point of entry, and trajectory with respect to the surface of the earth. The execution of roll maneuvers permits a small degree of range control. Spacecraft attitude and trajectory must be corrected to preclude a re-entry condition. Bouncing or skipping on the atmosphere may result from improper attitude or trajectory during the initial stages of entry. This constitutes a re-entry condition which will lead to a landing outside of the planned area.

7-35. Recovery. The recovery phase commences with the jettisoning of the forward heat shield when the command module has descended to an altitude of approximately 25,000 feet. The drogue chute is then deployed by mortar to assist the strakes in stabilizing the module attitude. At an altitude of about 15,000 feet the drogue chute is released and the three pilot chutes are mortar-deployed. The pilot chutes perform their function of deploying the main chutes. The VHF recovery beacon commences operation when it is activated by the crew. The crew has additional location aids, such as a dye marker, a SOFAR bomb, or an HF transceiver, which they may employ after landing at their discretion.

7-36. POSTFLIGHT OPERATIONS. Postflight operations consist of transporting the command module to an examination area for inspection and removal of all recorded data. All command module installations are subjected to checkout and laboratory tests. The data from tracking stations and from photographic sources is assembled to assist in a full evaluation of the mission and the planning of future missions.

## APPENDIX A

## REFERENCE INDEX OF APOLLO SUPPORT MANUALS

SM2A-01-1 (BP6)	Operation and Test Procedures for Assembly, Erection, System/Integrated System Check-out and Launch (BP6)
SM2A-01-1 (BP12)	Operation and Test Procedures for Assembly, Erection, System Integrated System Check-out and Launch (BP12)
SM2A-01-1 (BP13)	Operation and Test Procedures for Assembly, Erection, System/Integrated System Check-out and Launch
SM2A-01-2	Combined Systems Maintenance Procedures
SM2A-01-2 (BP12)	Combined Systems Maintenance Procedures (BP12)
SM2A-02	Spacecraft Familiarization
SM2A-04	Ground Crew Operations Procedures
SM2A-05	Transportation and Handling Procedures
SM2A-07 (BP6)	Spacecraft Description Manual, Pad Abort One
SM2A-07 (BP12)	Spacecraft Description Manual, High Dynamic Pressure Abort
SM2A-07 (BP13)	Boilerplate 13 Description
SM2A-07 (F-2)	Description Manual
SM3A-201	Transportation and Handling Data Sheets
SM3A-202	GSE Maintenance Handling Data Sheets
SM3A-203	Command Module Substitute Unit

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SM3A-204	Signal Conditioner Console
SM3A-205	Radar Transponder and Recovery Beacon Checkout Unit
SM3A-206	Launch Escape Tower Substitute Unit
SM3A-207	Pyrotechnics Initiators Substitute Set
SM3A-208	Data Distribution and Recording Console
SM3A-209	Command Module Substitute Unit
SM3A-210	Launch Escape Tower Substitute Unit
SM3A-211	Launch Escape Sequencer Bench Maintenance Equipment
SM3A-212	On-Board Recorders Checkout Unit
SM3A-213	Antenna Checkout
SM3A-214	Test Conductor Group
SM3A-215	Data Recording Group and Signal Conditioner Console
SM3A-216	Pyrotechnics Bench Maintenance Equipment
SM3A-217	Launch Vehicle Substitute Unit
SM3A-218	Pyrotechnics Initiators Substitute Set
SM3A-219	Checkout Trailer
SM3A-220	Telemetry Kit
SM3A-221	Ground Cooling Cart
SM3A-222	Calibration Unit
SM3A-224	Test Fixture Q Ball Analyzer



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SM3A-225	Battery Charging Unit
SM3A-226	Pyrotechnics Bench Maintenance Equipment
SM3A-227	Launch Escape Sequencer Bench Maintenance Equipment
SM3A-228	Launch Vehicle Substitute Unit
SM3A-229	Optical Alignment Set
SM3A-235	Launch Control Group
SM3A-236	Propulsion Checkout Group
SM3A-237	Service Propulsion System Checkout Unit
SM3A-238	Fluid Service Control Unit
SM3A-239	Service Propulsion System Test Control Unit
SM3A-240	Bench Maintenance Equipment-Service Propulsion System, Propellant Gaging System
SM3A-242	Helium Booster Unit
SM3A-243	Helium Transfer Unit
SM3A-244	Pyrotechnics Initiators Substitute Set
SM3A-263	Water-Glycol Cooling Unit
SM3A-281	Propulsion Test Fixture
SM3A-283	Engine Decontamination Unit
SM3A-284	Launch Escape Tower Substitute Unit
SM3A-604	Earth Landing System Sequencer Bench Maintenance Equipment
SM3A-605	Baro-Switch Test Unit

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SM3A-801	Service Module Propulsion Engine Check-out and Repair
SM3A-802	Nozzle Plug Maintenance Handbook
SM3A-805	Electromechanical Bench Maintenance Equipment
SM3A-806	Thrust Chamber Bench Maintenance Alignment Equipment
SM4A-200 (BP13)	Maintenance Procedures
SM4A-201	Launch Escape System Maintenance Procedures
SM4A-207	Earth Landing System Maintenance Procedures