SEPTEMBER 15, 1964

NPC 500-9

APOLLO

IN-FLIGHT EXPERIMENT GUIDE

TABLE OF CONTENTS

INTRODUCTION

This guide outlines the general procedures, constraints and schedules that may be of assistance to those interested in participating in the Apollo flight program with scientific, technological or medical in-flight experiments. Certain information contained herein represents a "best estimate" at the time of writing and is subject to change. Therefore, the guide will be revised and reissued periodically in an attempt to keep the data current.

The following general ground rules apply for all experiments proposed for inclusion in Apollo flights:

1. In-flight experiments (not to be confused with lunar exploration experiments) shall be conducted on a non-interference basis with the primary and alternate mission objectives.
2. All flight equipment used as part or in support of in-flight experiments must meet Apollo flight qualification requirements.
3. It is the responsibility of the sponsor to meet scheduled delivery dates for drawings, mockups, documentation, flight equipment, etc. In no case will a launching be delayed because of the non-availability of an experiment.
4. All contacts between the sponsor of an experiment and the space vehicle contractor shall be through the designated Experiment Monitor.

The flights which are identified herein were selected as those most likely to be able to accommodate in-flight experiments. For each of these flights, there is an effort to reserve a volume of two cubic feet and eighty pounds in the Command Module, accessible to the crew, for in-flight experiments. In addition to this volume, certain flights may permit the use of other areas within the Command Module, the Lunar Excursion Module and the Service Module. Although specific weight assignments for these areas cannot be stated for each flight at this time, the volumes and their locations are described in a later section.

Each Apollo flight with an Earth Orbit Mission places the S-IVB stage and the Instrument Unit in a decay orbit. Although these structures are destroyed during re-entry, eliminating the possibility of recovery, they may be attractive vehicles for the carriage of certain types of experiments if a weight allowance became available. A preliminary investigation indicates that in the forward skirt of the S-IVB stage, a total of approximately 500 pounds of experiments could be accommodated within a total volume of approximately 15 cubic feet. There are six locations in which the experiments could be placed with individual volumes ranging from approximately 1 to 5 cubic feet and individual weights from about 40 to 100 pounds. A detailed analysis of the technical feasibility of carrying experiments within these areas is currently being made. Additional data and the associated contraints will be included in the next revision of this guide.

At some point in the Saturn IB manned flight program (SA-200 series), the Saturn V launch vehicle will become man-rated. It is planned at that time to discontinue manned flights with the IB vehicle and launch all subsequent Apollo flights with the Saturn V (SA-500 series flights). In the event, certain IB launch vehicles may become available primarily for large experiment payloads.

PROCEDURE FOR SUBMITTING PROPOSALS FOR IN-FLIGHT EXPERIMENTS

Prospective experimenters should complete Section 1 of NASA Form 1067 "Manned Space Flight Experiments Board Proposal for In-Flight Experiment" and all of NASA-MSC Form 793A "Proposal for Flight Experiment", appended herein. Copies of NASA Form 1067 and NASA-MSC Form 793A may be obtained by contacting:

Mr. Leo X. Abernethy
Apollo Flight Operations Division
Code MAO
Office of Manned Space Flight
NASA Headquarters
Washington 25, D.C.

The completed forms, with supporting drawings, sketches and photographs as appropriate, are submitted to the following:

Scientific Experiments	Mr. W. B. Foster Director, Manned Space Science Division Office of Space Sciences and Applications NASA Headquarters
Technological Experiments	Mr. C. Wood Chief, Vehicle Technical Flight Experiments Office of Advanced Research and Technology
Medical Experiments	Dr. S. P. Vinograd Director, Space Medicine Division Office of Manned Space Flight NASA Headquarters
Department of Defense Experiments	Mr. B. A. Denicke Executive Secretary, MSFEB Office of Manned Space Flight NASA Headquarters

In each case, the appropriate office will evaluate the proposal and determine whether the experiment is of sufficient relative scientific, technological or medical merit to warrant inclusion in the Apollo Flight Program. Promising proposals will then be evaluated by the Apollo Program Office and appropriate field centers to determine the technical feasibility of carrying the experiment on a particular Apollo flight. Recommendations are then forwarded to the Manned Space Flight Experiments Board for final determination, whose membership consist of the following:

Dr. George E. Mueller, Associate Administrator, Manned Space Flight

Dr. Homer E. Newell, Associate Administrator, Space Science and Applications

Dr. Raymond L. Bisplinghoff, Associate Administrator, Advance Research and Technology

Dr. W. Randolph Lovelace, Director, Space Medicine

Mr. Edward Z. Grey, Director, Advanced Manned Missions

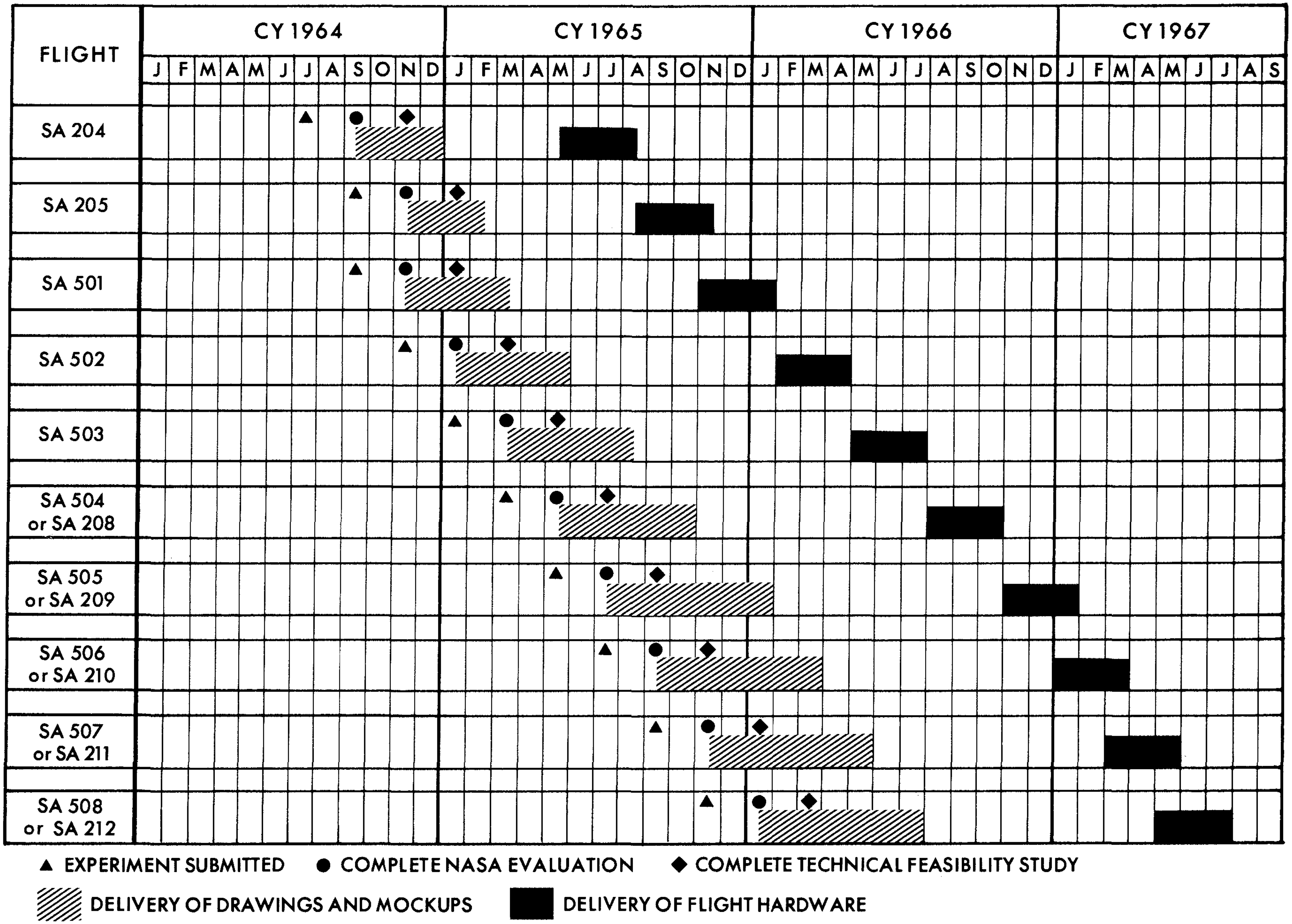
Maj. Gen. O. J. Ritland, AFSC Deputy Commander for Space

Dr. Wernher Von Braun, Director, Marshall Space Flight Center

Dr. Robert Gilruth, Director, Manned Spacecraft Center

Schedules for the submission of proposed experiments for inclusion in the Saturn IB (SA-200 series) and Saturn V (SA-500 series) flight program are outlined on page 7.

EXPERIMENT SCHEDULES - SATURN IB and SATURN V



MISSION PROFILES

To accomplish the objectives of Project Apollo, the landing of men on the moon for scientific observation and exploration of the lunar surface, the Apollo program is divided into three phases:

1. Earth Orbital Missions
2. Circumlunar and/or Lunar Orbital Missions
3. Lunar-Landing Missions

The earth orbital missions are programmed to increase flight crew proficiency, to confirm spacecraft/launch vehicle compatibility, and lunar excursion module/spacecraft performance. Unmanned missions will be conducted with each launch vehicle to qualify the launch vehicle and spacecraft systems operations and confirm spacecraft/launch-vehicle compatibility. Manned missions will be conducted to verify spacecraft systems operation and to increase crew and ground-support proficiency in all phases of the Apollo mission. The individual mission profile will be determined by the mission objectives for a given flight. The overall profile of earth orbital missions range from unmanned, shallow elliptical orbit to manned spacecraft orbit of high elliptical magnitude. Duration will vary from one orbit to missions extending up to 14 days. In-flight experimental capability for these missions will vary depending upon the mission objectives, the Engineering and Development instrumentation required, and the volume and weight capability available for the mission.

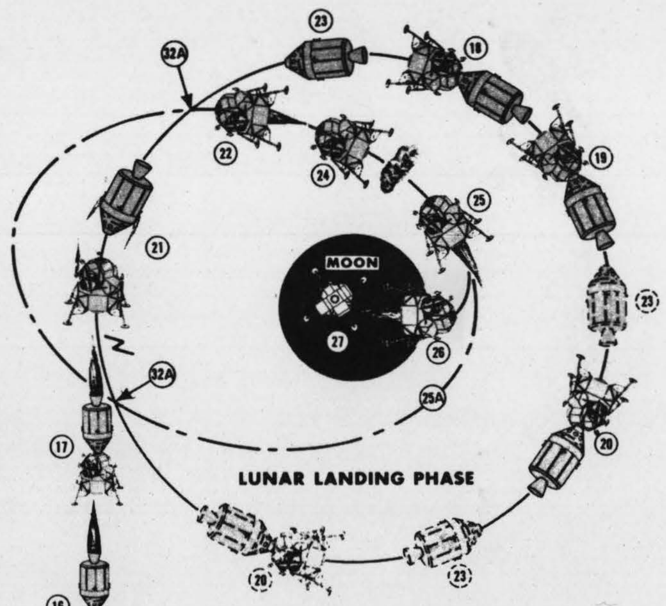
The circumlunar or lunar orbit mission will probably be scheduled prior to manned lunar landing and exploration. The purpose of this mission is to evaluate the effects of deep-space environment upon the flight crew, spacecraft, and ground operations. The experimental possibilities for these flights are greatly broadened.

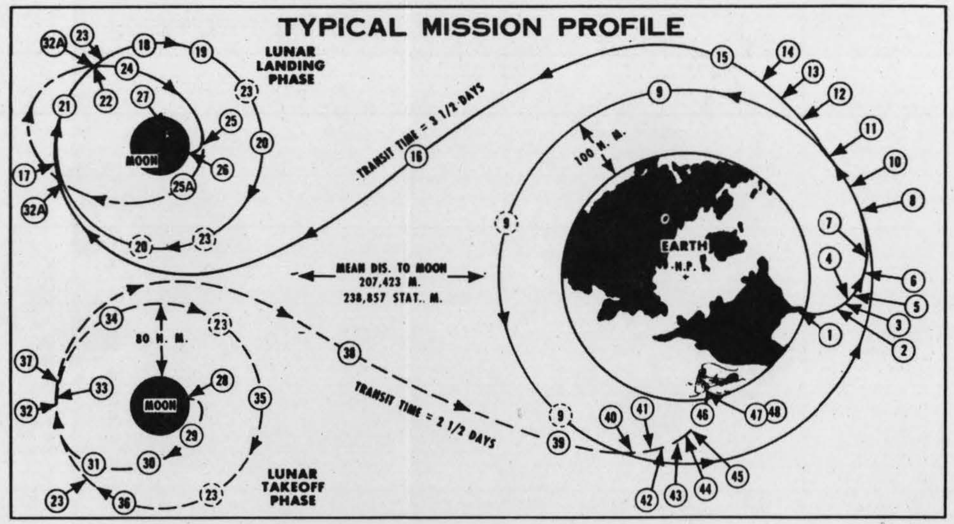
The lunar-landing mission, as outlined in Figure 1, has the specific objective of placing men on the moon for exploration and scientific investigation. The basic objective of this mission is to provide the ability to locate a scientific payload on the lunar surface and return scientific data and samples to earth. The Apollo vehicles are being designed to provide this capability.

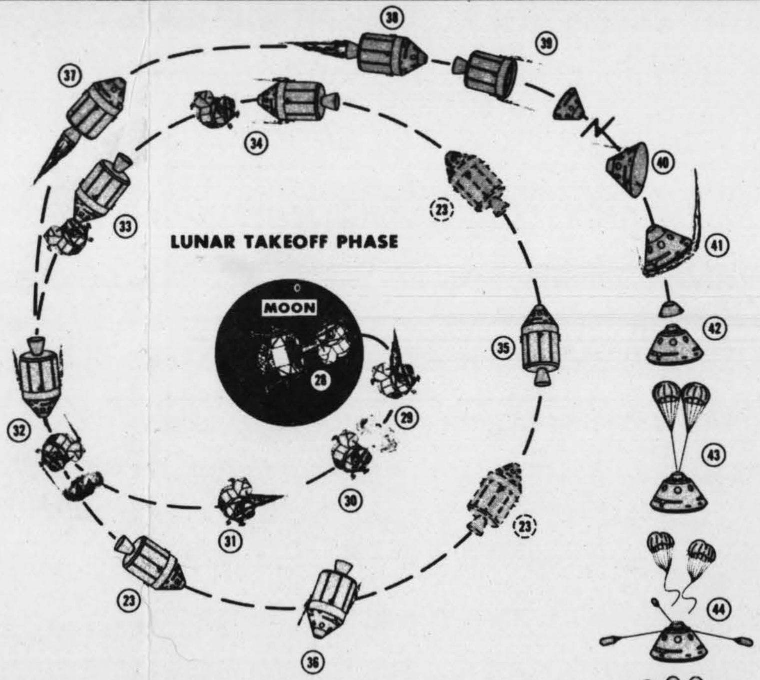
On manned flight, the time that the astronauts can devote to the performance of tasks in connection with experiments is limited. During orbital missions basic flight operations will occupy the crew during most of the first and last orbits. On three-orbit flights the astronauts are presumed to be available for participation in experiments for a portion of one orbit (the second). The limits for astronaut participation in an experiment or combination of experiments will be determined when the proposed experiments are evaluated for technical feasibility for a particular flight.

All experiments must be adapted to fit within the planned mission profiles, such as outlined on pages 11 and 12. It is recommended that prior to formally proposing an experiment for inclusion in a particular flight that this data be updated by contacting the Apollo Flight Operations Division, Office of Manned Space Flight, NASA Headquarters (telephone, WOrth 2-0506), Washington, D. C.

SATURN V APOLLO
LUNAR ORBITAL RENDEZVOUS MODE







SEQUENCE OF OPERATIONS*

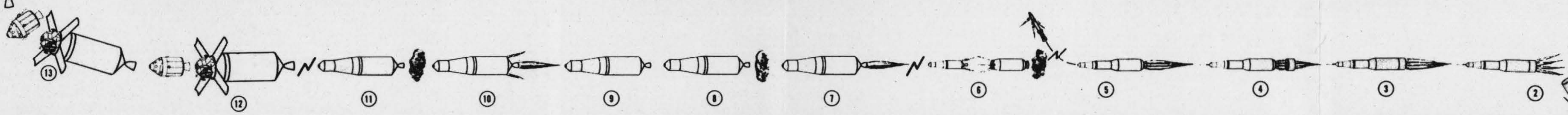
1. S-IC STAGE IGNITION & VEHICLE LAUNCH
2. S-IC STAGE CUTOFF & JETTISON (IGNITE S-IC RETRO & S-II ULLAGE ROCKETS)
3. S-II STAGE IGNITION & THRUST BUILDUP
4. JETTISON S-II AFT INTERSTAGE (AT APPROX. FULL THRUST)
5. LAUNCH ESCAPE SYSTEM JETTISON (AFTER FULL S-II THRUST & VEHICLE STABILIZATION)
6. S-II STAGE CUTOFF & JETTISON (IGNITE S-II RETRO & S-IVB ULLAGE ROCKETS)
7. S-IVB STAGE IGNITION & ORBITAL VELOCITY BUILDUP
8. INSERTION INTO 100 N. M. (185KM) EARTH PARKING ORBIT & S-IVB ENGINE CUTOFF
9. EARTH PARKING ORBIT COAST (CHECKOUT CREW & EQUIPMENT)
10. IGNITE ULLAGE ROCKETS, S-IVB RE-IGNITION & THRUST BUILDUP TO ESCAPE VELOCITY
11. INJECTION INTO EARTH-MOON TRANSIT & S-IVB ENGINE CUTOFF
12. EXPLOSIVE SEPARATION OF FORWARD SECTION OF I. U./APOLLO INTERSTAGE ADAPTER
13. CSM SEPARATION FROM LEM/I.U./S-IVB & CSM TURN AROUND
14. CSM DOCKING TO LEM/I.U./S-IVB
15. JETTISON APOLLO ADAPTER SECTION, I. U. & S-IVB
16. MIDCOURSE CORRECTION [IGNITION (S) & CUTOFF (S) OF SM PROPULSION]*
17. SM IGNITION & BRAKING INTO LUNAR PARKING ORBIT, ENGINE CUTOFF
18. LUNAR PARKING ORBIT COAST (CHECKOUT CREW, EQUIPMENT & LEM)
19. CREW TRANSFER (2 MEN) FROM CM TO LEM
20. PRE-DESCENT LEM CHECKOUT & LANDING SITE RECONNAISSANCE
21. SEPARATE LEM FROM CSM & TURN AROUND LEM TO DESCENT ATTITUDE
22. LEM LANDING STAGE IGNITION & BURNING TO DESCENT ELLIPSE
23. CSM CONTINUES IN LUNAR PARKING ORBIT (1 MAN)
24. LANDING STAGE PROP. CUTOFF & COAST VIA ELLIPTICAL ORBIT TO NEAR LUNAR SURFACE
25. LEM LANDING STAGE RE-IGNITION & BRAKING OUT OF ELLIPTICAL ORBIT
26. LEM HOVER, TRANSLATION, DESCENT MANEUVERS & LUNAR LANDING
27. LUNAR STAY (SCIENTIFIC EXPLORATION, EXPERIMENTS, & SAMPLE GATHERING)
28. LEM LUNAR LAUNCH STAGE IGNITION & LAUNCH (LEAVE LANDING STAGE ON MOON)
29. LUNAR LAUNCH STAGE POWERED ASCENT TO HOHMANN TRANSFER ELLIPSE
30. LUNAR LAUNCH STAGE PROP. CUTOFF & COAST TO LUNAR ORBIT VIA HOHMANN ELLIPSE●
31. MIDCOURSE CORRECTION [IGNITION (S) & CUTOFF (S) OF MAIN PROPULSION]*
32. MAIN ENGINE FIRING INTO CIRCULAR ORBIT, ENGINE CUTOFF, RENDEZVOUS & DOCKING
33. TRANSFER OF CREW (2 MEN) & SCIENTIFIC MATERIAL FROM LUNAR LAUNCH STAGE TO CM
34. JETTISON LEM LAUNCH STAGE (CONTINUES IN LUNAR ORBIT)
35. CHECKOUT OF CREW & CSM PRIOR TO LUNAR ORBIT ESCAPE
36. CSM ASSUME ATTITUDE FOR LUNAR ORBIT ESCAPE
37. SM IGNITION, INJECTION OF CSM INTO MOON-EARTH TRANSIT, ENGINE CUTOFF
38. MIDCOURSE CORRECTION [IGNITION (S) & CUTOFF (S) OF SM PROPULSION]*
39. CM SEPARATION AND JETTISON OF SM
40. CM ESTABLISH RE-ENTRY ATTITUDE
41. CM EARTH ATMOSPHERE RE-ENTRY & AERODYNAMIC MANEUVER TO NEAR LANDING SITE
42. JETTISON FWD. COMPARTMENT HEAT SHIELD (AT 50,000 FT.)
43. DROGUE CHUTE DEPLOYMENT (BY MORTAR AT 25,000 FT.)
44. PILOT CHUTE DEPLOYMENT (BY MORTAR AT 15,000 FT.) & DROGUE CHUTE RELEASE
45. MAIN CHUTE DEPLOYMENT (REEFED CONDITION)
46. FINAL DESCENT WITH FULL CHUTE
47. WATER LANDING AND MAIN CHUTE RELEASE
48. WATER RECOVERY

ALTERNATE EMERGENCY PROCEDURE

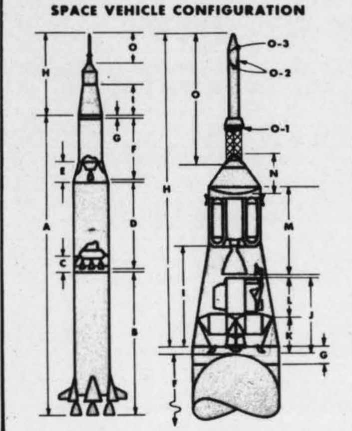
IF LEM CHECKOUT INDICATES LANDING NOT POSSIBLE, STEPS 25 THRU 32 ARE OMITTED AND THE FOLLOWING STEPS ARE TAKEN TO GET TO NO. 33:

25A. LEM CONTINUES IN ELLIPTICAL ORBIT COAST

32A. RENDEZVOUS & DOCKING AT POINT OF ELLIPTICAL & CIRCULAR ORBITS INTERSECTION



SPACE VEHICLE CONFIGURATION



TECHNICAL DATA*

DESCRIPTION	MISSION	WEIGHT (LBS) #	LENGTH (FT.)	DIAMETER (FT.)	ENGINE TYPE	TOTAL THRUST (LBS.)	LIQUID PROPELLANT CAPACITY (LBS.)
A. 3 STAGE SATURN V LAUNCH VEHICLE	PAYLOAD TO PARKING ORBIT & ESCAPE VELOCITY	426.5 K	281.2	VARIES	5 F-1, 6 J-2	-	5,560 K
B. S-IC BOOSTER (SEE NOTE 8-B)	INITIAL LIFT-OFF	300.0 K	138.0	33.0	5 F-1 LOX/RP-1	7,500 K (SEA LEVEL)	4,400 K
C. S-IC/S-II INTERSTAGE ADAPTER	TRANSMITS THRUST FORCES FROM S-IC TO S-II	15.0 K	18.3	33.0	-	-	-
D. S-II SECOND STAGE (SEE NOTE 8-B)	VEHICLE VELOCITY BUILDUP FOR ORBITAL INJECTION	80.0 K	81.6	33.0	5 J-2 LOX/LH_2	1,000 K (VACUUM)	930 K
E. S-II/S-IVB INTERSTAGE SHROUD	TRANSMITS THRUST FORCES FROM S-IC & S-II TO S-IVB	6.0 K	19.0	21.6 TO 33.0	-	-	-
F. S-IVB THIRD STAGE (SEE NOTE 8-A,B)	APOLLO INJECTION INTO EARTH ORBIT AND EARTH-MOON TRANSIT	22.0 K	58.6	21.6	1 J-2 LOX/LH_2	200 K (VACUUM)	230 K
G. LAUNCH VEHICLE INSTRUMENT UNIT (I. U.)	GUIDANCE & CONTROL OF LAUNCH VEHICLE	3.5 K	3.0	21.6	-	-	-
H. APOLLO SPACECRAFT	LUNAR BRAKING, ORBIT, LANDING, LAUNCH & EARTH RETURN	96.6 K	82.2	VARIES	3 HYPERGOLIC STORABLES**		76.4 K
I. I.U./APOLLO INTERSTAGE ADAPTER	TRANSMITS LAUNCH VEHICLE THRUST TO CSM, HOUSES & SUPPORTS LEM		28.8	12.8 TO 21.6	-	-	-
J. LUNAR EXCURSION MODULE (LEM)	MANNED LUNAR LANDING AND TAKE OFF		19.3	(27 + WITH	2 HYPERGOLIC STORABLES	-	
K. LEM LUNAR LANDING STAGE (SEE NOTE 8-A,C)	LUNAR ORBIT(S) BRAKING, LUNAR HOVERING, TRANSLATION, DESCENT & LANDING	90.0 K	9.8	LEGS EXTENDED)	1 HYPERGOLIC STORABLE	10.5 K (VACUUM)	
L. LEM LUNAR LAUNCH STAGE (SEE NOTE 8-A)	LUNAR LAUNCH & INJECTION INTO LUNAR ORBIT		9.5	15	1 HYPERGOLIC STORABLE	3.5 K	
M. SERVICE MODULE (SM) (SEE NOTE 8-A,B)	MIDCOURSE CORRECTIONS, LUNAR BRAKING & ESCAPE PROPULSION		24.7	12.8	1 HYPERGOLIC STORABLE	-	
N. COMMAND MODULE (CM)	MANNED LUNAR ORBIT & EARTH RETURN. MAIN APOLLO CONTROL		11.1	12.6	NONE	21.9 K	-
O. APOLLO LAUNCH ESCAPE SYSTEM (LES)	CREW ESCAPE DURING ABORT	6.6 K	33.8	2.2	3 SOLID FUEL MOTORS	-	
O-1 LAUNCH ESCAPE MOTOR	PULLS CM CLEAR OF ABORTED LAUNCH VEHICLE	-	-	-	SOLID FUEL	150 K FOR 3+ SECS.	-
O-2 TOWER JETTISON MOTOR	JETTISONS TOWER AFTER SUCCESSFUL LAUNCH OR ABORT	-	-	-	SOLID FUEL	33 K FOR 1.2 SECS.	-
O-3 PITCH MOTOR	PROVIDES TURN DIRECTION FOR LES TOWER OR LES/CM	-	-	-	SOLID FUEL	2.5K FOR .5 SECS.	-
LOR VEHICLE (TOTAL)	MANNED LUNAR LANDING AND RETURN	6,000 K	363.4	MAX 33.0	14 MAIN PROPULSION ENG'S.	-	

CSM = CM/SM — # UNDERLINED WEIGHTS INCLUDE LIQUID PROPELLANTS; OTHERS ARE DRY — K=1000

PHYSICAL DATA

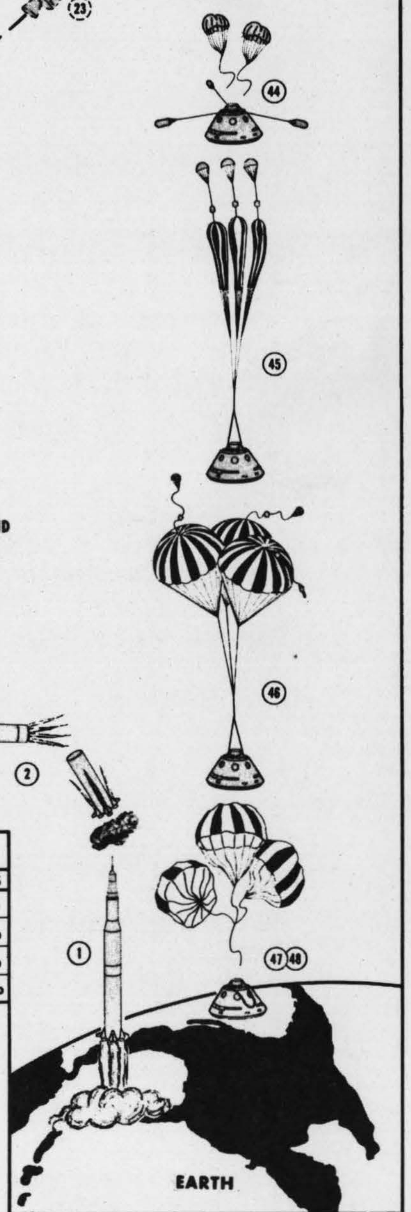
		EARTH	MOON
MEAN DIAM. IN MILES	NAUTICAL	6,875	1,877
	STATUTE	7,917	2,161
SURFACE GRAVITY		1 G	1/6 G
ATMOSPHERE		AIR	VACUUM
TEMPERATURE (°F)	IN SUN	MEAN 57.2°	+212°
	IN SHADOW		-243°

APPROXIMATE VELOCITIES REQUIRED

	MPH	KNOTS
INJECTION INTO 100 N. M. EARTH ORBIT	17,400	15,100
INJECTION INTO EARTH - MOON TRANSIT	24,300	21,100
INJECTION INTO MOON-EARTH TRANSIT	5,100	4,400
EARTH ATMOSPHERE RE-ENTRY	24,400	21,200

NOTES:

1. COAST PERIODS ARE BETWEEN POSITIONS 8 & 10, 11 & 16, 16 & 17, 17 & 22, 24 & 25, 30 & 31, 31 & 32, 32 & 37, 37 & 38, 38 & 41. (NO MAIN PROPULSION SYSTEM IN OPERATION).
2. ULLAGE ROCKET FIRING REQUIRED BEFORE IGNITIONS 3, 7, AND 10 TO FORCE PROPELLANTS TO BOTTOM OF TANKS BEFORE MAIN PROPULSION IGNITION
3. *MULTIPLE RESTARTS (AS REQUIRED DURING COAST PERIODS FOR TRAJECTORY CORRECTIONS).
4. **ENGINES THAT USE A FUEL AND OXIDIZER BIOPROPELLANT, STORABLE AT NORMAL TEMPERATURES, THAT IGNITE SPONTANEOUSLY WHEN THE FUEL & OXIDIZER ARE MIXED.
5. ●AN OPTIMUM FLIGHT PATH USING AN ELLIPTICAL COASTING TRANSFER WITH POWERED FLIGHT AT LAUNCH AND TERMINAL POINTS ONLY (VS. CONTINUOUS BURN) TO CONSERVE PROPELLANTS.
6. ~ INDICATES SCALE CHANGE IN STAGE AND MODULE SKETCHES.
7. ★ THESE DIAGRAMS HAVE BEEN PURPOSELY ALTERED IN SCALE AND PERSPECTIVE TO BETTER SHOW CONFIGURATIONS AND OPERATIONAL SEQUENCE, AND ARE FOR INFORMATIONAL PURPOSES ONLY FOR CLARITY'S SAKE, VERY LITTLE CONSIDERATION HAS BEEN GIVEN TO RELATIVE MOTIONS AND POSITIONS OF THE EARTH VS. THE MOON DURING ELAPSED TIME INTERVALS SHOWN. THIS CHART REPRESENTS ONE OF SEVERAL TYPICAL PROFILES CURRENTLY BEING CONSIDERED AND IS SUBJECT TO CONTINUOUS CHANGE. ALL TECHNICAL DATA SHOWN IS APPROXIMATE.
8. PROPULSION SYS. CAPABLE OF (A) RESTART (B) GIMBALLING (C) THROTTLING



MARSHALL SPACE FLIGHT CENTER	
EX-R-500 e	APRIL 29, 1964
ENGINEER: B. E. ABBOTT	ILLUSTRATOR: JOE MADDOX

FIGURE 1

SUMMARY OF MISSION CHARACTERISTICS FOR SATURN IB FLIGHTS

Flight No.	204, 205*	208 - 212
Type	Manned	Manned
Structures placed in orbit	Command Module Service Module Instrument Unit S-IVB Stage	Command Module Service Module Lunar Excursion Module Instrument Unit S-IVB Stage
Profile	Insert into 105 NM circular orbit Separation of the Command & Service Modules from the Instrument Unit & S-IVB Stage Use Service Module Propulsion system to achieve higher orbit (approx. 140 NM circular). Use Service Module Propulsion system to de-orbit Separation of service module from command module Reentry Recover command module	Insert into 105 NM circular orbit Transportation & docking of the Lunar Excursion Module Separation of the command, service & lunar excursion modules from the instrument unit and S-IVB stage. I Rendezvous and docking operations. (command & service modules active). Lunar Excursion module propulsion operations II Rendezvous & docking operations(lunar excursion module active). Use Service Module Propulsion system to de-orbit. Separation of service module from command module. Reentry Recover Command Module.
Flight Azimuth	72 degrees	72 degrees
Flight Duration	10 - 14 days	3 days

*Due to weight limitations flights 206 and 207 are not available for experiments.

SUMMARY OF MISSION CHARACTERISTICS FOR SATURN V FLIGHTS

Flight No.	501 - 506	503 - 509*
Type	501-503 Unmanned 504-506 Manned	Manned
Structures placed in orbit	Command Module Service Module Lunar Excursion Module Instrument Unit S-IVB stage	Command Module Service Module Lunar Excursion Module Instrument Unit S-IVB stage
Profile	Insert into 100 NM circular orbit. After achieving circular orbit, inject into an elliptical orbit. Separation of command, service and lunar excursion modules from the Instrument Unit and S-IVB stage. Use Service Module Propulsion System to achieve desired re-entry conditions. Separation of Service Mod from Command **Module.** Re-entry Recover Command Module.	Insert into 100 NM circular orbit. Balance to be developed to simulate lunar mission and verify crew/space vehicle/ ground systems.
Flight Azimuth	72 degrees	72 degrees
Flight Duration	3 - 6 orbits	10 days

*Exact missions for Saturn V flights 503-506 vehicles will be determined at a later date. The vehicles may be used in the 501-506 mission profile or in the 503-509 profile depending upon needs as developed.

LAUNCH VEHICLES

An outline of the vehicles to be used for launching Apollo spacecraft is shown in figure 2. The Saturn I is a development vehicle which can boost about 20,000 pounds into earth orbit. Six Saturn I launchings were made between October 1961 and May 1964. Four additional launchings will complete the Saturn I program. These will be unmanned orbital flights which are intended primarily to develop launch vehicle structural, propulsion and guidance technology and determine the structural and aerodynamic suitability of the Apollo spacecraft. In addition, flights SA-8, SA-9 and SA-10 will place large micrometeoroid detection experiments in orbit with an anticipated lifetime of approximately one year each.

The Saturn IB will be used for several unmanned Apollo launches as well as for the initial phases of Apollo manned earth-orbital flights. This booster is capable of delivering about 32,000 pounds in earth orbit.

The Saturn V launch vehicle is planned to boost the Apollo vehicle on later earth-orbital missions and to launch Apollo on the lunar-orbit and lunar-landing missions. This vehicle is capable of placing over a quarter million pounds in earth orbit and about 90,000 pounds in lunar orbit.

LAUNCH VEHICLES CONFIGURATION

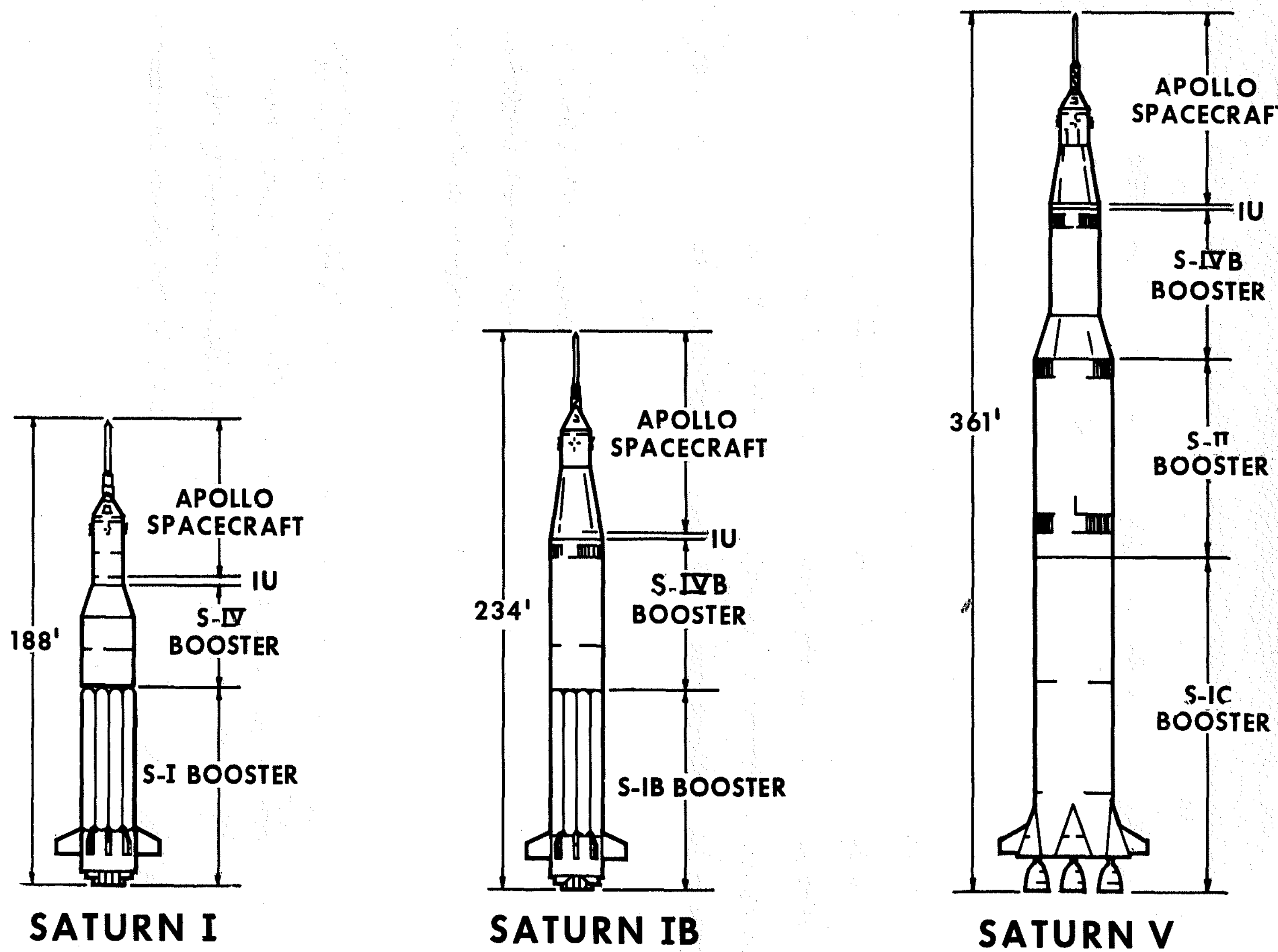


FIGURE 2

SPACECRAFT

The Apollo spacecraft consists of the command module (C/M), service module (S/M), and lunar excursion module (LEM). Figure 3 shows the spacecraft in its launch configuration including the launch escape tower and adapter. Figure 4 shows the spacecraft in flight after transposition of the command-service module combination and docking with the LEM. A brief description of each of these modules is presented to provide better understanding of the spacecraft, its functions and its usefulness as an experimental platform for in-flight experiments.

COMMAND MODULE. The Apollo command module will house the crew during earth launch, translunar and transearth flight, and during earth reentry and landing. The module (see Figures 5 & 8 for internal arrangement) will contain crew-support systems, displays, controls, equipment requiring direct access by the crew, and all systems needed for earth entry and landing.

The module is divided into three basic compartments: the crew compartment, the forward compartment, and the aft compartment.

The crew compartment, which comprises the major portion of the command module, is approximately 365 cu. ft in volume. About 220 cu ft of this space is available for the crew. This compartment is an oxygen pressurized, three-man cabin that maintains shirt-sleeve environment for the crew during space flight. The crew compartment contains spacecraft controls and displays, observation windows, food, water, sanitation, and survival equipment.

APOLLO SPACECRAFT

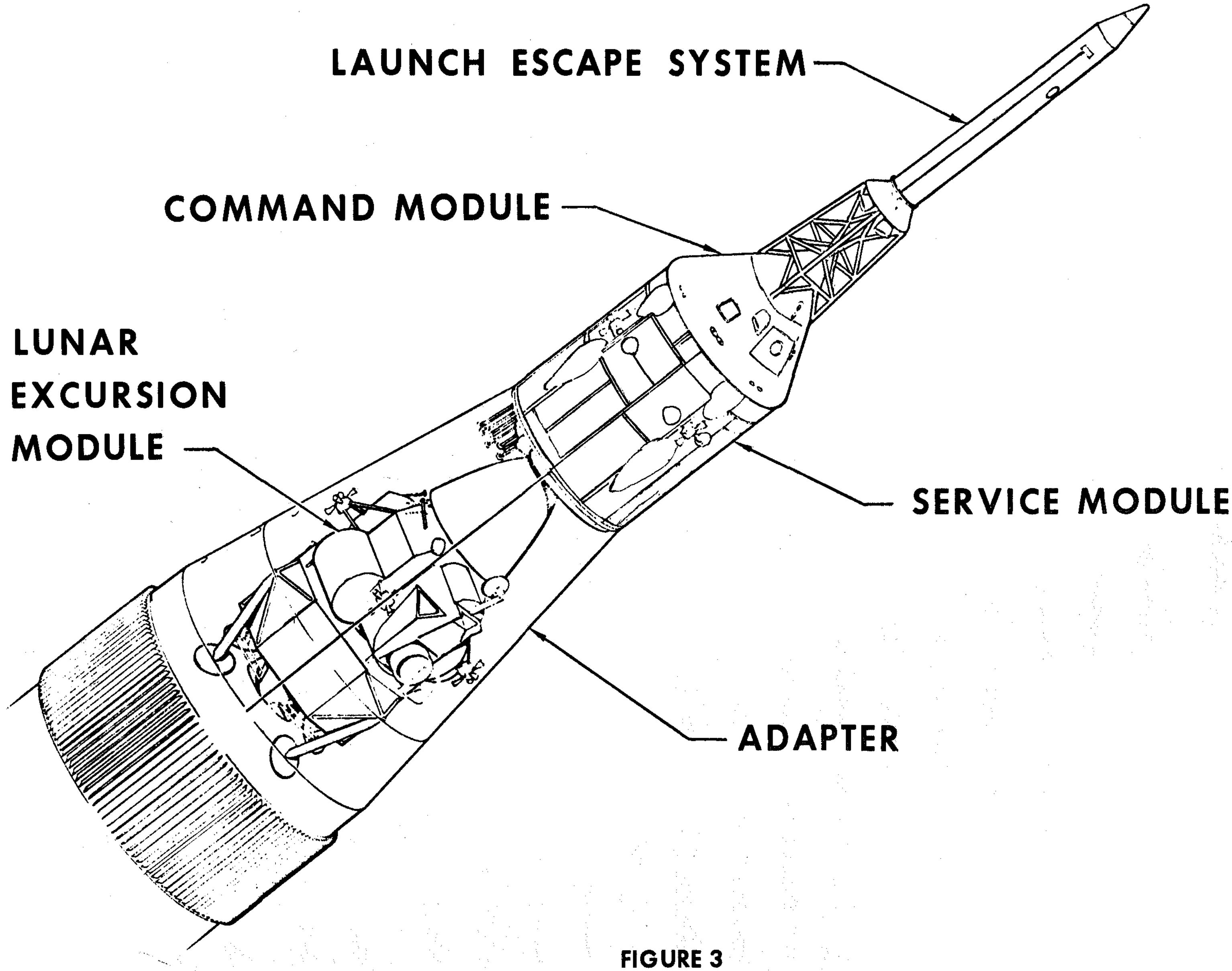


FIGURE 3

SPACECRAFT - INFLIGHT

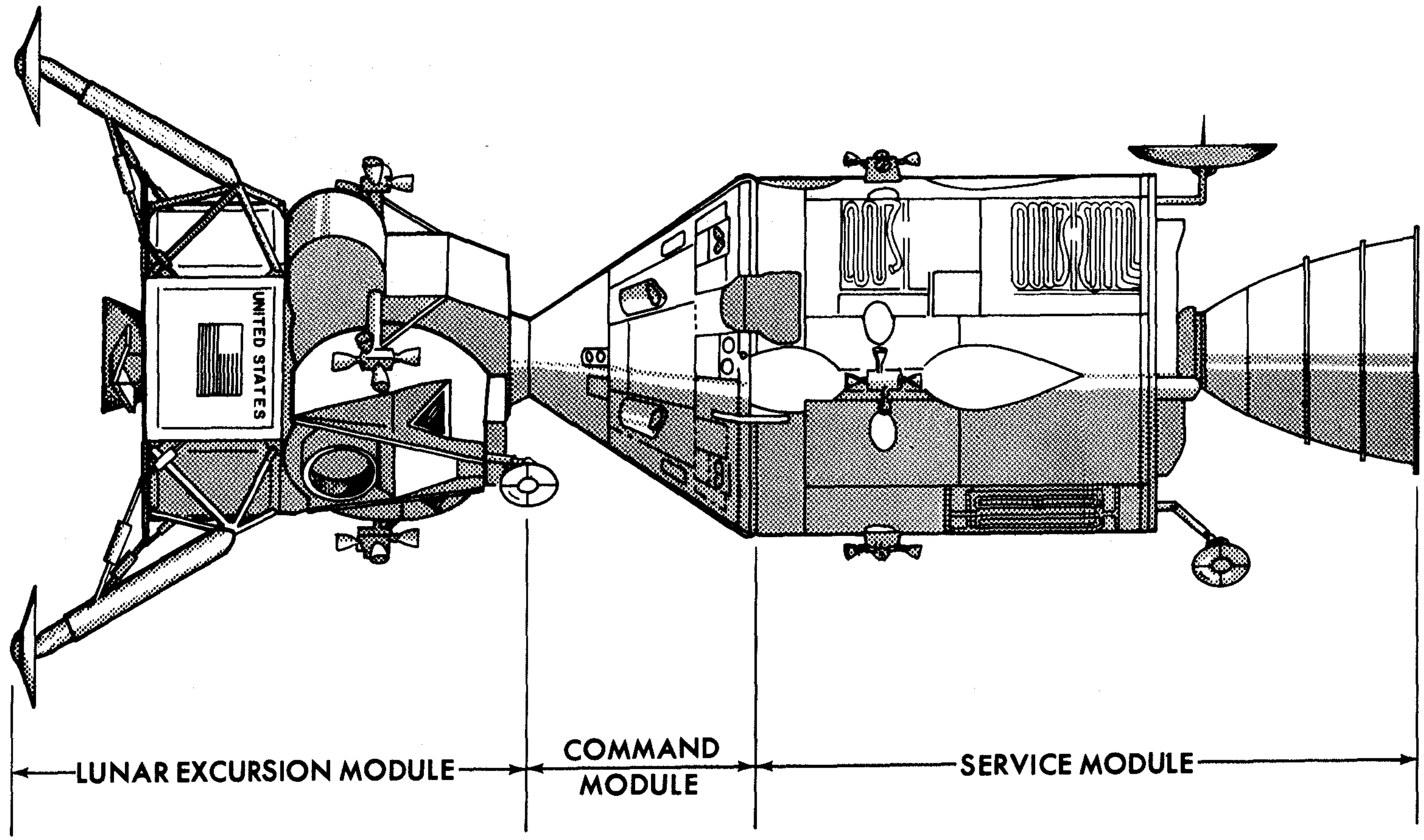


FIGURE 4

COMMAND MODULE LIVING AREA

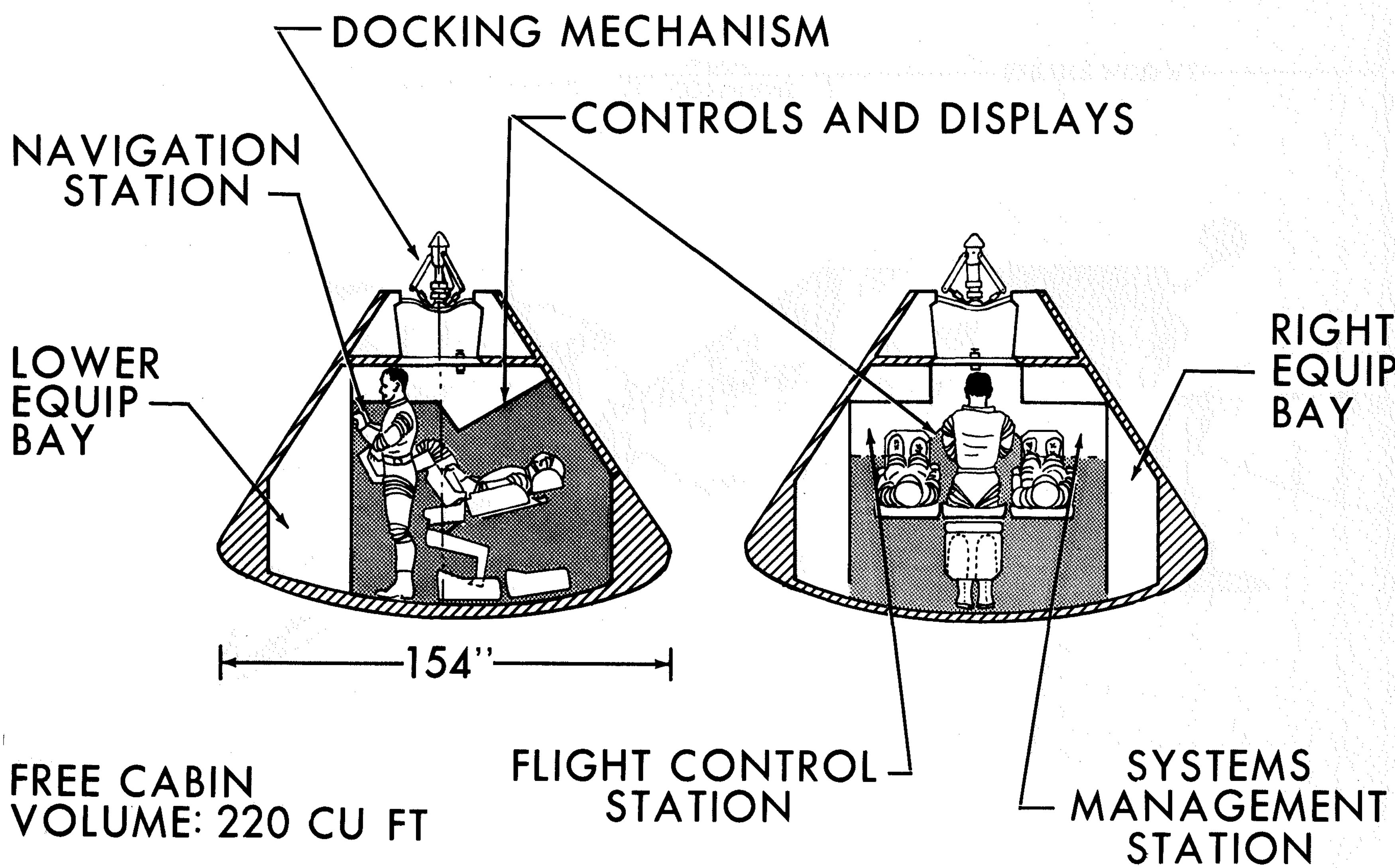


FIGURE 5

The forward compartment is located at the apex of the conical-shaped crew module. This compartment is unpressurized, and the center portio is occupied by the egress tube to permit the crew to debark from the spacecraft during flight. The major portion of the remaining area is occupied by the earth-landing system.

The aft compartment is an area located around the lower rim of the conic body. This area also is unpressurized and not accessible to the crew. It contains the reaction control motors, impact attenuation equipment, instrumentation, and consumable stowage.

The windows for the command module are illustrated on Figure 6. It has five windows: a general observation window in the entrance hatch, two forward-looking rendezvous windows, and two side-observation windows for horizon and earth-landing reference. All of these windows are opaque to ultraviolet transmissions; however, NASA is studying the possibility of incorporating quartz panes in the observation window. The command module windows are supplemented by a scanning telescope and sextant, which are part of the spacecraft navigation system. The scanning telescope is a one-power, single-line-of-sight instrument with a 60-degree field of view, and it can be rotated about a 104-degree solid angle viewing area. The sextant makes use of a beam-splitting arrangement to provide simultaneous viewing along two lines-of-sight. Along one line of sight, the sextant provides 28-power magnification and has a 2 degree fixed field of view. The other line-of-sight is non-magnified and can cover a 104-degree solid-angle viewing area.

COMMAND MODULE

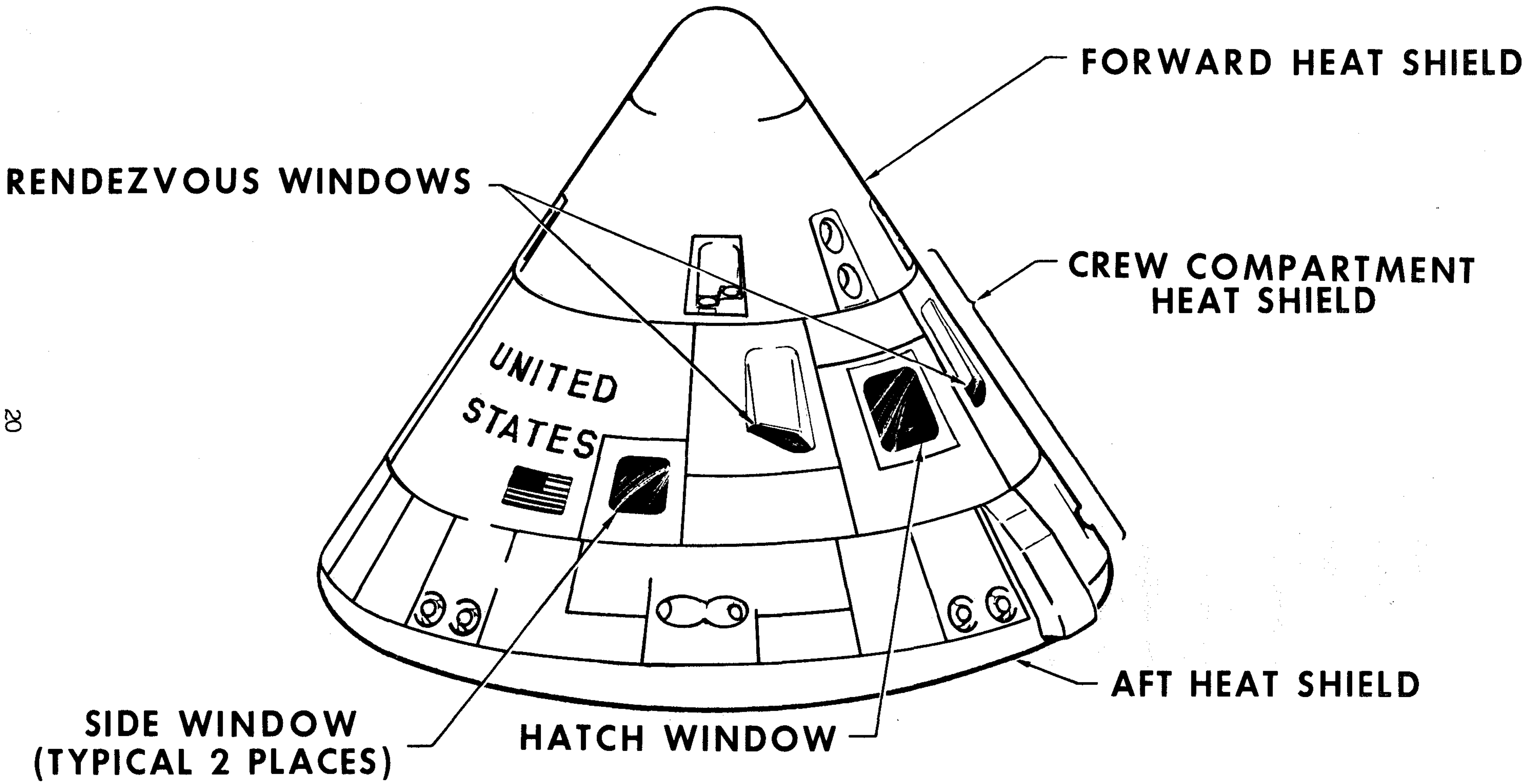


FIGURE 6

The command module is designed to provide a suitable crew environment for flights up to 14 days in duration during both earth-orbital and lunar missions. The command module is the only recovered portion of the Apollo spacecraft on all manned space flights.

SERVICE MODULE. The service module (see Figures 3 and 4) is an unmanned, non-pressurized vehicle which contains stores and systems which do not require direct crew accessibility. This module contains the propulsion utilized for midcourse correction and for insertion into and from lunar orbit, fuel cells which provide spacecraft power, radiators for spacecraft cooling, and oxygen and hydrogen supplies. Any experimental equipment stored in this vehicle would be exposed to the surrounding space environment and would be available to the crew only by extravehicular activity (EVA). EVA capability is not currently planned for the early Apollo-Saturn IB missions. The service module remains attached to the command module as shown in Figure 3 throughout the entire space flight; however, it is separated from the command module just prior to earth reentry and is not recovered.

LUNAR EXCURSION MODULE. The LEM will house the crew during lunar landing. During earth launch, the LEM will be contained within the spacecraft adapter (see Figure 3). After injection into translunar trajectory, the LEM will be docked to the small end of the command module as shown in Figure 4. During lunar orbit, two members of the Apollo crew will enter the LEM. The LEM will then separate from the command module, land on the moon, launch from the lunar surface into lunar orbit, and rendezvous with the command module. After transfer of the men and the scientific data into the command module, the LEM is jettisoned and left in lunar orbit.

As shown in Figure 7, the LEM consists of two stages; the descent stage which provides the braking-and-hovering capability needed for lunar landing and the ascent stage for return to lunar orbit. The descent stage is unmanned and not accessible to the crew except during extravehicular operation. This stage is useful for experimental purposes only to transport scientific equipment to the lunar surface.

The ascent stage houses the two crewmen during lunar operations. It provides a pressurized oxygen environment, food, water communications equipment, and environmental control for the crew for a period up to 45 hours. The ascent stage has the necessary propulsion and guidance to return the crew from the lunar surface to lunar orbit and rendezvous with the command and service modules. Thus, any equipment or data to be returned from the lunar surface must be stored in the ascent stage. Since this vehicle is not retained on the return journey to earth, all equipment within the ascent stage to be returned to earth must be transferred to the command module prior to leaving lunar orbit.

LUNAR EXCURSION MODULE

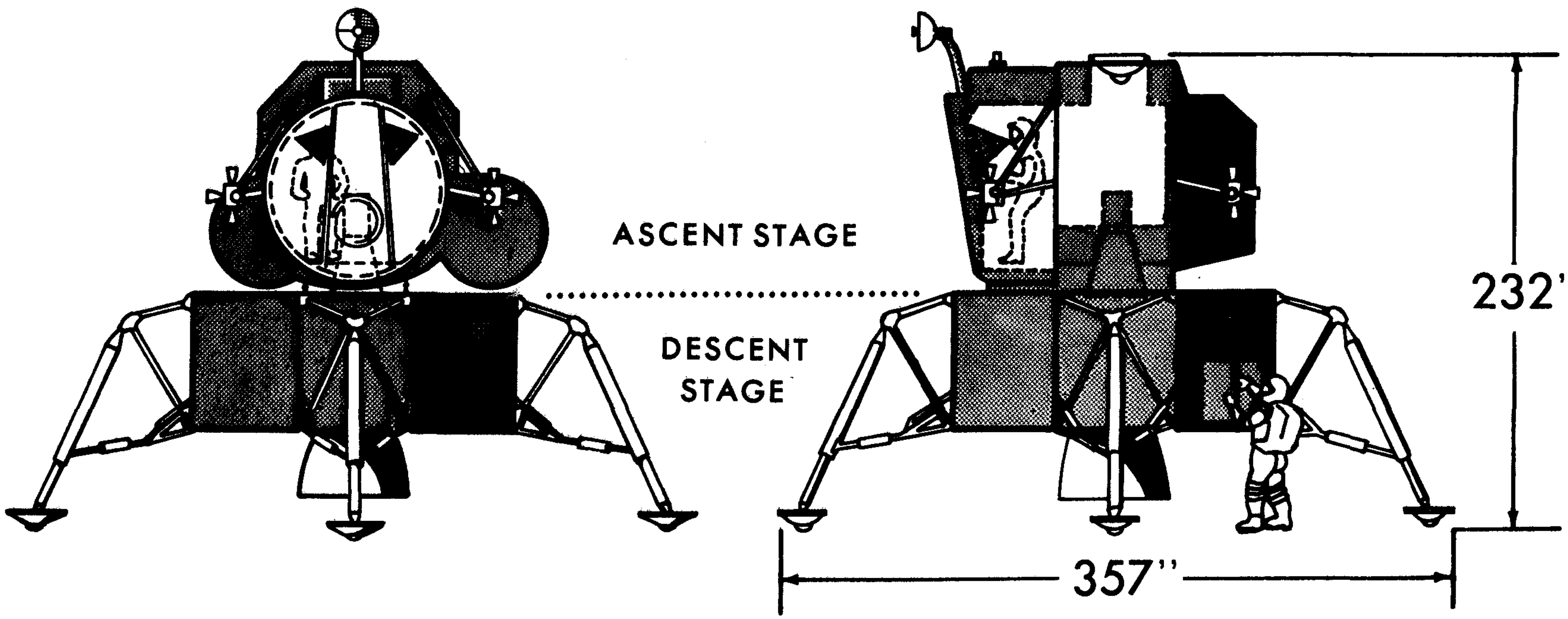


FIGURE 7

ENVIRONMENTAL DESIGN AND TEST CRITERIA

Unified environmental and design criteria for all Apollo systems are currently being developed; spacecraft/scientific equipment interface specifications containing such criteria will be available in late 1964. Although such criteria are generally applicable to the design of all Apollo systems, specific analysis must be performed for each system, subsystem, component, and item of experimental hardware. Careful examination of the mission phase and location of the experiment must be made to determine in which environments the equipment must survive and remain operable, and in which the equipment must survive "intact for mission safety".

A very brief summary of some of the extreme qualification test environments are given below:

a. Temperature - Inside cabins: 90 - 140°F.
External surfaces (except during reentry):
-260 to +390°F.

b. Noise, Vibration, Buffet - Very high loads during earth launch and reentry; substantial loads during lunar landing, lunar launch and other periods of thrusting.

c. Acceleration - Earth launch: 6 g for 140 seconds.
Earth launch aborts: 20 g for 4 seconds.
Reentry: 20 g for 120 seconds.

d. Shock - Lunar Landing: 14 g
Earth Landing: 78 g

e. Humidity and Free Moisture - 100% humidity and free moisture within spacecraft cabin.

f. Atmosphere and Pressure - pure oxygen at 5 psia; vacuum during emergencies.

Additional criteria exist for sand and dust, meteoroids, fungus, salt spray, ozone, hazardous gases, particle radiation, electromagnetic radiation, electromagnetic compatibility, explosion, wind, precipitation, and sea state.

FLIGHT CONTROL CHARACTERISTICS OF THE APOLLO COMMAND MODULE

Attitude hold, Stabilization Control System or Guidance and Navigation Mode

Selectable ± 0.5 deg. or ± 5 deg. deadband

Rates in attitude hold mode ± 0.2°/sec.

Attitude constraints - avoid 0° , 0°, 0°

Minimum rate in control stick steering mode 0.5°/sec

Direct mode - do not exceed 25°/sec

The following table lists minimum angular velocity and acceleration in each axis for three spacecraft configurations.

	ROLL		PITCH		YAW	
	deg/sec	deg/sec^2	deg/sec	deg/sec^2	deg/sec	deg/sec^2
TRANS LUNAR	7.461×10^{-3}	1.658×10^{-1}	1.047×10^{-3}	2.326×10^{-2}	1.016×10^{-3}	2.259×10^{-2}
LUNAR ORBIT	2.100×10^{-2}	4.666×10^{-1}	7.623×10^{-3}	1.694×10^{-1}	7.461×10^{-3}	1.658×10^{-1}
TRANS EARTH	3.247×10^{-2}	7.216×10^{-1}	1.031×10^{-2}	2.292×10^{-1}	1.031×10^{-2}	2.292×10^{-1}

Although the flight attitude of the command module can be controlled as outlined above, prime mission requirements or conflicting experiment requirements may restrict flight attitudes or the duration of attitude holds. Detailed flight control constraints will be determined when proposed experiments are evaluated for technical feasibility.

ELECTRICAL/ELECTRONIC INTERFACES

The following power and data handling capabilities exist aboard the spacecraft. Additional power, telemetry, and recording capability may be made available if experiment proposals are received early. Otherwise, experiments which have requirements in excess of that indicated below must include their own telemetry and recording equipment. Use of spacecraft antennas will be possible; LEM antenna will be erected by astronaut and left on lunar surface.

	POWER	TELEMETRY CHANNELS	TAPE RECORDER
Command Module Block I - Early Orbital Flights	None allocated; Some may be available, depending on experiment and mission length.	None allocated; Some may be available depending on experiment and mission length.	Several 25 KC channels are currently unassigned. These will probably be available for experiment data.
Command Module Block II - Lunar and LEM Flights	None allocated; Some may be available, depending on experiment and mission length.	None allocated; Some may be available, depending on experiment and mission length.	No capability allocated; Some may be available, depending on experiment and mission length.
Lunar Excursion Module	2400 watt hours 28 volt d.c.; available during lunar stay time only.	None allocated; Some may be available, depending on experiment and mission length.	No data capability; A voice operated recorder with time indications is now planned.

SCIENTIFIC EQUIPMENT STOWAGE

Since no two Apollo spacecraft will be perfectly identical in configuration, it is extremely difficult to assign specific spaces that will be available for stowage of scientific equipment on every flight. Therefore, experiments will be placed in many locations throughout the spacecraft. When integrating experiments into the spacecraft, efforts will be made to secure the optimum location for success of the experiment subject to constraints of primary mission requirements, safety, weight control, difficulty of modifying the spacecraft, etc.

The command module compartment configuration is illustrated in Figure 8. In order to insure stowage location for that scientific equipment which must be handled by the crew, portions of the "premium" space reaily accessible to the crew have been reserved in the command module for scientific equipment stowage, Figures 9 and 10. Again, these stowage areas should not be regarded as absolutely restrictive but rather as flexible enough to accommodate irregular-shaped equipment if the necessary modifications are feasible.

The service module is not accessible to the crew in flight, however, there is stowage space available around spherical and circular tanks. Experiments which need exposure to the space environment but no crew access nor recovery will generally be located in or on the service module.

COMMAND MODULE COMPARTMENT CONFIGURATION

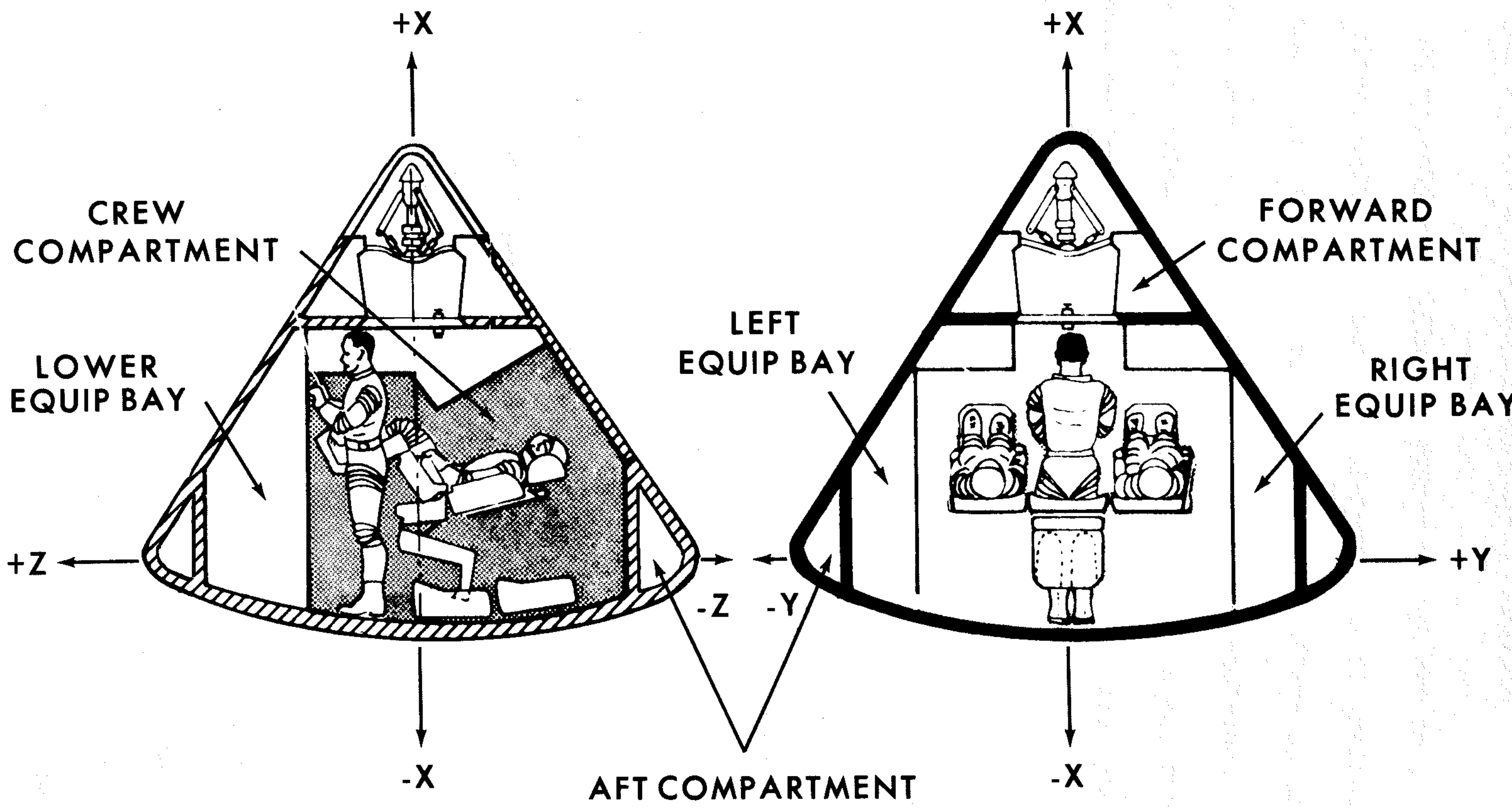
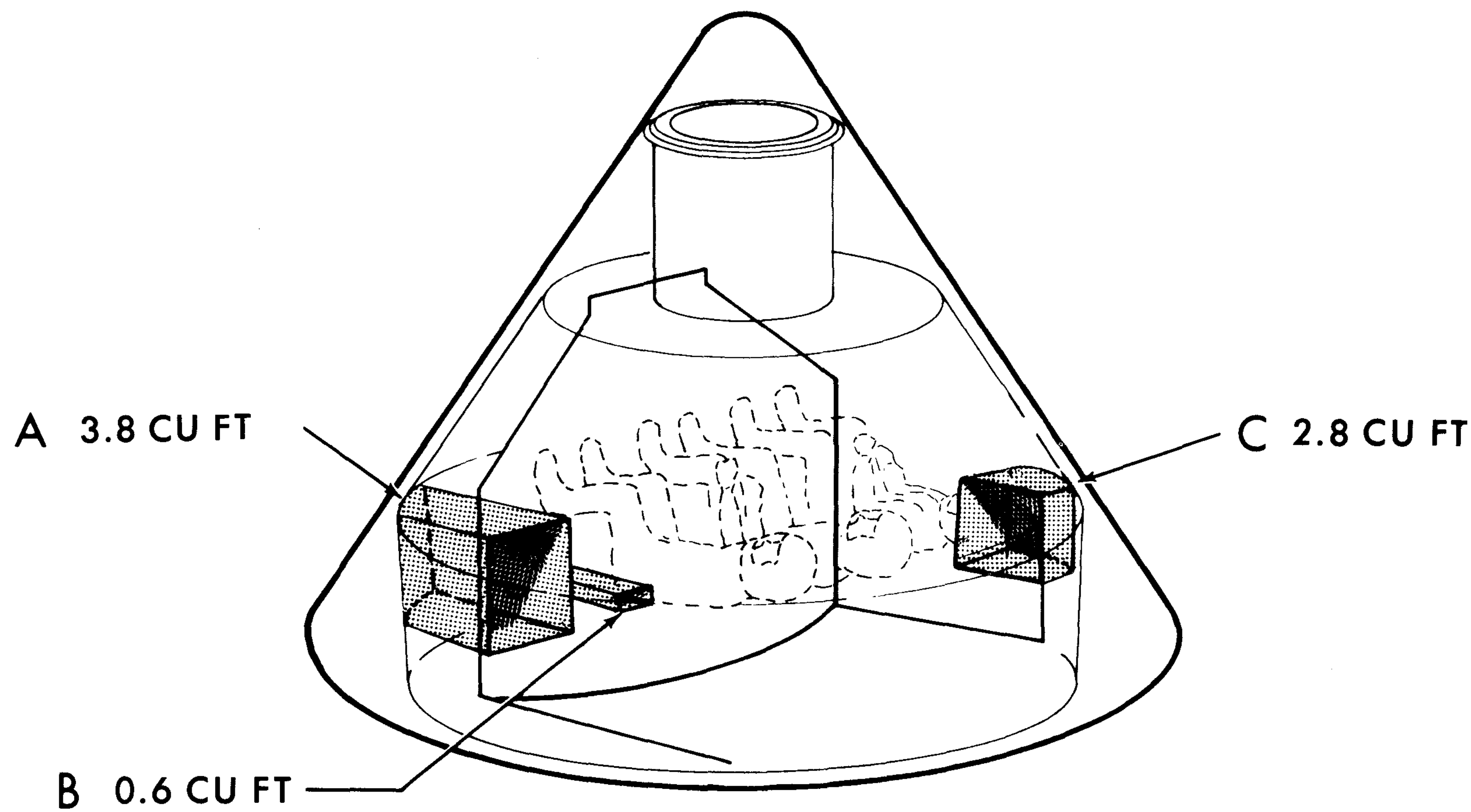


FIGURE 8

SCIENTIFIC EQUIPMENT STOWAGE

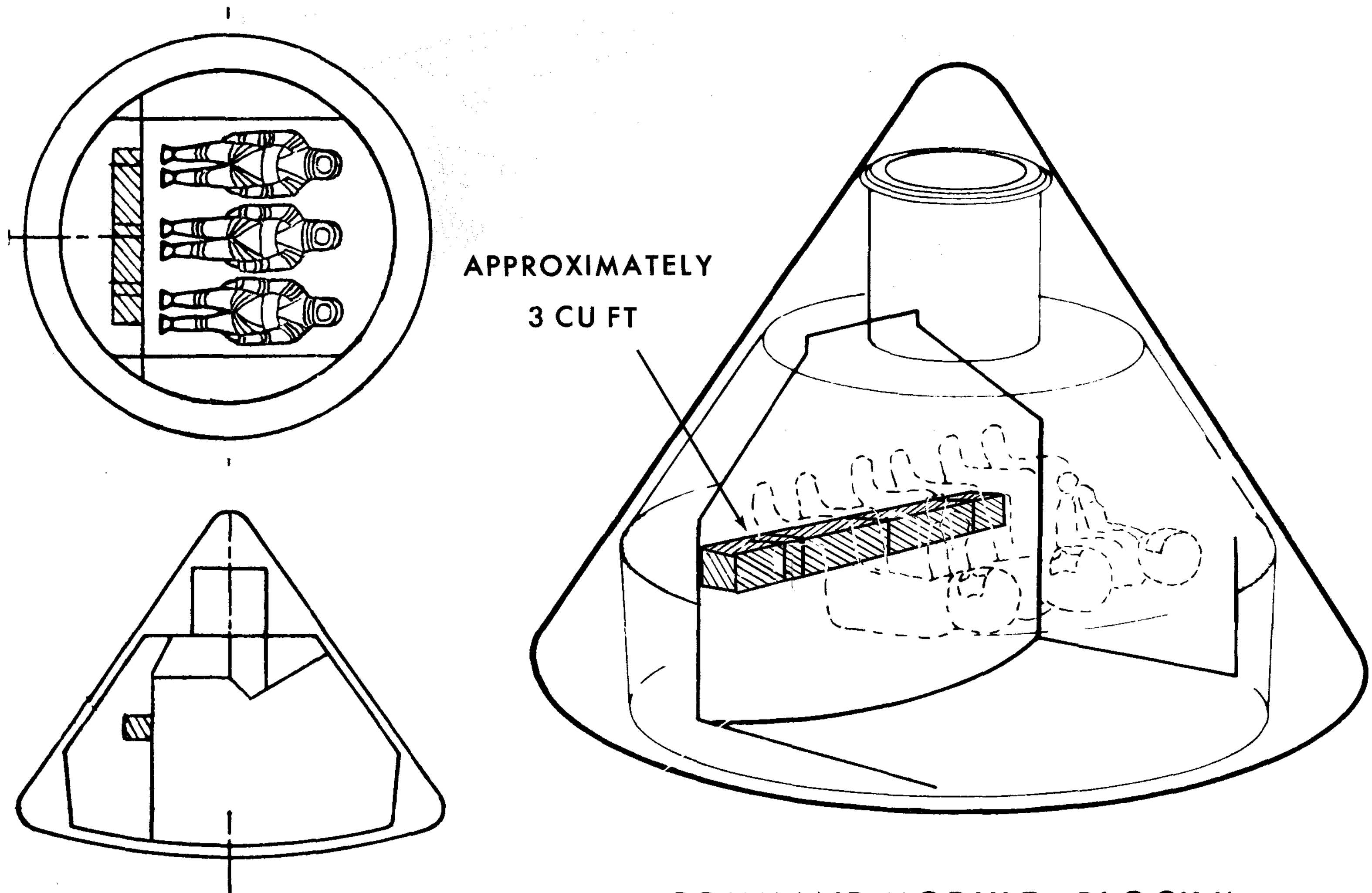
EARLY ORBITAL FLIGHT



COMMAND MODULE - BLOCK I

FIGURE 9

SCIENTIFIC EQUIPMENT STOWAGE



COMMAND MODULE - BLOCK II

FIGURE 10

The lunar excursion module, Figure 11, will have a total of approximately 18 cu ft of stowage space enroute to the moon. However, 15 cu ft are in the descent stage to be abandoned on the moon (or in space on non-lunar flights) and only 3 cu ft are available in the ascent stage for eventual return to earth. On lunar landing flights, 2 cu ft are reserved for lunar samples leaving only about 1 cu ft (made up of various small spaces) available for equipment.

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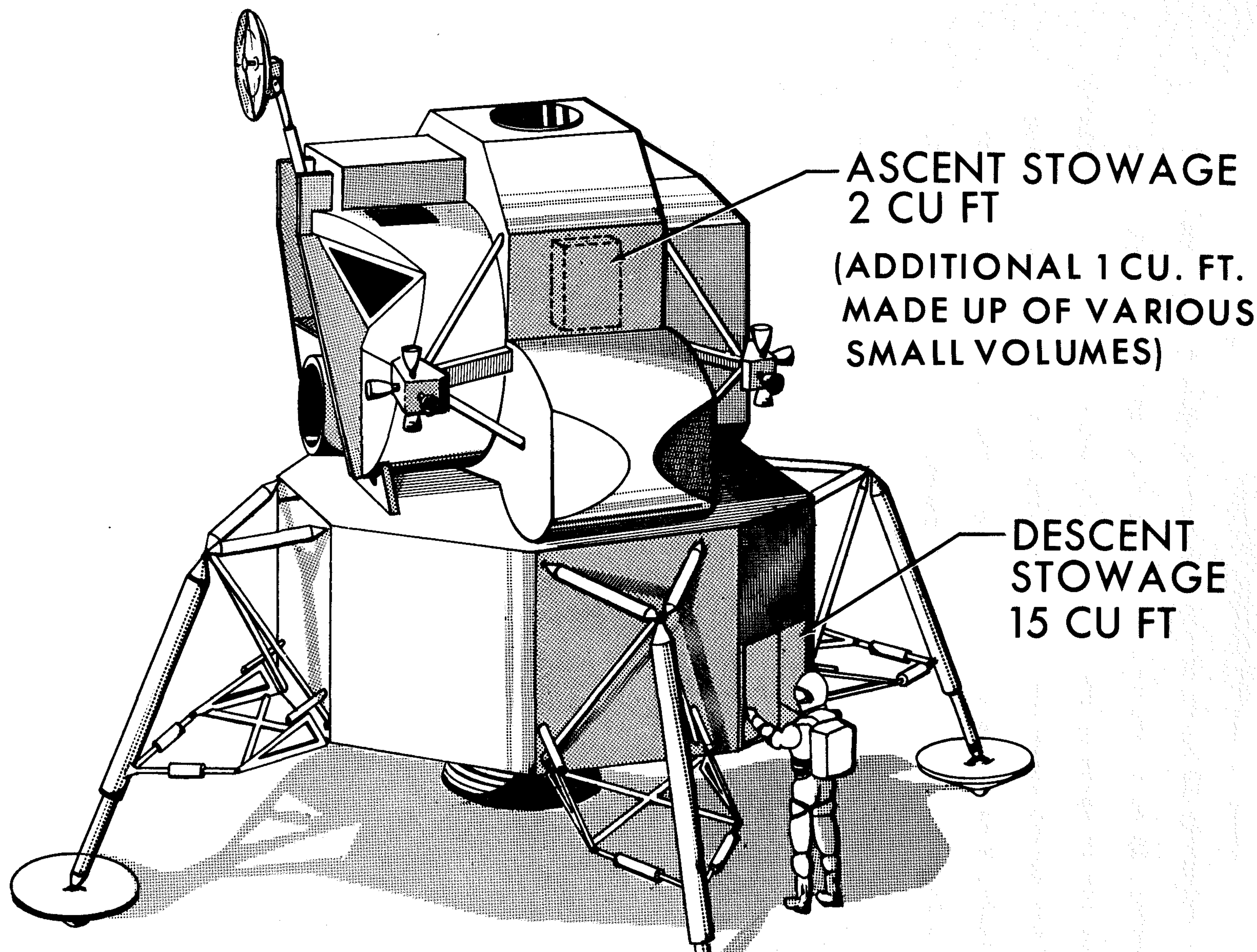
SCIENTIFIC EQUIPMENT STOWAGE



LUNAR EXCURSION MODULE

FIGURE 11

SCIENTIFIC EQUIPMENT STOWAGE

Module	Approximate Weight	Location	Volume	Remarks
Command (Block I-Early Orbital Flights)	80 lbs (including containers)-Additional weight may be available on some flights.	Lower Equipment Bay (Fig.9"A")	3.8 cu ft	Cold plates available.
		Lower Equipment Bay (Fig 9"B")	0.6 cu ft	
		Right Equipment Bay (Fig. 9"C")	2.8 cu ft	
Command (Block II - LEM will be attached for all flights, orbital and lunar)	80 lbs (including containers)-Additional weight may be available on some flights.	Lower Equipment Bay (Fig. 10)	2 cu ft	Two 19"X11.5" containers to be utilized for returning lunar samples transferred from LEM; therefore not available for experiments on flights which land on moon.
			1 cu ft	Various small volumes; limited cold plates area may be available.
Service Module		No specific spaces reserved.		For experiments requiring no crew access nor recovery.

Module	Approximate Weight	Location	Volume	Remarks
Lunar Excursion Module	80 lbs capability in ascent stage	Ascent stage (Fig. 11)	2 cu ft	Will be utilized for **return** of lunar samples to be transferred to C/M. Therefore, this space is not available for experiments on flights which land on moon.
			1 cu ft	Various small volumes
Lunar Excursion Module (continued)	210 lbs capability in descent stage	Descent stage (Fig. 11)	15 cu ft	Approximate dimensions: 2'X2'X4'. Accessible to crewman operating on lunar surface - will be abandoned on moon or in space on non-lunar-landing flights.
	250 lbs total			

MANNED SPACE FLIGHT EXPERIMENTS BOARD PROPOSAL FOR IN-FLIGHT EXPERIMENT

TO: Executive Secretary	FROM:	
	SIGNATURE	DATE SIGNED

SECTION I. ORIGINATOR'S PROPOSAL

1. EXPERIMENT TITLE			1A. EXPERIMENT NO.
2. PROPOSAL ORIGINATOR			
3. EXPERIMENT COORDINATOR			
4. MISSION	5. TOTAL WEIGHT		6. TOTAL VOLUME
7. ASTRONAUT'S TIME REQUESTED	7A. PREFLIGHT	7B. IN-FLIGHT	7C. POSTFLIGHT
8. ELECTRICAL POWER REQUIREMENTS			
9. CONTROL FUEL REQUIREMENTS			

10. PURPOSE AND APPLICATION OF EXPERIMENT

11. DESCRIPTION OF EXPERIMENTAL PROCEDURE

12. DESCRIPTION OF EQUIPMENT AND SPACECRAFT MODIFICATIONS REQUIRED

NASA FORM 1067 MAR 64

13. DESCRIPTION OF EQUIPMENT DEVELOPMENT *(Give milestones and delivery dates)*

14. RESPONSIBILITY FOR DEVELOPMENT PROGRAM - ORGANIZATION AND FUNDING

15. DESCRIPTION OF THE EQUIPMENT QUALIFICATION PROGRAM

16. DESCRIPTION OF REQUIREMENTS ON THE ASTRONAUT *(Preflight, In-flight, Postflight, etc.)*

17. PREFLIGHT AND RECOVERY FACILITIES AND PROCEDURES REQUIRED

A. PREFLIGHT

B. RECOVERY

SECTION II. ACTION

18. ☐ APPROVED ☐ DISAPPROVED	19. MEETING NO.	20. DATE OF MEETING

21. REMARKS

22. SIGNATURE OF EXECUTIVE SECRETARY

NASA - Manned Spacecraft Center

PROPOSAL FOR FLIGHT EXPERIMENT

TO: Experiments Coordination Office	FROM:	Date

SECTION I. ORIGINATOR'S PROPOSAL

1. Experiment Title

2. Proposal Originator

3. Experiment Coordinator

4. Mission	5. Total Weight	6. Total Volume

7. Astronaut's Time Requested

In-flight	Preflight	Postflight

8. Electrical Power Requirements

9. Control Fuel Requirements

10. Purpose and Application of Experiment

11. Description of Experimental Procedure

12 Description of Equipment and Spacecraft Modifications Required

MSC Form 793A (Rev Jun 64)

13. Description of Equipment Development (Give milestones and delivery dates)

14. Responsibility for Development Program - Organization and Funding

15. Description of the Equipment Qualification Program

16. Description of Requirements on the Astronaut - Preflight, In-flight, Postflight

17. Preflight and Recovery Facilities and Procedures Required

I have read the instructions covering flight experimentation in MSC Management Instruction 37-1-1 and agree that, if this proposal is accepted, I will conform to these regulations.

(Signature) ______________________
Experiment Coordinator

GPO 881-921