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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO LUNAR EXPLORATION MISSIONS

(ALEM)

PROGRAM AND MISSION DEFINITION

NOVEMBER 1, 1969

ADVANCED MISSIONS PROGRAM OFFICE
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC FORM 2026A (REV MAY 68)

SPD-9P-052

NASA

National Aeronautics and Space Administration

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November 1, 1969

Contract NAS 9-8166

APOLLO

Manned Spacecraft Center
Houston, Texas

NASA

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PROGRAM AND MISSION DEFINITION

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for
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Manned Spacecraft Center
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ABSTRACT

PURPOSE

This document is the Manned Spacecraft Center plan for a program of Apollo lunar exploration. Its purposes are to present the plan for the program and to be a basic tool for mission design and control. Its companion document, the Apollo Lunar Exploration Missions (ALEM) Program Plan, provides the schedule and milestone control aspects of the program.

AUTHORITY

The authority for preparation of this plan was assigned to the Advanced Missions Program Office by MSC announcement 69-61*. This plan has been completed and the responsibility for its implementation was transferred to the Apollo Spacecraft Program Office by MSC announcement 69-138*.

As the MSC approved plan for the Apollo Lunar Exploration Program, this document is controlled by the Apollo Configuration Control Board (CCB). At the time that a Mission Requirements (MR) document is issued for a particular mission, approximately nine months prior to launch, the data contained herein pertinent to that mission assumes an information only status and the MR becomes the planning authority for that mission.

The program described here was developed through MSC and contractor efforts with the approval of the Office of Manned Space Flight. With certain exceptions, the NASA is fully committed to performing this program. Those committments that are not yet fully approved are noted by dashed lines (≡) in margins of the text and by shading ( ) in the appropriate areas of the tables. The material contained within the appendices is provided as supporting information and not as a part of the approved plan.

REVISIONS

Revisions to this document will be issued on an "as required" basis in order to keep it current. Correspondence concerning such changes should be addressed to the Apollo Spacecraft Program Office, Code PD12.

*Reference Appendix F MSC Announcements

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NOMENCLATURE

AES	Advanced Extravehicular Suit
AFMAD	Apollo Flight Mission Assignments Directive
AGS	Abort Guidance System
ALEM	Apollo Lunar Exploration Missions
ALEP	Apollo Lunar Exploration Program
ALSEP	Apollo Lunar Surface Experiment Package
AM	Amplitude Modulation
C	Crater
CCB	Configuration Control Board (Apollo)
CDR	Commander
CFE	Contractor Furnished Equipment
CM	Command Module
CSM	Command and Service Module
CWEA	Caution and Warning Electronics Assembly
DECA	Descent Engine Control Assembly
DPS	Descent Propulsion System
DSE	Data Storage Equipment
EASEP	Early Apollo Scientific Experiment Package
ECA	Electronic Control Assembly
ECG	Electro-cardiograph
ECS	Environmental Control System
ED	Explosive Device(s)
EEG	Electro-encephalograph
EM	Electromagnetic
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
ESS	Emplaced Science Station
EV	Extravehicular
EVA	Extravehicular Activity
EVCS	Extravehicular Communications System
FM	Formation (lunar surface); Frequency Modulation
GFE	Government Furnished Equipment
GLEP	Group for Lunar Exploration Planning

NOMENCLATURE (CONTINUED)

GNCS	Guidance, Navigation and Control System
GOX	Gaseous Oxygen
HFE	Heat Flow Experiment
HGA	High Gain Antenna
IMP	Interplanetary Monitoring Probe
IMU	Inertial Measurement Unit
IR	Infrared
KSC	John F. Kennedy Space Center
LAC	Lunar Aeronautical Chart
LiOH	Lithium Hydroxide
LM	Lunar Module
LMDE	Lunar Module Descent Engine
LMP	Lunar Module Pilot
LO	Lunar Orbit
LOI	Lunar Orbit Insertion
LOPC	Lunar Orbit Plane Change
LPD	Landing Point Designator
LR^3	Laser Ranging Retroreflector
LRV	Lunar Roving Vehicle
LSM	Lunar Surface Magnetometer
LSS	Life Support System
LV	Launch Vehicle
MCC	Mission Control Center
MESA	Modularized Equipment Stowage Assembly
MPAD	Mission Planning and Analysis Division
MR	Mission Requirements
MSC	Manned Spacecraft Center
MSFN	Manned Spaceflight Network
MSL	Mapping Sciences Laboratory
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NR	North American-Rockwell
OPS	Oxygen Purge System
P	Peak (lunar surface)

NOMENCLATURE (CONTINUED)

PCM	Pulse Code Modulation
PDI	Powered Descent Initiation
PLSS	Portable Life Support System
PSE	Passive Seismic Experiment
RCS	Reaction Control System
RCU	Remote Control Unit
RF	Radio Frequency
RSS	Root-sum-square
SCEA	Signal Conditioning Electronic Assembly
SCS	Stabilization and Control Subsystem
SEA	Sun Elevation Angle
SEQ	Science Equipment
SHe	Supercritical Helium
SIDE	Suprathermal Ion Detector Experiment
SIM	Scientific Instrument Module
SLA	Spacecraft LM Adapter
SLSS	Secondary Life Support System
SM	Service Module
SODB	Spacecraft Operational Data Book
SPS	Service Propulsion System
SRC	Sample Return Container
SV	Saturn V
SWE	Solar Wind Experiment
TBD	To Be Determined
TEI	Transearth Injection
TLI	Translunar Injection
TV	Television
UV	Ultraviolet
VCO	Voltage Controlled Oscillator
VHF	Very High Frequency

1. SUMMARY CHARTS

The following tables and figures present a capsule view of program goals and objectives, mission assignments, and equipment modifications. The details from which these data were derived are presented in the succeeding sections.

Table 1-1. Goals and Objectives in Lunar Exploration

GOALS

- Extend man's capability to operate in space, advance man's knowledge of the universe and use this knowledge for man's benefit
- Make effective use of Apollo equipment toward achievement of the Lunar Program objectives and of the overall NASA goal of maintaining preeminence in space.

SCIENTIFIC OBJECTIVES

- Investigate the major classes of lunar surface features (mare and highlands).
- Investigate surface processes (impact, volcanism, mountain building).
- Investigate regional problems (mare-highland relation, major basins and valleys, volcanic provinces, major faults, sinuous rilles).
- Collect samples at each landing site for detailed analysis on earth.
- Establish surface instrumentation to measure seismic activity, heat flow and disturbance in the Moon's axis of rotation for determination of the gross structure, processes and energy budget of the lunar interior.
- Survey and measure as much as possible of the lunar surface from lunar orbit with high-resolution photography and remote sensing.

Table 1-1. Goals and Objectives in Lunar Exploration (Continued)

SCIENTIFIC OBJECTIVES (continued)

- Investigate the near-Moon environment and the interaction of the Moon with the solar wind.
- Map the lunar gravitational field and any internally produced magnetic field.
- Detect atmospheric components resulting from neutralized solar wind and micrometeorite impacts.

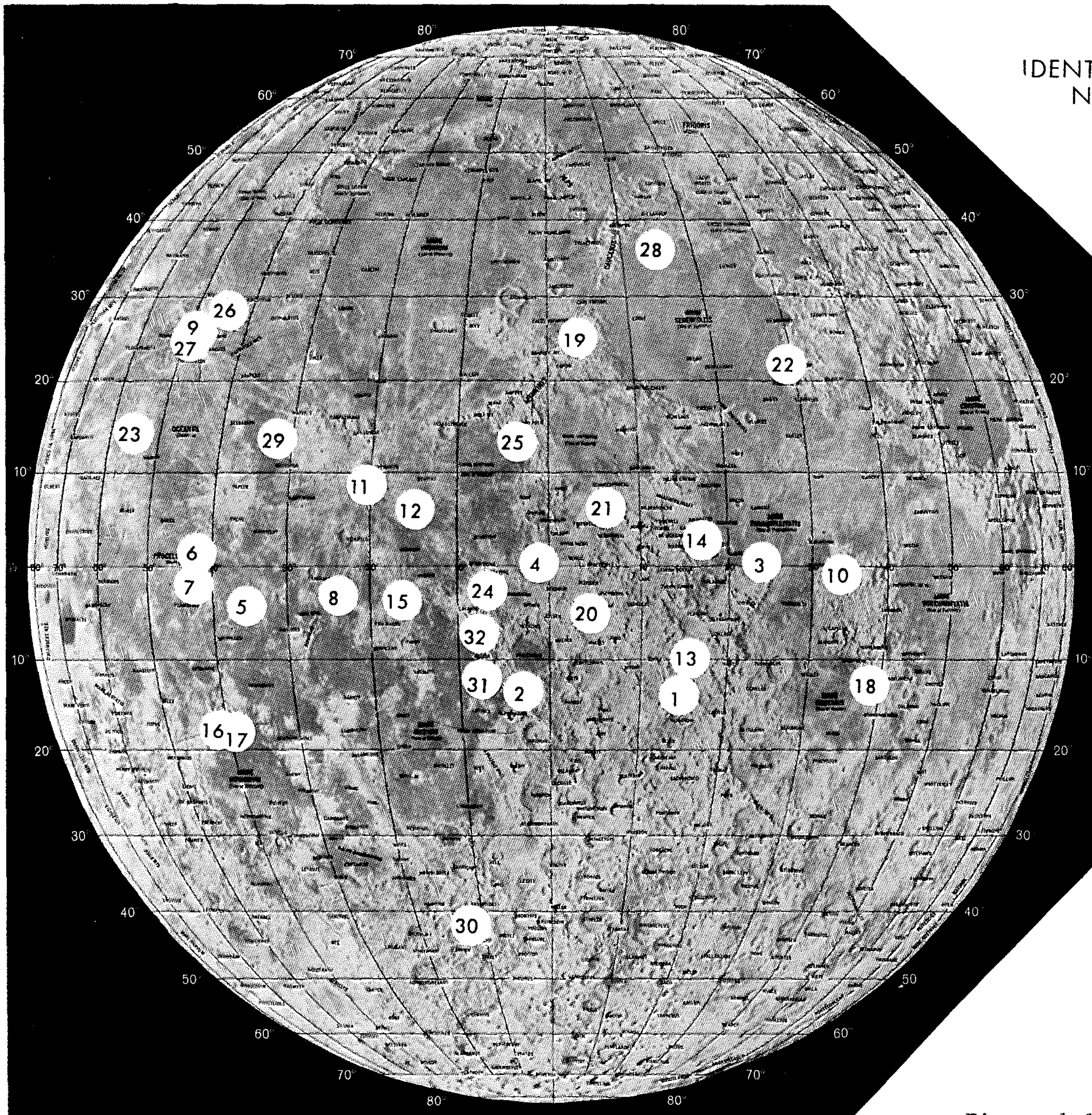
TECHNOLOGICAL OBJECTIVES

- Increase scientific payload to lunar orbit and to the lunar surface.
- Enable high flexibility in landing site selection.
- Increase lunar orbit and surface staytime.
- Increase lunar surface mobility by development of a self-propelled vehicle.
- Develop and demonstrate advanced techniques and hardware for expanded manned space mission capabilities.
- Develop techniques for achieving point landings.
- Develop a base of physical data about the lunar surface which can be used for design of future lunar surface hardware.
- Investigate techniques for real time assessment and certification of landing sites.

Table 1-2. Apollo Lunar Exploration Assignments

1 NOVEMBER 1969

MISSION TYPE			APOLLO LUNAR LANDING	H SERIES MISSIONS				J SERIES MISSIONS				
			APOLLO 11 (G)	APOLLO 12 (H1)	APOLLO 13 (H2)	APOLLO 14 (H3)	APOLLO 15 (H4)	APOLLO 16 (J1)	APOLLO 17 (J2)	APOLLO 18 (J3)	APOLLO 19 (J4)	APOLLO 20 (J5)
LAUNCH READINESS			7/69	11 OR 12/69	3 OR 4/70	7 OR 8/70	10 OR 11/70	3 OR 4/71	7 OR 8/71	2 OR 3/72	7 OR 8/72	2 OR 3/73
CANDIDATE LANDING SITE	PRIME		APOLLO 2	APOLLO 7	FRA MAURO FM	LITTROW	CENSORINUS	DESCARTES	MARIUS HILLS	COPERNICUS	HADLEY	TYCHO
	ALTERNATE			NONE	HYGINUS	NONE	FRA MAURO FM	CENSORINUS	NONE	DAVY RILLE	NONE	COPERNICUS
	RECYCLE		APOLLO 2,3,5	APOLLO 5	APOLLO 6R	APOLLO 6R	APOLLO 6R	APOLLO 6R	NONE	APOLLO 6R	TBD	APOLLO 6R
SUMMARY OF PRIMARY OBJECTIVES	SCIENTIFIC			SELEONOLOGICAL SURVEY AND SAMPLING (MARE) ALSEP DEPLOYMENT	SELENOLOGICAL SURVEY AND SAMPLING ALSEP DEPLOYMENT	SELENOLOGICAL SURVEY AND SAMPLING (HIGH-LANDS) ALSEP DEPLOYMENT	SELENOLOGICAL SURVEY AND SAMPLING ALSEP DEPLOYMENT	SELENOLOGICAL SURVEY AND SCIENCE ACTIVITY SURFACE EXPERIMENT DEPLOYMENT LUNAR ORBITAL SCIENCE SURVEY	SELENOLOGICAL SURVEY AND SCIENCE ACTIVITY SURFACE EXPERIMENT DEPLOYMENT LUNAR ORBITAL SCIENCE SURVEY	SELENOLOGICAL SURVEY AND SCIENCE ACTIVITY SURFACE EXPERIMENT DEPLOYMENT LUNAR ORBITAL SCIENCE SURVEY	SELENOLOGICAL SURVEY AND SCIENCE ACTIVITY SURFACE EXPERIMENT DEPLOYMENT LUNAR ORBITAL SCIENCE SURVEY	SELENOLOGICAL SURVEY AND SCIENCE ACTIVITY SURFACE EXPERIMENT DEPLOYMENT LUNAR ORBITAL SCIENCE SURVEY
	TECHNOLOGICAL		MANNED LUNAR LANDING AND RETURN	POINT LANDING DEVELOPMENT SURFACE EVA ASSESSMENT	POINT LANDING EVALUATION SURFACE EVA ASSESSMENT			DEMONSTRATE CAPABILITIES OF THE SIM AND MODIFIED LM, CSM, AND EVA EQUIPMENT				
	BOOTSTRAP PHOTOGRAPHY			LALANDE, FRA MAURO, DESCARTES	CENSORINUS	HADLEY	DAVY RILLE	DAVY RILLE	COPERNICUS	NONE	NONE	NONE
BASIC HARDWARE CONFIGURATION	SPACE VEHICLE SERIAL NO.	SATURN V	506	507	508	509	510	511	512	513	514	515
		CSM	107	108	109	110	111	112	113	114	115	115A
		LM	5	6	7	8	9	10	11	12	13	14
	SPACECRAFT TYPE	CSM	←		STANDARD BLOCK II		→	←		MODIFIED BLOCK II		→
		LM	←		STANDARD		→	←		MODIFIED		→
	EXTRAVEHICULAR	SUIT/PRIMARY LSS	←		A7L/6 PLSS		→	←	→	SURFACE: A7L-B/-7 PLSS ORBITAL: A7L-B/SLSS	←	→
		BACKUP LSS	←		OPS		→	←	→	SURFACE SLSS ORBITAL UMBILICAL	←	→
		COMMUNICATION	←		STANDARD		→	←		VOICE AND TV RELAY		→
	PAYLOAD	ORBITAL INSTRUMENTS LOCATION	←		CM MOUNTED		→	←		CM & SIM		→
		SIM DATA LINK	←		NOT REQUIRED		→	CURRENT SYSTEM	←	EXPANDED DATA SYSTEM		→
		SURFACE	EASEP	ALSEP ARRAY A	ALSEP ARRAY B	ALSEP ARRAY C	ALSEP ARRAY A-2	ALSEP ARRAY D	←	ROVER AND EMPLACED SCIENCE		→
MISSION PROFILE	TRANSLUNAR TRAJECTORY TYPE		FREE RETURN	←	FREE RETURN OR HYBRID		→	←		HYBRID		→
	LM SEPARATION ORBIT ALT (N MI)		← 60 X 60	→	←			60 X 8				→
	LANDING ACCURACY (99% CONF)(KM)		±6.5 X 2.6	±2.9 X 1.9	±1.9 X 1.9	←		POINT LANDING (< 1.0KM)(GOAL)				→
	LUNAR SURFACE STAYTIME (HR)		UP TO 22	← UP TO 32 →	←	UP TO 35	→	←		UP TO 62		→
	SIM OPERATIONAL TIME (HR)		←		NOT APPLICABLE		→	←			57 - 77	→
EVA	LUNAR SURFACE	NUMBER	1	2	2	2	2	3	3	3	3	3
		MAXIMUM RADIUS (KM)	UP TO 0.1	UP TO 0.5	←	UP TO 1.0	→	UP TO 4.0 KM (1:00 HR SCIENCE TIME & 4KM/HR TRAVERSE RATE)	UP TO 9.5KM (1:00 HR SCIENCE TIME & 5KM/HR TRAVERSE RATE)	UP TO 9.5KM (1:00 HR SCIENCE TIME & 5KM/HR TRAVERSE RATE)	UP TO 9.5KM (1:00 HR SCIENCE TIME & 5KM/HR TRAVERSE RATE)	UP TO 9.5KM (1:00 HR SCIENCE TIME & 5KM HR TRAVERSE RATE)
		DURATION (HR:MIN) (DEP TO REP)	2:40	←	3:30 AT 1250 BTU/HR		→	←		4:30 AT 1250 BTU/HR		→
		MAXIMUM MANHOURS	5:20	←	14:00		→	←		27:00		→
	L.O.	SIM DATA RETRIEVAL	←		NOT APPLICABLE		→	←		YES		→



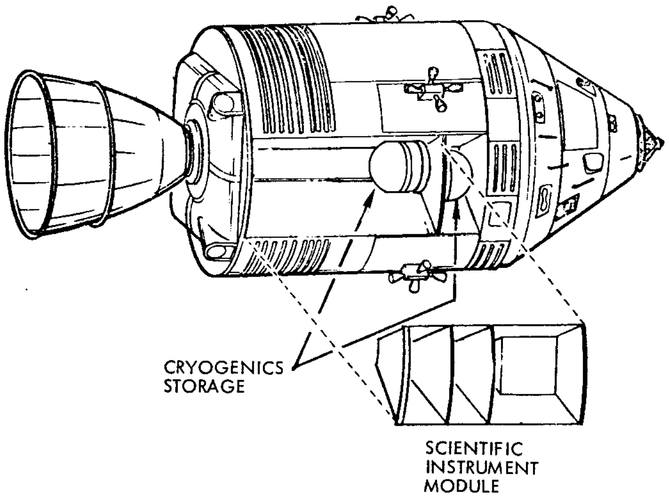
SITE IDENTIFICATION NUMBER

1	ABULFEDA
2	ALPHONSUS
3*	APOLLO 2
4	APOLLO 3
5	APOLLO 4
6***	APOLLO 5
7***	APOLLO 6R (FLAMSTEED P)
8*	APOLLO 7
9	ARISTARCHUS PLATEAU
10*	NORTHWEST OF CENSORINUS
11*	COPERNICUS PEAKS
12	COPERNICUS CD
13*	DESCARTES
14	DIONYSIUS
15*	FRA MAURO FM
16	GASSENDI (WEST)
17	GASSENDI (EAST)
18	GAUDIBERT A
19*	HADLEY RILLE
20	HIPPARCHUS
21**	HYGINUS
22*	LITTROW AREA
23*	MARIUS HILLS
24	MÖSTING C
25	RIMA BODE II
26	RIMA PRINZ I
27	SCHRÖTER'S VALLEY
28	SOUTH OF ALEXANDER
29	TOBIAS MAYER
30*	NORTH OF TYCHO
31**	DAVY RILLE
32**	LALANDE

*PRIME SITE
**ALTERNATE SITE
***RECYCLE SITE

Figure 1-1. Candidate Lunar Exploration Sites

COMMAND AND SERVICE MODULE MODIFICATIONS
(Effective CSM 112)



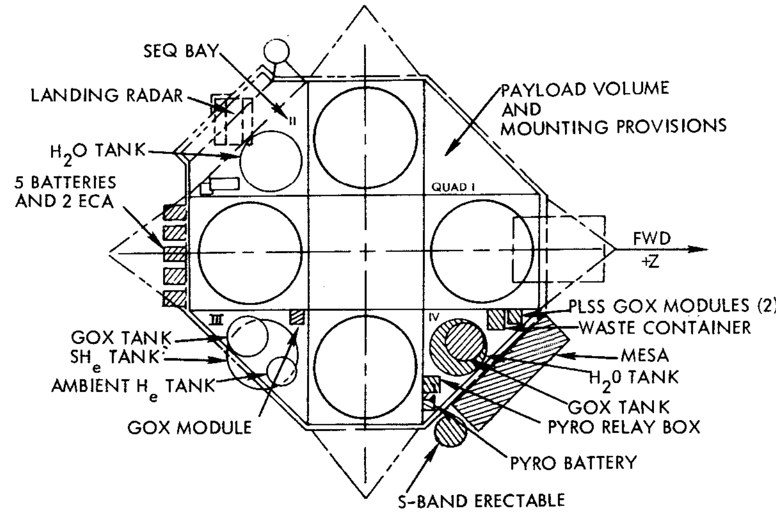
<u>FOR INCREASED MISSION FLEXIBILITY</u>

- ADDITIONAL CRYOGENICS (ONE O_2 AND ONE H_2 TANK)
- DISPLAYS- CONTROLS AND WIRE HARNESS FOR CRYOS
- ADDITIONAL STOWAGE CAPABILITY
  - CM SCIENCE EXPERIMENTS
  - CM MEDICAL EXPERIMENTS
  - CREW CONSUMABLES- SUPPLIES AND GARMENTS

<u>FOR SCIENCE PAYLOAD</u>

- SCIENTIFIC INSTRUMENT MODULE (SIM)
- JETTISONABLE SIM DOOR
- INSTRUMENT DEPLOYMENT MECHANISM
- WIRE HARNESS (CSM UMBILICAL TO SIM)
- DISPLAYS AND CONTROLS FOR INSTRUMENTS
- RETURN DATA STOWAGE (FILM ETC)
- EVA CAPABILITY TO SM
- EXPANDED DATA SYSTEM (CSM 113 AND SUBS)

LUNAR MODULE MODIFICATIONS
(Effective LM-10)



<u>FOR INCREASED MISSION FLEXIBILITY</u>

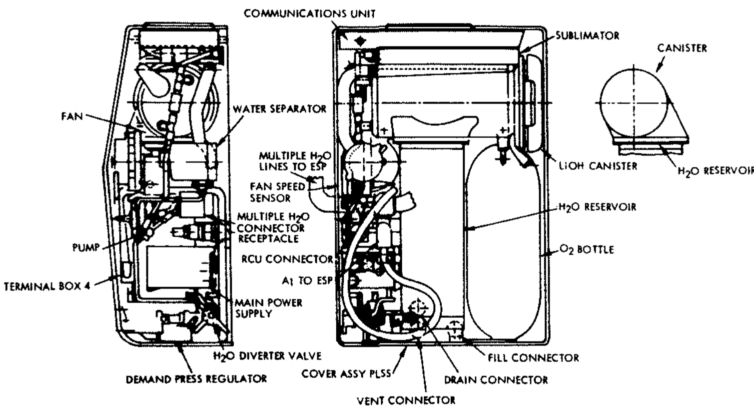
- IMPROVED PROPULSION
  - LARGER DESCENT TANKS
  - INCREASED SHe STANDBY TIME
- FIVE DESCENT BATTERIES
- ADDITIONAL CONSUMABLES
  - H_2O, FOOD, O_2, LiOH
- IMPROVED CABIN HABITABILITY
  - SUITABLE ENVIRONMENT
  - URINE AND PLSS CONDENSATE WASTE MGMT SYSTEM
  - EXPENDABLES
  - MODULARIZED STOWAGE
- IMPROVED LANDING CAPABILITY
  - GUIDANCE & NAVIGATION SOFTWARE CHANGES

<u>FOR SCIENCE PAYLOAD</u>

- OPEN QUADRANT IN DESCENT STAGE FOR LRV OR OTHER PAYLOAD
- LARGER, REDESIGNED MESA
- THIRD SAMPLE RETURN CONTAINER

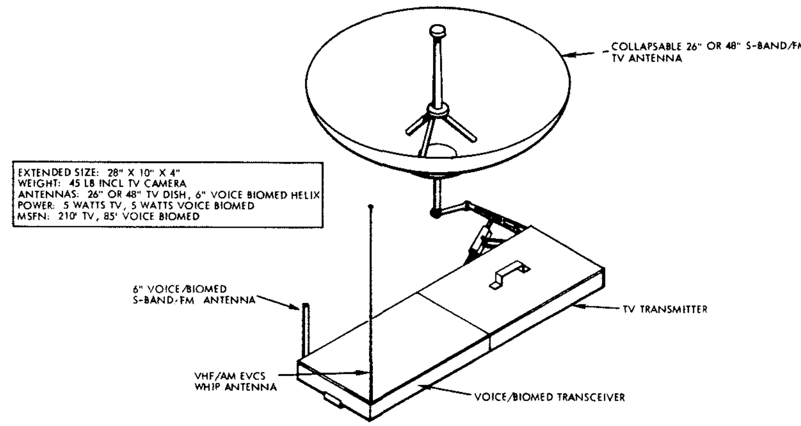
Figure 1-2. Basic CSM and LM Improvements

MODIFIED (-7) PORTABLE LIFE SUPPORT SYSTEM (PLSS)

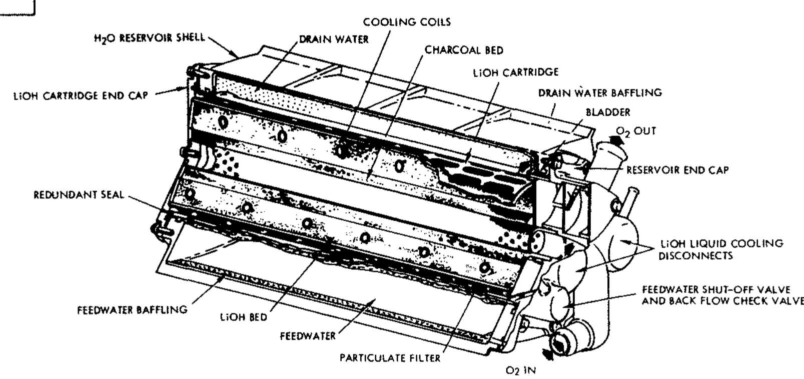


INCREASE BTU CAPACITY FROM 4800 TO 6000
CO_2 SENSOR ADDED (EFFECTIVE MISSION H2)
O_2 CHARGE PRESSURE INCREASED FROM 1020 TO 1380 PSIA
O_2 CAPACITY INCREASED FROM 1.16 TO 1.78 LB
H_2O CAPACITY INCREASED FROM 8 TO 11.8 LB
H_2O QUANTITY SENSING MONITOR ADDED

DEPLOYED EVCS-EARTH COMMUNICATIONS RELAY UNIT



SECONDARY LIFE SUPPORT SYSTEM (SLSS)



2400 BTU CAPACITY
LIQUID COOLING
RECHARGEABLE H_2O
60-LB WEIGHT
SAME MOUNTING INTERFACES AS OPS
NEW H_2O INTERFACE

Figure 1-3. Advanced Extravehicular Activity Components

2. SCIENTIFIC OBJECTIVES IN LUNAR EXPLORATION

2.1 LUNAR EXPLORATION TO DATE

Prior to the inception of the Apollo Lunar Exploration Program, considerable information regarding the nature of the moon was obtained from telescopic observations and from programs such as Ranger, Surveyor, Lunar Orbiter, Luna, Anchored IMP, and Apollo missions 8, 10 and 11.

The Ranger and Lunar Orbiter Programs have increased photographic resolution to 150 to 500 feet on the near side and 150 to 1500 feet on the far side. Detailed views of selected sights have resolution to three feet. Surveyor and Luna Programs indicated a basalt-like composition for the mare. Data from Luna II indicated that any lunar magnetic field must be less than 1/10,000th that of the Earth. Data from Anchored IMP (Explorer 35) suggests a surface magnetic field of even less strength.

By tracking spacecraft in lunar orbit, the lunar orientation and rates of change and the physical librations are now known to about 650 feet.

Tracking data from the Lunar Orbiter series and Apollo missions indicate the presence of mass concentrations in the moon and/or variations in its shape. These anomalies arouse curiosity regarding their origin and since their distribution is not well known they pose operational problems (trajectory perturbations) for low orbital altitudes.

Finally, the Apollo 11 mission has demonstrated that man can readily adapt to and work effectively in the lunar environment. Samples of lunar material have been returned to Earth for analysis and a passive seismic experiment and laser retroreflector were emplaced on the Moon for monitoring from the Earth.

More detailed information about the moon and its exploration can be obtained from References 1 through 4.

2.2 APOLLO LUNAR EXPLORATION

The Apollo Lunar Exploration Program will initially use existing Apollo capability. This capability will be augmented with new developments (see Section 3) which will increase the payload delivered to lunar orbit and to the lunar surface, enable high flexibility in landing site selection, and increase the stay time and mobility on the lunar surface. The preferred landing sites for the Apollo Lunar Exploration Program are shown in Figure 1-1, page 1-5, and are described in detail in Section 5, page 5-1. The salient features of the program are summarized in Table 1-2, page 1-3.

The broad objectives of the Apollo Lunar Exploration Program are:

- To understand the Moon in terms of its origin and evolution
- To search its surface for evidence related to the origin of life
- To apply new data on the differences and similarities between the Earth and Moon to the reasonable prediction of dynamic processes that shape our planet.

The specific objectives supporting these broad objectives are as follows:

- Investigate (a) the mare and highland lunar surface features, (b) the impact, volcanic, and mountain-building surface processes, and (c) the regional problems such as mare-highland relation, the major basins and valleys, the volcanic provinces, the major faults, and the sinuous rilles.
- Collect and completely characterize lunar material samples by detailed analysis on Earth, including rock identification, chemical composition and rock dating.
- Determine the gross structure, processes and energy budget of the lunar interior by measuring seismic activity, heat flow, and disturbance in the Moon's axis of rotation with long-lived surface instrumentation.
- Survey and measure the lunar surface from orbit about the Moon with metric and high resolution photography and remote sensing, tying together local studies into a regional framework. Provide detailed information for science planning of surface missions, and lunar-wide control of surface position and profile.
- Investigate the near-Moon environment and the interaction of the Moon with the solar wind; map the gravitational field and any internally produced magnetic fields; and detect atmospheric components resulting from the neutralized solar wind and micro-meteorite flux-impact effects by long-term monitoring with lunar orbiting satellites.

- Return uncontaminated samples to Earth for analysis of biologically related organics, such as prebiotic material, fossil life forms, and micro-organisms, and determine their origin; conduct in-situ analyses of lunar samples for biological material; and relate these data to a comprehensive theory on the origin of life by comparison with the Earth and planets.

- Determine how geologic processes work on the Moon in the absence of an atmosphere, fully exposed to the solar wind and with one-sixth the force of gravity, in order to gain a much deeper understanding of the dynamic processes that shape our terrestrial environment.

2.3 POST-APOLLO LUNAR PROGRAM

According to present plans, the completion of the current Apollo missions would come in 1972 or 1973. In 1978, a space station module would be placed into lunar polar orbit by a reusable nuclear stage. A new landing vehicle, the space tug, would permit continuing manned sorties to any part of the lunar surface for mission durations of up to 14 days with an emergency capability for an additional 14 days. This vehicle would make possible lunar rescue capability. Resupply and crew rotation from earth would be accomplished by using the space shuttle for transportation between the Earth and Earth orbit and by using the nuclear shuttle to transport the space tug between Earth orbit and lunar orbit. In 1980, a space station module would be landed as part of the first permanent lunar base. By 1984, there would be a 25-man lunar orbital base in operation and by 1986, a 50-man surface base. The nuclear stage, the space tug, and the Earth-to-orbit shuttle would provide low cost logistics support to both orbital and surface lunar activities.

3. APOLLO LUNAR EXPLORATION EQUIPMENT

This section provides a description of the equipment which will be used to fulfill the goals and objectives of the Apollo Lunar Exploration Program. The missions of the program have been grouped according to similarities which exist in equipment configuration and mission profile in the following manner:

Mission Type	CSM Configuration	LM Configuration	Mission Category	Mission Designation
G	Standard Block II	Standard	First Lunar Landing	Apollo 11
H	Standard Block II	Standard	Lunar Surface Science	Apollo 12 - 15
J	Modified Block II	Modified LM	Lunar Surface and Orbital Science	Apollo 16 - 20

Current program plans call for one G-type mission, four H-type missions, and five J-type missions.

3.1 COMMAND SERVICE MODULE

To support extended lunar surface exploration and perform lunar orbital surveys, CSM's serial 112 and subsequent are to be modified (see Figure 1-2, page 1-6, and Reference 5) to satisfy the following mission requirements:

- To provide the capability for flight missions up to 16 days total duration
- To deliver a heavy weight LM (up to 36,000 pounds manned) to a 60 x 8 nautical mile lunar orbit

- To provide the capability to carry and operate a scientific instrument payload through the addition of a general purpose scientific instrument module (SIM) with interfacing subsystem modifications, including EVA recovery of stored SIM data

The general design approach used was as follows:

- No compromise to the basic lunar mission capability
- CSM safety and reliability are not degraded by the modifications
- Minimum numbers of CSM hardware and procedural changes
- Basic provisions are the same for all vehicles
- Maximum utilization of existing Apollo qualified hardware
- Qualification for modified CSM's only to be accomplished on new or major modified hardware items
- Subsystem modifications are "add-on" types (SM modifications will be made only to bay I except in select cases and to the CM only in localized areas)
- Experiments are normally installed prior to CSM shipment to KSC (but could be installed later in the flow)

Specifically, the CSM modifications for increased mission flexibility and duration are as follows (see Figure 1-2, page 1-6):

- Provide 50 percent additional cryogenic storage capability - one H_2 and one O_2 tank
- Add controls and displays for cryogenics management
- Add a wiring harness for cryogenics management
- Provide additional stowage capability in the CM for the following items:
  - Up to three sample return containers
  - CM science experiments
  - CM medical experiments
  - Crew supplies and consumables
  - Returned data such as film cassettes
- Provide additional housekeeping equipment and supplies

The incorporation of the Scientific Instrument Module (SIM) requires that the following CSM additions be made:

- A pyrotechnically jettisonable door for the SIM. The jettison velocity will be great enough to deorbit the door from a 60 x 60 n mi circular orbit (approximately 85 fps)*
- Individual instrument deployment mechanisms as required
- A wire harness from the CSM umbilical to the SIM
- Displays and controls for scientific instruments
- EVA provision for data retrieval from lunar mapping camera, panoramic camera, and solar wind mass spectrometer
  - SLSS for primary life support and umbilical for backup
  - Umbilical for primary communications and biomed instrumentation
  - Handrails on CM and SM
  - Body restraint provisions
  - Natural lighting
  - Provisions for data or equipment transfer to the CM
- Additional housekeeping equipment and supplies
- Expanded data system for experimental data, thermal measurements on SIM structure and experiment equipment and cryogenic measurements
  - DSE modified to provide one hour recording time
  - One to one dump speed, transmit real time and recorded data simultaneously
  - New PCM
  - New 50 input multiplexer in SIM interfacing with existing PCM analog channel
  - New modulator package containing three VCO's for recording, three for real time and one for tape speed monitoring signal
  - All inputs will utilize the existing RF multiplexer and HGA

*Individual ports in the SIM door will be provided for experiments that are to be operated prior to CSM/LM rendezvous.

3.2 LUNAR MODULE

The first five missions will utilize standard Apollo configuration LM's (LM-5 through LM-9). LM-10 and subsequent will be modified to provide increased capability for lunar exploration. The design requirements for these advanced lunar modules are as follows:

- Maintain the existing structural factors of safety
- Configure the system for a nominal lunar stay time of up to 62 hours. Note: All planned consumables capacity except electrical power will support a stay time of up to at least 78 hours.
- Provide one descent stage corner quadrant and SEQ bay for payload stowage
- Increase the descent and ascent stage stowage facilities
- Provide suitable crew facilities for mission requirements
- Improve the liquid waste management system
- Provide a suitable ascent stage cabin environment
- Accomplish necessary guidance software modifications to increase landing accuracy and the capability to descend over rough terrain

In order to accomplish this expanded LM capability, the following modifications will be made (see Figure 1-2, page 1-6, and Reference 6):

- Propulsion:
  - Increase the length of the cylindrical section of the descent propellant tanks by 3.36 inches maintaining the current hemispherical domes (increases usable propellant by 1140 pounds)
  - Increase the supercritical helium pressurization standby time to 190 hours by adding a controlled vent bleed assembly
  - Remove the 16 RCS thrust chamber isolation valves (reduces weight by 25 pounds)
  - Remove the descent propulsion tank balance lines (reduces weight by 40 pounds)
- Consumables and stowage:
  - Open quadrant I for payload stowage and provide mounting provisions for either a lunar roving vehicle (LRV) or other payload
  - Provide a redesigned, larger modularized equipment stowage assembly (MESA) on the descent stage that includes palletized stowage for one-day consumables packages (sufficient consumables capacity for a 78-hour surface stay)

- Add one descent stage battery and mount all five batteries on -Z bulkhead cold rails (allows up to 62 hours of surface stay time)
- Add one each GOX and H_2O tank to provide the capability to support a 78-hour surface stay
- Provide a new PLSS oxygen pressurization module which will increase the pressurization level from 980 to 1380 psia to support extended EVA operations (increases total PLSS O_2 recharge capacity from 0.92 to 1.78 pounds) and maintain the present control module to provide redundancy
- Rearrange and modularize crew provisions stowage for easier access and pre-packing
- (An access door may be installed in the spacecraft LM adapter (SLA) to permit site specific reconfiguring of the science payload in the LM SEQ bay)

- Crew habitability:

  - Add a urine and PLSS condensate waste management system for extended stay times
  - Add insulation to the area of the docking tunnel to limit cabin temperature
  - Add crew expendables
  - Rework the umbilical to provide independent connections for communications, liquid cooling and oxygen

- Ascent stage structure:

  - Strengthen the mid-section deck for a third sample return container
  - Add support fittings for modularized stowage assemblies
  - Add support fittings for the fecal receptacle on the ascent engine cover
  - Add pressure shell penetrations for waste management and PLSS O_2 recharge lines

- Descent stage structure:

  - Redesign the descent stage structure to accommodate the larger propellant tanks
  - Provide battery supports on the -Z bulkhead
  - Provide a MESA support structure and deployment mechanism in quadrant IV
  - Provide scientific payload support and deployment mechanism interfaces in quadrant I for a rover and/or scientific payload (Support and deployment mechanism interface for an ALSEP-type payload will be retained in quadrant II)

- Revise and add fluid and electrical line runs
- Relocate the explosive devices relay box, pyro battery and GOX control module
- Modify the RCS plume deflectors and reduce exterior insulation to reduce weight
- Add support structure for the new H_2O and GOX tanks and for the waste management container

- Displays, controls and instrumentation: modify the displays controls, instrumentation and wiring to support the above changes

- Guidance: improve landing accuracy and the ability to land over rough terrain by guidance software changes including:

  - The addition of the capability to update the location of the landing point
  - The provision of a landing radar signal prefilter to smooth the results of the lurain variations
  - The addition of "delta guidance" to improve efficiency of powered descent

3.3 EXTRAVEHICULAR MOBILITY UNIT (EMU)

3.3.1 Life Support Systems

The first five missions of the program will utilize the standard (-6 configuration) portable life support system (PLSS) and the oxygen purge system (OPS). The last five missions will use a modified (-7) PLSS and a secondary life support system (SLSS) (Figure 1-3, page 1-7).

The capabilities of these life support systems are as follows:

Life Support System	Metabolic Rating	Operating Time Limit
-6 PLSS	4800 BTU	Battery; 6.25 hours
-7 PLSS	6000 BTU	Battery; 6.25 hours
SLSS	2400 BTU	Battery; 2.0 hours
OPS	Not Applicable	30 minutes*

The modifications to the -6 PLSS are:

- The addition of a CO_2 sensor at the LiOH outlet to provide a warning of canister failure and of CO_2 accumulation. This modification will be effective on the Apollo 13 and subsequent missions
- Increased charge pressure and capabity of O_2. The minimum charge pressure would be increased to 1382 psia for an O_2 quantity of 1.78 pounds, as opposed to the current values of 1020 psia and 1.16 pounds
- Increased H_2O capacity from 8.5 to 11.8 pounds by changing the tank end domes to volumetric rather than structural efficiency. This change will require a dry launch of the PLSS and a water charge prior to use to minimize launch and abort weight penalties
- Addition of a water quantity sensing monitor to provide more accurate knowledge of PLSS state and crew condition

The secondary life support system will be a small version of the PLSS using existing components where possible and repackaging them into a smaller volume. It will weigh 60 pounds and will meet the same mounting interfaces and occupy the same volume as the OPS. It will furnish liquid cooling to the astronaut and may be recharged with water to furnish an additional 800 BTU of metabolic capacity. This additional capacity may be used for contingency transfer from the LM to the CM or

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* The OPS is assumed to be limited to 30 minutes since it operates at the fixed O_2 flow rate of 8 pounds per hour.

for orbital EVA following docking. The SLSS does not provide variable rate cooling, communications, telemetry or crew displays.

3.3.2 Spacesuit

For Apollo missions types H1 through H4, astronauts will use the current A7L model spacesuit.

For the subsequent missions, there will be modifications to the A7L suit to improve mobility and visibility. This suit is designated the A7L-B. These modifications are as follows (see Reference 7):

- Addition of a joint in the neck area to improve neck mobility and downward visibility

- Addition of a bellows joint in the waist to allow forward bending mobility

- Movement of the torso zipper from the crotch to the chest area will be necessitated by the addition of the waist joint. This will result in better leg mobility

- Modification of the shoulder area to reduce the torque requirement for shoulder movement

- Addition of a thumb joint for greater grasping ability

- Enlargement of the wrist ring to permit easier and faster glove donning and doffing

An advanced extravehicular suit (AES) with dynamic bearings at the major body joints is under development as a backup for the A7L-B suit. Such a suit would allow almost total body mobility, reduced leakage and helmet distortion, improved visibility, and easier donning and doffing.

3.4 LUNAR SURFACE COMMUNICATIONS

The capability of the LM to operate as a communications relay during extended traverses may be limited in some cases by the effects of local terrain variations between the LM and the EVA astronauts. In addition, there are requirements for television coverage of certain portions of these traverses. In order to provide the capability for full-time voice and biomedical data coverage as well as for remote TV, a portable relay system for direct to earth communications is being developed. Availability of this relay is such that the first operational unit will be available for use on the Apollo 16 mission (J1). The salient features of this unit are as follows (see Figure 1-3, page 1-7):

- Size: 10 X 28 X 4 inches (deployed)
- Weight: 45 pounds including TV camera
- TV antenna: collapsable 26 or 48 inch dish, approximately 16° or 8°, beamwidth, and stowable to 30 X 8 inches for traverse
- Voice/biomed antenna: 6 inch helix, ±60° beamwidth
- Transmitter power: 5 Watts voice/biomed, 5 Watts TV
- Thermal control: Passive radiation, 140 sq. inch for VHF and biomed and 140 sq. inch for TV
- Operating time: 5 hours voice/biomed, 2 hours TV
- Power: replaceable, modified PLSS type battery (28 V. tap for S-band and 18 V. tap for VHF)
- Redundancy: 2 each VHF/AM transmitters and receivers for EVCS link; high and low power S-band/FM transmitters switchable to 6-inch helix
- Planned S-band frequencies: 2277.5 mHz down, voice/biomed; 2250.5 mHz down, TV; 2101.8 mHz up
- MSFN antennas: 85 foot, voice/biomed; 210 foot, TV

3.5 LUNAR ORBIT EXPERIMENTS

Table 3-1, page 3-11, lists candidate lunar orbit experiments and supporting equipment together with tentative mission assignments. Table 3-2, page 3-13, summarizes the information that the lunar orbit experiments contribute to the several scientific disciplines.

3.6 LUNAR SURFACE EXPERIMENTS

Tables 3-3 and 3-4, pages 3-15 and 3-16, list candidate lunar surface experiments and supporting equipment together with tentative mission assignments. An early Apollo scientific experiment package (EASEP) was emplaced on the Moon by Apollo 11 and three Apollo lunar surface experiment packages (ALSEP) are available for the next three lunar landing missions. A fourth ALSEP, whose central station was pre-empted to assemble the EASEP, will be rebuilt for the fifth landing mission. Development and/or new procurements are required to provide emplaced science stations for the subsequent lunar landing missions. For these missions, a tentative matrix of assignments will be released in mid-November and final assignments will be made in December.

Table 3-5, page 3-17, summarizes the information that the lunar surface experiments and equipment contribute to the several scientific disciplines.

3.7 MEDICAL EXPERIMENTS

A list of candidate medical experiments and associated requirements for their integration into the Apollo Lunar Exploration Program are presented in Table 3-6, page 3-19. These experiments have not yet been approved by the MSC Configuration Control Board or the Office of Manned Space Flight.

3.8 ENGINEERING EXPERIMENTS

A number of advanced techniques and hardware configurations for expanding manned spaceflight capabilities have been proposed and are under study for performance on Apollo missions.

3.9 MOBILITY AIDS

Astronaut mobility aids will be available for use on missions J2, J3, J4, and J5. A Request for Proposals was released to industry on 11 July 1969 for a manned lunar roving vehicle, and two contractors have been selected for contract negotiation. A summary of the vehicle specification is presented in Table 3-7, page 3-21.

3.10 SPACECRAFT AND EQUIPMENT WEIGHT SUMMARY

Spacecraft weight data are presented in Reference 8, "Revision II, to Apollo Spacecraft Weight and Mission Performance Definition."

Table 3-1. Lunar Orbit Experiments

EXPERIMENTS		12	13	14	15	16	17	18	19	20
		APOLLO MISSION								
COMMAND MODULE										
S-158	Lunar Multispectral Photography	X								
S-176	Apollo Window Meteoroid			X	X					
S-177	UV Photography of Earth and Moon					X	X			
S-178	Gegenschein from Lunar Orbit	X		X (shaded)	X (shaded)					
S-179	250 mm Hasselblad Camera			(TBD)						
--	500 mm Hasselblad Camera	X								
S-181	Questar Contarex Camera			(TBD)						
S-182	Lunar Surface in Earthshine	X		X (shaded)	X (shaded)					
--	Hycon RA-74 Camera		X							
SERVICE MODULE										
S-160	Gamma-Ray Spectrometer					X	X	X		
S-161	X-Ray Fluorescence					X	X	X		
S-162	Alpha Particle Spectrometer					X	X	X		
S-163	24-inch Panoramic Camera					X	X	X		
S-164	S-Band Transponder					X	X	X	X	X
S-165	Mass Spectrometer						X	X		
S-166	3-inch Mapping Camera						X	X	X	X
S-167	Sounding Radar								X	X
S-168	Lunar Electromagnetic Sounder "A"								X	X
S-169	Far Ultraviolet Spectrometer								X	X
S-170	Downlink Bistatic Radar								X	X
S-171	Lunar Infrared Scanner								X	X
S-173	Lunar Particle Shadows and Boundary Layer								X	X
S-174	Subsatellite Magnetometer								X	X
S-175	Laser Altimeter						X	X	X	X

X (shaded) Program Commitments Not Fully Approved

Table 3-2. Lunar Orbit Instrument Information

Scientific Discipline / Orbital Experiment	Geology	Geophysics	Geochemistry	Geodesy and Cartography	Lunar Atmospheres	Astronomy
S-158 Lunar Multispectral Photography	Composition of Lunar Surface Materials, Landing Site Evaluation					
S-160 Gamma-Ray Spectrometer	Granite - Basalt Discrimination		Detection of Fe, Al, Na, Si Concentrations			Environmental Data for Film Storage
S-161 X-ray Fluorescence	Granite - Basalt Discrimination		Detection of O, Na, Mg, Al, Si, K, Ca, Fe			Environmental Data for Film Storage
S-162 Alpha Particle Spectrometer	Thermal History of Moon	Natural Radioactivity, Isotopic Composition	Detection of Gas Emanation from Lunar Interior, Rn^{222} and Rn^{220} Radioactivity			
S-163 24-Inch Panoramic Camera	High Resolution Photography, Site Evaluation			High Resolution Photography		Observatory Site Location Data
S-164 S-band Transponder		Satellite Tracking for Gravitational Field Modelling		Satellite Tracking for Gravitational Field Modelling		
S-165 Mass Spectrometer			Detection of Gas Emanation		Atmosphere Composition, Temporal and Spacial Variations	
S-166 3-Inch Mapping Camera				Metric Photography, Attitude		Observatory Site Location Data
S-167 Sounding Radar	Surface and Subsurface Features (in cm range), Minerals Location, Topography			Dark Side Topography		
S-168 Lunar Electromagnetic Sounder "A"		Subsurface Structure, Temperature, Moisture, Dielectric Constant, Conductivity				
S-169 Far Ultraviolet Spectrometer					Atmosphere Composition and Density	
S-170 Downlink Bistatic Radar	Subsurface Mapping (Layers), Pore Moisture or Permafrost Detection	Subsurface Electrical Parameters, Electron Density and Distribution of Lunar Ionosphere				
S-171 Lunar Infrared Scanner	Location of Thermal Anomalies, Surface Temperature Mapping	Thermal Conductivity, Bulk Density, Specific Heat of Lunar Surface				Thermal Mapping
S-173 Lunar Particle Shadows and Boundary Layer		Information on External Plasma, Lunar Interior, Surface and Ionosphere				
S-174 Subsatellite Magnetometer		Topology of Magnetotail, dc Electric Fields, Direction of Convection of Energetic Magnetotail Plasma				
S-175 Laser Altimeter				Spacecraft Altitude		
S-176 Apollo Window Meteoroid						Lunar Orbit Meteoroid Environment
S-177 UV Photography of Earth and Moon	Lunar Fluorescence, Color Intensity	Earth Atmosphere Structure				Mars and Venus Atmospheres
S-178 Gegenschein from Lunar Orbit						Gegenschein Photography
S-179 250 mm Hasselblad Camera	Photographs of Specific Lunar Surface Features					
S-180 500 mm Hasselblad Camera S-181 Questar Contarex Camera	High Resolution Photographs of Specific Lunar Features			High Resolution Photography of Potential Landing Sites		
S-182 Lunar Surface in Earthshine (Description not Available)						

Table 3-3. Emplaced Lunar Surface Experiments

		APOLLO MISSION									
	EXPERIMENTS	11	12	13	14	15	16	17	18	19	20
M-515	Lunar Dust Detector	X	X	X	X	X			X	X	X
S-031	Passive Seismic	X	X	X	X	X	X		X	X	X
S-033	Active Seismic				X		X				X
S-034	Lunar Surface Magnetometer		X			X	X				
S-035	Solar Wind		X			X					
S-036	Suprathermal Ion Detector		X		X	X					
S-037	Heat Flow			X			X				X
S-038	Charged Particles Lunar Environment			X	X						
S-058	Cold Cathode Gauge			X							
S-078	Laser Ranging Retroreflector	X					X	X			
–	Astronomy Radiometer								X		
–	Electric Field Gradiometer									X	X
–	Gravimeter								X	X	
–	Mass Spectrometer								X	X	
–	Radiometer								X	X	

X (shaded) Program Commitments Not Fully Approved

Table 3-4. Astronaut Experiments and Equipment

		APOLLO MISSION									
EXPERIMENTS / EQUIPMENT		11	12	13	14	15	16	17	18	19	20
S-080	Solar Wind Composition	X	X								
S-151	Cosmic Ray Detection	X					X		X		
-	Low Energy Nuclear Particle Detection							X		X	
-	Water Detector								X	X	
-	Cone Penetrometer						X	X			
-	Hasselblad Camera	X	X								
-	Stereo Camera			X	X	X	X	X	X	X	X
-	Closeup Camera	X	X	X							
-	Television Camera	X	X	X	X	X	X	X	X	X	X
-	Lunar Survey Staff								X	X	X
-	Apollo Lunar Hand Tools	X	X	X	X	X					
-	Upgraded Hand Tools						X	X	X	X	X
-	Drill (3-meter)			X			X				X
-	Sample Return Container	X	X	X	X	X	X	X	X	X	X

(shaded) X Program Commitments Not Fully Approved

Table 3-5. Lunar Surface Experiment Information

Surface Experiment/Equipment \ Scientific Discipline	Geology	Geophysics	Geochemistry	Bioscience	Geodesy and Cartography	Lunar Atmospheres	Particles and Fields	Astronomy
M-515 Lunar Dust Detector		Surface Material Transport						Microparticle Environment
S-031 Passive Seismic Experiment	Meteoroid Impacts, Interior Structure, Tectonism, Volcanism	Free Oscillations, Tides, Secular Strains, Tilt, Velocity						Vibration Environment for Observatory Site Evaluation
S-033 Active Seismic Experiment	Mapping Velocity, Elastic Moduli	Surface and Near Surface Physical Properties						Soil Mechanics Data for Observatory Site Evaluation
S-034 Lunar Surface Magnetometer	Magnetic Anomalies, Subsurface Features, Lunar History	Remnant Fields, Bow Shock, Magnetosheath, Stagnation Region, Interplanetary Diffusion into Moon					Magnetic Field, Plasma-Moon Interaction	
S-035 Solar Wind Experiment		Energy Distribution, Density, Incidence Angle, Temporal Variation of Electron and Proton Flux in Solar Wind					Energy Distribution, Density, Incidence Angle, Temporal Variation of Electron and Proton Flux in Solar Wind	
S-036 Suprathermal Ion Detector		Flux, Density, Velocity, Energy per Unit Charge of Positive Ions					Density, Velocity, Energy per Unit Charge of Positive Ions	
S-037 Heat Flow Experiment		Vertical Thermal Conductivity						Thermal Environment
S-038 Charged Particles Lunar Environment Experiment		Energy Distribution of Electrons and Protons, Low-Energy Solar Cosmic Rays					Energy Distribution of Electrons and Protons, Low-Energy Solar Cosmic Rays	
S-058 Cold Cathode Gauge		Atmospheric Pressure, Atmosphere Contamination				Atmospheric Pressure		
S-078 Laser Ranging Retroreflector		Librations, Variations in Earth Rotation Rate, Earth-Moon Distance			Lunar Ephemeris, Librations, Orientation			
S-080 Solar Wind Composition		Solar Wind Heavy Particle Content	Solar Wind Composition				Solar Energetic Particles Detection	
S-151 Cosmic Ray Detection		High Energy Particle Detection				High Energy Ion Detection	Galactic Cosmic Ray Measurement	
Astronomy Radiometer	Limited Data on Surface Materials from Impedance	Surface Impedance						Ambient Background Noise Level; Dynamic Spectra of Solar, Jovian, Terrestrial Radio Bursts
Electric Field Gradiometer		Data for Analysis of Solar Wind Interaction with Moon				Data for Analysis Lunar Atmosphere	Electric Field Strength Above Surface, Surface Charge and Polarity	
Gravimeter	Density Discontinuities, Isostatic Equilibrium of Surface Features	Gravitational Field, Secular Variations, Elastic and Inelastic Properties			Gravitational Field			Surface Stability
Mass Spectrometer			Monitor Gaseous Evolution	Detection of Organic Molecules in Surface Atmosphere		Atmosphere Composition, Density, Gas Escape Rates		
Low-Energy Nuclear Particle Detection		Radiation Dose in Event of Enhanced Solar Activity	Chemical Composition of Low-Energy Nuclear Particles				Flux, Energy Spectrum of Low-Energy Nuclear Particles	
Radiometer		Local Heat Rates Resulting from Ascent Engine Exhaust						
Water Detector	Water Detection		Water Detection	Water Detection				
Cone Penetrometer	Bearing Strength, Trafficability, Surface Processes, Sampling and Drilling Characteristics							Soil Mechanics Data for Observatory Site Evaluation
Hasselblad Camera, Stereo Camera	Sample Site Documentation		Sample Site Documentation	Sample Site Documentation				
Closeup Camera	Stereoscopic Macrophotography of Lunar Samples		Stereoscopic Macrophotography of Lunar Samples					
Television Camera	Real-time TV Coverage of Lunar Exploration							
Lunar Survey Staff	Sample Site Location, Communications Support, Sample Documentation		Sample Site Location, Communications Support, Sample Documentation	Sample Site Location, Communications Support, Sample Documentation				
Apollo Lunar Hand Tools, Upgraded Hand Tools	Sampling		Sampling	Sampling				
Drill (3-Meter)	Subsurface Sampling, Utility Drilling		Sampling	Sampling				Soil Mechanics Data
Sample Return Container	Sample Storage and Identification, Contamination Protection		Sample Storage and Protection	Sample Storage and Protection				

Table 3-6. Medical Experiments

No.	Title	Objective	Hardware	Earth Weight (lb)	Size	S/C Power Requirements	Telemetry Requirements	Interfaces	Hardware Availability	Crew Time Required
1	Microbial Survival in Lunar Environment	Determine the survival rate of viable microorganisms (common astronaut strains) under lunar surface conditions and effect of this environment on spores of bacteria, fungi, higher plant forms and their progeny (mutations).	Polycarbonate multicell chamber containing known quantities of organisms, with decompression valving and filtered vent	1.5 per unit	3 x 7 x 0.5 in.	None	None	CM storage: 2 units LM transfer: 1 unit; return in lunar sample box	May 1970	15 min
2	Time and Motion Analysis at 1/6 g	Evaluate dexterity and locomotion during lunar surface activities.	Operational television only	11	342 cu in.	7 Watts at 28 V	Operational TV transmissions	Defined by operational hardware	Available	2 min per transmission for additional camera positioning
3	Metabolic Rate Assessment at 1/6 g	Approximate the metabolic cost of operational work tasks during lunar EVA using heart rate, oxygen supply pressure and liquid cooled garment temperatures. Compare with values derived from ground based simulations.	Current Apollo operational hardware	None	None	None	None	Requires return of LiOH canister and measurement of remaining PLSS feedwater	November 1969	30 min (interface activities)
4	Inflight Aerosol Analysis	Quantitate aerosol burden of spacecraft atmosphere by sampling at periodic intervals.	Self-contained portable unit developed for Apollo 204. Requires delta qual.	6 1/2	281 cu in. (5 x 7 1/2 x 7 1/2 in.)	None	None	Stowage only	July 1970	3 hrs total for 10-day mission.
5	Lunar Surface Reflected Radiation	Firm data on U-V and IR reflectances are required for updating design of vision protective devices.	Automatic spotmeter 1 deg	2	60 cu in.	Battery pack	None	None	November 1970 (H-3 mission)	10 min (5 min surface plus 5 min debriefing)
6	Sleep Analysis	Determine effects of spaceflight and lunar surface environment on quality and quantity of sleep to provide firm data for planning of work rest schedules for future missions.	Gemini Cook recorder and amplifiers contained in fireproof container. Cap with nonadhesive sensors.	15	8 x 7 x 3 in. recorder-amplifier combination 2 x 5 x 8 in. stowage container for 4 caps	28 V dc	None	Stowage for caps and recorder	Mid-1970 flight	Four sleep periods (1 prelunar, 2 lunar, 1 postlunar)
7	Pre- and Postflight Biomedical Operational Measurements	Same measurements as those of Apollo 9 or 11 (depending upon whether quarantine requirements are still mandatory), but with the addition of experiments 7A and 7B.	No flight hardware	N/A	N/A	None	None	None		
7A	Direct Bone Densitometry	Determine effect of subgravity environment upon bone mass and structure.	Radionuclide source detector and scanning apparatus for pre- and postflight measurements						May 1970	45 min per crew member; 3 times pre- and postflight
7B	Total Body Gamma Spectrometry	Measure induced radioactivity in bodies of crew personnel exposed to space radiation. Measure changes in body-muscle-mass through measurement of natural occurring 40 potassium.	All required equipment is located in radiation counting laboratory, Lunar Receiving Laboratory.						Operational	30 min each examination. One preflight exam, two postflight exams required.

Table 3-7. Lunar Roving Vehicle Characteristics

- Propulsion - Drive motor for each wheel
  - Battery powered
  - Four wheels
- Net Weight - 400 pounds (including battery and deployment mechanism)
- Payload - Two men plus 170 pounds equipment
- Speed - Specification - 16 km/hr maximum
  - 8 km/hr average
  - Planning - 10 km/hr maximum
  - 5 km/hr minimum
- Range - 90 km
- Slope - 25 degrees maximum
- Obstacle Clearance Capability - 16 inches
- Stowable in LM Quad I
- Communications - As provided by EVCS & Relay
- Operation - Manned only
  - Sunlight only
- Navigation Aid - Gyro azimuth indicator
  (For return to LM) - Odometer
  - Computer display of distance and direction to LM

4. APOLLO LUNAR EXPLORATION MISSIONS

This section describes the ten missions of the Apollo Lunar Exploration program with respect to profiles and objectives, spacecraft operations, lunar surface operations, lunar orbit science operations, planning assumptions and spacecraft performance.

4.1 MISSION PROFILES AND OBJECTIVES

The following sections define the three types of missions (G, H, and J) in greater detail and present the objectives and profiles of the planned missions. Where appropriate the controlling Mission Requirements document for the information presented is referenced.

Both primary and detailed objectives are presented for each mission. Primary mission objectives are established by the NASA Office of Manned Space Flight and are documented in the Apollo Flight Mission Assignments Directive (AFMAD) (Reference 9). Primary objectives have not yet been established and documented for the later missions of the program, so for these missions representative objectives are presented for information only. Detailed mission objectives are developed by the Manned Spacecraft Center and are documented in the Mission Requirements (MR's). Where the MR's are not yet available, representative detailed objectives are presented for information only.

Primary and detailed mission objectives are defined as follows:

- Primary Objective - A statement of a primary purpose of the mission. When used in NASA Center control documentation it may be amplified but not modified.

- Detailed Objective - An objective generated by a NASA Center to amplify and fulfill a primary objective.

4.1.1 Type G Mission (Information only; controlling document, Reference 10)

Apollo 11, the first lunar landing mission, was of the G type. The translunar trajectory was targeted as a free return trajectory. The LM landed at Apollo site 2 in the Sea of Tranquility (see Figure 1-1, page 1-5) and remained on the lunar surface for 22 hours. The lunar surface operations included a single two-man EVA period during this interval.

The commander was on the lunar surface for approximately 2 hours, 31 minutes and the lunar module pilot for approximately 1 hour, 50 minutes. The total mission duration from launch to earth splashdown was 8 days, 4 hours.

Primary objective (Reference 9):

Perform manned lunar landing and return

Subordinate objectives (Reference 10):

- Perform selenological inspection and sampling
- Obtain data to assess the capability and limitations of the astronaut and his equipment in the lunar surface environment

Detailed objectives (Reference 10):

- Collect a contingency sample
- Egress from the LM to the lunar surface, perform lunar surface EVA operations and ingress into the LM from the lunar surface
- Perform lunar surface operations with the EMU
- Obtain data on the landing effects on the LM
- Obtain data on the characteristics and mechanical behavior of the lunar surface
- Collect samples of lunar material
- Determine the position of the LM on the lunar surface
- Obtain data on the effects of illumination and contrast conditions on crew visual perception
- Demonstrate procedures and hardware used to prevent contamination of the earth's biosphere
- Obtain television coverage during the lunar stay period
- Obtain photographs during lunar landing and the lunar stay period

Detailed experiments (Reference 10):

- Deploy the Passive Seismic Experiment (S-031)
- Deploy the Laser Ranging Retroreflector Experiment (S-078)
- Conduct the Solar Wind Composition Experiment (S-080)
- Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission G

Passive experiments not detailed (Reference 10):

- Conduct experiments S-051, Cosmic Ray Experiment, and T-029, Pilot Describing Function

4.1.2 Type H Missions (Apollo 12 through 15)

Missions H1 through H4 follow Mission G and all will be flown with standard Apollo hardware. The translunar trajectories may be of either the free-return or hybrid type. The technique of CSM transport (descent orbit insertion using SPS propulsion) will be developed and demonstrated during this series of missions. The LM will remain on the lunar surface for an open-ended interval up to 35 hours, during which there will be two periods of EVA by both LM crew members, each approximately 3-1/2 hours in duration (from LM depressurization to repressurization). Other EVA's using the LM top hatch for panoramic observation may be planned. The maximum radius of operation from the LM will be limited by the purge capability of the OPS and is estimated to be approximately one kilometer. After the LM ascent stage has been jettisoned, it will be impacted on the lunar surface to stimulate the passive seismic experiment and to eliminate orbital debris. Total mission duration will be approximately 10 days.

4.1.2.1 Mission H1 (Information only; controlling document Reference 11)

The prime mission H1 landing site is Apollo 7 with Apollo 5 as the recycle target.*

Primary objectives (Reference 9):

- Perform selenological inspection, survey and sampling in a mare area
- Deploy ALSEP consistent with a seismic net
- Develop techniques for a point landing capability
- Develop man's capability to work in the lunar environment

*Refer to Section 5, page 5-1, for landing site details.

Detailed objectives (Reference 11):

- Collect a contingency sample
- Perform lunar surface EVA operations
- Perform PLSS recharge in the landed LM
- Collect samples of lunar material
- Obtain photographs of candidate lunar exploration sites
- Obtain data on the characteristics and mechanical behavior of the lunar surface
- Obtain data on the effects of illumination and contrast conditions on crew visual perception
- Determine the position of the LM on the lunar surface
- Obtain photographs during lunar landing and the lunar stay period
- Obtain television coverage during the lunar stay period
- Obtain data from the Surveyor III spacecraft and the related landing area
- Obtain lunar landmark tracking data related to the earth-based control coordinate system

Detailed experiments (Reference 11):

- Deploy the Apollo Lunar Surface Experiments Package Array A (ALSEP I)
- Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission H1
- Conduct the Solar Wind Composition Experiment (S-080)
- Obtain multispectral colorimetric photographs of the lunar surface (S-158)

Passive experiments not detailed (Reference 11):

- Conduct experiment T-029, Pilot Describing Function
- Conduct experiment M-515, Lunar Dust Detector

4.1.2.2 Mission H2 (Information only: controlling document Reference 12)

The primary landing site is Fra Mauro FM and the recycle site is Apollo 6R.

Primary objectives (Reference 9):

- Perform selenological inspection, survey and sampling in a TBD structure. Note: If the backup site (i.e., Apollo site 6R) is used in lieu of the prime site, then the data will be related to a mare basin instead of a highland structure.

- Deploy ALSEP consistent with a seismic net
- Develop the capability to conduct a mission to a specific site
- Demonstrate the point landing capability
- Develop man's capabilities to work in the lunar environment

Detailed objectives (Reference 12):

- Obtain photographs during lunar landing and the lunar stay period
- Obtain color television coverage during the lunar stay period
- Collect a contingency sample
- Collect samples of lunar material
- Obtain data on trajectory control techniques related to lunar landing accuracy
- Obtain photographs of candidate lunar exploration sites
- Investigate communication loss modes of the EVA communications system during lunar surface operations
- Obtain data on the lunar soil mechanical behavior, and on the surface and sub-surface characteristics
- Obtain photographs of dim astronomical light phenomena
- Obtain lunar landmark tracking data related to the earth-based control coordinate system
- Determine the sure elevation angle and scattered light limits for horizon definition and star availability

Detailed experiments (Reference 12):

- Deploy the Apollo Lunar Surface Experiments Package Array B (ALSEP III)
- Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission H2
- Obtain multispectral colorimetric photographs of the lunar surface (S-158)

Passive experiments not detailed (Reference 12):

- Conduct experiment T-029, Pilot Describing Function

4.1.2.3 Mission H3

The primary landing site is the Littrow area and the recycle site is Apollo site 6R.

Primary objectives (Reference 9):

- Perform selenological inspection, survey, and sampling in a highland structure
- Deploy ALSEP consistent with a seismic net

Detailed objectives (Reference 13):

- Collect a contingency sample
- Collect samples of lunar material
- Obtain photographs of candidate lunar exploration sites
- Obtain data on the lunar surface and subsurface characteristics, and on the soil mechanical behavior
- Obtain photographs during lunar landing and the lunar stay period (photos of lunar surface during descent and after landing and of the LM and EVA)
- Obtain color television coverage during the lunar stay period
- Obtain lunar landmark tracking data related to the earth-based control coordinate system
- Determine the sure elevation angle and scattered light limits for horizon definition and star availability

Detailed experiments (Reference 13):

- Deploy the Apollo Lunar Surface Experiments Package Array C (ALSEP IV)
- Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission H3
- S-178 Gegenschein from Lunar Orbit (details not available)
- S-182 Lunar Surface in Earthshine (details not available)

Passive experiment not detailed (Reference 13):

- Conduct experiment T-029, Pilot Describing Function
- S-176 Apollo Window Meteoroid (details not available)

4.1.2.4 Mission H4

The primary lunar landing site for Mission H4 is the Censorinus area and the recycle site is Apollo site 6R.

Primary objectives (Reference 9):

- Perform selenological inspection, survey and sampling
- Deploy ALSEP

Detailed objectives and experiments (representative; for information only)

- Conduct those portions of the Apollo Lunar Field Geology Experiment (S-059) assigned to Apollo Mission H4
- Collect a contingency sample

- Deploy Apollo Lunar Surface Experiments Package Array A-2 (ALSEP II)
- Obtain color television coverage during the lunar stay period
- Collect samples of lunar material
- Obtain photographs of candidate lunar exploration sites
- Obtain photographs during lunar landing and the lunar stay period
- Conduct experiment T-029, Pilot Describing Function
- Obtain lunar landmark tracking data related to the earth-based control coordinate system
- S-176 Apollo Window Meteoroid (details not available)
- S-178 Gegenschein from Lunar Orbit (details not available)
- S-182 Lunar Surface in Earthshine (details not available)

4.1.3 Type J Missions (Apollo 16 through 20)

Missions J1 through J5 follow the H-series and will be flown with modified Apollo hardware designed to extend mission duration and lunar surface staytime, to increase landed payload and sample return, to extend lunar surface EVA operations and increase mobility, and to provide for scientific experiments and mapping to be accomplished in lunar orbit. Hybrid translunar trajectories and CSM transport will be required because of the increased gross weight of the spacecraft. In addition, 3-burn LOI maneuvers may become necessary to satisfy site accessibility requirements. The LM may remain on the lunar surface up to 62 hours, during which a maximum of three periods of two-man EVA's can be accomplished. This will probably include one EVA on landing day, one on the succeeding day, and one on the ascent day. The modified PLSS (6000 BTU rating) to be used on these missions may allow extending the duration of each EVA to 4 hours, 30 minutes at 1250 BTU/hr (from LM depressurization to repressurization). The maximum radius of operation from the LM will be limited by the level of activity and the capability of the PLSS. This radius is estimated to be approximately 5 kilometers without a lunar roving vehicle and 11 kilometers with the LRV. (See Figure 4-10, page 4-34.)

An interval of lunar orbit coast up to 77 hours will be available between rendezvous and TEI for lunar orbit experiments operation and mapping. Command Module experiments may be operated during LM surface stay. Those experiments mounted in the service module SIM will not be operated until after CSM/LM docking when the SIM door is jettisoned unless special windows are provided for their earlier operation. An EVA period of approximately 44 minutes nominal (from hatch egress to ingress) will be conducted in lunar orbit or during transearth coast to recover data from the SIM. Total mission duration will not exceed 16 days (384 hours).

Neither primary nor detailed objectives have yet been established for type J missions. The objectives that follow are representative and are for information only.

4.1.3.1 Mission J1

The primary lunar landing site for Mission J1 is Descartes, and the recycle site is Apollo 6R.

Primary objectives (for information only):

- Deploy emplaced surface experiments
- Perform a lunar orbital science survey
- Obtain photographs of candidate lunar exploration sites
- Perform traverse: selenological inspection, survey and sampling
- Demonstrate the capability to perform an extended lunar surface mission including up to 3 EVA's
- Demonstrate the capabilities of the SIM
- Demonstrate the extended capabilities of the modified CSM and LM
- Demonstrate the capabilities of the modified PLSS and of the SLSS
- Demonstrate the capabilities of the communications relay

4.1.3.2 Mission J2

The primary lunar landing site for Mission J2 is in the Marius Hills. No recycle site is designated for this mission.

Primary objectives (for information only):

- Perform traverse: selenological inspection, survey, and sampling using the LRV
- Perform a lunar orbital science survey
- Deploy emplaced surface experiments
- Obtain photographs of candidate lunar exploration sites
- Demonstrate the capabilities of the LRV

4.1.3.3 Mission J3

The primary landing site for Mission J3 is in the Crater Copernicus, and the recycle site is Apollo 6R.

Primary objectives (for information only):

- Deploy emplaced surface experiments
- Perform a lunar orbital science survey
- Perform traverse: selenological inspection, survey and sampling

4.1.3.4 Missions J4 and J5

The primary landing site for Mission J4 is Hadley. The recycle site for this mission is TBD. The primary landing site for Mission J5 is north of Tycho, and the recycle site is Apollo 6R.

Primary objectives (for information only):

- Perform traverse: selenological inspection, survey and sampling using the LRV
- Perform a lunar orbital science survey
- Deploy emplaced surface experiments
- Examine and return components of the Surveyor VII spacecraft (Mission J5 only)

4.2 MISSION SPACECRAFT OPERATIONS

This section contains a description of spacecraft operations that will be employed to satisfy objectives of the lunar exploration program and those constraints most likely to impact these operations.

Spacecraft operations, hardware, software, and techniques are discussed in terms of differences or changes, between the baseline Apollo Mission G and the advanced missions (H1 and subsequent). The implementation dates of these changes are indicated on a per-mission basis. Mission G activities are documented in the Apollo 11 Flight Plan and Apollo Mission Techniques documents and are discussed in this section only to the extent necessary to provide continuity between them and the advanced missions. In a similar manner, only those constraints most likely to impact implementation of new operations are discussed in this section. A complete listing of spacecraft and operational constraints is documented in Spacecraft Operational Data Books, Joint Operational Constraints, and The Lunar Surface Operations Plan.*

Experiments and science-related activities are discussed in this section only to the extent necessary to describe their interface with mission operations.

Landing mission (types H and J) operations are detailed in Table 4-1, pages 4-11 to 4-19. This information is presented as a sequence of operational phases arranged in familiar groupings that are convenient for description and further analysis.

Continuity in the exploration program will be enhanced by factoring the results of a given mission into subsequent missions. This can be accomplished by timely post-mission assessment of scientific and technological objectives and incorporation of the results of analysis into the flight plans of subsequent missions.

*Planning assumptions effecting mission operations are discussed in section 4.5, page 4-41.

Table 4-1. Spacecraft Operations - Landing Missions

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
PRELAUNCH	
Long range mission planning and objective assignments will be conducted on the assumption that program objectives are accomplished on their assigned missions. However, preflight planning should be flexible enough to allow changes to flight plans as dictated by knowledge acquired on preceding missions. KSC installation and checkout of experiment packages at KSC will be required only if they cannot be accomplished prior to shipment. Increased scientific training of the crew will be required with a corresponding reduction in training for landing at multiple sites. A total of four launch opportunities on two consecutive months will be provided for each primary site. (See paragraph 4.5.1, page 4-41, for greater detail.)	The time between topping off the SHe pressurization system and the first DPS burn must not exceed 180 hours on Missions H1 through H4. This limitation is based on measured SHe system pressure rise rates of 8 psi per hour during 30 hours of pre-launch operations and 6.5 psi per hour in flight. The SHe system for missions J1 and subsequent will be modified to increase the hold time to 190 hours.
BOOST THROUGH TLI	
The SV must be qualified for increased spacecraft weights resulting from modifications to the CSM and LM. The launch azimuth will be from 72 to 96 degrees.	On the J-type missions, the total injected spacecraft weight will increase to 106,500 lbs. Verification of the SV ability to inject this weight is required.
TRANSLUNAR COAST	
The hybrid trajectory option may be used on any mission including G. The hybrid maneuver will be conducted in the time frame allocated for the first midcourse correction of the free return trajectory.	It is mandatory that the hybrid maneuver be targeted to allow a safe abort using the DPS following SPS failure to ignite for LOI.

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
TRANSLUNAR COAST (Continued)	
Translunar coast time may be increased as much as 25 hours by use of the hybrid trajectory option.	The translunar coast time must be limited in accordance with the SHe time constraint.
SPS mission dependent ΔV may be decreased by use of the hybrid trajectory option.	Landing site approach azimuths may be constrained by local approach lurain.
Following LM ejection the S-IVB trajectory will be modified in a manner to cause the S-IVB to impact the lunar surface and stimulate the siesmic sensor(s). This change is effective on missions H2 and subsequent.	
On missions J1 and subsequent, the requirement may exist to operate certain SIM-mounted experiments during translunar coast. Special windows or doors will be installed in the SIM door for this purpose.	
LUNAR DESCENT LM Operations (Landing Accuracy)	
On missions H3 and subsequent, it will be necessary to land in rough terrain and within astronaut EVA range of selenological features. The actual landing accuracy requirement is dependent on astronaut mobility, exploration requirements, and safety considerations. It has been determined that a landing error of less than ±1.0 km would guarantee successful missions and this accuracy is required for Mission H3 (Littrow) and subsequent. Techniques for achieving this goal will be developed on Missions H1 and H2. Reduction in landing error will be accomplished by improvement in unredesignated accuracy and by landing point redesignation.	On Apollo Mission G, the LM was targeted to land in large smooth areas devoid of selenological features. The estimated non-redesignated landing errors (for mission G) were within ±6.5 km downrange on ±3.6 km crossrange with 99% probability. The actual landing was +6.7 km downrange and 1.22 km south of the center of the landing ellipse. In general, improved landing accuracy must be accomplished within the following constraints and ground rules: • A budget of 60 fps ΔV is allocated for landing site redesignation at 4000 feet of altitude. The redesignation distance available from this ΔV budget is a function of the descent trajectory, time of redesignation

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
LUNAR DESCENT LM Operations (Landing Accuracy) (Continued)	
• Reduction of propulsive forces: use of balanced RCS maneuvers and firing tests; elimination of waste dumps and venting following state vector update; nulling of LM ΔV resulting from undocking.	and procedures. • The maneuver and hover time below 500 feet altitude may be determined by use of the trade-off curve, Figure 4-1, page 4-15. This time will be budgeted for automatic or manual descent, obstacle avoidance, pilot discretionary maneuvers and for margin following touchdown as appropriate for a given site.
• State vector update during the PDI revolution based on tracking conducted during the orbit preceding PDI, i.e., one orbit later than on the G mission.	
• Descent targeting based on Lear processor updates and MSFN ranging updates obtained during the PDI revolution. • Updating the landing site location during the descent burn on the basis of comparisons between the actual descent trajectory and the planned trajectory.	• The DPS is rated for a burn time of 910 seconds (Reference 14). If burn times greater than this are required, verification of its ability to utilize the increased quantity of DPS propellant is required. Note: The descent engine has been tested, at TRW, to burn durations of 1029 and 969 seconds.
Redesignation capability may be enhanced as follows: • Targeting short and to the right of the desired landing point to preclude the possibility of having the LM structure obstruct visibility of the landing site. See Reference 15. • Redesignating early to increase the redesignation range.	• The landing site must be within the field-of-view of both astronauts for at least 120 seconds prior to touchdown to enhance visibility and crew safety. • The field-of-view of the astronauts is obstructed by the LM structure as indicated in constraint CS-4 of the LM SODB (Reference 15). • The time between LM activation and touchdown shall be minimized to conserve LM EPS and ECS consumables required for lunar surface operations.

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
LUNAR DESCENT LM Operations (Landing Accuracy) (Continued)	
	• The ability to abort the mission using the AGS shall be maintained during descent operations, for one CSM orbit following LM touchdown, and for nominal ascent.
LUNAR DESCENT LM Operations (Rough Terrain)	
It is required that the LM be capable of landing on sites surrounded by rough terrain. A landing radar signal prefilter is being developed to smooth the results of lurain variations.	
LUNAR DESCENT LM Operations (Payload)	
The LM payload and performance limits are shown in Figure 4-1, page 4-15. Studies to determine the optimum tradeoff between surface staytime, payload and redesignation budget will be required on a per-mission basis.	The relationship between LM payload and CSM scientific payload is shown in Figure 4-2, page 4-15.
LUNAR DESCENT CSM Operations	
In order to increase the DPS ΔV allocation for landing site redesignation, the SPS will be used to insert the CSM/LM into a 60 n mi X 50,000 ft orbit. This maneuver will be conducted in lieu of the second LOI maneuver. Following separation of the CSM/LM and prior to PDI, the CSM will return to a 60 n mi circular orbit. This technique (SPS DOI) will be developed on Mission H2.	The CSM will be returned to a 60 n mi circular orbit so an abort using the AGS (and Apollo 11 techniques) can be accomplished in the time span from CSM/LM separation to completion of the first CSM orbit following LM landing. Return to this orbit will also permit landmark tracking to be conducted at lower line-of-sight rates.

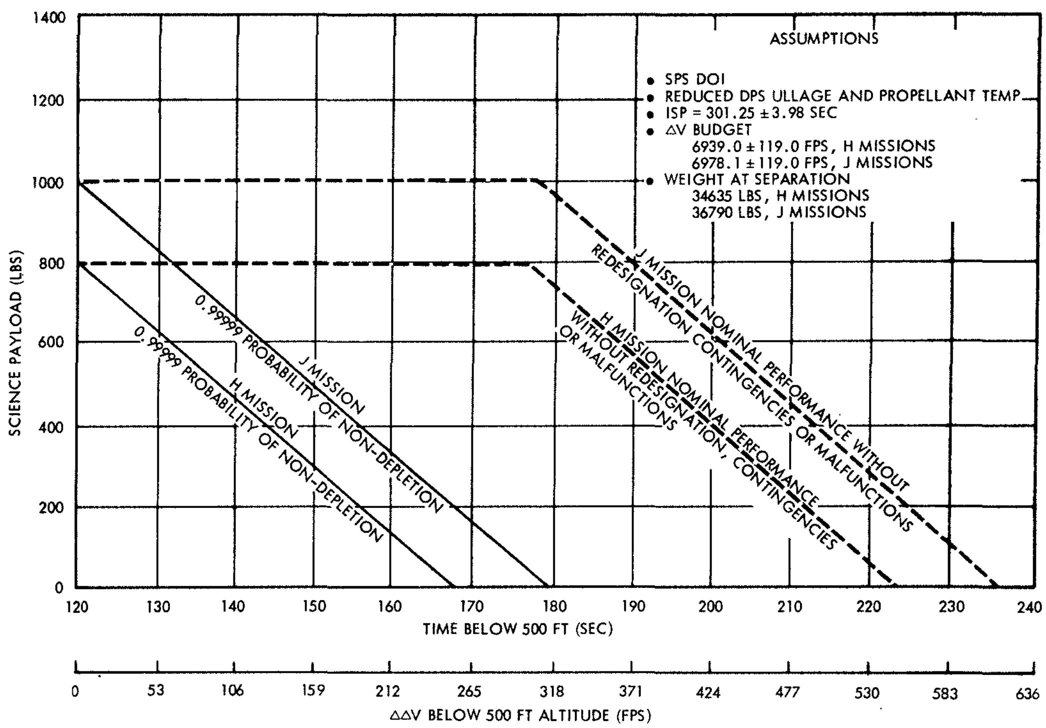

Figure 4-1. LM Performance Capability*

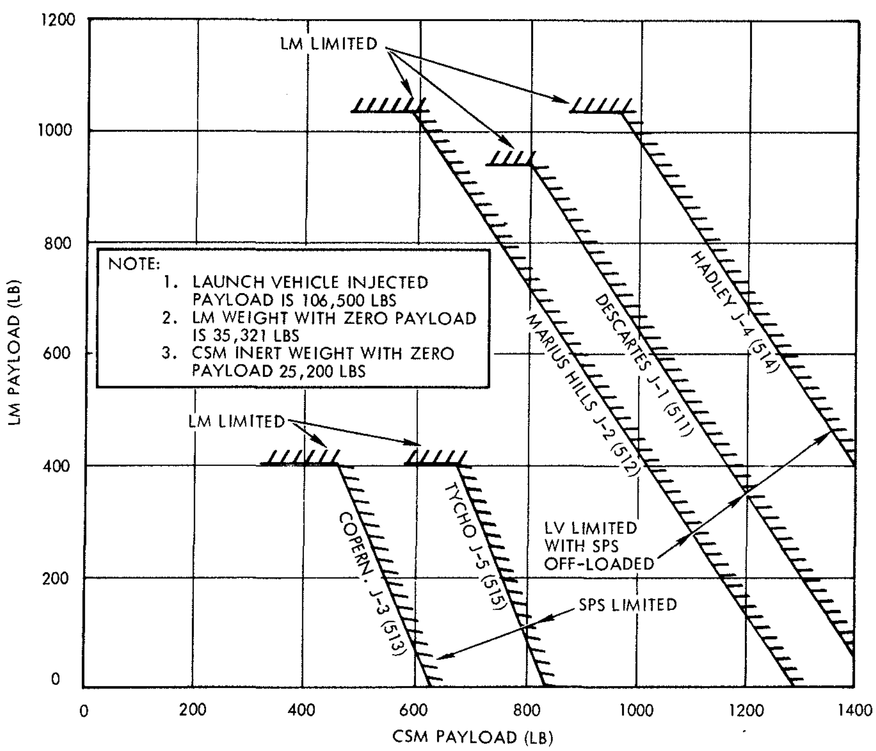

Figure 4-2 Space Vehicle Performance Summary for Zero SPS Propellant Margin*

*Reference 16

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
LUNAR DESCENT CSM Operations (Continued)	
Software changes as required to drive the CSM optics at line-of-sight rates will be provided. This will ease crew burden when tracking landmarks from low orbital altitude. The effectivity of this change is Mission H2 and subsequent.	
LUNAR SURFACE LM Operations	
Surface stay time for H-type missions is consumables limited to 35 hours. Stay time for J-type missions is limited to 62 hours by battery capacity. Surface activities will be conducted in accordance with operations described in Section 4.3, page 4-20. The manned rover will be employed on Missions J2, J3, J4 and J5. For J-type missions the LM ECS/thermal system must provide an acceptable environment for the expected heat load resulting from: • Landing at sun elevation angles of up to 27 degrees • Lunar stay time of up to 62 hours	Radiation resulting from a solar flare will reach the Earth/Moon system in approximately 11 hours. The capability to return the crew to the shielding provided by the CM within 11 hours must be maintained during surface operations.
With the exception of short periods of time (up to 5 min) when LM to crew line-of-sight is obstructed by the lurain, communications between MCC and the crew must be maintained at all times during surface operations. On missions J1 and subsequent a voice and data relay will be employed (see paragraph 3.4, page 3-9).	The LM to EVCS communication distance using the current system is limited to about 5 km for line-of-sight conditions on the lunar surface. Use of the voice and data communication relay will eliminate this constraint on J missions. EVCS to EVCS communication distance on the lunar surface is limited to approximately 1.8 km.

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
LUNAR SURFACE CSM Operations	
The CSM orbital plane will be changed as required to maintain LM/CSM communications and to permit coplanar rendezvous.	
LUNAR ASCENT	
Maximum sample payload for H-type missions is 98.6 lb, consisting of two sample return containers and one contingency sample.	
Maximum ascent payload for J-type missions is 175 lb, consisting of three sample return containers, a cosmic ray detector package, and film cassettes or magazines.	
CSM LUNAR ORBITAL SCIENCE	
On H-type missions orbital experiments using CM mounted equipment will be conducted during the lunar stay period and following rendezvous.	Refer to paragraph 4.4, page 4-37 for detailed information regarding conduct of experiments.
On J-type missions orbital experiments using SIM mounted equipment will be conducted following rendezvous. Prior to conduct of experiments the SIM bay door will be jettisoned so as to impact the lunar surface. (The jettison velocity is approximately 85 fps.)	NR analysis indicates that RCS plume impingement will degrade the optical and electrical characteristics of certain instruments. Thus certain jets will be inhibited during their operation. Although the effects of venting may not be detrimental (to experiments), ECS venting and water and urine dumps will be scheduled to occur during times that the experiments are not operating. Additional electrical heating must be provided following the jettison of the SIM door to augment passive thermal control. These considerations dictate the SIM door be retained in place until after rendezvous.
The spacecraft will be retained in the docked configuration during the conduct of orbital science experiments.	

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
CSM LUNAR ORBITAL SCIENCE (Continued)	
On Mission H1, and subsequent the LM (spent ascent stage) will be deorbited to impact in the vicinity of the passive seismic experiment(s) using the LM RCS as commanded via the data uplink. It is also desirable that long term tracking of the jettisoned LM be accomplished to satisfy requirements of the S-band transponder experiment. LM consumables capacity may not be adequate to allow conduct of the S-band transponder experiment and the deorbit of the LM.	The allowable weight of the CSM carried scientific instruments is a function of launch vehicle and SPS capabilities. LM/CSM payload and system performance data are shown in Figure 4-2, page 4-14. The thermal design of the SIM requires that it be oriented toward the surface of the Moon except for short intervals where specific maneuvers away from this attitude are required, e.g., IMU realignment.
Retrieval of film cassettes and experiments data will normally be accomplished by EVA prior to TEI but may be performed during transearth coast.	
The time available for orbital experiments will be determined on a per-mission basis but will nominally be no more than 77 hours.	
From 220 to 240 kWh of electrical energy will be available for conduct of orbital experiments.	
With Bay 1 looking down at the lunar surface and with the X-axis along the velocity vector, reverse pointing of the spacecraft X-axis may be required to maintain SIM temperature control.	The current SIM thermal design will not allow operation in lunar orbits inclined in excess of ±45 degrees without additional thermal control design changes and/or maneuvers and operational duty cycles for the instruments.
CSM ΔV allocation for conduct of experiments will be determined on a per-mission basis.	The LM rescue SPS ΔV budget may be used after LM recovery to reposition the CSM orbital plane as required to achieve desired surface coverage (approximately 500 fps for plane change and 400 fps for additional TEI ΔV requirements resulting from the plane change).

Table 4-1. Spacecraft Operations - Landing Missions (Continued)

OPERATIONAL CHANGE FROM G MISSION	CONSTRAINTS AND COMMENTS
CSM LUNAR ORBITAL SCIENCE (Continued)	
The experiments will be mounted in Sector 1 of the SM and are boresighted in the spacecraft Y-Z plane approximately 38 degrees from the -Z axis toward +Y.	NR analysis indicates that experiment pointing errors will be within ±1.3 degrees (3 σ) using GNCS as the data reference. This analysis is based on the assumption that the instruments are boresighted to the navigation base at Downey and in flight IMU alignments are conducted within 6 hour intervals.
TRANSEARTH INJECTION	
None	
TRANSEARTH COAST THROUGH CM SPLASHDOWN	
Specific SIM mounted experiments may be conducted during transearth coast. Individual experiments must have protection from RCS jet plume impingement because all jets are required for certain maneuvers (ullage or translation).	Film retrieval must be completed prior to entry into the Earth's radiation belt and must not be done in solar flare flux.
CM RECOVERY THROUGH MISSION COMPLETION	
Crew quarantine and sample isolation requirements will be reevaluated based on experience gained on Mission G.	
POST MISSION ANALYSIS	
Assessment of scientific objectives will be performed so they can be factored into subsequent mission plans.	

4.3 LUNAR SURFACE OPERATIONS

The purpose of this section is to provide a broad basis for the planning of lunar surface extravehicular activity. Criteria presented for EVA planning include the number of EVA periods that can be scheduled during LM lunar stay, life support systems capabilities, general EVA timelines, preliminary ALSEP deployment timelines, metabolic rates for various kinds of activity, traverse speeds, and EVA guidelines and contraints.

4.3.1 Number of EVA Periods

Gross timelines for LM descent, lunar surface stay and ascent have been prepared and analyzed to determine the number of lunar surface EVA periods that can be scheduled on H and J type missions (Figure 4-3, page 4-22). The first two timelines in Figure 4-3 represent Apollo 11 and Apollo 12 flight planning. The assumptions and timeline criteria used for the H and J mission timelines were:

- One EVA period on the day of lunar landing is the maximum allowable for planning
- One EVA period during each succeeding work/rest cycle
- Rest period preceding LM ascent if possible (not incorporated into the Apollo 12 Flight Plan)
- The work/rest cycle includes EVA, at least two eating periods and one rest period
- The work/rest cycle should be as close to 24 hours in duration as possible
- Two hours of preparation before each EVA period and 1 hour, 30 minutes for post-EVA activities are required (included in blocks labeled EVA in Figure 4-3)
- Back-to-back EVA periods on the same day are undesirable and should be employed only when science gain justifies such a strenuous timeline.

Based on these assumptions and criteria, it is concluded that the maximum practicable number of EVA periods is as shown below.

Lunar Stay (hours)	EVA Periods
Up to 35	2
Up to 62	3

Increased EVA hours can be realized within a given lunar stay time by extending the duration of each EVA period. One hour of useful surface time is gained for each additional hour of PLSS time, since overhead time (Section 4.3.3) would remain the same for each EVA period. The extension of EVA duration in this manner would be limited ultimately by human factors considerations (requirements for eating, drinking and waste elimination, suit chafing, etc.), rather than by EMU equipment limitations.

4.3.2 Life Support Systems

The EVA life support systems to be used in this program are described in Section 3.3.1, page 3-7. The operating time limits given for the -6 PLSS, -7 PLSS and for the SLSS are based on battery capacity only and are independent of EVA activity. The actual useful life support time corresponding to a full charge of consumables varies inversely with the average metabolic rate demand and will probably be less than the battery limited time. Based on Apollo 11 data, the average demand is believed to be on the order of 1000 to 1200 BTU per hour. The OPS life support time of 30 minutes is independent of metabolic rate demand. The utilization of PLSS consumables as experienced on Apollo 11 and planned for Apollo 12 is illustrated by Figure 4-4, page 4-23. An estimate of -7 PLSS consumables usage is shown in Figure 4-4, page 4-23.

4.3.3 General EVA Timelines

A typical period of lunar surface extravehicular activity is preceded by a period of EVA preparation and followed by a period of EVA termination activities, as shown in Figure 4-6, page 4-25. The EVA period itself is defined as the interval during which the LM crew members are dependent upon the EMU for life support; i.e., when the LM cabin pressure is less than 3.5 psia.

Near the end of EVA preparations the extravehicular suit is sealed and a pressure integrity check is performed, followed by cabin depressurization. PLSS oxygen consumption begins when the suit is sealed. PLSS time and pressurized suit time are both defined to begin when the suit is sealed and to end when the suit is reopened, immediately after LM cabin pressure reaches 3.5 psia during repressurization (Figure 4-6).

PLSS time is devoted partially to effective EVA and partially to overhead. Effective EVA includes the deployment of scientific instruments

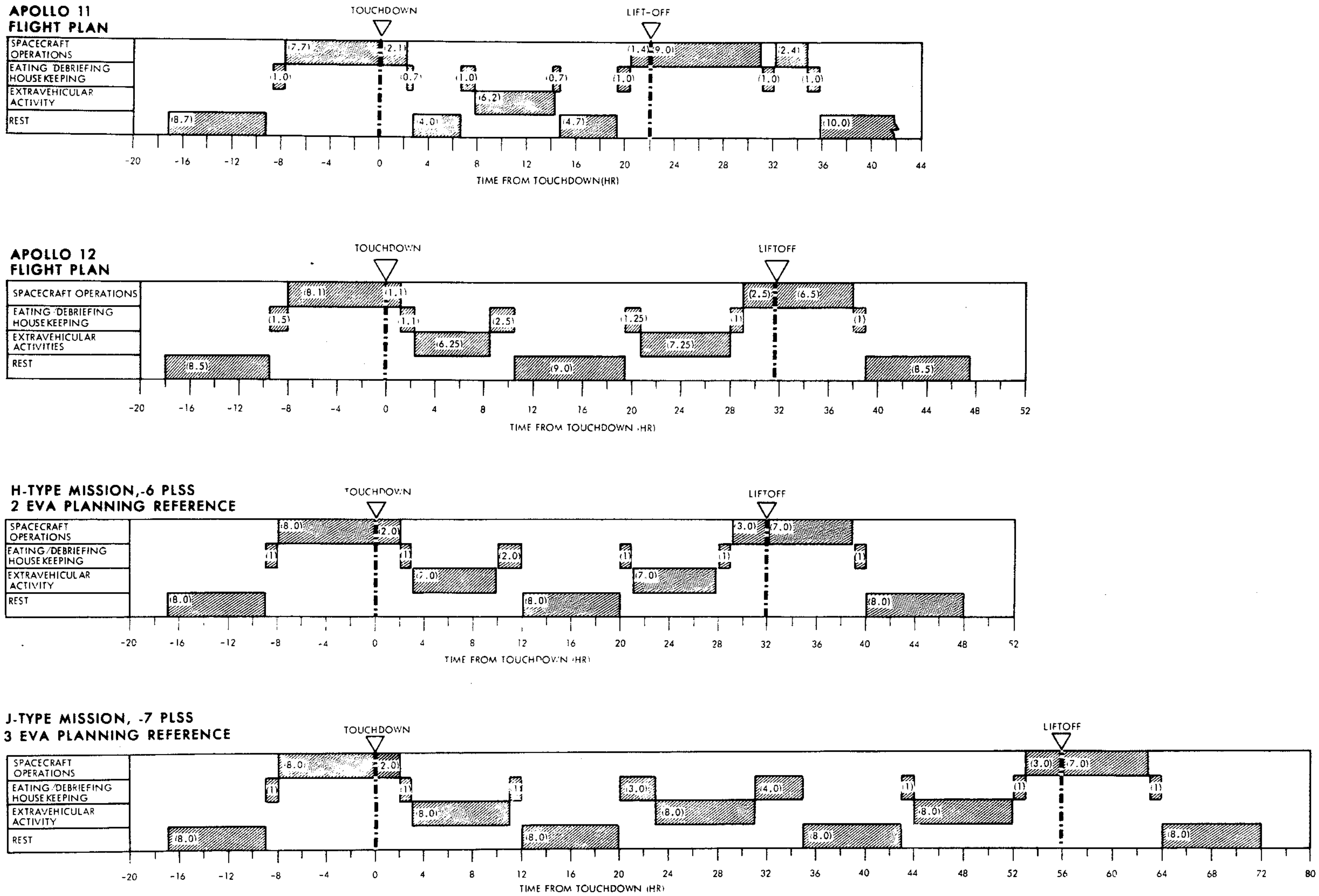

Figure 4-3. Lunar Surface Timelines

APOLLO 11 EXPERIENCE AND APOLLO 12 PLANNING

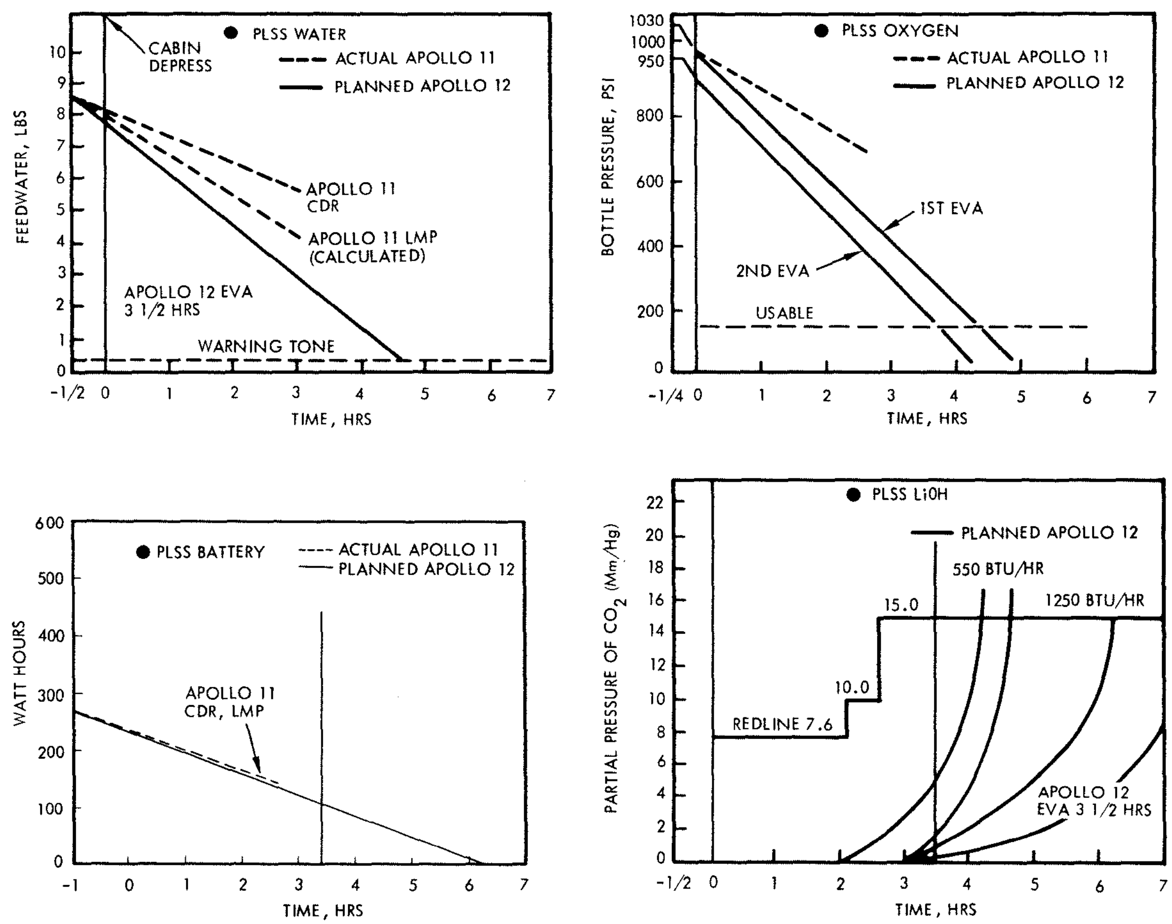

Figure 4-4. Utilization of -6 PLSS Consumables - Apollo 11 Experience and Apollo 12 Planning

FIGURE TO BE SUPPLIED
AT A LATER DATE

Figure 4-5. Estimated -7 PLSS Consumables Usage

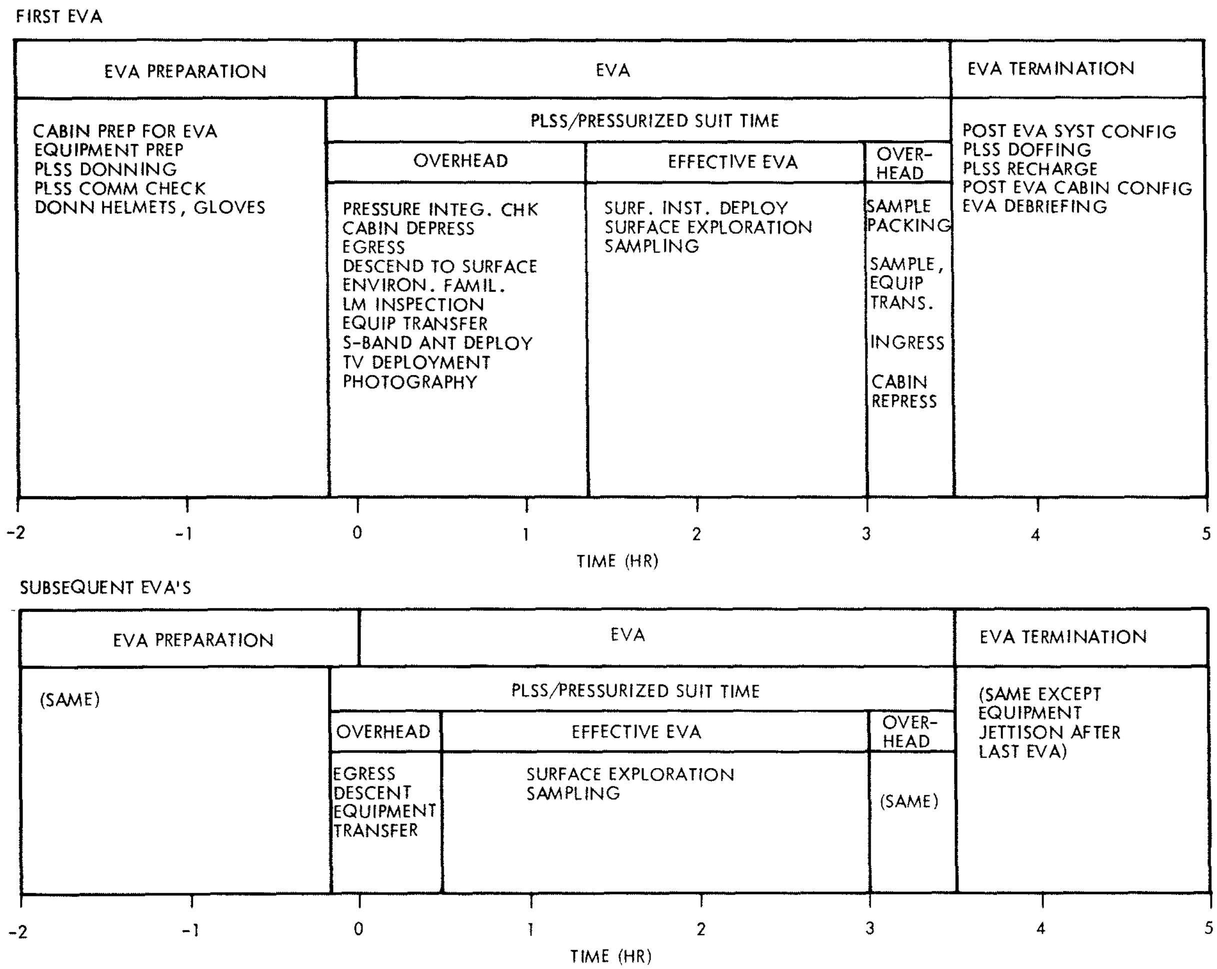

Figure 4-6. Generalized EVA Timelines (-6 PLSS)

and/or exploration of the landing area and sampling. Overhead includes activities not directly related to scientific activities or lunar surface exploration (Figure 4-6).

The first EVA involves more overhead activity than subsequent EVA's, as indicated in Figure 4-6, and consequently affords less time for effective EVA. The overhead allocations in Figure 4-6 were based on the Apollo 12 Flight Plan (Reference 17). The EVA duration of 3.5 hours was based on the -6 PLSS, an average metabolic rate of 1250 BTU per hour and a margin of approximately 20 minutes for contingency. Use of the -7 PLSS would extend the duration of the EVA period to 4.5 hours with approximately the same margin for contingency. The effective EVA time per man may be summarized as follows:

	-6 PLSS (3.5 hr EVA)	-7 PLSS (4.5 hr EVA)
First EVA period	1 hr, 40 min	2 hr, 40 min
Subsequent EVA periods	2 hr, 30 min	3 hr, 30 min

4.3.4 ALSEP Deployment Timelines

For missions configured with ALSEP's (see Table 1-2, page 1-3), EVA planning must provide for their offloading, deployment and activation. Figure 4-7, page 4-27, summarizes the ALSEP Array A deployment as presented in the Apollo 12 Flight Plan (Reference 17). The same array will also be carried on Apollo 15. For the other ALSEP arrays, the deployment timeline must be modified consistent with the assigned experiments. Best estimates for the overall deployment times of Arrays B and C (Apollo 13 and 14, respectively) are approximately 1 hour, 45 minutes each.

4.3.5 Metabolic Rates

The metabolic energy requirement of a given EVA plan can be estimated (1) from the duration of the timeline and an average metabolic energy demand rate (Section 4.3.2), or (2) by summing the energy demands of the individual tasks in the timeline. Estimated metabolic rates for various kinds of activity are presented in this section, to be used in estimating individual task requirements. The values are based on very limited

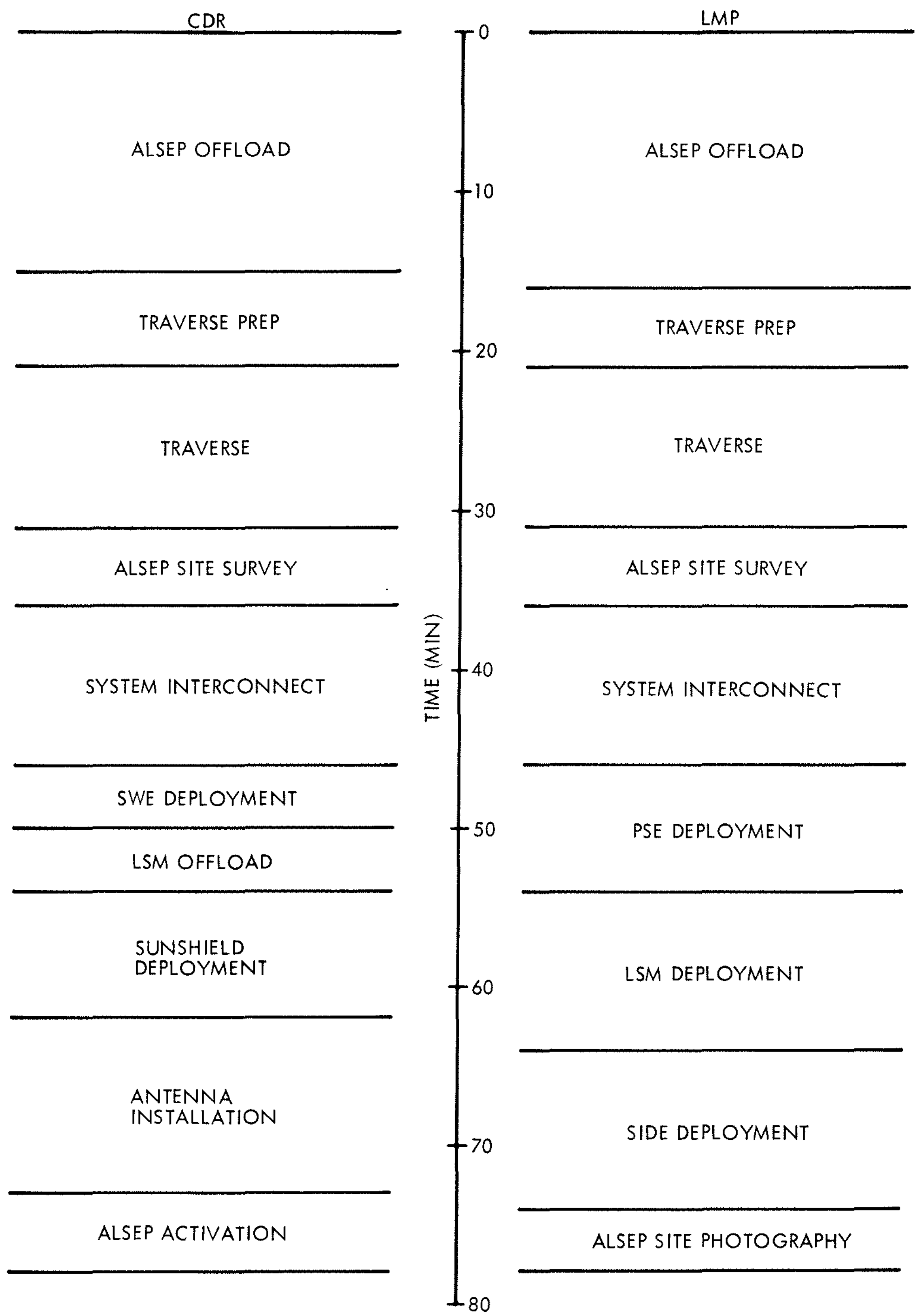

Figure 4-7. ALSEP Array A Deployment
(Apollo 12 and 15)

experimental data and are believed to vary considerably among individuals. For this reason, liberal contingency margins should be planned and real time PLSS monitoring should be planned as practicable.

4.3.5.1 Foot Traverse

Simulations have been conducted at MSC to evaluate the metabolic cost of walking on the lunar surface. The results are presented in Figure 4-8, page 4-29. The test conditions simulated lunar gravity and soil and a level surface. The metabolic rate versus speed relationship in Figure 4-8 is representative of a 160 pound astronaut wearing a 188-pound EMU (A7L suit, PLSS-6 and OPS) and without additional payload. The basic metabolic rate from Figure 4-8 must be corrected for differences in gross weight and slope as discussed in subsequent paragraphs.

When the gross weight of the astronaut, EMU and payload differs from the 348-pound baseline associated with Figure 4-8, the metabolic rate correction for the difference can be obtained from Figure 4-9, page 4-29.

The metabolic cost is greater when walking upgrade and lower when walking downgrade than when walking horizontally. However, the penalty upgrade exceeds the savings downgrade for the same slope, so there is a net slope penalty for a round trip over rolling terrain, even when the same route is followed in both directions. There is a further penalty in the point-to-point cost of a traverse when it is necessary to deviate from the direct route to avoid obstacles. The slope and wander penalties will vary with the nature of the lunar surface in the vicinity of the landing site. For planning purposes it is estimated that the combined penalties increase the cost of a point-to-point traverse by 40 percent.

4.3.5.2 Lunar Roving Vehicle (LRV) Traverse

Riding on the rover involves a relatively low level of physical activity without metabolic rate penalties for payload and slope. The metabolic rate for riding is assumed to be independent of vehicle speed and is estimated to be 700 BTU per hour in the A7L suit.

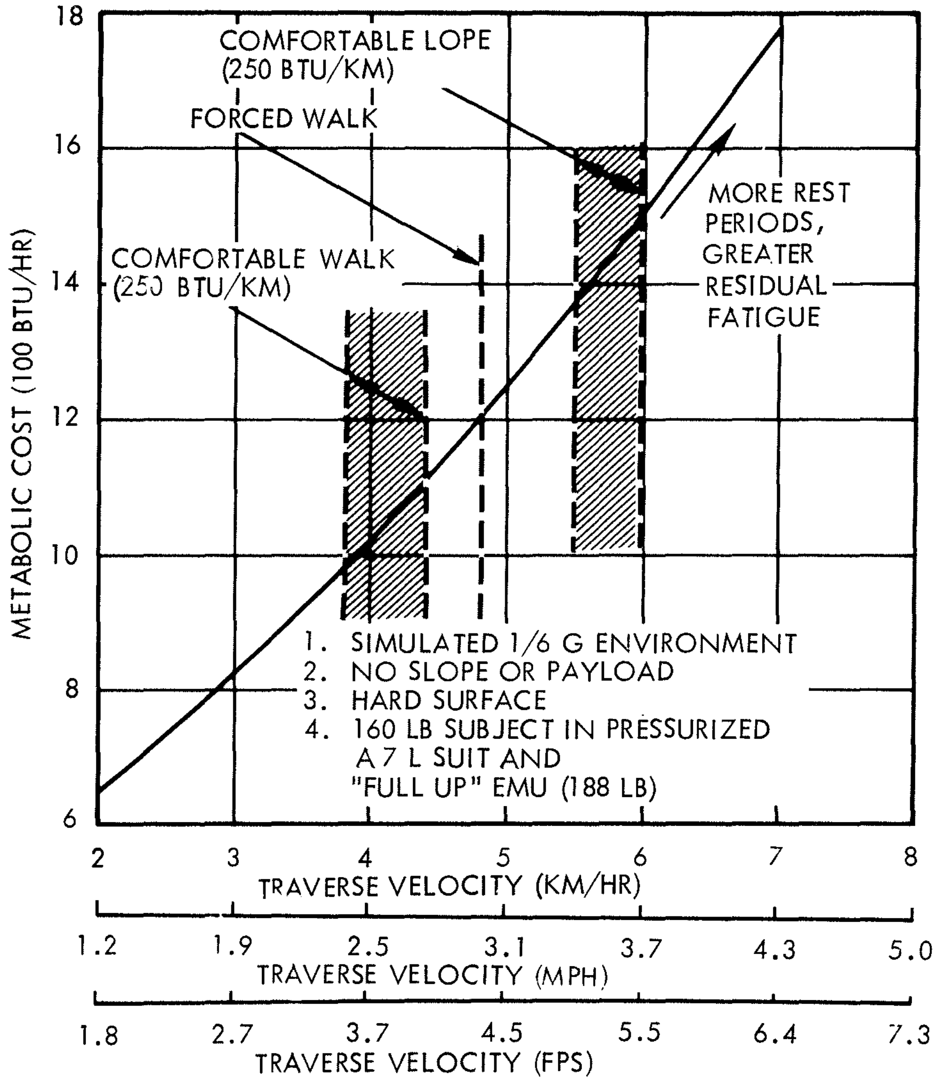

Figure 4-8. Metabolic Rate for Travel on Foot

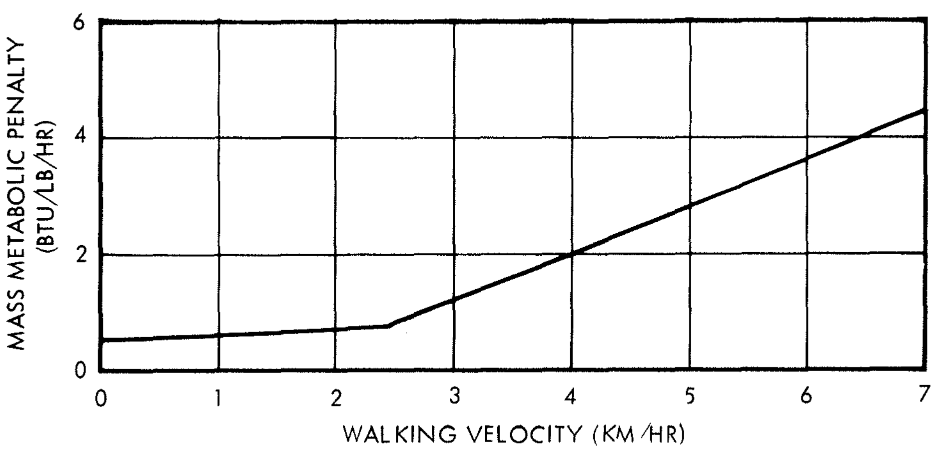

Figure 4-9. Metabolic Weight Penalty for Additional Gross Weight

4.3.5.3 Scientific and Essential Overhead Tasks

Scientific and overhead activities are expected to be carried out at a comfortable level of effort that can be maintained without fatigue. The average metabolic rate for these activities is estimated to be 1100 BTU per hour in the A7L suit.

4.3.6 Traverse Speeds

4.3.6.1 Walking

Under normal conditions the astronaut can be expected to walk at a comfortable average speed that he can maintain without fatigue. Referring again to Figure 4-8, the comfortable speed range for the test conditions indicated was found to be 3.8 to 4.5 kilometers per hour, corresponding to a metabolic rate of 1000 to 1100 BTU per hour. On slopes or when carrying additional weight, the astronaut can be expected to adjust his speed downward to maintain a comfortable level of effort. Thus, his metabolic rate is expected to remain more nearly invariant than his speed.

A significant parameter in budgeting PLSS capacity is the metabolic energy cost per unit travel distance. This parameter can be computed for points on the curve in Figure 4-8 by dividing the metabolic rate by the corresponding speed. Note that over the speed range encompassing both the comfortable walk and comfortable lope regions, this parameter remains nearly constant at approximately 250 BTU per kilometer. Payload, slope and wander penalties will increase the value, but it will remain approximately independent of speed as long as a comfortable speed is maintained. For PLSS budgeting purposes a foot travel speed of 4 kilometers per hour has been assumed and the corresponding metabolic rate has been computed to establish the metabolic cost per unit distance. It should be noted, however, that a comfortable speed may be less than 4 kilometers per hour.

4.3.6.2 Riding

Rover speed will be variable up to a maximum of approximately 16 kilometers per hour. Average speed is expected to be in the region of 5 to 10 kilometers per hour, a representative value being 8 kilometers per hour.

4.3.7 Guidelines and Constraints

4.3.7.1 Physiological Capability

The rate at which an astronaut can work without excessive fatigue is an important consideration in EVA planning. Figure 4-10, page 4-32 presents an envelope of metabolic expenditure based on tests conducted at Grumman, Flagstaff and at Langley for subjects considered to be in good physical condition. The envelope labeled "fatigue" represents the metabolic energy output above which the subject could not fully recover with a normal rest period. The envelope labeled "exhaustion" represents the output beyond which the subject could not continue working.

The fatigue and exhaustion limits vary considerably from subject-to-subject and beyond three or four hours of activity they are not well defined, as indicated by the shaded area of Figure 4-10. As a guide for EVA planning it is recommended that the integral of metabolic expenditure rate be maintained below the fatigue limit of Figure 4-10 throughout the EVA period.

4.3.7.2 Additional Guidelines and Constraints

Following is a list of additional guidelines (G) and constraints (C) to be observed in EVA planning.

- Nominal PLSS residuals at the end of an EVA period should be adequate for at least 20 minutes additional life support. (C)
- Nominal time in the pressurized suit shall not exceed six hours. (C)
- Both LM crewmen shall participate in all excursions away from the immediate vicinity of the LM. (C)
- EV crewmen shall not be out of communication with Mission Control for more than five minutes at a time. (C)
- EV crewmen shall not be out of communication with each other for more than five minutes at a time. (C)
- EV crewmen shall remain within sight of each other at all times. (C)
- In the event of a PLSS failure, the astronauts shall be able to return to the LM, reenter it and repressurize the cabin within the capability of the backup life support system. Fifteen minutes or 300 BTU shall be allowed for LM reentry and repressurization. (C)

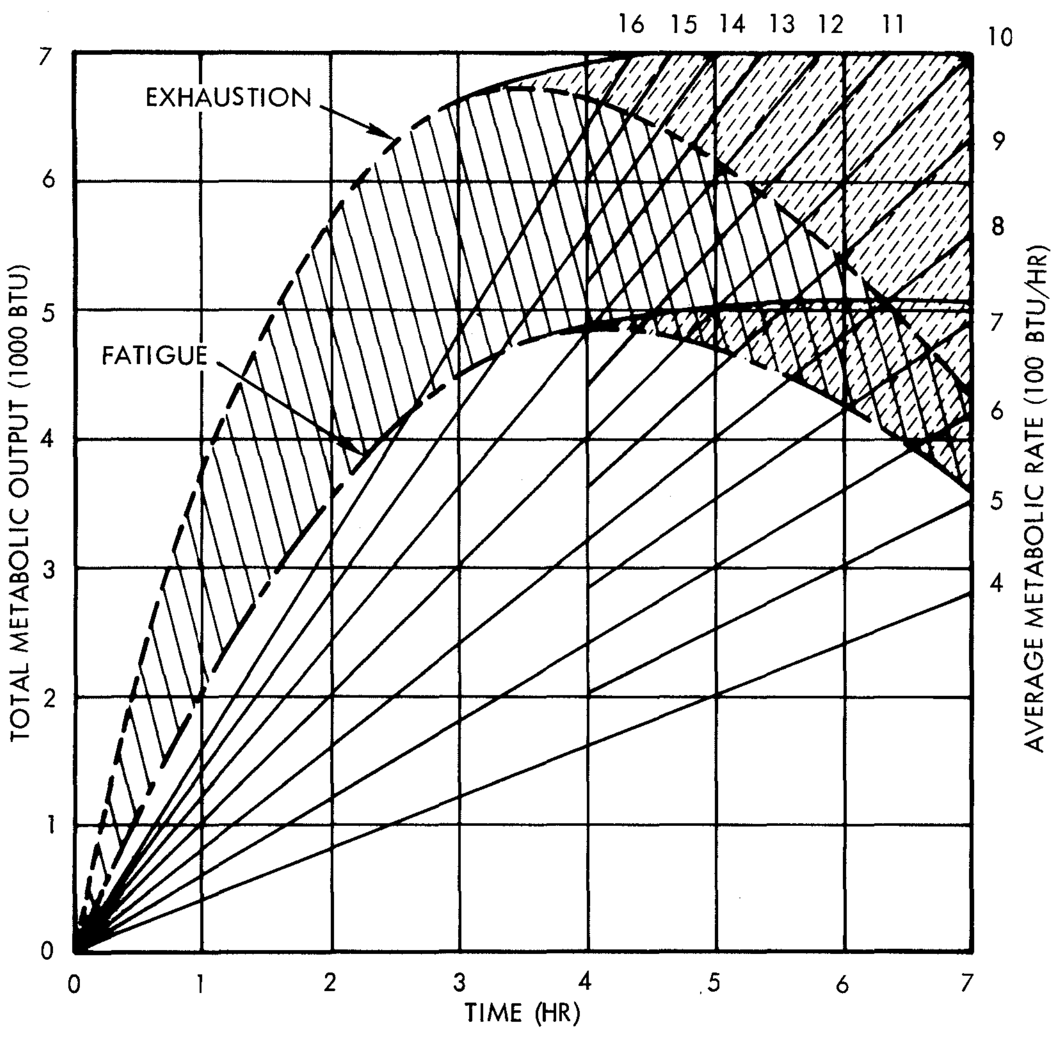

Figure 4-10. Physiological Limits

- Maximum radius of operation from the LM on missions with a mobility aid shall not exceed the ride-back range of the SLSS.
- In the event of an emergency requiring immediate walk-back to the LM, it may be assumed that all payload would be dropped and that the return would be via the most direct route. (G)

4.3.8 Science Time vs Distance From LM

The effective EVA period as defined in Section 4.3.3 may be divided into science time and travel time, the former being time spent at points of interest within the landing area and the latter being the time spent in traveling among these points. The considerations that limit science time, travel and distance from the LM are discussed in this section.

4.3.8.1 PLSS Capacity

The total metabolic energy demand per man for overhead activities, travel and scientific activities during an EVA must remain within the PLSS capacity less margin requirement. PLSS budgeting for a rover excursion is illustrated by Figure 4-11, page 4-34. The budgeting for a walking excursion is similar.

The portions of PLSS capacity budgeted for margin and final overhead activities are shown at the bottom of the figure. The emergency overhead budget is sufficent for the crew members to reenter and pressurize the LM. Overhead requirements prior to the excursion are shown at the top of the figure. The portion of PLSS capacity between points A and B is available for travel and scientific activities.

4.3.8.2 Walk Back Limit

In the event of a rover failure the crew must be able to walk back to the LM, arriving with residual PLSS capacity at least equal to the emergency overhead requirement plus margin. The slope of the "walk back limit" line is equivalent to the metabolic energy cost per unit distance for a man walking without payload. Residual PLSS capacity must not fall below the value indicated by the walk back limit at any time during the excursion.

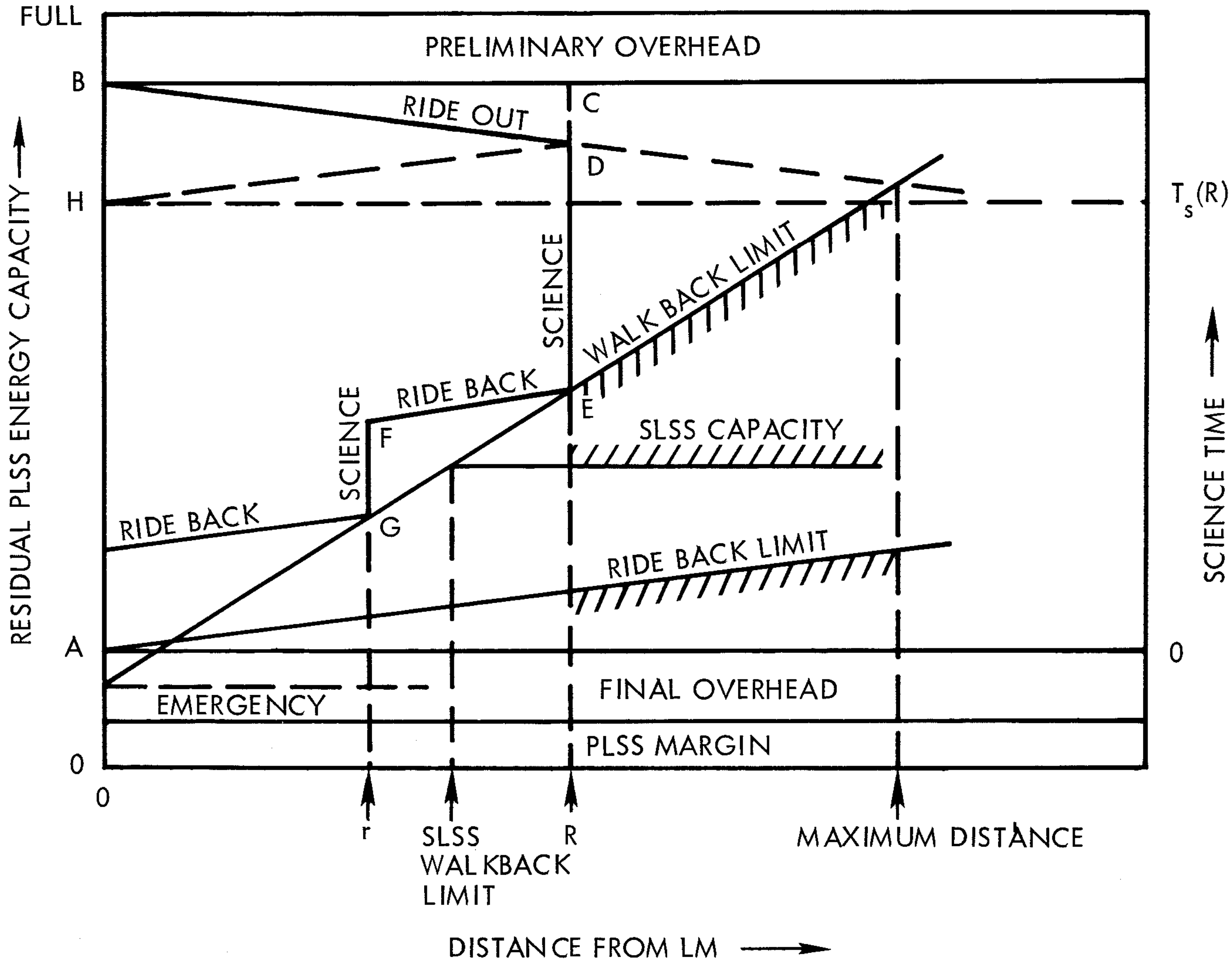

Figure 4-11. PLSS Budgeting for a Rover Excursion

4.3.8.3 Ride Back Limit

The "ride back limit" represents the metabolic energy cost per man of returning to the LM on the rover. Residual PLSS capacity must remain above this limit throughout the excursion.

4.3.8.4 Available Science Time

In a typical excursion the crew might ride out to a distance R from the LM, the travel cost per man being represented by $\overline{CD}$ in Figure 4-11, page 4-34. The PLSS capacity available for scientific activities at this distance without violating the walk back limit is indicated by $\overline{DE}$. The crew could, however, ride back to a distance r from the LM and there expend additional energy equivalent to $\overline{FG}$ on scientific activities. Any schedule of travel and scientific activities that remains above both the walk back and ride back limits is acceptable.

The maximum PLSS capacity available for scientific activities within a distance R from the LM can be seen by projection onto the vertical axis to be equivalent to $\overline{AH}$. This can be converted to science time, using the average metabolic rate for scientific activities. A science time scale can be drawn as indicated at the right hand side of the figure, with $T_s(R)$ indicating the maximum science time available within a distance R from the LM, as limited by PLSS capacity only.

4.3.8.5 SLSS Limit

In the event of a PLSS failure the crew must be able to return directly to the LM with SLSS residual capacity at least equal to emergency overhead and margin requirements. On a rover mission they would ride back, this being more economical in terms of metabolic energy cost than walking.

SLSS metabolic energy capacity can be plotted as shown in Figure 4-11. Distance from the LM is limited by the SLSS to the value corresponding to the intersection of the SLSS capacity line with the walk back limit for a walking excursion, or with the ride back limit for a rover excursion.

4.3.8.6 OPS Limit

The OPS limits emergency walk back time to 15 minutes. The corresponding limit on distance from the LM is proportional to emergency walking speed, assumed to be 4 kilometers per hour. Thus, the OPS limits distance from the LM to one kilometer.

4.3.8.7 Pressurized Suit Limit

The time that must be spent in the pressurized suit during an EVA period is the sum of overhead time, travel time and science time. This sum must not exceed the specified limit on time in the pressurized suit (Section 4.3.7.2, page 4-31).

4.3.8.8 Examples

Figure 4-12, (below) shows the relationship between maximum available science time and maximum distance from the LM for several cases of interest.

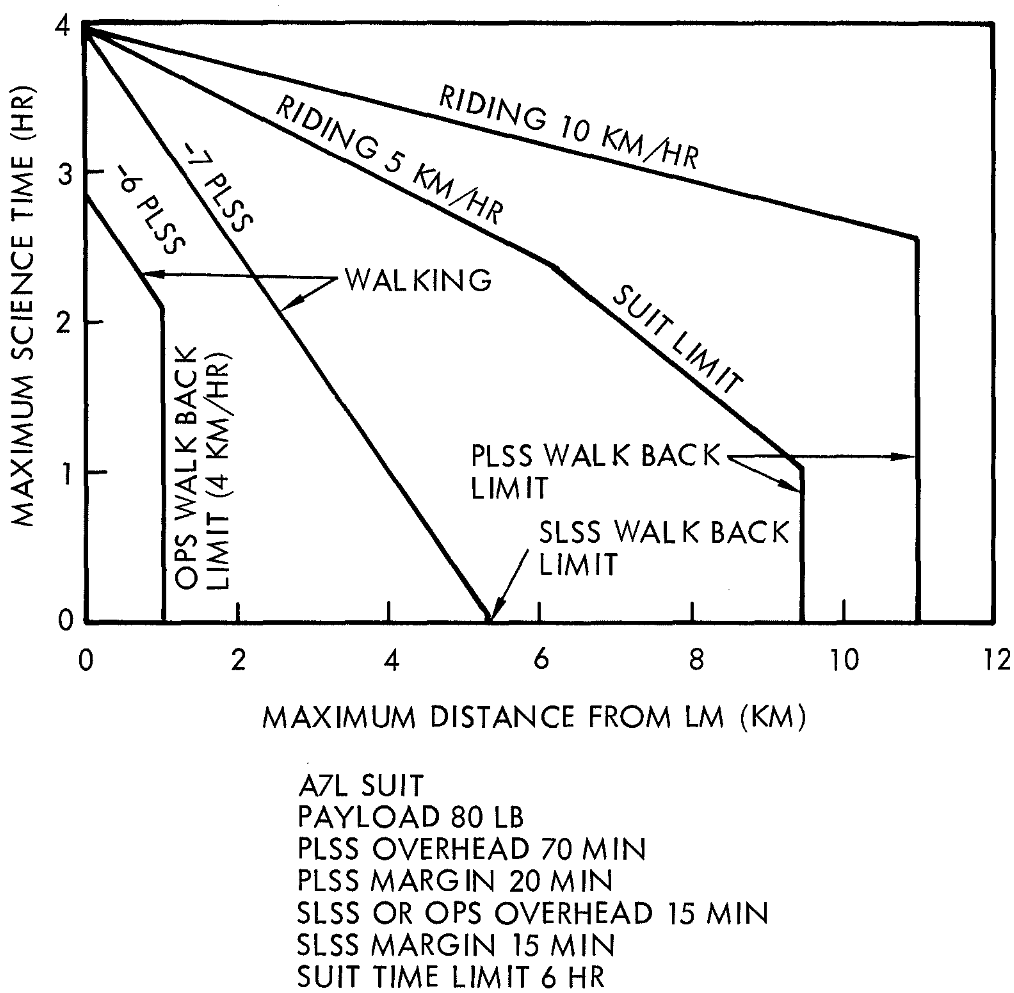

Figure 4-12. Maximum Available Science Time vs. Maximum Distance from the LM

4.4 LUNAR ORBITAL SCIENCE OPERATIONS

Lunar orbit experiment assignments are presented in Table 3-1, page 3-11. Some of the considerations affecting the development of timelines for lunar orbit experiment operations and a representative 40-hour portion of the timeline for the type J missions are presented in this section, together with the associated power profile. Summary descriptions of the orbital instruments are presented in Appendix A.

4.4.1 Guidelines

- Orbital experiment operations will be conducted after lunar orbit rendezvous and crew return to the CSM. CM experiments may be conducted during LM surface stay.
- The door of the scientific instrument module (SIM) is to be jettisoned after rendezvous with sufficient velocity ($\Delta V \simeq 85$ fps) to cause it to impact the lunar surface.
- During the period of service module experiments operation the spacecraft will be maintained in a local vertical attitude hold with the SIM door down, except during brief periods when certain experiments require other attitudes.
- The three crewmen will sleep simultaneously and no experiment operations requiring their attention may be scheduled during sleep periods.
- Crew support of experiments scheduled during meal periods must be limited to momentary functions, such as switching.
- If sufficient propellants are available, an orbit change may be made after rendezvous to provide more favorable lunar surface coverage for the experiments.
- The mission power profile assumes electromagnetic compatibility of the experiment payload.
- Exposed camera film will nominally be recovered from the scientific instrument module by EVA in lunar orbit. This EVA may be accomplished during transearth coast, if a SLSS and extra-vehicular suit can be carried through TEI. In this case it must be completed before passage through the radiation belts. In either case it must not be done in the presence of flux from solar flares.

4.4.2 Timeline Requirements

Operating time and power requirements for the orbital experiments are presented in Table 4-2, page 4-39. Other requirements are listed below.

- Several experiments require warmup or standby power after the SIM door is jettisoned. A more realistic mission power profile can be made when the door-off SIM thermal conditions are better established.
- Most experiments require a field of view along the local vertical when mounted in the SIM. However, for calibration purposes some experiments require CSM orientation to other attitudes for various time periods. In the case when the SIM is not pointing along the local vertical, some experiments should be turned to standby or off. This would in effect modify the power profile.
- Since the exact configuration of antenna booms, experiments mounted on booms, etc., is not presently known, time sharing of experiment operating time may be required to prevent interference in the fields of view of the various instruments.
- Each 24 hours of lunar orbit operations shall include an eight-hour sleep period and one-hour meal periods immediately preceding and following the sleep period. A third one-hour meal period shall be scheduled approximately midway between sleep periods.
- Fuel cell purges, IMU alignments and other necessary functions shall be scheduled as required.
- The S-band transponder experiment requires that the spacecraft be free of forces and torques due to thrusting, venting, or attitude control. Attitude rates must be zeroed as well as possible prior to the experiment and the crew must remain as motionless as possible during the experiment.

4.4.3 Illustrative Timeline

In any specific mission the nominal schedule of daylight-darkness intervals and MSFN communication intervals relative to lunar orbit insertion will be mission-dependent. Time-critical operations such as LM separation and descent, LM liftoff and rendezvous, and transearth injection will also be mission-dependent. Experiment operations must

Table 4-2. Timeline and Power Requirements For Orbital Experiments

Experiment	Standby Time	Standby Watts	Operate Time	Operate Watts
X-Ray Spectrometer	Note 1	26	Continuous	40
Gamma-Ray Spectrometer	-	7	Continuous	8
Far UV Spectrometer	-	-	1:30 hr/rev	5
Mass Spectrometer	-	-	Continuous	13
Downlink Bistatic Radar	No additional power requirement.			
IR Scanning Radiometer	30 min warm-up	2	Continuous	13
24" Panoramic Camera	3 hr warm-up	150	1 hour	250 (Note 2)
3" Mapping Camera	3 hours*	25*	1 hour*	125*
S-Band Transponder	No additional power requirement.			
Alpha Particle	Note 1	4	Continuous	6
EM Sounder "A"	-	-	Continuous	70
Subsatellite	Power supply self-contained.			
Radar Sounder	-	-	10 hours	150
Laser Altimeter	15 min warm-up	32	4 hours	48

*Estimated.

Notes: 1) Standby power is required continuously after SIM door has been jettisoned, except when experiment is operating.

2) Maximum load is approximately 400 watts at peak heater demand.

be scheduled relative to these events consistent with experiment requirements and without interference with essential mission profile operations.

An illustrative orbital experiments timeline is presented in Figure 4-13, page 4-40. The 40 hours of experiment operations shown in Figure 4-13 are typical of the entire period of experiment operations, up to 77 hours between rendezvous and TEI. The X-ray and gamma-ray spectrometers may operate continuously throughout the entire period.

A representative profile for the orbital experiments is also shown in Figure 4-13. The highest peaks can be seen to correspond to operation of the mapping and panoramic cameras, and peak demands may at times be even higher depending upon heating requirements. A total of 220 to 240 kilowatt-hours is available for experiments operation. The maximum experiment power load should be limited to 400 watts dc and in no case shall it be high enough to cause the dc bus voltage to decrease below 25 volts (Reference 18).

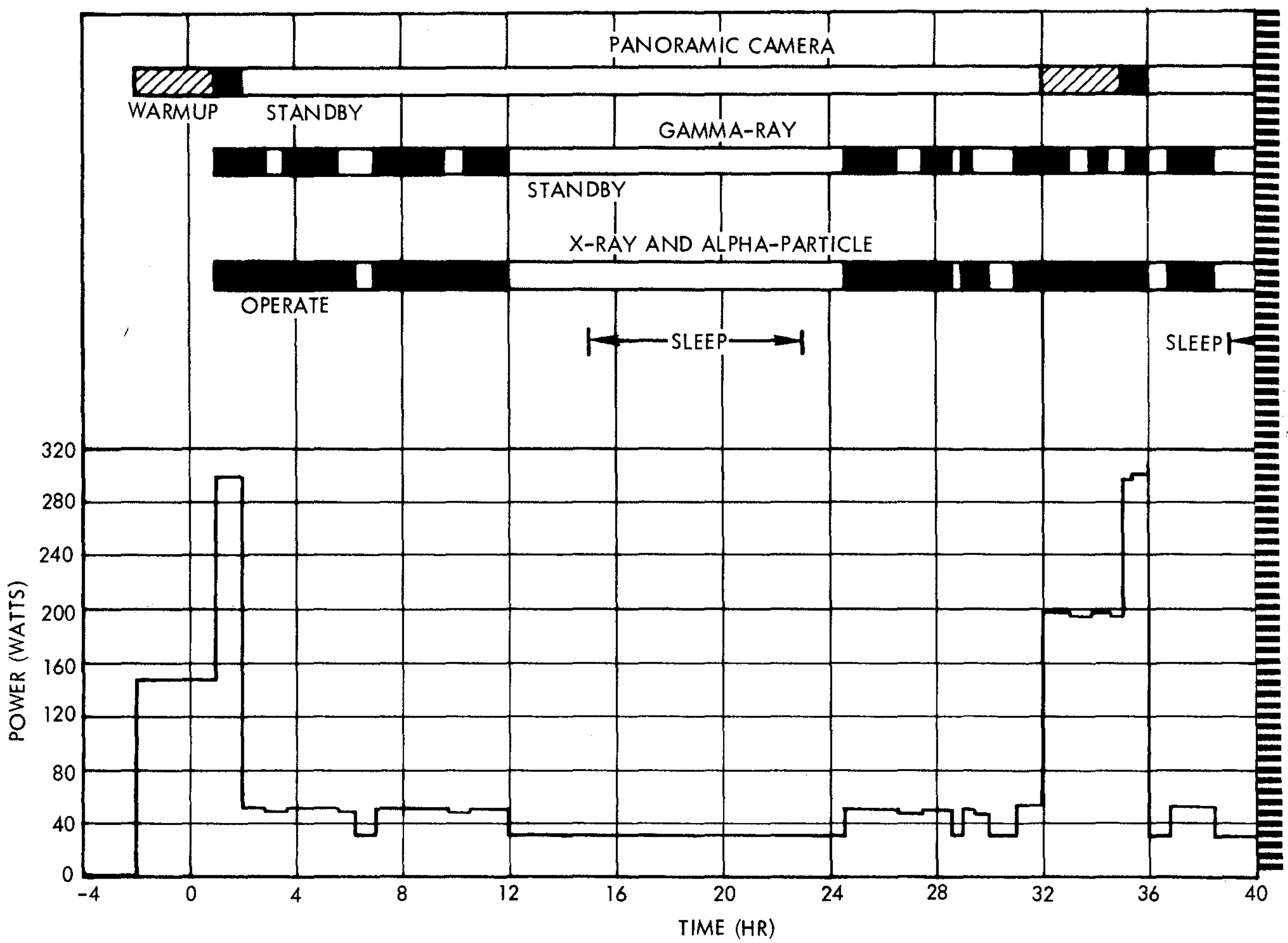

Figure 4-13. Illustrative Orbital Experiments Timeline and Power Profile

4.5 PLANNING ASSUMPTIONS AND PERFORMANCE

The purposes of this subsection are to enumerate some of the basic assumptions upon which mission plans were developed and to present information on significant aspects of Apollo system performance.

4.5.1 Planning Assumptions and Considerations

There are a number of assumptions which have been made in order to provide preliminary data on missions which have not yet been planned in detail. These assumptions are as follows (also see Reference 19):

- Consumables data and time increments between major mission milestones are shown in Appendix D.

- For missions H2 and subsequent, planning will be done to provide multiple launch opportunities for each mission in accordance with the following table:

	Launch Opportunity		
Launch Month	First	Second	Third
First Month	Prime site at SEA* = 5 - 14°	Prime site at SEA = 18 - 27°	No attempt for recycle site landing
Second Month	Prime site at SEA = 5 - 14°	Prime site at SEA = 18 - 27°	Recycle site at SEA = 5 - 14°

*SEA: Sun Elevation Angle

  - Launch opportunities will be approximately 3 hours in duration.
  - Primary and recycle sites are indicated in Table 1-2, page 1-3.

- The launch schedules for the Apollo Lunar Exploration Program and the Apollo Applications Program are independent.

- The translunar trajectory will be constrained such that the descent propulsion system (DPS) can provide sufficient ΔV to return the CSM to Earth at any time between LM extraction from the Saturn to 2 hours after an SPS ignition failure at LOI (DPS constraint). Refer to Figures 4-14 and 4-15, pages 4-42 and 4-43 for lunar sites accessible within the confines of this constraint. Waiving of this constraint will be considered for a single mission if scientific gains justify the added risk.

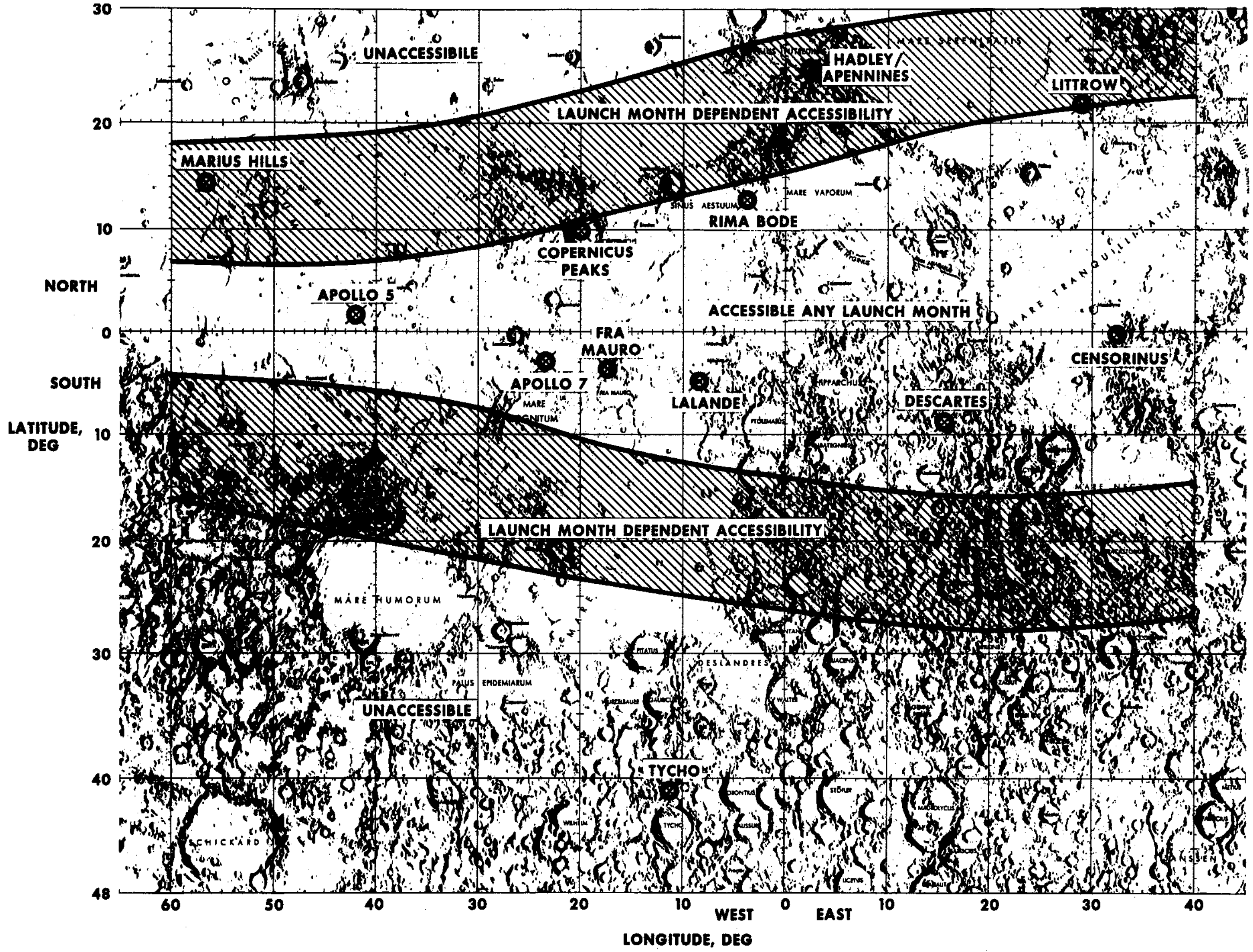

Figure 4-14. Approximate Lunar Accessibility with Hybrid Constrained to DPS Abort Capability for H Missions

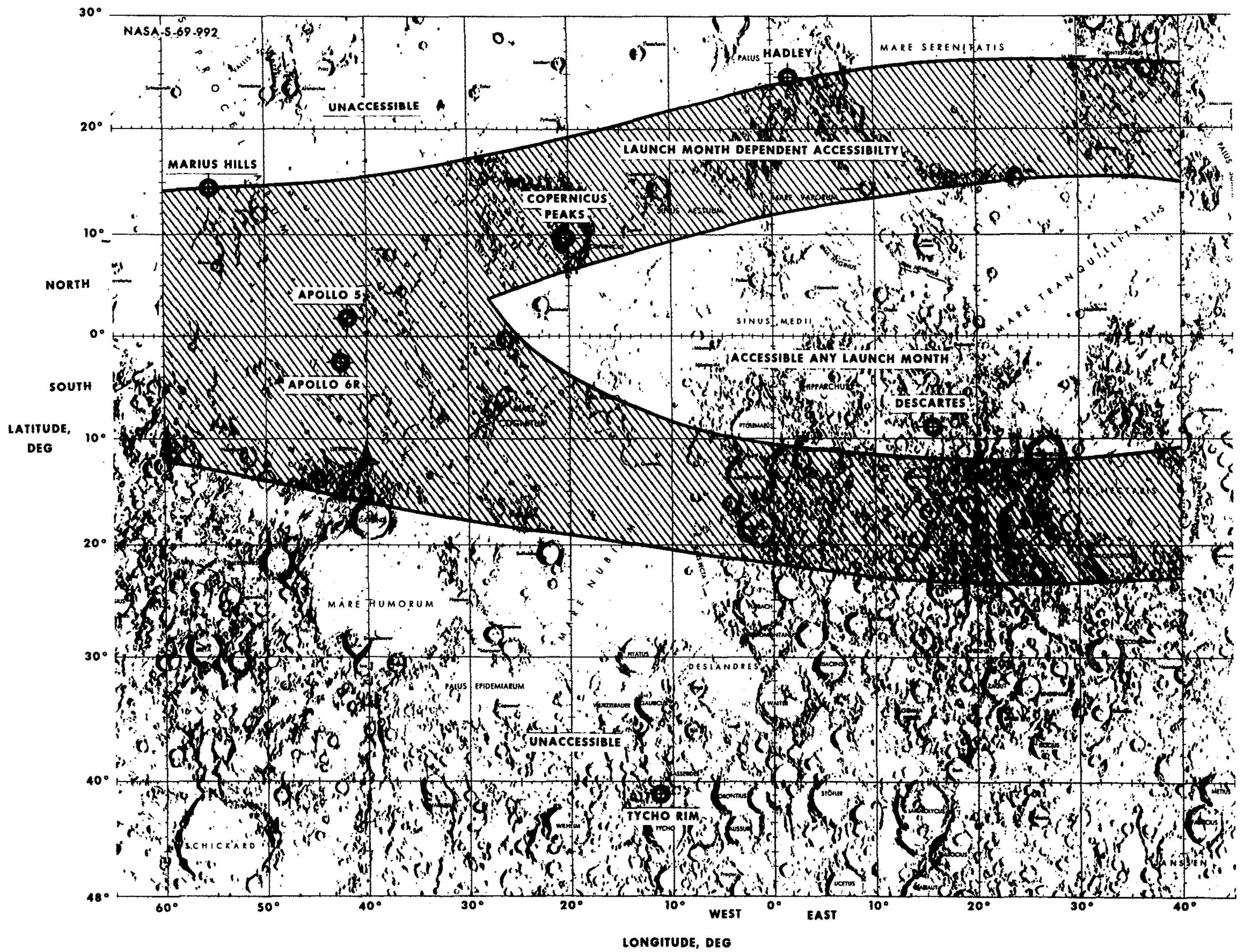

Figure 4-15. Approximate Lunar Accessibility with Hybrid Constrained to DPS Abort Capability for J Missions

- SHe "hold time" is 180 hours for H-type missions and 190 hours for J-type missions.

- Range of launch azimuth is 72 to 96 degrees.

- Launches will be in daylight and translunar injection will be over the Pacific.

- The 210 foot MSFN antenna is required for coverage of the lunar landing and for backup communications during EVA.

- Twelve or thirteen revolutions will be spent in lunar orbit prior to PDI (same as Apollo 11).

- Lunar liftoff may be accomplished during any revolution.

- The capability to return to Earth (with mid-Pacific landing) on any revolution is required, including the cryo tank failure case.

- The maximum nominal transearth return inclination is 40 degrees. For the contingency case the return inclination may be up to 30 degrees.

- The hybrid trajectory may be employed on any mission.

- The DOI maneuver will be conducted using the SPS on missions H2 and subsequent.

- The mission independent SPS ΔV budget is as follows:

- CSM LM docked		
- 3σ Translunar and LOI dispersion allowance		120 FPS
- SPS DOI*		75 FPS
	TOTAL	195 FPS
- CSM solo		
- Post-DOI circularization*		75 FPS
- Contingencies		
- LM rescue**	900 FPS	
- Weather avoidance	500 FPS	
- SCS TEI	150 FPS	
- RSS contingencies		1,040 FPS
	TOTAL	1,115 FPS
- 3σ Engine performance, unbalance meter, outage		585 lb

*Not applicable to Mission H-1; DOI performed with DPS.
**The LM rescue budget may be used to change the CSM orbital plane after completion of a nominal rendezvous to extend orbital instrument surface coverage.

4.5.2 Major Maneuvers

The estimated impact of operational flight mode changes currently planned for use in the Lunar Exploration Program are discussed in the following paragraphs. Precise data will depend on trajectory and spacecraft specifications which will be defined at a later date as the Flight Operations Directorate develops design reference and operational trajectory data.

4.5.2.1 Free Return and Hybrid TLI Maneuvers

Current flight plans call for the free return constraint on TLI for all missions. The hybrid trajectory option, i.e., transfer to a non-free return profile after TLI, as constrained by DPS abort following failure to accomplish LOI, can be used for any of the missions. The planned midcourse maneuver on the hybrid trajectory profile will be performed with the first required midcourse correction and will provide the opportunity for an SPS confidence burn. See Figure 4-15, page 4-43 for the hybrid lunar profile.

4.5.2.2 Multiple Impulse LOI - TEI

The precise maneuver sequences and ΔV requirements for multi-impulse LOI and TEI under development by the Flight Analysis Branch of the MPAD and the data are not available at the present time. The requirements necessitating their use are described below:

- A multiple impulse LOI may be required so that the plane change necessary for insertion into high inclination orbits can be accomplished. The requirements of the maneuver will be defined at a later date depending on spacecraft configuration, launch date and mission profile.

- A multiple impulse TEI maneuver may be required to provide nominal and/or any-time return to Earth capability. Mission design provides a unique maneuver execution time where a single impulse TEI maneuver may be used. Multiple impulse TEI maneuvers may be able to provide continuous return to Earth capability.

4.5.2.3 CSM DOI

Beginning with mission type H2, SPS docked maneuver LOI-2 will become known as DOI. This maneuver will be performed on LOI day and will

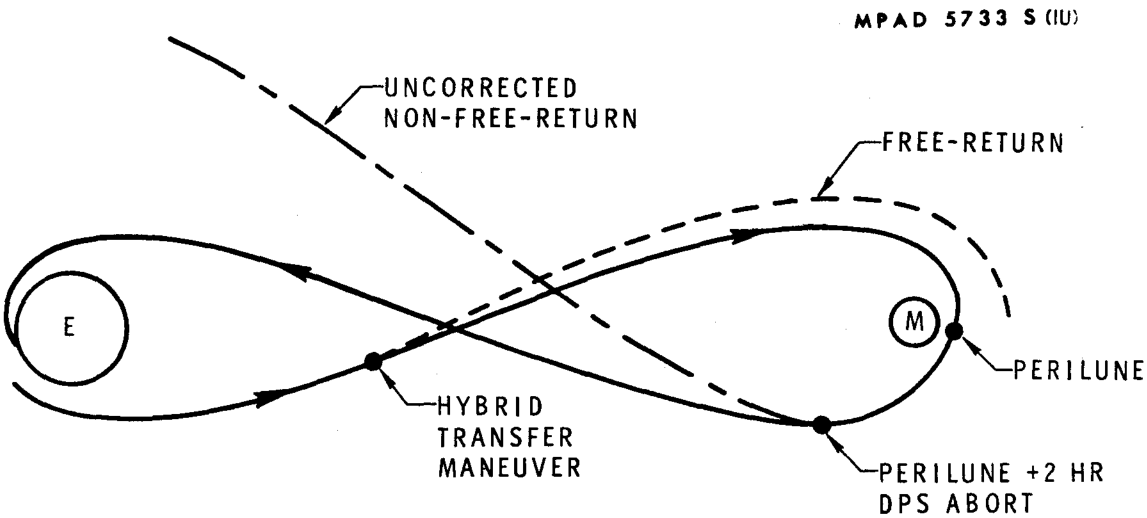

Figure 4-16 Hybrid Lunar Profile with DPS Abort Constraint

insert the spacecraft into a 60 X 8 n.mi. orbit. Trim maneuvers will be required if the pericynthion is less than 30,000 ft or greater than 70,000 ft of altitude. This change will reduce the LM ΔV required to descend to the lunar surface. The ΔV savings are to be used to enhance the capability to land heavier payloads on the lunar surface and to enhance precision landing capability. At some time prior to PDI, the CSM recircularizes at 60 nautical miles. The LM begins powered descent at some subsequent pericynthion passage. The LM ΔV requirement is reduced by about 71 feet per second, while the CSM ΔV budget is increased by approximately 142 feet per second.

4.5.2.4 Propellant Reserve Estimates

An analysis of the SPS ΔV margins for the lunar landing sites has been conducted by MPAD (Reference 19). The assumptions to be used in this analysis are those specified in Section 4.5.1. The results of this analysis are shown in Table 4-3, page 4-47.

Table 4-3. Estimated Gross Systems Performance
(Launch Vehicle Injected Payload = 106,500 lbm)

Mission	H1	H2	H3	H4	J1	J2	J3	J4	J5
Launch Date	11/69	3/70	7/60	11/70	3/71	7/71	2/72	7/72	2/73
(1) Landing Site	Apollo 7	Fra Mauro	Littrow	Censorinus	Descartes	Marius Hills	Copernicus	Hadley	Tycho
(1) LM Redesignation ΔV (fps)	60	60	60	100	60	60	100	60	100
(1) LM Manual Maneuvering (sec)	170	184	184	175	125	120	150	120	150
(1) LM Payload Capability (lbm)	350	350	350	350	940	1025	390	1025	390
(2) SPS Propellant Reserve Category	III	III	III	III	I	I	I	I	I
(1) CSM Payload Capability	NA	NA	NA	NA	800	600	450	1650	650

(1) Data obtained from References 20 and 21.
(2) SPS end of mission propellant reserve data obtained from Reference 19.
(3) CSM payload assumes maximum LM payload, see Figure 4-2, page 4-15.

Propellant Reserve Category	SPS End of Mission Propellant Fuel Reserve (lb)
I	less than 500
II	500 to 1000
III	greater than 1000

5. SITES AND SCIENTIFIC COVERAGE

The purpose of this section is to present a picture of the candidate lunar landing sites and to show their relationships with possible scientific coverage.*

5.1 SURFACE SCIENCE COVERAGE

5.1.1 Landing Site Selection

The criteria for selection of a lunar landing site include the following significant factors:

- Scientific interest and uniqueness--its own characteristics and how they relate to those of the rest of the Moon with regard to providing answers to scientific questions.
- Scientific variety--the number of varied features which could be explored in the vicinity of the landing
- Instrument networks--the selenographic location as a part of a viable network of scientific instruments (primarily seismic)
- Photography, i.e., data availability--sufficient high resolution photography of the site and its landing approach to determine landing feasibility capabilities and to verify scientific interest
- Match to capability--the ability of the Apollo system and program of missions to achieve a landing site and of the surface exploration to achieve scientific objectives.

Table 5-1, page 5-9, lists the candidate landing sites which have received most serious consideration. It also presents a brief picture of their characteristics and scientific interest. The landing site coordinates in Table 5-1 indicate the points of primary scientific interest or surveyor spacecraft location at each site. The location of these sites on a map of the Moon is shown in Figure 1-1, page 1-5. Also tabulated is the available photography (medium or high resolution and stereoscopic) for each candidate landing site, obtained by Lunar Orbiter Missions II through V.

*The data presented in this section were obtained from References 6, 19, 22, 23, 24, 25 and through informal discussions and working meetings with Bellcomm and MSC personnel.

The scientific objectives of the Apollo Lunar Exploration Program are listed in Table 1-1, page 1-1, and are discussed in Section 2.0. In order to maximize the scientific return from the first ten lunar exploration missions a set of landing sites should include:

- The two types of mare material, "old or Imbrian and young or Eratosthenian"
- Regional stratigraphic units such as blanket (ejecta) deposits around mare basins
- Various types and sizes of impact craters in maria and in highlands
- Morphological manifestations of volcanism in maria and in highlands
- Areas which may give clues to the nature and extent of processes, other than impact and volcanism, which may have acted upon the lunar surface.

These requirements meet both the geological and geochemical objectives of lunar exploration. The geophysical objectives require a specific mission assignment plan particularly for the construction of seismic networks. Other scientific objectives do not call for much that would contradict this rationalization.

With these considerations in mind for planning the Apollo 12 to Apollo 20 missions, nine prime landing sites (Table 1-2, page 1-3), have been selected for study by the Group for Lunar Exploration Planning (GLEP). The alternate landing sites listed in Table 1-2 are one of a set selected for planning by the GLEP (Reference 23). The list of both prime and alternate landing sites will be reviewed periodically by the GLEP and updated through recommendations to the Apollo Site Selection Board. Additional sets of alternate landing sites are provided in Reference 23. It should be noted that the set of alternate landing sites is autonomous and represents the program option in which the Fra Mauro mission has been delayed to take advantage of more precision landing experience and the Tycho mission has been deleted in order to retain the DPS abort capability for all missions. The approximate locations on the lunar surface of the prime sites and alternates are shown in Figure 5-1, page 5-13. The mission sequence assignments were based largely on the geophysical requirements, i.e., the construction of geophysical networks, landing site accessibility and photography considerations.

The LM payload for each mission will be selected on the basis of the science objectives for each landing site, payload availability, and LM landed payload capability. Four ALSEP's have been made available for the four H type lunar exploration missions. The science requirements for the five J-type mission landing sites are listed in order of priority in Table 5-2, page 5-11. The emplaced science objective for each site, although called out separately in Table 5-2, can be combined with a geological traverse to constitute a single EVA. The current projection of LM landed payload (see Table 4-3, page 4-47) indicates a significant restriction on emplaced science payload for those missions which require a roving vehicle and/or a precision landing. These payload estimates are preliminary and are determined on the basis of spacecraft weights, the launch vehicle weight limit, and the landing accuracy requirements at each of the science sites. When these factors which determine the LM landed payload capability become better defined, the appropriate combination of surface experiments, surface stay time and mobility aids will be selected for each of the J class mission landing sites.

5.1.2 H-Type Mission Landing Site Descriptions

Following are brief descriptions of the four H-type mission prime landing sites. The approximate location of these landing sites relative to major lurain features are shown in Figures 5-2 through 5-5, pages 5-14 through 5-17.

Apollo 7, Mission H1

This site is located entirely within relatively old (Imbrian) mare material and also shares the characteristic distribution of large subdued 200-600 m diameter craters as well as the characteristic lower density of 50-200 m diameter craters. This site includes the crater in which Surveyor III landed. One of the primary scientific objectives of landing at this site is to effectively sample a second mare for comparison with Apollo 11 and Surveyor data in order to learn the variability in composition and age of the "Imbrium" mare unit.

Fra Mauro Formation, Mission H2

The site of the Fra Mauro Formation is in an extensive geologic unit covering great portions of the lunar surface around Mare Imbrium. Therefore, a mission to this site would result in an understanding of the nature, composition, and origin of this widespread formation. The latter is interpreted as ejecta from Imbrium.

Littrow Area, Mission H3

The Littrow area is characterized by an abundance of fresh looking wrinkle ridges in the mare. Mare Serenitatis in this area is also characterized by a number of minute cracks forming systems subparallel to the ridges, and thus, appears to be a stage in wrinkle ridge formation. In one spot, the dark blanketing material conspicuously covers part of a fresh ridge, which suggests that the dark material is relatively young and may be of volcanic origin.

The dark materials occur mostly on a level, cratered plateau, here called the Serenitatis Bench, between typical mare to the west and rugged uplands to the east. However, part of the mare and uplands in the immediate vicinity of the plateau are anomalously dark.

Censorinus (northwest), Mission H4

Censorinus is a 3.8 km probable impact crater located within, but near the edge of a highland block south-southeast of Mare Tranquillitatis. The proposed landing site is to the northwest of the crater and within the ejecta blanket. The site offers a unique opportunity to sample, early in the lunar exploration plan, both highland material and features associated with a fresh impact crater. Censorinus is large enough to exhibit clear signs of impact, but small enough to be investigated on a foot traverse.

5.1.3 J-Type Mission Landing Site Descriptions

Following are brief descriptions of the five J-type mission prime landing sites. The approximate landing site locations are shown on medium resolution photography in Figures 5-6, 5-8, 5-10, 5-12 and 5-14, pages 5-18, 5-20, 5-22, 5-24 and 5-26, respectively. Layouts of three sample EVA's for each site are shown on high resolution photography in Figures 5-7, 5-9, 5-11, 5-13 and 5-15, pages 5-19, 5-21, 5-23, 5-25 and 5-27, respectively, with the exception of the traverses for Descartes. Without high resolution photography for Descartes, determination of the length and location of traverses is premature. Only an enlargement of the landing area is provided in Figure 5-7, and a word description of tentative EVA activity is included with the landing site description. A summary of analyses of the three EVA's for each landing site is included in Table 5-3, page 5-12. This table summarizes the traverse distance and time, and the available science time for each EVA period illustrated in Figures 5-9, 5-11, 5-13 and 5-15. Rover traverses have been evaluated at speeds of both 5 and 10 kilometers per hour for comparison. The option to emplace scientific equipment similar to ALSEP on the first EVA of the missions planned at a rover speed of 10 km/hr is also illustrated in Table 5-3. The primary effect of such an emplacement is to reduce the number of stations examined rather than the traverse distance due to the low metabolic rate while riding on the Rover. On walking missions, the scientific equipment emplacement has a greater impact on the traverse distance due to the relatively higher walking metabolic rate.

Descartes, Mission J1

The area of the southern highlands north of the crater Descartes is characterized by hilly, groovy, and furrowed deposits. It is bound on the west by a hilly and pitted stratigraphic unit and on the east by rugged hills which bound Mare Nectaris. The Descartes region, which is very similar to an area to the west and northwest of Mare Humorum, is thought to include a distinctive pattern of morphological manifestations of volcanism in the lunar terrae. Many of the elongate grooves and furrows are reminiscent of terrestrial volcanos. It is believed that a mission to a region of intensive and prolonged volcanism within the lunar terrae is most important, from both the geological and geochemical viewpoints. An alternative to this site would be that of Abulfeda.

Tentatively, the Orbiter IV photographs suggest that a single loop traverse north of the landing site would suffice for examination of the hilly and furrowed material. From a landing site 1 km south of the furrowed ridge, the traverse would entail first a 1 km walk to the ridge, then a 500 m walk westward along the base of the ridge and into the furrow then a 500 m walk towards a fresh, probably blocky 1 km crater whose ejecta probably includes material from the hilly and furrowed unit, and finally, a 1 km walk back to the LM. The second and third EVA's will be devoted to the plains material or to other objects of interest revealed by later high-resolution photographs.

Marius Hills, Mission J2

The Marius Hills are domes and cones near the center of Oceanus Procellarum, and west-northwest of the crater Marius, where isolated hills and clusters of hills rise above the mare surface and form part of a major north-south median ridge system that stretches irregularly for some-1900 km through Oceanus Procellarum. Many of the hills exhibit the convex upward shapes suggestive of terrestrial laccolithic intrusions; and some resemble terrestrial shield volcanos. The variety of these features and their similarity to terrestrial volcanic structures strongly suggests that the area has been subjected to intensive and prolonged volcanic activities.

Copernicus (peak), Mission J3

The crater Copernicus is a bright rayed crater, 90 km in diameter, whose visible radial rays spread out distances of several hundred kilometers. The walls of the crater Copernicus expose a vertical section of about 4 km of the lunar crust. The floor, 60 km in diameter, is nearly circular, and contains a small, almost central, multiple peak, with large masses to the east and the west, where the highest peak rises 800 meters. These peaks may have brought to the surface material that once lay at considerable depth. A mission to the central peaks would be mainly a sampling mission, with some emphasis on structural relationships. Samples of large blocks on the peaks, of the floor material, and of the mounds on the floor would be of significance to the geochemistry of the moon.

Hadley, Mission J4

The Apennine Mountains constitute by far the most imposing of the lunar mountain ranges, and form the southeastern boundary of Mare Imbrium. They form the base of a triangle-shaped elevated highland region between Mare Imbrium, Mare Serenitatis, and Mare Vaporum. At the area of the proposed site, the mountain front rises 1,280 meters above the adjacent mare to the west, i.e., the southeastern portion of Palus Putredinis.

Rima Hadley is a V-shaped sinuous rille which terminates to the south at an elongate depression and runs in a northeasterly direction, parallel with the Apennine front, for over 50 km until it merges with Rima Fresnel II to the north. Fresh exposures, possibly of stratified mare beds, occur along the top of the rille walls from which numerous blocks have rolled down the walls to settle on the floor of the rille.

In the area of the site, a small (5.5 km in diameter) but conspicuously sharp and round crater appears to have partly covered the rille. This crater, Hadley C, is characterized by a raised rim and an ejecta blanket, which covers the mare craters and Autolycus secondaries in the vicinity. The origin of Hadley C is a matter of controversy, although its morphologic characteristics suggest that it is probably a maar.

Tycho (rim), Mission J5

Tycho is a fresh impact crater, in the southern highlands. However, it is much larger than Censorinus (about 85 km in diameter) and thus offers an opportunity of studying the many features common to large, fresh impact events, including associated volcanism. The vicinity of the landing site of Surveyor VII is the proposed landing site. In that area, one encounters several generations of flows, a pond or pool, ejected blocks (probably from Tycho), other ejecta features and structures, and last, but not least, the Surveyor VII spacecraft.

Table 5-1. Major Characteristics of Candidate Lunar Exploration Sites

CANDIDATE SITE	LONGITUDE	LATITUDE	SOURCE	TERRAIN FEATURES	SCIENTIFIC/TECHNOLOGICAL INTEREST	MOBILITY EVALUATION	LANDING EVALUATION	PHOTOGRAPHY AVAILABLE MED. RESOL. (METERS)	HI. RESOL. (METERS)	STEREO.
ABULFEDA	14°00'E	14°50'S	LAC 78	ROUGH • CRATER CHAIN • GROOVES, FURROWS	VOLCANIC CRATER CHAIN • HIGHLAND VOLCANICS • ALTERNATIVE TO DESCARTES	-	-	20.0	2.5	NONE
ALPHONSUS	4°18'W	13°23'S	LAC 77	ROUGH APPROACH • LARGE CRATER LANDING	MAJOR PROCESS INDICATOR • COMPOSITION • VOLCANIC PROCESSES • TRANSIENT EVENTS SITE	-	-	20.0	2.5	MED.RES.
APOLLO 2	23°42'E	0°43'N	MSL TRIANGULATION	SMOOTH	EASTERN MARE MATERIAL (OLD) • AGE DATING • COMPOSITION	WALKING MISSION	-	8.0	1.0	HI.RES.
APOLLO 3	1°18'W	0°21'N	MSL TRIANGULATION	SMOOTH	EASTERN MARE MATERIAL (OLD)	WALKING MISSION	-	8.0	1.0	HI.RES.
APOLLO 4	36°37'W	3°39'S	MSL TRIANGULATION	SMOOTH	WESTERN MARE MATERIAL (YOUNG)	WALKING MISSION	-	8.0	1.0	HI.RES.
APOLLO 5	41°54'W	1°41'N	MSL TRIANGULATION	SMOOTH	WESTERN MARE MATERIAL (YOUNG)	WALKING MISSION	-	8.0	1.0	HI.RES.
APOLLO 6R (FLAMSTEED P)	42°41'W	2°46'S	MSL TRIANGULATION	SMOOTH	WESTERN MARE MATERIAL (YOUNG) • AGE DATING • COMPOSITION OF FLAMSTEED P • GEOPHYSICAL STATION EMPLACEMENT	WALKING MISSION	-	8.0	1.0	HI.RES.
APOLLO 7	23°27'W 23°22' 18"W	2°57'S 3°11' 46"S	III P-9 PRELIMINARY MANUSCRIPT LUNAR MAP, SURVEYOR III SITE SCALE 1:2000, JAN 1968	SMOOTH	IMBRIAN MARE (OLD)	WALKING MISSION	-	8.0	1.0	HI.RES.
ARISTARCHUS PLATEAU	49°05'W	26°25'N	LAC 38	ROUGH • COMPLEX OF FEATURES (DOMES, RILLES, CONES, CRATER CHAINS)	VOLCANIC PLATEAU • VOLCANIC PROCESSES • MATERIALS EROSION • AGE DATING • TRANSIENT EVENT REGION	-	-	22.5	2.8	MED.RES.
NORTHWEST OF CENSORINUS	32°35'E	0°20'S	MAY 1969 EDITION LUNAR PHOTOMAP	ROUGH • LARGE ROCKS AT RIM • SMALL CIRCULAR CRATER IN HIGHLANDS, DIA = 3.8 KM	HIGHLAND MATERIALS-SMALL IMPACT CRATER • FRESH IMPACT CRATER • EJECTA BLANKET MATERIALS • STRUCTURES, TEXTURES • GEOPHYSICAL STATION EMPLACEMENT • AGE DATING	WALKING MISSION • ±1.5 KM RADIUS	PIN-POINT LANDING	19.4	2.4	30 METERS MED. RES. (APOLLO 10)
COPERNICUS PEAKS	20°18'W 19°55'W	9°42'N 9°44'N	LAC 58 LUNAR UNCONTROLLED MOSAIC, COPERNICUS ORB-V-37 (200), JUNE 1968	ROUGH • CENTRAL PEAKS OF LARGE IMPACT CRATER	A CLASSIC LARGE IMPACT CRATER • AGE DATING • COMPOSITION OF FLOOR MATERIAL • DEEP SEATED MATERIAL (PEAKS) • STRUCTURAL STUDIES • GEOPHYSICAL STATION EMPLACEMENT	-	ROUGH APPROACH BUT SMOOTH LANDING • PIN-POINT LANDING	18.0	2.2	MED.RES.
COPERNICUS CD	15°00'W	6°32'N	LAC 58	ROUGH • COPERNICAN EJECTA & SECONDARIES	PROCESS INDICATORS • CRATERING-IMPACT, VOLCANISM • VOLCANIC DOMES AND FLOWS • AGE DATING	-	-	18.0	2.2	NONE
DAVY RILLE	6°00'W	10°52'S	LAC 77	-	HIGHLANDS MATERIALS • FRESH IMPACT CRATER • EJECTA BLANKET MATERIALS • STRUCTURE, TEXTURE • GEOPHYSICAL STATION EMPLACEMENT • AGE DATING	WALKING MISSION	-	-	~60	-
DESCARTES	15°30'E	8°50'S	LAC 78	ROUGH • HIGHLAND REGION	VOLCANIC FEATURES IN HIGHLAND • COMPOSITION • VOLCANIC PROCESSES • GEOPHYSICAL STATION EMPLACEMENT	MOBILITY AID DESIRED	-	500.0	59.0	NONE
DIONYSIUS	17°53'E	2°48'N	LAC 60	ROUGH • BRIGHT RIMMED CRATER • ALTERNATING LIGHT AND DARK RAYS	PROCESS INDICATOR • IMPACT CRATER AND EJECTA	-	-	17.0	2.2	MED.RES.
FRA MAURO FM	17°30'W 17°24' 36"W	3°44'S 3°36' 48"S	LAC 76 LUNAR PHOTOMAP, FRA MAURO ORB-III-S23 (250), JUNE 1969	ROUGH • VAST AREA	FRA MAURO FORMATION • MAJOR SURFACE UNIT • GEOPHYSICAL STATION EMPLACEMENT • AGE DATING	WALKING MISSION	AREA LANDING	8.0	1.0	MED.RES.
GASSENDI (WEST) (EAST)	40°14'W 39°23'W	17°29'S 17°18'S	LAC 93	ROUGH • RILLES • MARE FLOODING	LARGE FLOODED CRATER • REBOUND CRATER FLOOR • COMPOSITION AND AGE DATING • FAVORABILITY FOR ASTRONOMY STATION	-	-	18.0	2.3	NONE
GAUDIBERT A	38°00'E	12°01'S	LAC 79	ROUGH • VOLCANIC FEATURES	VOLCANIC CALDERA • GAMBART-TYPE CRATER • COMPOSITION AND PROCESSES	-	AREA LANDING	500.0	60.0	NONE
HADLEY RILLE	2°52'E 2°28'E	25°12'N 24°48'N	LAC 41 LUNAR UNCONTROLLED MOSAIC, RIMA HADLEY ORB-V-26.1b (200), JULY 1968	SMOOTH LANDING • MARE LANDING • ROUGH APPROACH	APENNINES/HADLEY C • AGE DATING • HIGHLAND MATERIALS • SURFACE AND EJECTA SAMPLES • ORIGIN OF SINUOUS RILLE • ORIGIN OF CONTROVERSIAL CRATER HADLEY C	MOBILITY AID DESIRED	-	22.0	2.8	NONE
HIPPARCHUS	3°51'E	4°40'S	LAC 77	ROUGH • CRATER WITH HIGHLAND BASIN FILL	PROCESS INDICATORS • AGE DATING • HEAT FLOW MEASUREMENT	-	AREA LANDING	17.5	2.2	HI.RES.
HYGINUS	6°11'E	7°58'N	LAC 59	SMOOTH LANDING • LINEAR RILLE • CRATER CHAIN	CRATER AND RILLE FORMATION • VOLCANIC MATERIALS • AGE DATING	-	-	18.0	2.3	MED.RES.
LALANDE	8°30'W	4°55'S	LAC 77	-	HIGHLANDS MATERIALS • FRESH IMPACT CRATER • EJECTA BLANKET MATERIALS • STRUCTURE, TEXTURE • GEOPHYSICAL STATION EMPLACEMENT • AGE DATING	WALKING MISSION	-	-	~60	-
LITTROW AREA	29°02'E 28°58'E	21°44'N 21°35'N	JUNE 1969 EDITION LUNAR PHOTOMAP LUNAR UNCONTROLLED MOSAIC, RIMAE LITTROW ORB-V-14 (200), JULY 1968	ROUGH APPROACH • MARE LANDING	DARK VOLCANIC BLANKET MATERIAL • DARK MANTLING MATERIAL • PLATEAU MATERIAL • FRESH WRINKLE RIDGE	WALKING MISSION	PIN-POINT LANDING	21.0	2.6	MED.RES.
MARIUS HILLS	56°34'W 56°29'W	14°36'N 15°07'N	LAC 56 LUNAR UNCONTROLLED MOSAIC, MARIUS F ORB-V-51 (200), JULY 1968	ROUGH • LARGE DOMES, CONES • SINUOUS RILLES	REGION OF VOLCANIC DOMES • VOLCANIC MATERIALS • MATERIAL TRANSPORT • GEOPHYSICAL STATION EMPLACEMENT • HEAT FLOW MEASUREMENT	MOBILITY AID DESIRED	MULTIPLE LANDING AREAS • ONE PREFERRED FOR SCIENCE	19.5	2.4	MED.RES.
MOSTING C	8°04'W	2°01'S	LAC 77	ROUGH • FRESH IMPACT CRATER	FRESH IMPACT CRATER IN MARE • IMPACT CRATER • EJECTA MATERIALS • AGE DATING	-	PIN-POINT LANDING	8.0	1.0	MED.RES.
RIMA BODE II	3°47'W	12°53'N	LAC 59	SMOOTH LANDING • APPROACH OVER HIGHLANDS ROUGH • LANDING AREA SMOOTH • LINEAR RILLE AND CRATER CHAIN	COMBINES LITTROW/HYGINUS OBJECTIVES • DARK MANTLING MATERIAL • VOLCANIC PROCESSES • AGE DATING • GEOPHYSICAL STATION EMPLACEMENT	WALKING MISSION	ACCURATE LANDING DESIRED	18.7	2.3	MED.RES.
RIMA PRINZ I	44°22'W	28°06'N	LAC 39	SMOOTH • MARE LANDING • SINUOUS RILLES	SINUOUS RILLE EXAMINATION • EROSION AND DEPOSITION OF MATERIALS • AGE DATING • COMPOSITION AND LAYERING • GRAVITY FLOW AND SLUMP PROCESSES • GEOPHYSICAL STATION EMPLACEMENT	MOBILITY AID DESIRED	-	24.0	3.0	MED.RES.
SCHRÖTER'S VALLEY	49°56'W	25°31'N	LAC 38	ROUGH (APPROACH) • LARGE SINUOUS RILLE	ALTERNATE TO RIMA PRINZ I	-	-	23.4	2.9	MED.RES.
SOUTH OF ALEXANDER	14°05'E	37°55'N	LAC 26	ROUGH APPROACH • COMPLEX OF FEATURES IN THE HIGHLANDS (DOMES, SCARPS, RILLES)	COMPLEX HIGHLAND REGION • VOLCANIC PROCESSES • HIGHLAND MATERIALS • AGE DATING	-	SMOOTH LANDING IN MARE	31.0	3.8	MED.RES.
TOBIAS MAYER	31°02'W	13°03'N	LAC 57	ROUGH • MARE DOMES	REGION OF LARGE DOMES • VOLCANIC PROCESSES	-	-	18.8	2.3	MED.RES.
NORTH OF TYCHO	11°15'W 11°35'W	40°56'S 41°07'S	LAC 112 LUNAR UNCONTROLLED MOSAIC, TYCHO ORB-V-30b (200), JULY 1968	ROUGH • BLOCK RIM	LARGE FRESH IMPACT CRATER IN HIGHLANDS • TYCHO ROCK EJECTA SAMPLES • GEOPHYSICAL STATION EMPLACEMENT • EXAMINE SURVEYOR VII SPACECRAFT • SAMPLES TO EVALUATE SURVEYOR SAMPLING TECHNIQUE	-	ACCURATE LANDING REQUIRED • NORTH OF TYCHO CRATER RIM	37.4	4.6	MED.RES.

NOTE: ADDITIONAL PHOTOGRAPHY DESIRED OR REQUIRED AT ALL SITES EXCEPT APOLLO 2, 3, 4, 5, 6R, 7; HIPPARCHUS.

Table 5-2. Science Requirements for J-Mission Landing Sites

	PRIORITY				
SITE	1	2	3	4	OBJECTIVES
Tycho	Emplaced Science PSE/LR[3]	First Geological Traverse	Second Geological Traverse	Third Geological Traverse	Seismic/Selenodetic Network Highland Sample Flow Sample Pool Materials Surveyor VII
Copernicus	Mobility Aided Geological Traverse	Mobility Aided Geological Traverse	Emplaced Science PSE/Questar Camera	Mobility Aided Geological Traverse	Peaks (Deep-Seated Material) Floor (Fill Material) Seismic Net, Wall Photos Domes (Volcanic?)
Descartes	Emplaced Science PSE/HFE	First Geological Traverse	Second Geological Traverse	Third Geological Traverse	Seismic Net Highland Plains Furrowed Terra Elongated Cones and Crater Chains
Marius Hills	Mobility Aided Traverse	Mobility Aided Traverse	Emplaced Science PSE/LR[3]/HFE	Mobility Aided Traverse	Plains Material Volcanic Landforms Seismic and Selenodetic Net Volcanic Landforms
Hadley	Mobility Aided Traverse	Mobility Aided Traverse	Emplaced Science PSE/MASS SPEC	Mobility Aided Traverse	Sinuous Rille Apennine Ridge Seismic Net, Outgassing Elongated Depression Materials

Note: First Priority During First EVA is a Preliminary Geological Sample

Table 5-3. Sample Traverse Summary[1]

SITE	METHOD OF LOCOMOTION	EVA NO.	NO. OF STATIONS	TRAVERSE Dist.(km)	TRAVERSE Time(hr)	SCIENCE TIME AVAILABLE(hr)
Descartes	Walking (4 km/hr)	1	TBD	TBD	TBD	TBD
		2	"	"	"	"
		3	"	"	"	"
Marius Hills	Rover (5 km/hr)	1[2]	5	12.2	2.44	1.06
		2	7	9.3	1.86	1.64
		3	8	7.8	1.56	1.94
	Rover (10 km/hr)	1A[3]	5	12.2	1.22	2.28
		1B	8	14.8	1.48	2.02
		2	9	11.2	1.12	2.38
		3	10	11.2	1.12	2.38
Copernicus	Rover (5 km/hr)	1[2]	5	10.8	2.16	1.34
		2	3	10.7	2.14	1.36
		3	9	6.0	1.20	2.30
	Rover (10 km/hr)	1A[3]	5	10.8	1.08	2.42
		1B	9	11.2	1.12	2.38
		2	10	12.0	1.20	2.30
		3	11	7.8	0.78	2.72
Hadley	Rover (5 km/hr)	1[2]	3	13.4	2.68	0.82
		2	4	11.8	2.36	1.14
		3	3	13.6	2.72	0.78
	Rover (10 km/hr)	1A[3]	3	13.4	1.34	2.16
		1B	6	16.0	1.60	1.90
		2	7	16.0	1.60	1.90
		3	6	18.0	1.80	1.70
Tycho	Walking (4 km/hr)	1[3]	4	4.2	1.05	2.42
		2	6	6.3	1.57	1.63
		3	4	7.9	1.97	1.04

(1) EMU Configuration:
A7L Suit
Primary LSS, -7 PLSS, 6000 BTU
Secondary LSS, SLSS, 2400 BTU

Metabolic Rates (BTU/hr)
Walking - 1625
Riding - 700
Science and Overhead - 1100

Overhead Times
Nominal - 1.5 hr
Emergency - 0.25 hr

Scientific Equipment
Deployment Time ~ 1 hr

Time in Pressurized Suit
Nominal $\leq$ 5 hr
Emergency $\leq$ 6 hr

(2) The number of stations and the traverse distance must be decreased to provide for emplacement of scientific equipment.

(3) Includes time for the emplacement of scientific equipment.

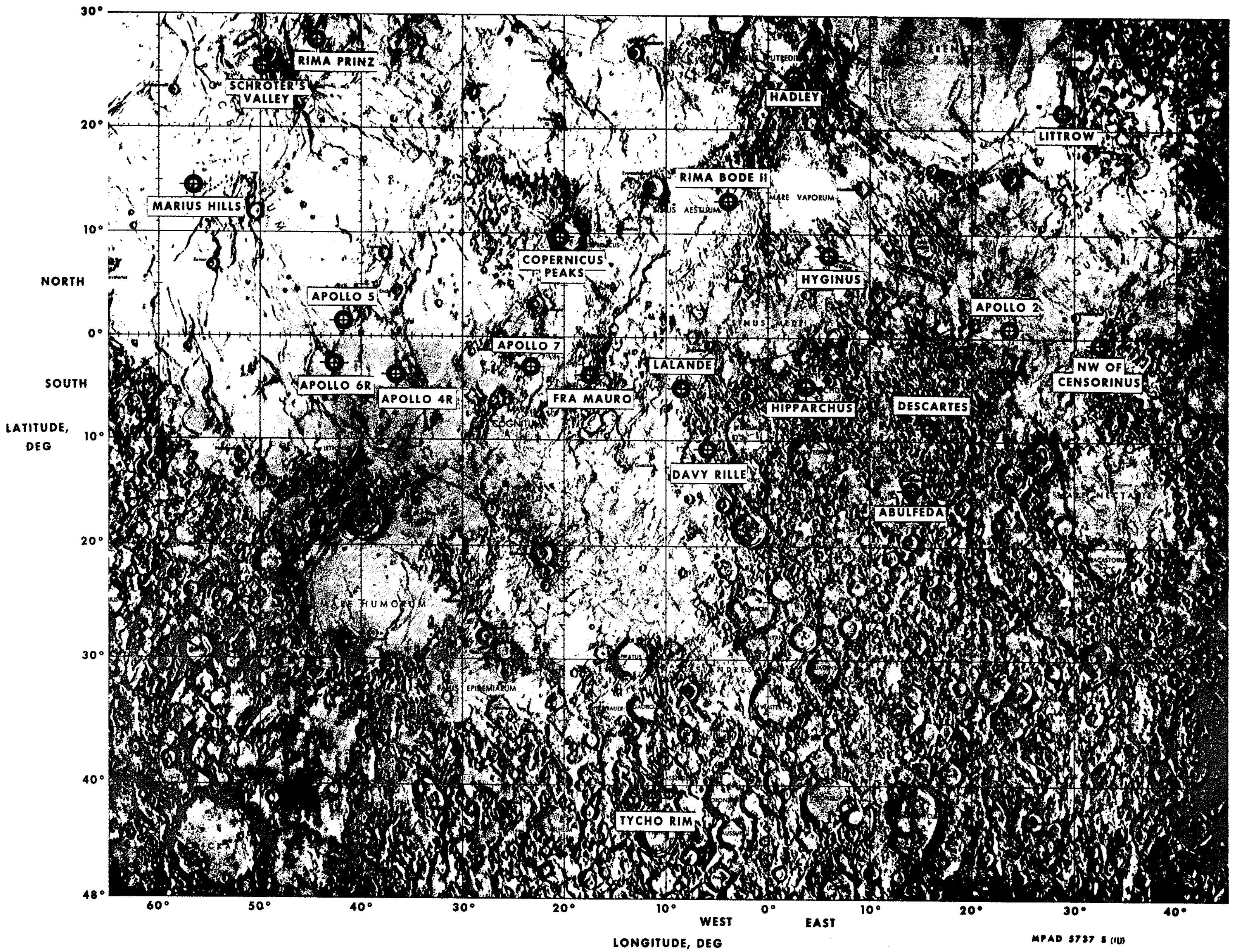

Figure 5-1. Lunar Exploration Sites

North

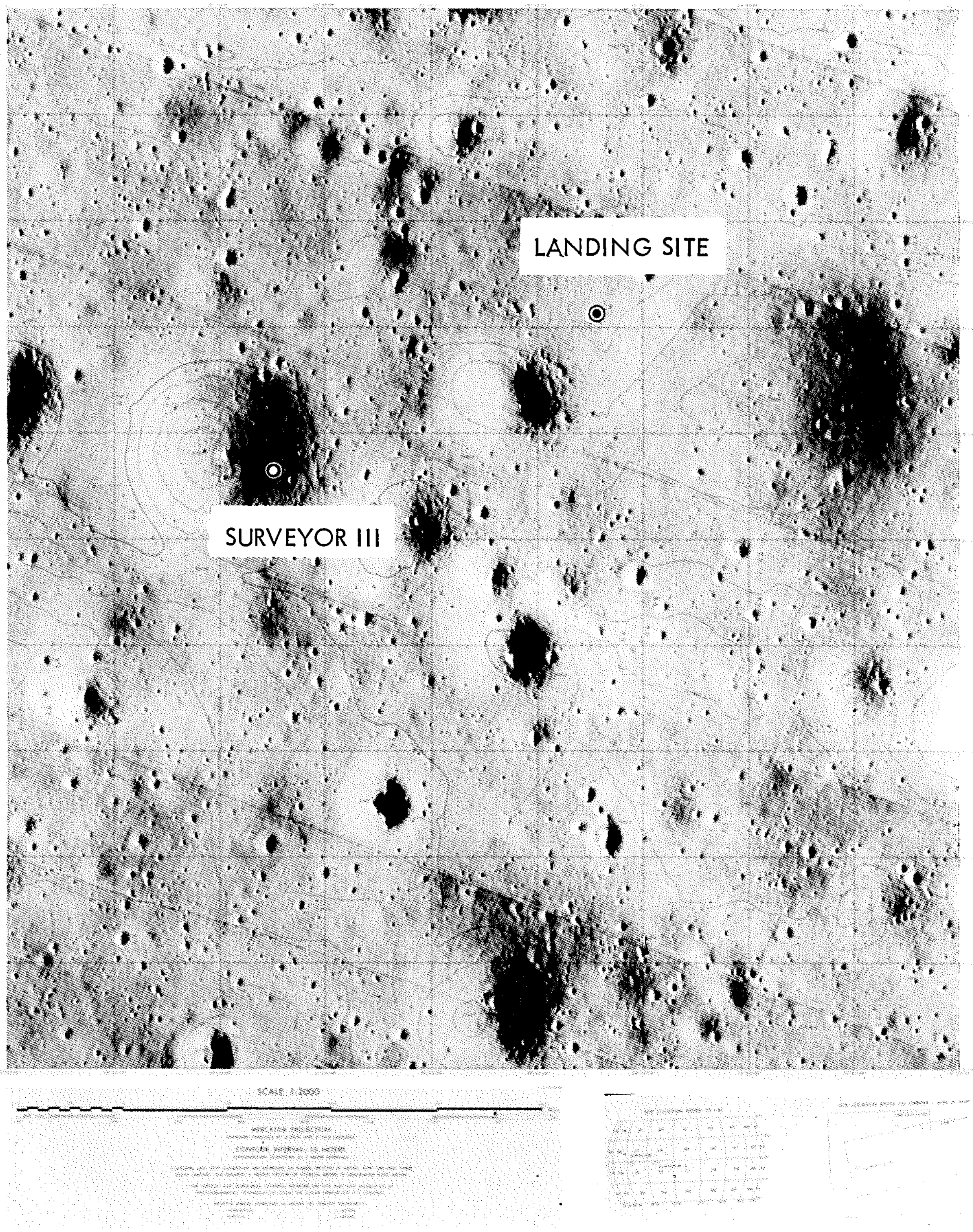

Figure 5-2. Apollo 7 Landing Site, Mission H1

North

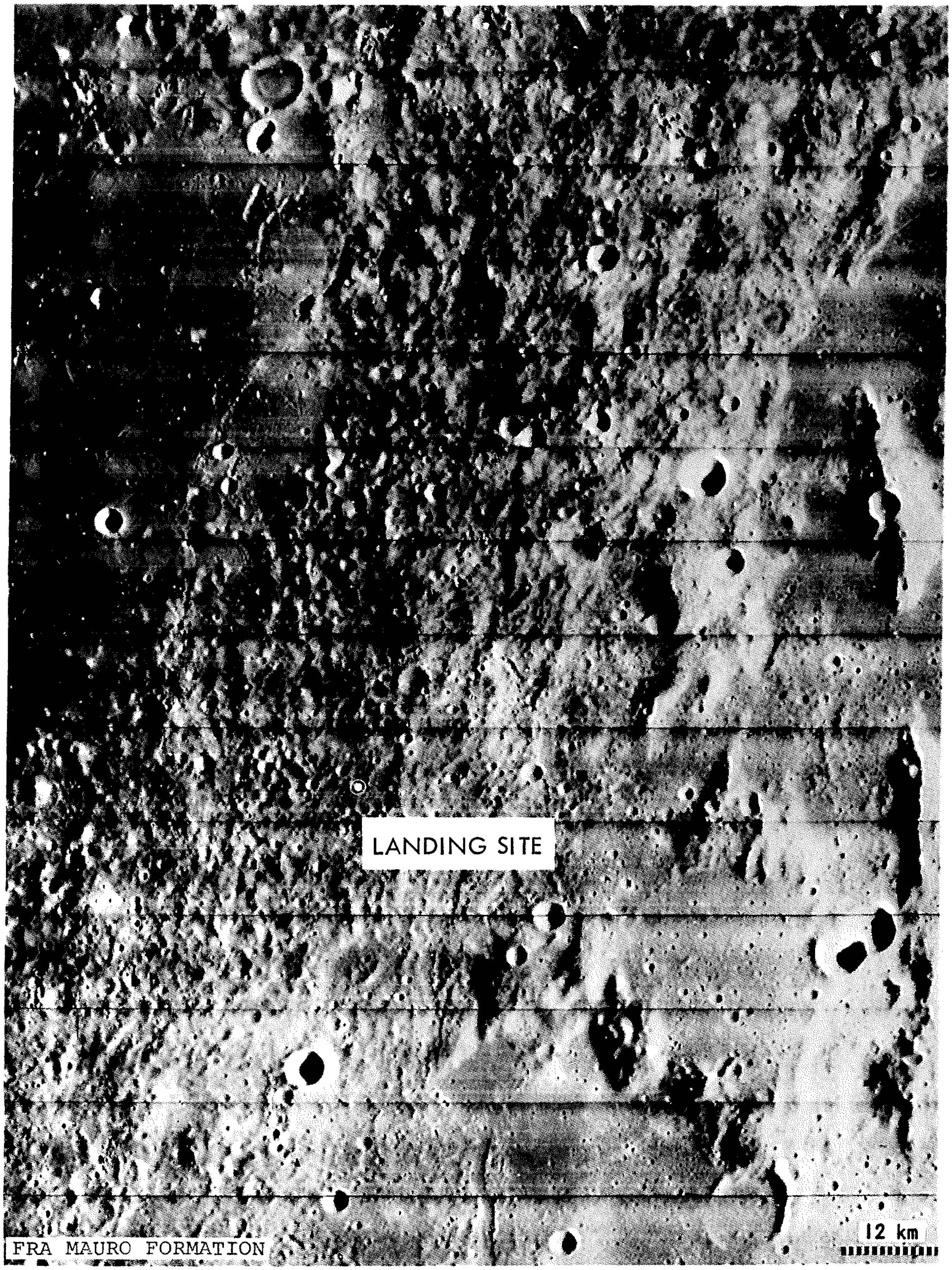

Figure 5-3. Fra Mauro Landing Site, Mission H2

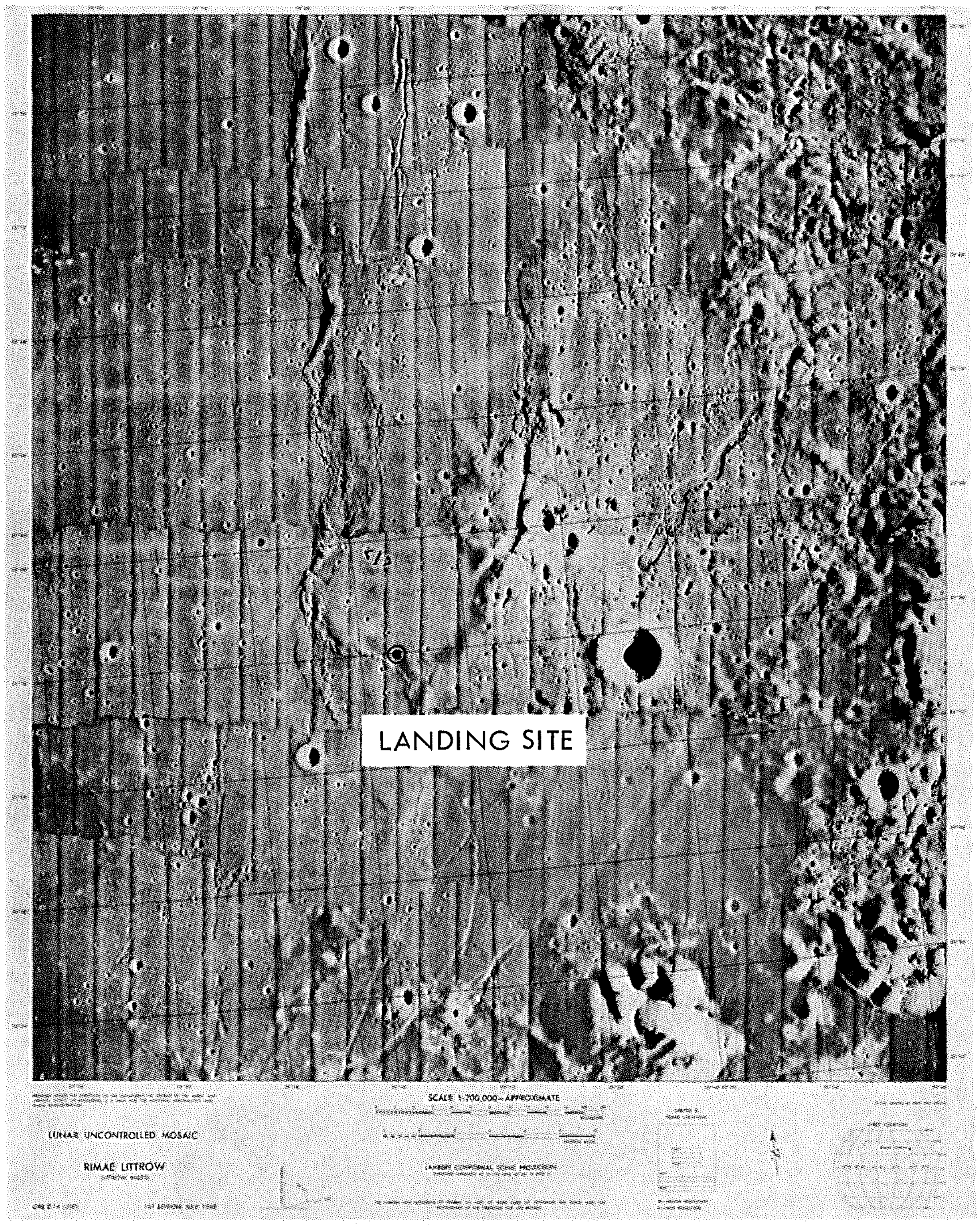

Figure 5-4. Littrow Landing Site, Mission H3

North

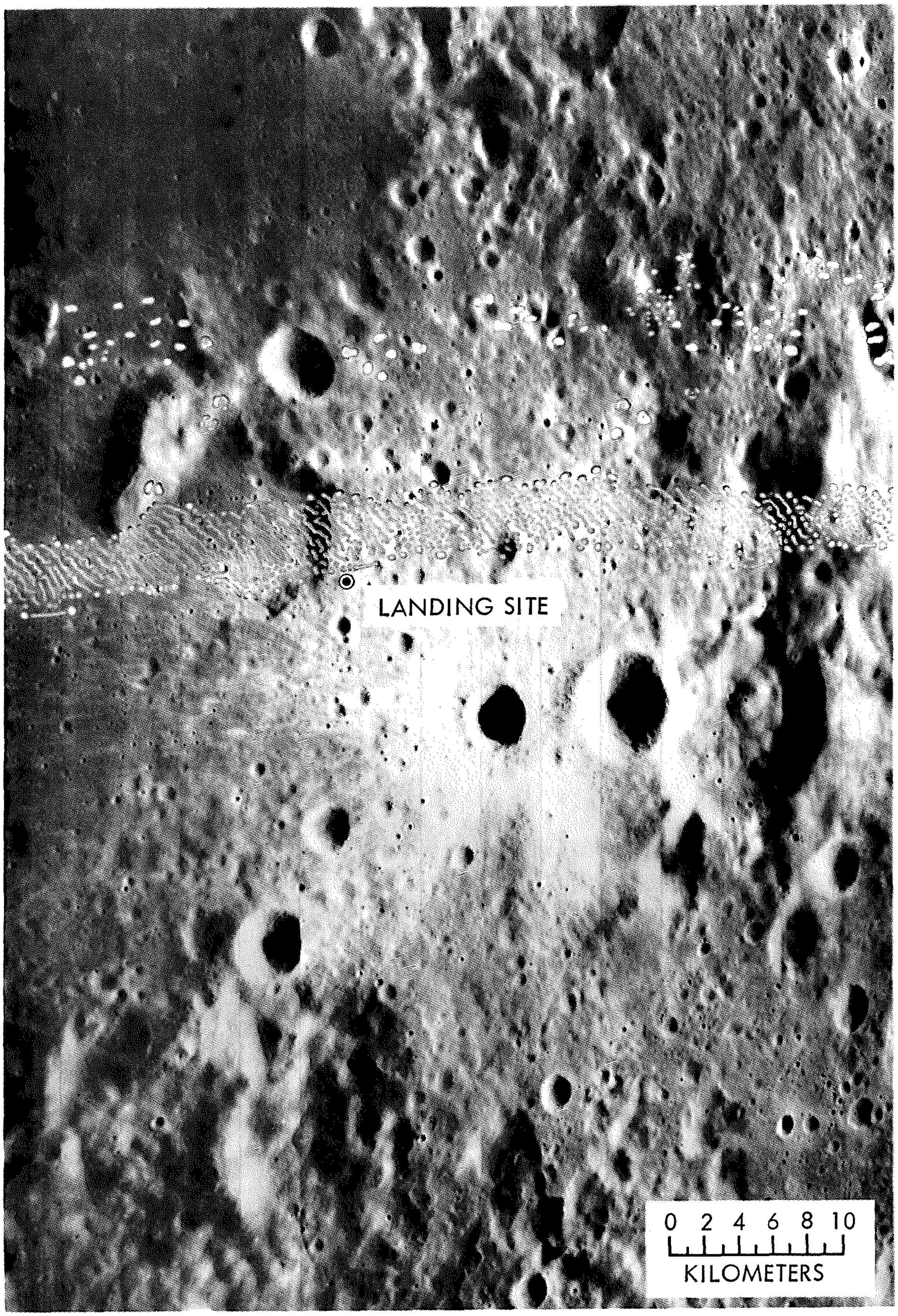

Figure 5-5. Censorinus Landing Site, Mission H4

North

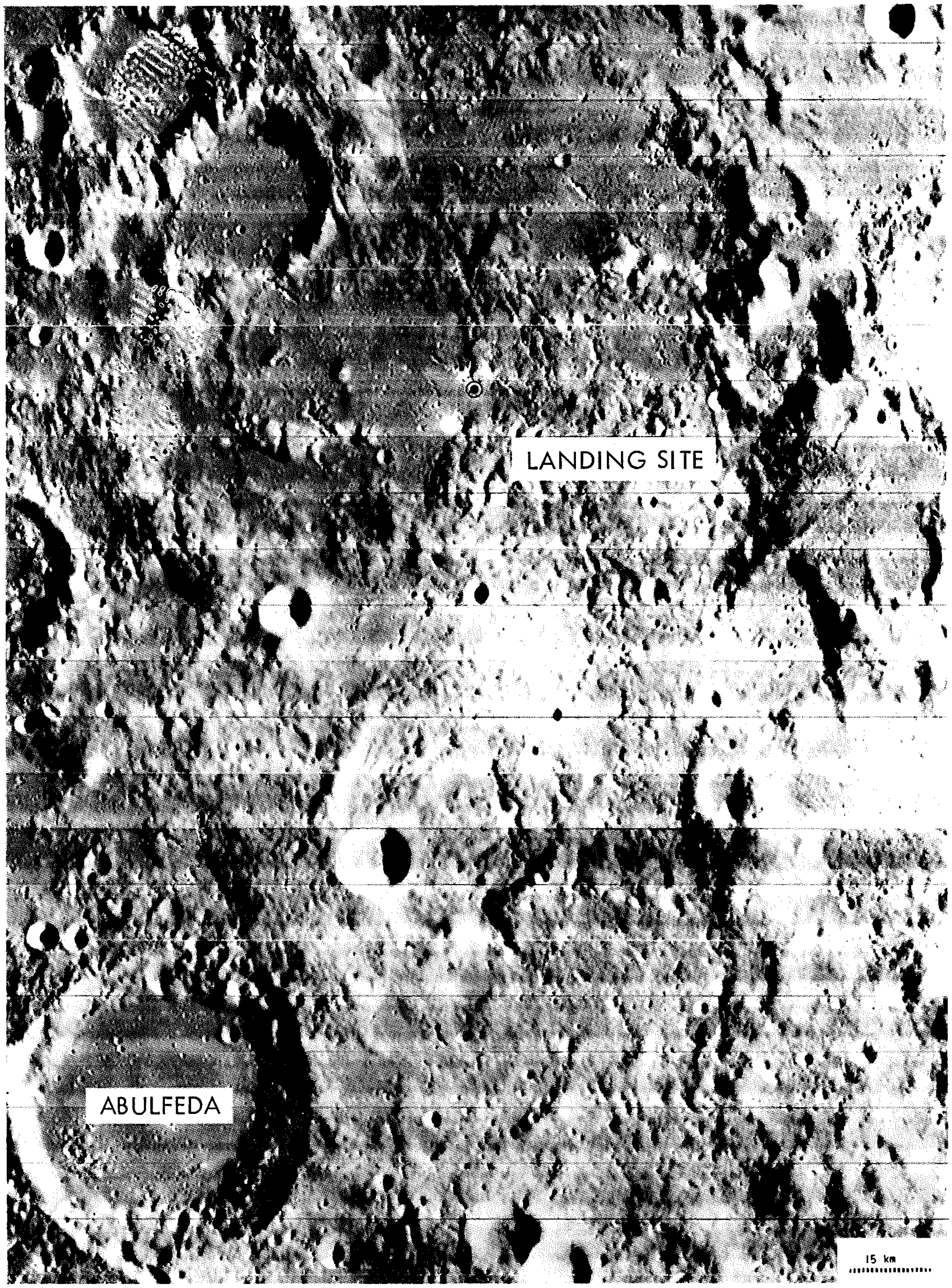

Figure 5-6. Descartes Landing Site, Mission J1

North

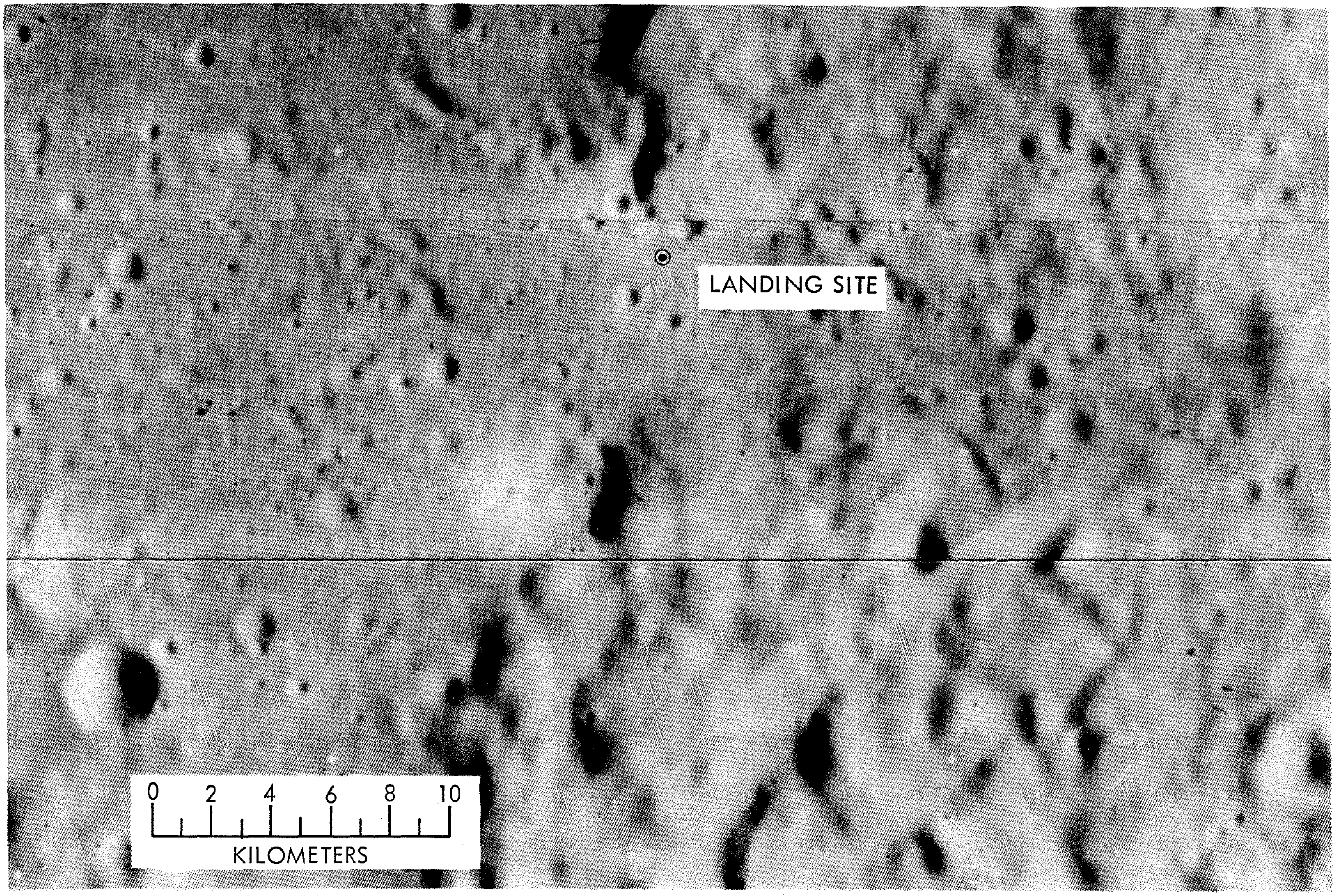

Figure 5-7. Enlargement of Descartes Landing Area

North

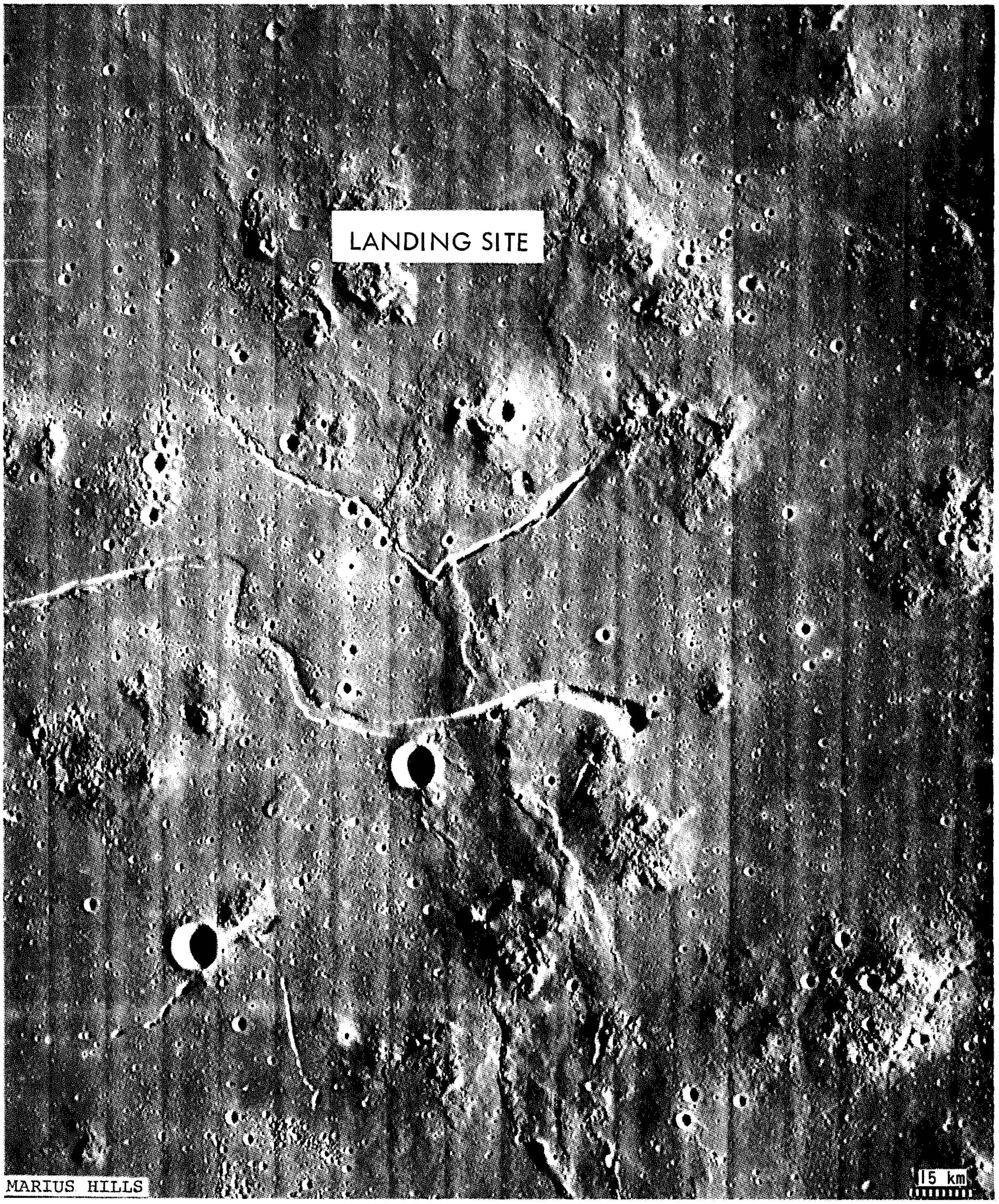

Figure 5-8. Marius Hills Landing Site, Mission J2

North

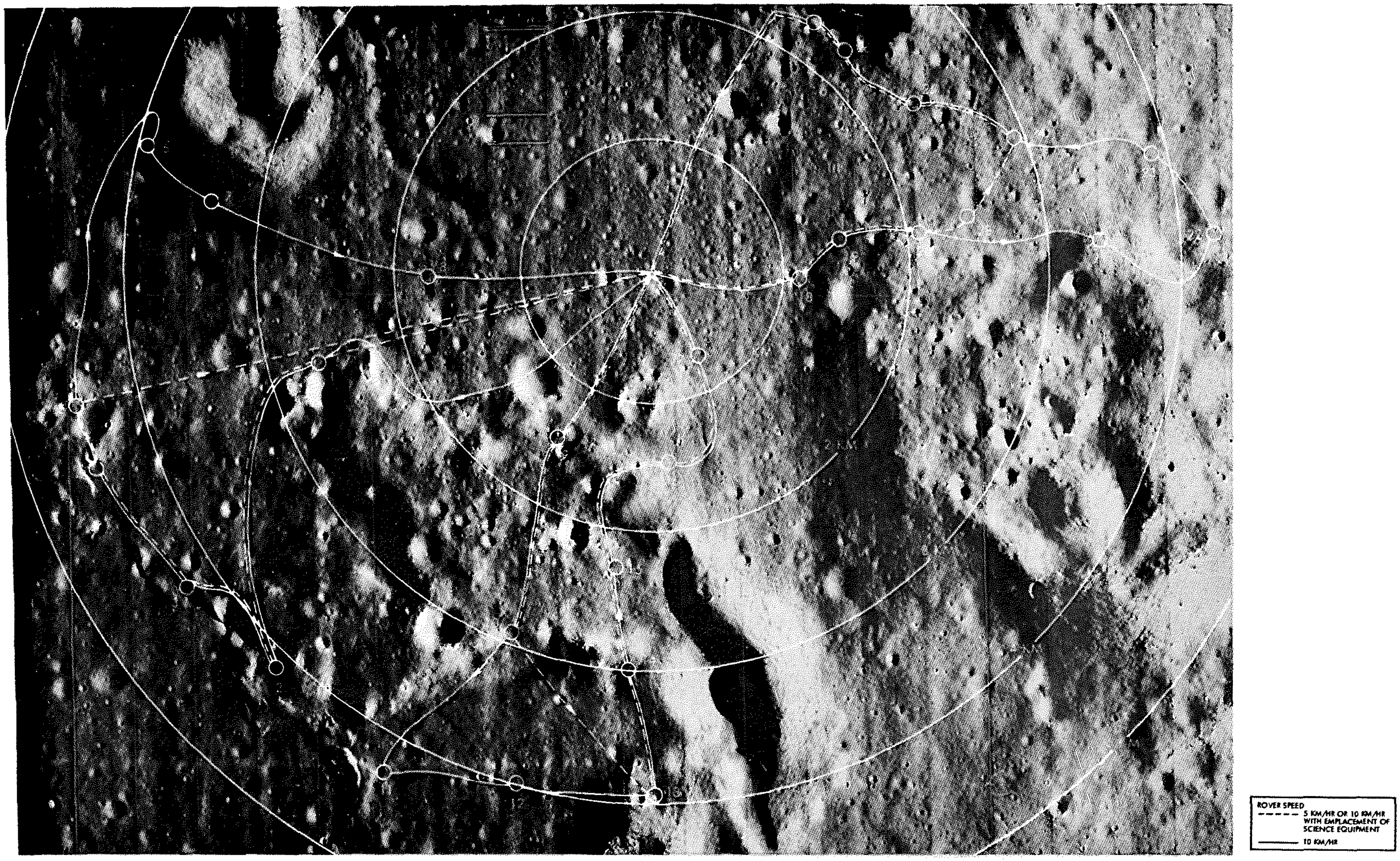

Figure 5-9. Sample Marius Hills EVA Traverses

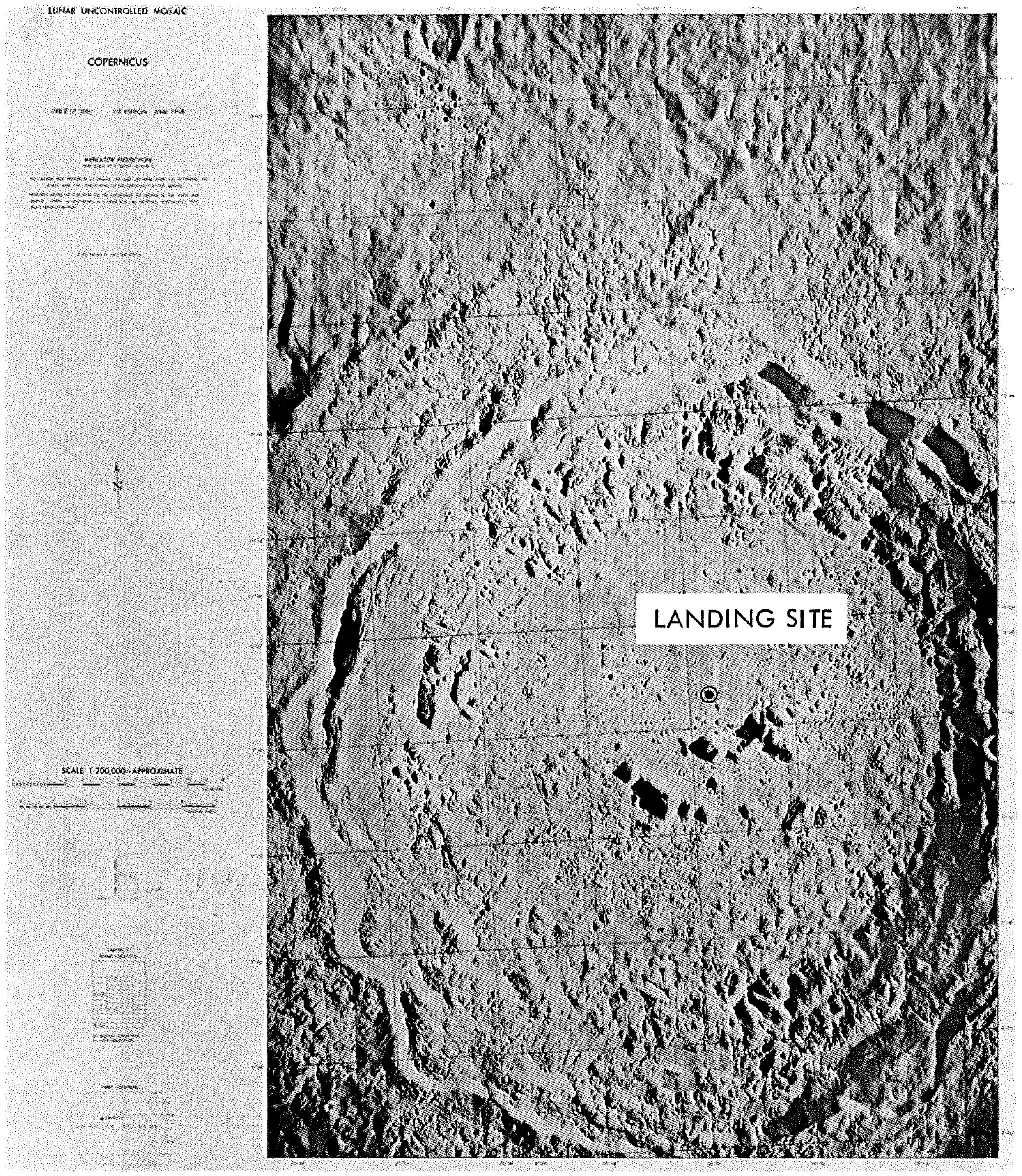

Figure 5-10. Copernicus Landing Site, Mission J3

North

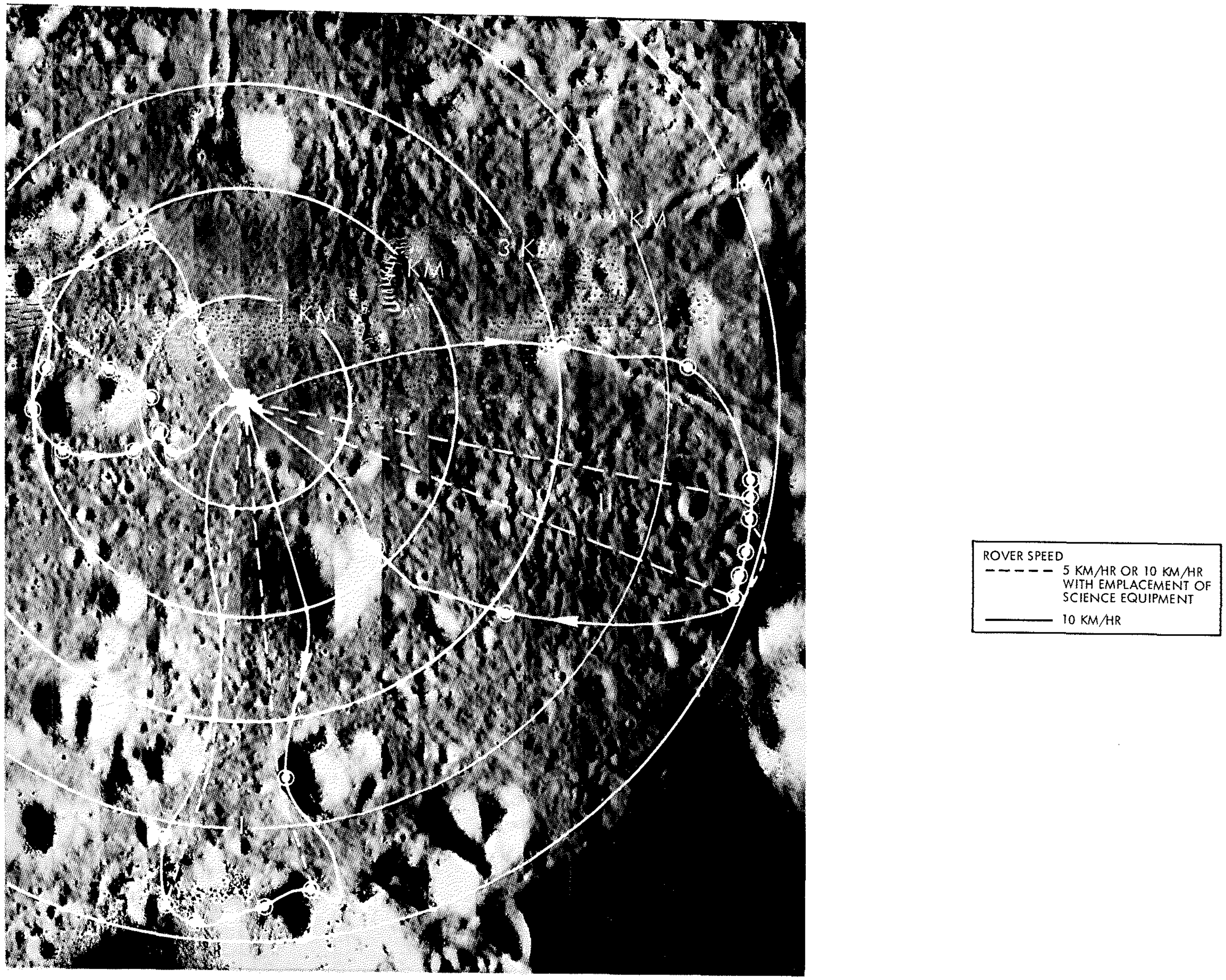

Figure 5-11. Sample Copernicus EVA Traverses

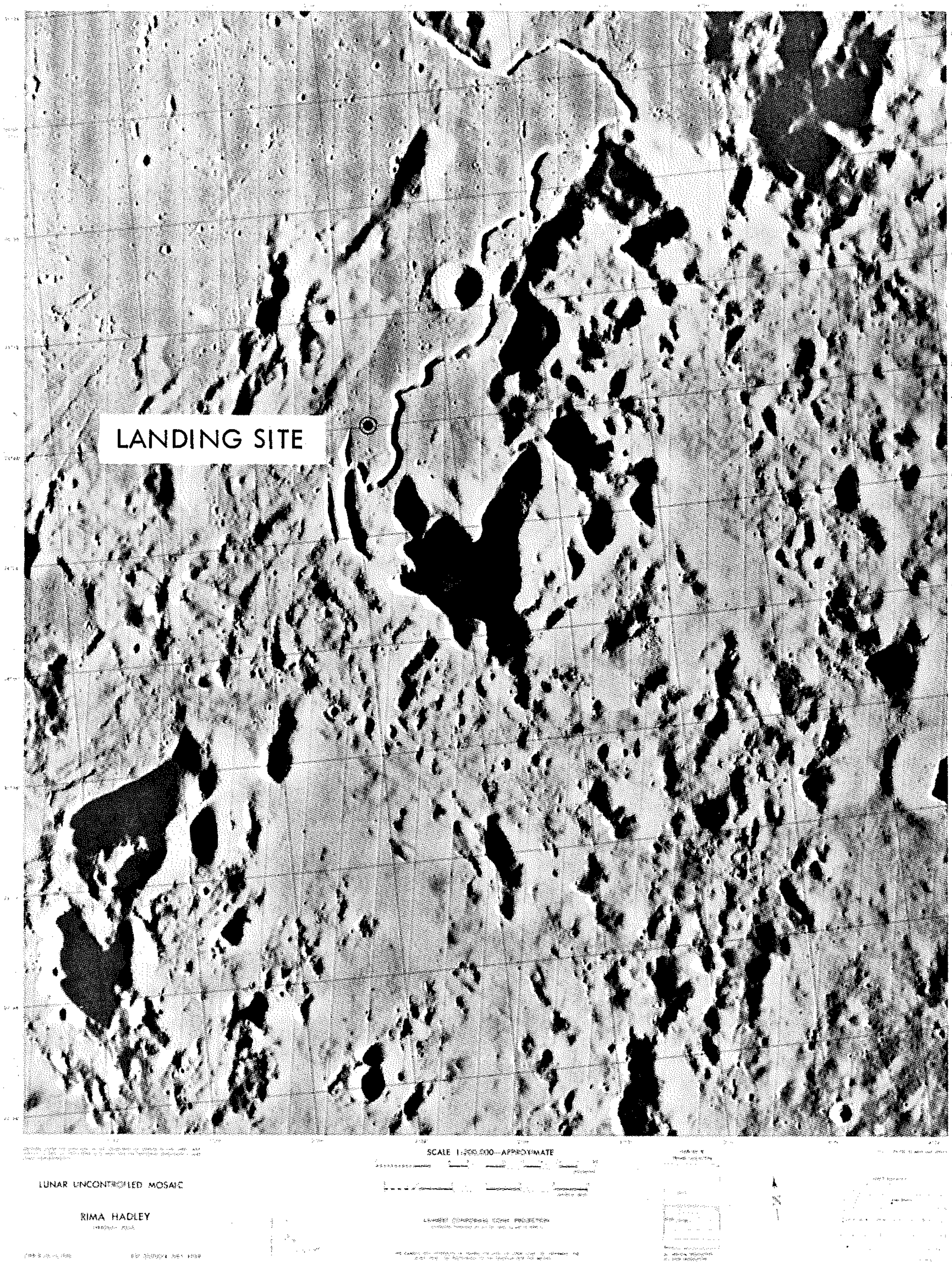

Figure 5-12. Hadley Landing Site, Mission J4

North

Figure 5-13. Sample Hadley EVA Traverses

North

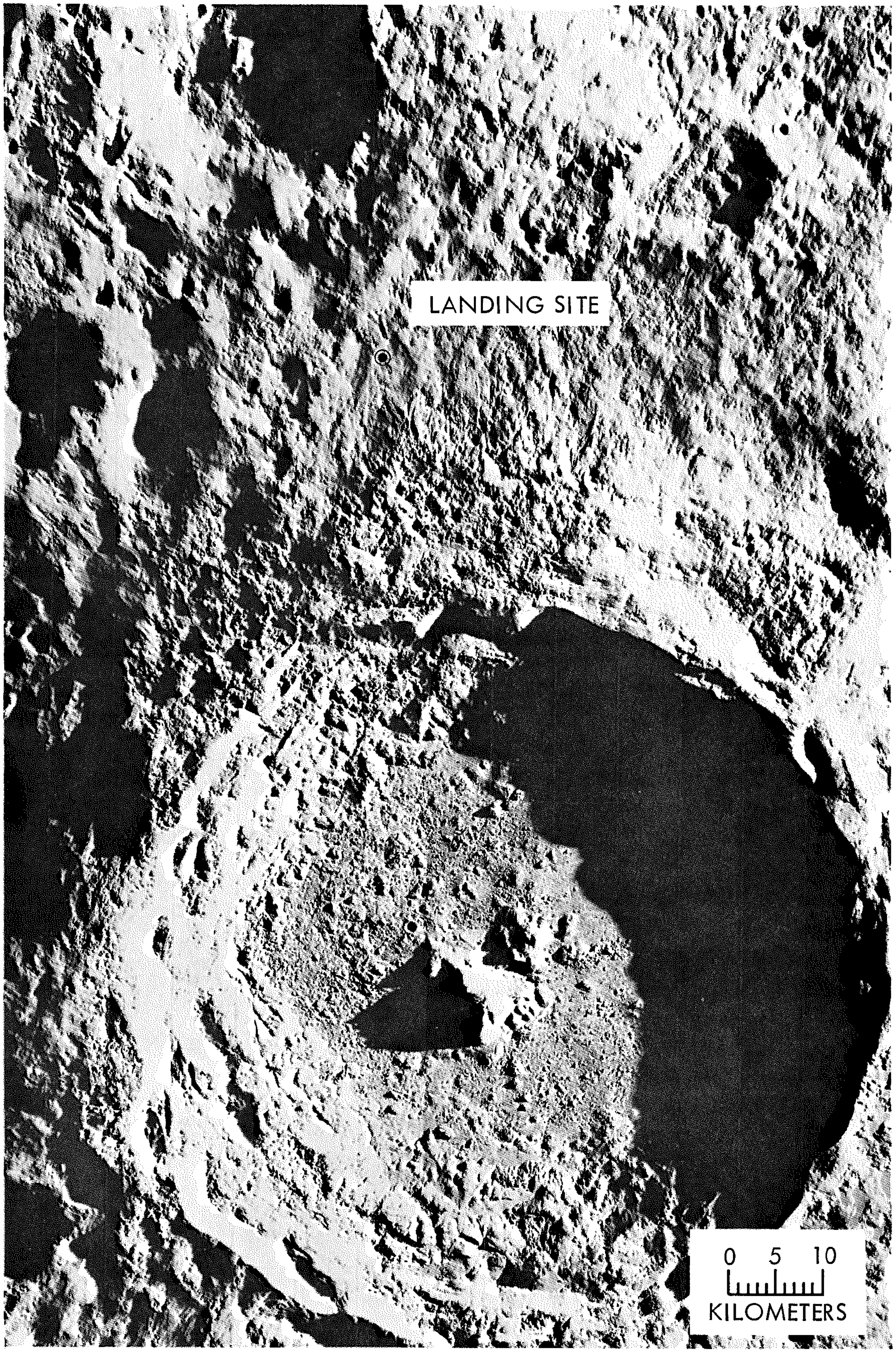

Figure 5-14. Tycho Landing Site, Mission J5

North

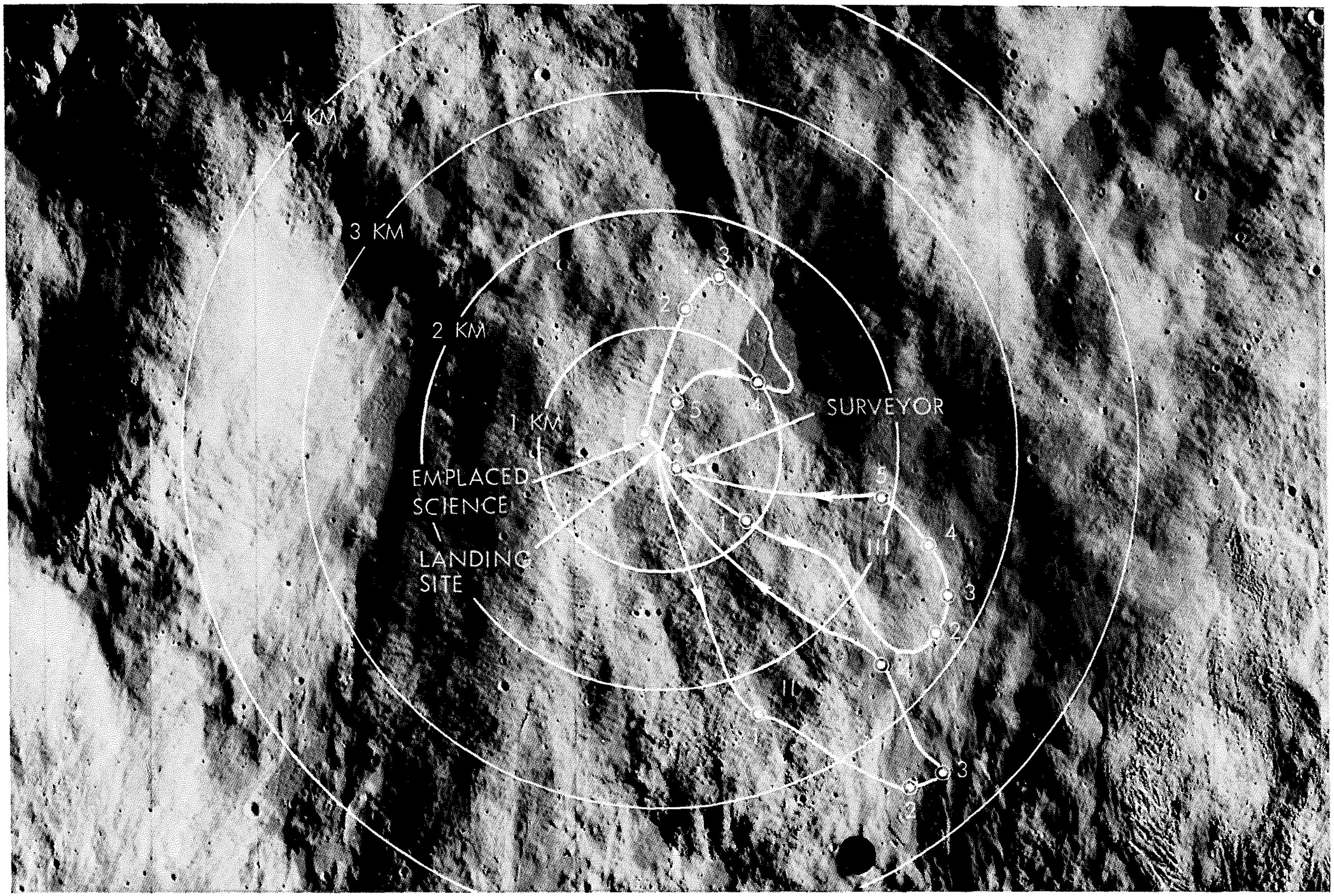

Figure 5-15. Sample Tycho EVA Traverses

5.2 SEISMIC NETWORK DEVELOPMENT

The emplacement of detectors in such a way as to form networks for locating and measuring lunar seismic activity is a very significant part of the scientific exploration program. The ground rules used for the development of seismic networks for this program are as follows.

- ALSEP design goal lifetime $\approx$ 1 year
- ALSEP maximum lifetime $\approx$ 2 years
- Acceptable seismic networks require three concurrently operating stations where the included angle between any two of the three legs of the triangle is greater than five degrees.

Figure 5-16, page 5-29, presents a lifetime analysis of the possible networks which result from transducer emplacement according to the above criteria, selected sites, and landing schedule.

Figure 5-17, page 5-30, shows the planned landing site locations. where the seismic experiments will be emplaced.

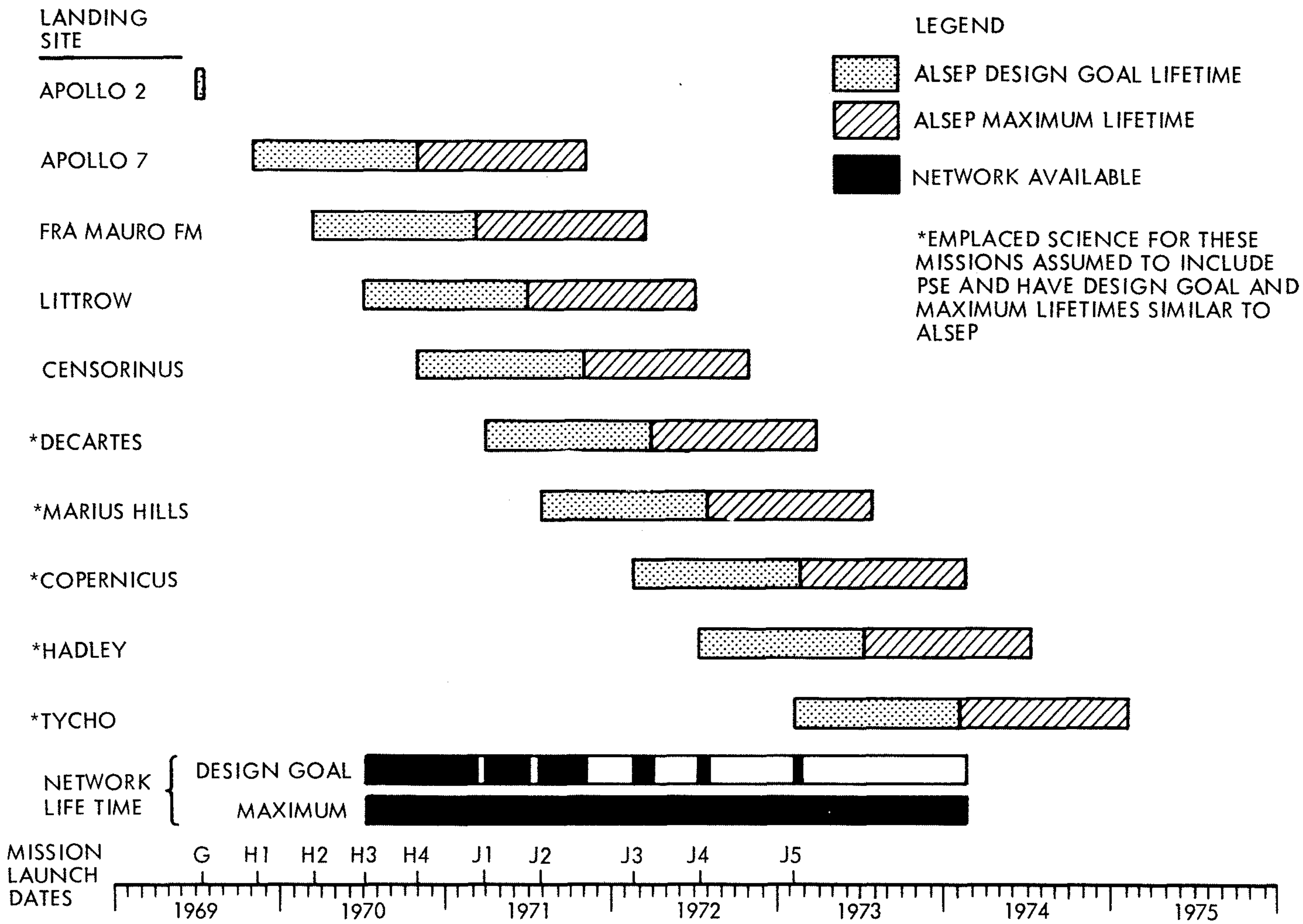

Figure 5-16. Seismic Network System Lifetime

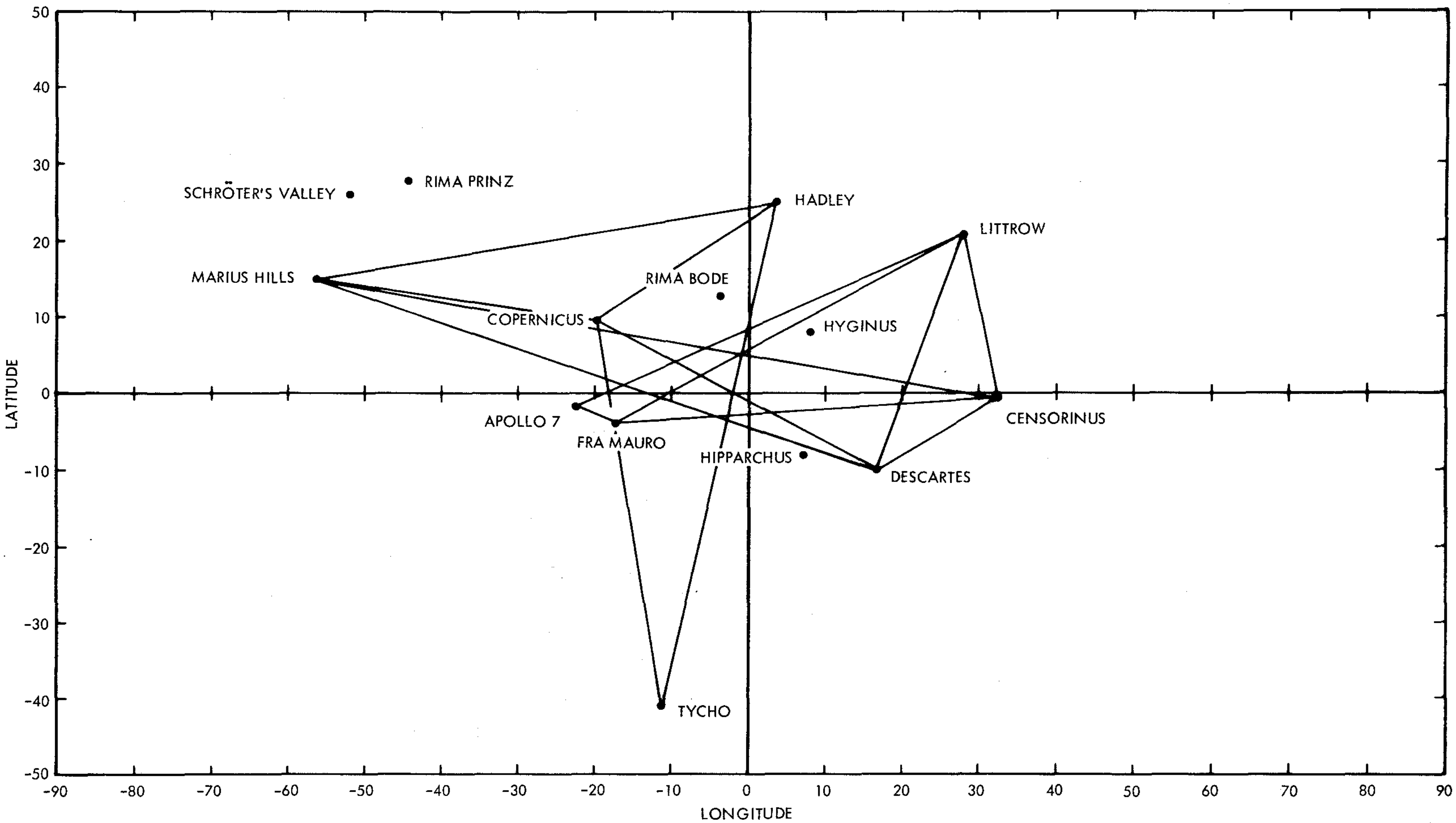

Figure 5-17. Seismic Net Coverage

5.3 ORBITAL SCIENCE COVERAGE

The primary purpose of orbital surveys is for lunar wide understanding and geodetic control. These objectives will be accomplished by instrumentation in the CSM consisting of remote sensing and photography. These accomplishments will include metric mapping of the lunar surface to provide both the regional framework for interpretation of data from local studies and traverses and the geometric data for mapping control; high resolution imagery of many key sites and regional areas for science planning and interpretation; compositional mapping of major portions of the lunar surface with remote sensing instrumentation (e.g., alpha ray, gamma ray, infrared, UV and X-ray spectroscopy); measurement of the lunar gravitational potential by earth-based tracking; and precision altimetry along a number of selected profiles around the moon. A list of candidate lunar orbit experiments and supporting equipment together with tentative mission assignments is provided in Table 3-1, page 3-11. The relationship of the lunar orbit experiments to the several scientific disciplines is summarized in Table 3-2, page 3-13.

The surface area of the moon covered on each mission is determined by the landing site location and launch date dependent trajectory characteristics. Since the landing site and mission sequence assignments are preliminary (i.e., approved for planning only), the precise area of surface coverage cannot be defined at this time. An approximation to this coverage is provided, however, in Appendix E. The coverage charts presented in this Appendix are based on preliminary trajectory data and could change significantly with refinement of the mission plans.

The objectives of orbital surveys are best satisfied by maximizing surface coverage and/or overflying targets of specific interest. The flexibility to select one of these options on each mission is available with the LM rescue budget after a nominal rendezvous sequence is completed. The targets of opportunity and maximum surface coverage achievable with plane change after rendezvous are also approximated in Appendix E. It should be noted that first priority will be given to bootstrap photography requirements for this program option.

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APPENDIX A

LUNAR ORBIT EXPERIMENTS

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(Ref. APO-CCB Directive No. 164A Experiment Assignments, 14 October 1969)

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-158 Lunar Multispectral Photography	To obtain colorimetric data simultaneously in three photographic bands (blue, red, near infrared), which may be used to identify future lunar sample areas in Apollo landing areas and as a tool in geologic mapping.	Three Hasselblad cameras synchronized for simultaneous exposures of a common field will obtain spectral data in the blue, red and near infrared regions. The cameras will be fastened together by a frame and aligned before flight. They will be electrically driven and powered by internal batteries. The camera assembly will be attached to the CM hatch window. The hatch window will be pointed toward the surface and held at the local vertical during the exposure sequence(s). The sequence(s) will be timed to obtain photographs when the sun angle is above approximately 30 degrees.	Exposure Rate: 3 exposures per minute
S-160 Gamma-Ray Spectrometer	To obtain evidence relating to the origin and evolution of the Moon by determining the degree of chemical differentiation the Moon has undergone during its development. Secondarily, to monitor the cosmic gamma-ray flux.	The detector of the gamma-ray spectrometer consists of a sodium iodide crystal for detecting gamma-rays from the lunar surface and a plastic scintillator for detecting cosmic and solar particle flux. The plastic scintillator surrounds the sodium iodide crystal and serves to shield it from the particle radiation. Photomultipliers are used with both detectors. The gamma-radiation detector is calibrated by using a small quantity of Am^{241} to provide a reference.	The gamma-ray spectrometer will be sensitive to gamma radiation in the energy spectrum from 0.1 to 10 mev.
S-161 X-Ray Fluorescence (Adler)	The purpose of the X-ray fluorescence spectrometer is to monitor the instantaneous X-ray fluorescence flux from the lunar surface and the direct solar X-ray flux which induces the lunar fluorescence. These data will enable a gross analysis of the elemental composition of the lunar surface materials along the sunlit portion of the ground track. In particular, it should be possible to discriminate among regions that are granitic, basaltic, or meteoritic in nature and to detect relative abundances of elements O, Na, Mg, Al, Si, K, Ca, and Fe.	The X-ray spectrometer will have a set of lunar surface detectors and one solar monitor. The surface detectors will consist of a collimator, a filter wheel, and a sensor set. The collimator will be an aluminum cellular grid providing the required surface resolution. The filter wheel, interposed between the collimator and the sensors, will consist of sectors of metal foil of different thickness to produce the necessary spectral pass bands. The sensor set will consist of proportional counters with beryllium foil windows and a windowless photomultiplier surrounded by a cylinder of scintillating plastic. The solar monitor will also be a proportional counter with beryllium foil window. It will be mounted to view the sun while the surface detectors are directed toward the nadir.	Spectral range (Approximate): 2 to 25 angstroms Lunar surface resolution (60 n mi orbit attitude): 27 x 27 n mi

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-162 Alpha Particle Spectrometer	To provide basic information on the natural radioactivity of the lunar surface. To determine the gross rate of radon evolution from the Moon and search the localized sources of enhanced radon emission. This information will be used to determine the major element compositon of the lunar surface and infer the thermal history of the Moon.	An alpha particle sensor consisting of several silicon surface barrier detectors operating in parallel will be mounted so that it is directed to the local vertical. A look angle of ± 30 degrees is achieved by collimation. Each particle count registered will result in an analog signal from the detector of amplitude proportional to energy. Each event in the correct energy range will be encoded digitally by a pulse height analyzer (PHA) and stored by incrementing one of the 250 registers by one unit. At the end of the accumulation cycle, the contents of the PHA will be transferred to a storage system from where it can be telemetered. A positive effect will be indicated by statistically significant peaks in the energy spectrum at 5.48 and 6.28 mev from the decay of Rn^{222} and Rn^{220}, respectively.	Energy range 4 to 9 mev Look angle ± 30 degrees Spacial resolution 16 elements per rev.
S-163 24-Inch Panoramic Camera	To acquire photographs of the lunar surface from orbital altitudes on stable base film as part of the exploration program of the Moon. The purpose of the photography is to support manned lunar landing missions as well as general scientific investigations of the Moon.	To provide wide-angle coverage normal to the ground track, the panoramic camera will scan in a plane normal to the flight path. Fore and aft tilt will be provided so that successive frames can be made to overlap, thus providing stereoscopic photographs. Exposure will be controlled by varying the width of a slit which is mounted on the lens scanning arm and moves across the film as the lens is scanned. Calibration of the camera will be accomplished by photographing star fields.	Focal length 24 inches Aperture f/3.5 Scan angle 120 degrees total Stereo convergence angle 20 degrees Film 5 inches Width 6500 feet Capacity 135 lines per millimeter Resolution 0.20 to 4.8 milliseconds Frame rate 1 every 17.5 seconds to 1 every 1.75 seconds.

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-164 S-Band Transponder (William L. Sjogren, JPL)	The purpose of the S-band transponder experiment is to track the CSM or LM in lunar orbit by means of S-band doppler measurements during periods when the spacecraft is unperturbed by maneuvers, attitude control, or astronaut activity. Accurate measurement of a satellite's natural lunar orbit position over meaningful periods of time allows definition of a lunar mass model which will support future landing activities by permitting greater surface landing accuracy, backside landings, and more accurate orbit determinations and will provide a basic model for studies of lunar origin and subsurface structure.	The present Apollo S-band transponder will be used for doppler tracking of either the CSM or LM. Non-gravitational movement of the spacecraft will be rigidly controlled. Tracking of the LM ascent stage after jettison is preferred. A relatively long overall period of tracking is desired with measurements taken throughout several front-side passes. If feasible, the LM altitude over the front face should be reduced to 10 km and later to 2 km (or crash at approximately 60°W longitude) for verification of a lunar atmosphere.	Frequency Earth transmitter 2106.40625 mHz Transponder 2287.1500 mHz
S-165 Mass Spectrometer	To obtain data on the composition of the lunar atmosphere.	The instrument is basically a magnetic sector-field mass spectrometer with a Nier-type thermionic election bombardment ion source. Ions produced by election bombardment of the lunar atmosphere constituent gases are accelerated by a scanned high voltage sweep and directed between the poles of a 90-degree sector permanent magnet. The ions emerge as two beams with a mass ratio of 2.3 to 1. Two collection slits are set to simultaneously scan the two mass ranges corresponding to the two beams. The instrument is mounted on a 10-foot boom deployed from the service module and is oriented along the longitudinal axis of the spacecraft.	Low mass range 12 to 28 amu High mass range 28 to 66 amu Sensitivity 10^{-13} torr
S-166 3-Inch Mapping Camera (James H. Sasser, NASA-MSC)	To obtain simultaneous precision metric photographs of the lunar surface and star fields for geodetic and cartographic control.	The mapping camera consists of a terrain camera and a stellar camera integrated into a single unit. The cameras will be oriented for operation such that the terrain camera will be pointed toward the nadir and the stellar camera toward a star field at 90 degrees from the direction of flight. Photographs will be taken with approximately 78 percent overlap to provide stereoscopic imagery. The exposed film will be recovered from the cameras by the astronauts and returned to earth.	Terrain Camera Film 5-inch Focal length 3 inches Field of view 74 x 74 degrees Shutter speed Variable Stellar Camera Film 35 millimeter Resolution 44 lines/millimeter Sensitivity 65h magnitude stars Focal length 85 millimeters Aperture f/1.8 Shutter speed 2 seconds Field of view 18 degrees

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-167 Sounding Radar	To determine the geological lunar subsurface features with radar, to locate surface features within 100 meters in conjunction with optical photography, and to survey relative lunar surface electrical and geometrical properties.	The measurement device is essentially a two-frequency, side-looking imaging radar that employs a synthetic antenna length (aperture) to obtain a high aximuthal resolution. The radar illuminates the lunar surface with periodic short pulses of energy that sweep the surface in range as the motion of the spacecraft provices azimuthal sweep. Amplitude and phase of the echo signals are recorded on film, which is returned to earth. The continuous film records of Doppler frequency and range echo patterns are converted to imagery. The radar can also look directly beneath the spacecraft to obtain a profile image. The dual frequency mode enables simultaneous near-surface and subsurface imagery of the same surface region. Targets that appear in the longer wavelength image will tend to be related to subsurface anomalies and those in the shorter wavelength image to near-surface anomalies.	Wavelength: 25 cm, 30 m Range accuracy: ±15 m Resolution 25 cm radar: 50 x 50 m 30 m radar: 300 x 300 m
S-168 Lunar Electromagnetic Sounder "A" (Dr. Stanley H. Ward, University of California, Berkeley)	To map the electrical conductivity, the dielectric constant, and possibly the magnetic permeability of lunar surface materials over the lunar globe and to a depth of one to ten kilometers. Such information will give a physical description of the lunar materials and provide a three-dimensional extrapolation of surface geologic mapping. Secondary objectives are: o Detection and characterization of a postulated lunar ionosphere o Measurement of the sheath of charge on the sunlight side of the Moon	A center-fed dipole antenna transmits sinusoidal electromagnetic waves in pulses at a repetition rate of 30 per second. Subsequent to each pulsed transmission, the antenna is used for reception. The outgoing electromagnetic wave is reflected from the lunar surface, and possibly from interfaces above or beneath the surface. Information on the electrical parameters can be obtained from the shape amplitude, or time of the reflected pulse relative to the shape, amplitude, or time of the transmitted pulse. Information on the character and particle content of any assumed lunar ionosphere might also be obtained. The carrier frequency can be swept or fixed at any frequency within the range of the transmitter.	Frequency: 1.0 to 20 mHz Frequency sweep period: 26 seconds Pulse repetition frequency: 30 pulses per second Surface penetration: Up to 10 km

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE	
S-169 Far Ultraviolet Spectrometer (William G. Fastie, Johns Hopkins University)	To determine the lunar atmospheric composition and density with a far ultraviolet Ebert spectrometer.	The measurement technique involves observing spectral emissions from atmospheric species by reasonance reradiation of absorbed solar flux in the spectral range 1000 to 1800 Angstroms. The proposed instrument is a one-half meter focal length Ebert spectrometer with 0.5 x 6 centimeter slits, a 100 square centimeter grating with 3600 grooves per millimeter, and collecting optics to direct the dispersed radiation to a photomultiplier tube which employs pulse counting circuitry to measure light intensity.	Output Limit of detection for tens of seconds observation time Detectable density limit	200 photoelectrons per Rayleigh Approximately 0.05 Rayleigh Approximately 10^2 atoms/cm^2
S-170 Downlink Bistatic Radar (H. Taylor Howard, Stanford Electronic Laboratories)	To gather S-band bistatic radar data on the lunar crust. Specifically, a. To determine the Brewster angle of the lunar crust at S-bands. b. To measure the spectral properties of bistatic radar echoes from low altitude orbit. c. To gain operational experience with Apollo systems and operations as an aid in the design of future bistatic radar experiments.	S-band transmissions from the spacecraft will be received by the Earth-based tracking station both directly and via reflection from the lunar surface. The two received signals will be distinguishable by Doppler difference. The data reduction process will consist of a digital spectral analysis for separation of the direct and reflected signals. Appropriate corrections for spacecraft geometry will then be applied to obtain a measure of lunar surface reflectivity and roughness.		
S-171 Lunar IR Scanner (Frank J. Low, Rice University)	To locate, identify and study anomalous temperature regions on the lunar surface at a high resolution by obtaining a surface temperature map of the unilluminated portions of the lunar surface. Characterization of such physical parameters as thermal conductivity, bulk density, and specific heat will be possible.	The infrared scanning radiometer consists of a scanner unit, and electronic module, and a signal conditioning module. The scanner unit consists of a rotating mirror and drive motor, a folded Cassegrain telescope, baffles, an infrared focusing lens, and an infrared detector. The field-of-view is constricted to 100 milliradians by the baffles and the incident energy is focused on the detector by the IR lens.	Spectral range Scanning angle Field-of-view Frequency range	21 to 100 microns 150 degrees 100 milliradians 0 to 150 Hz

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
<u>Subsatellite Experiments</u> S-173 Lunar Particle Shadows and Boundary Layer (Kinsey A. Anderson, University of California, Berkeley) S-174 Subsatellite Magnetometer (Paul J. Coleman, UCLA)	To obtain data relative to two basic problems of space physics: o Formation and dynamics of the Earth's magnetosphere o The boundary layer of the solar wind as it flows over the Moon The magnetosphere experiment will determine: a. The topology of the magnetotail b. D.C. electric fields c. The direction in which the energetic magnetotail plasma is covected. The boundary layer experiment will obtain data on the physics of the interaction region or boundary layer between the solar wind and the Moon. Study of the interaction region will yield information on on the external plasma, the interior of the Moon, the surface, and the lunar ionosphere.	Experiments S-173 and S-174 will be carried in a subsatellite that will be ejected into lunar orbit from the service module. The subsatellite will be a regular octahedron of 14 inch edge and will carry a magnetometer and charged particle detectors. It will be spin-stabilized at 3 rpm, with spin axis normal to the orbit plane. It will have a VHF command and telemetry system, powered by solar cells and battery. The magnetometer will be of the biaxial fluxgate type, similar to the ATS-1 used on the IMP. Particle counters of several types will be used to cover the range of particle energies expected to be encountered.	<u>Magnetometer</u> Dynamic range: 0 to ±200 γ Resolution: 5 to 7 γ Frequency response: 0 to 0.05 Hz <u>Particle Detectors</u> Proton energy range: 0.3 to 6 meV Electron energy ranges: 0.5 to 1.0 keV; 2.0 to 3.0 keV; 6 to 9 keV; 13.5 to 16.5 keV; 20 to 300 keV Minimum detectable flux: From 0.01 $(cm^2 \text{ sec sr})^{-1}$ for most energetic particles to 10^4 $(cm^2 \text{ sec sr})^{-1}$ for least energetic particles.
S-175 Laser Altimeter (William M. Kaula, Institute of Geophysics and Planetary Sciences, UCLA)	The purpose of the laser altimeter is to measure altitude with high precision and high ground resolution. Specific objectives are: 1. To determine altitude for metric camera reference. 2. To relate surface features (topography) to lunar shape, as determined from orbital data.	Altitude will be determined by measuring the time delay between transmission and reception of light pulses reflected off the lunar surface. Transmitted pulses will be collimated into a beam of 40 microradian width by an optical transmitting telescope. The receiving telescope will have a field of view of 10^{-8} steradian. The pulse dalay will be measured by counting pulses of a 100 megahertz clock.	Wavelength: 6943 angstroms Pulse width: 20-30 nanoseconds Pulse energy (Approximate): 0.07 joule Pulse repetition rate: 6 per minute Telescopes, transmitting and receiving: Focal length: 9 inches Aperture: f/1 Optical bandwidth: 20-30 angstroms System accuracy $(1\ \sigma)$: 2 meters or less

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-176 Apollo Window Meteroid	To determine the meteroid cratering flux for masses of 10^{-12} gram and larger; i.e., those particles responsible for the degradation of surfaces exposed to the space environment.	This experiment uses the Apollo command module windows as a meteroid detector. The windows are scanned before flight at 20X magnification to determine the general background of chips, scratches, etc. After the flight and recovery of the windows, the windows are scanned twice at 20X to accurately map all visible defects. The map is then used to relocate each point of interest for examination at magnifications up to 765X. From past experience with hypervelocity impacts, it is possible to separate the meteroid impacts from other surface effects. Every meteoroid crater found will be analyzed, photographed and measured in detail. Some impact areas may require sectioning of the spacecraft window to permit observation of the crater cross-section. Additional testing will be performed or selected impacts to look for residue from the impacting meteroid.	
S-177 UV Photography of the Earth and Moon	To obtain ultraviolet photographs of the Earth and analysis on the basis of existing knowledge of the structure and composition of the atmosphere and the albedo of surface materials. The resulting correlations would be used to interpret unexplained features that appear in UV photographs of Mars and Venus. The ultimate goal is a better understanding of the atmospheres of Mars and Venus. To photograph the Earth at 2600 Å, below the present limit for planetary photography, in order to examine the appearance of the atmosphere above the ozone layer. To obtain photographs of the lunar surface with the 2600 Å filter to search for possible fluorescence and to extend ground-based colorimetric data.	Photographs of the Earth are to be taken from Earth orbit, from lunar orbit and from intermediate positions. A minimum of three UV filters will be used, centered at 3750Å, 3250Å, and 2600Å. Eastman Kodak spectroscopic film of emulsion class IIa-0 is adequate. The camera should be provided with sensitometric calibration, so that a grey scale of several magnitudes can be impressed on the film for subsequent conversion of densitites to intensities.	

EXPERIMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-178 Gegenschein From Lunar Orbit	To make photographic observations of the Gegenschein and Moulton point regions in order to determine their spacial distribution of surface brightness. From these results a determination will be made of the extent of the contribution of dust particles, if any, at the Moulton point to the Gegenschein phenomenon.	Photographs are to be taken in the anti-Sun direction and at 10 degrees and 20 degrees from this direction while the spacecraft is neither in sunshine nor in earthshine. The Hasselblad camera with f/2.8 or faster lens and Kodak 2485 film will be used. Photometric isodensity traces will be made on the photos at GSFC and analysis will be by isodensitometry. Interpretation will be by inspection to see whether there is or is not any brightness at the Moulton point.	
S-179 250 mm Hasselblad Camera	To obtain photographs of the lunar surface in accordance with the photographic plan and to provide the means for photographing targets of opportunity on the lunar surface, identifying future targets for high-resolution photography.	The crew will utilize a Hasselblad camera with a 250 mm lens, photographing the lunar surface through the Apollo command module windows. MCC-Houston will advise in real time to supplement the photographic plan. Particular emphasis will placed on photographing lunar features with unusual characteristics, thus identifying candidate targets for future high-resolution photography.	
S-180 500 mm Hasselblad Camera	To obtain high resolution photographs of the lunar surface from lunar orbital altitudes.	The flight crew will obtain high resolution photographs of the lunar surface using a Hasselblad camera with a 500 mm lens. Photographs will be taken through the Apollo command module windows. MCC-Houston will advise in real time to supplement the photographic plan. Particular attention will be given to photographing lurain features with unusual characteristics, thus identifying potential candidates for surface or other further investigation on future lunar exploration missions.	
S-181 Questar Contarex Camera	Not available		
S-182 Lunar Surface in Earthshine	Not available		

APPENDIX B

LUNAR SURFACE EXPERIMENTS AND EQUIPMENT

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EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
M-515 Lunar Dust Detector	To obtain data for the assessment of dust accretion on ALSEP and provide a measure of the thermal degradation of thermal surfaces.	The dust detector sensors are three photocells oriented on three sides of the sensor package to face toward the ecliptic. Dust accumulation on the surfaces of the photocells will reduce the solar radiation detected. The outputs of the photocells are amplified and conditioned for application to commutated channels of the ALSEP data systems.	
S-031 Passive Seismic Experiment	To monitor seismic activity at selected sites on the lunar surface. The objective is to detect seismic disturbances resulting from tectonic activity, meteoroid impacts, tidal deformations, and free oscillations of the lunar body. Analysis of the velocity, frequency, amplitude, and attenuation characteristics of the seismic waves should provide data on the number and character of lunar seismic events, the approximate azimuth and distance to their epicenters, the physical properties of subsurface materials, and the general structure of the lunar interior.	The passive seismic experiment (PSE) consists of a tri-axial long period seismometer and a single axis short period seismometer. The long period seismometer detects the displacement amplitude of low frequency seismic motions along the vertical axis and mutually perpendicular horizontal axes (seismic output). It also detects two components of surface tilt and changes in the vertical component of gravitational acceleration (tidal output). the short period seismometer detects the displacement amplitude of higher frequency seismic motion along the vertical axis. The PSE is connected to the ALSEP central station for receipt of commands from the Earth and data return.	Dynamic range: Seismic amplitude components — 1.0 mμ to 10μ Surface tilt components — 0.01 to 10 arc sec Vertical acceleration (long period) — 8.0 μ gal to 8.0 m gal Sensitivity at maximum gain: Seismic amplitudes — 5 v/μ Surface tilt — 5.0 v/arc sec Vertical acceleration — 0.625 v/m gal Frequency range (approximate): Long period seismometer — 0.004 to 3.3 Hz Short period seismometer — 0.2 to 25 Hz μ = micron m μ = millimicron v/μ = volts per micron μ gal = microgal m gal = milligal gal = 1 cm/sec/sec
S-033 Active Seismic Experiment	To generate and monitor artificial seismic waves in the 3 to 250 Hz range. The ASE can also be used to monitor natural seismic waves in the same frequency range. The objective is to acquire information to enable determination of the physical properties of lunar surface and near subsurface materials.	Seismic waves will be artificially produced by explosive devices and detected by geophones. By varying the location and magnitude of the explosions with respect to the geophones, penetration of the seismic waves to depths of approximately 500 feet can be achieved and wave velocities through several layers of subsurface materials investigated. (Continued)	Frequency — Response* 3.0 to 10 Hz — +1 db, -6 db 10 to 100 Hz — ±3 db 100 to 250 Hz — ±6 db 250 to 450 Hz — Less than +1 db 450 to 500 Hz — Less than -35 db Above 500 Hz — Less than -40 db *Relative to mean response within the 10 to 100 Hz range.

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-033 Active Seismic Experiment (continued)		The seismic detectors are three identical geophones, whose output signals are proportional to the rates of subsurface motion. The geophones will be deployed along a line at distances of 10, 160 and 310 feet from the ALSEP central station. Two artificial seismic energy sources will be employed. A thumper device containing 21 explosive initiators will be fired by the astronaut at 15-foot intervals along the geophone line. Wave velocity can be determined from the intervals between firing and detection by the three geophones. A mortar and four grenades will be used near the end of the operational life of the experiment. The grenades are designed to impact at ranges of 500, 3000, and 5000 feet with explosive charges proportional to their ranges. Means are provided for detecting firing instant, initial velocity, elevation, and time of flight. In the passive listening mode the geophones will detect natural seismic activity generated by tectonic disturbances or meteoroid impacts.	
S-034 Lunar Surface Magnetometer	To measure the vector magnetic field and its temporal variations at selected points on the lunar surface. Objectives are: a. To obtain the diffusive flow of field through the lunar interior b. To measure the equatorial surface field due to magnetic flux tubes captured from the solar wind field c. To obtain the sunward and antisolar surface hydromagnetic radiation density and spectrum, from which statistically will be given the internal magnetic Reynolds number of the electromagnetic diffusivity. (Continued)	The lunar surface magnetometer consists of three magnetic sensors, each located in a sensor head and located at the end of a three-foot long support arm. The magnetic sensors, in conjunction with the sensor electronics, measure the magnetic field components parallel to three orthogonal axes. Each sensor has three selectable dynamic ranges. The magnetometer is connected to the ALSEP central station for receipt of commands and data return to Earth. The magnetometer has three modes of operation: site survey, scientific, and calibration. The site survey is performed once after magnetometer deployment to identify and locate any magnetic influences permanently inherent in the site so they will not affect interpretation of (Continued)	Dynamic ranges: -100 to 100 gamma*; -200 to 200 gamma*; -400 to 400 gamma* Frequency response: 0 to 50 Hz Resolution: 0.2 gamma *1 gamma $\equiv 10^{-5}$ Oersted

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-034 Lunar Surface Magnetometer (Continued)	d. To determine from interplanetary transients the lunar response to shock wave and contact disconinuities. e. To look for the onset of turbulence in the lunar bow shock. f. To determine the angular extent of the magnetospheric tail of the Earth's field at the distance of the Moon.	magnetic flux sensing. The scientific mode is the normal mode of operation. The calibration mode is used periodically to determine the absolute accuracy of the sensors and to correct any drift from their laboratory calibration.	
S-035 Solar Wind Experiment	To measure the energies, densities, incidence angles, and temporal variations of the electron and proton components of the solar wind plasma striking the surface of the Moon. From these data the existence and general properties of the solar wind at the lunar surface and the properties of the magnetospheric tail of the Earth can be inferred.	Seven Faraday cups collect and detect the solar wind electrons and protons. The cups open toward different but slightly overlapping portions of the lunar sky. Data from each cup individually and from all seven cups combined are processed and fed to the ALSEP data subsystem for Moon-to-Earth transmission. With the additional knowledge of the positioning of the solar wind spectrometer on the lunar surface, the direction of the bulk of charged particle motion can be deduced. Voltages on modulation grids of the cups are changed in sign and varied so the cups will differentiate between electrons and protons and among particles of different energies.	Measurement ranges Electrons High gain modulation: 10.5 to 1376 ev Low gain modulation: 6.2 to 817 ev Protons High gain modulation: 75 to 9600 ev Low gain modulation: 45 to 5700 ev Field-of-view: 6.0 steradians Angular Resolution: 15 degrees (approximately)
S-036 Suprathermal Ion Detector	To measure the ionic environment of the Moon by detecting the ions resulting from the ultraviolet ionization of the lunar atmosphere and the free streaming and thermalized solar wind. The suprathermal ion detector will measure the flux, number density, velocity, and energy per unit charge of positive ions in the vicinity of the lunar surface.	Two curved plate analyzers are used to detect and count ions. The low energy analyzer has a velocity filter of crossed electric and magnetic fields. The velocity filter passes ions with discrete velocities and the curved plate analyzer passes ions with discrete energy, permitting determination of mass as well as number density. The second curved plate analyzer, without a velocity filter, detects higher energy particles, as in the solar wind. The experiment is emplaced on a wire mesh ground screen and a voltage is applied between the electronics and the ground plane to overcome any electrical field effects. (Continued)	Low-energy ion detector Velocity range: 4×10^4 to 9.35×10^{-6} cm/sec Number of velocity steps: 20 Energy range: 0.2 to 48.6 ev Number of energy steps: 6 Number of mass per unit charge steps: 120 (Continued)

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-036 Suprathermal Ion Detector (Continued)		Low energy ions will be counted in selected velocity and energy intervals. The distribution of ion masses up to 120 amu can be determined from this data. In addition, the electric potential between the electronics and the ground plane will be controlled by applying known voltages. If local electric fields exist, they will be offset at one of the voltage steps. By accumulating ion count data at different ground plate potentials, an estimate of local electric fields and their effects on ion characteristics can be made. The suprathermal ion detector is connected to the ALSEP central station for receipt of commands and data return.	High-energy ion detector Energy range: 10 to 3500 ev Number of energy steps: 20
S-037 Heat Flow Experiment	To measure the net outward flux of heat from the interior of the Moon. Measurement of the lunar heat flux will provide: a. A comparison of the radioactive content of the Moon's interior and the Earth's mantle b. A thermal history of the Moon c. A temperature versus depth profile d. The value of thermal parameters in the first three meters of the Moon's crust. Heat flow data, together with seismic measurements, will provide information on the composition and physical state of the Moon's interior.	The major components of the heat flow experiment are two sensor probes and an electronics package. Each probe has two sections, each 55 cm long, spaced 2 cm apart. A gradient sensor and a heater coil are located at each end of each section. Ring sensors are located 10 cm from each end of each probe section. Four thermocouples are located in the cable of each probe. The probes are inserted into 3-meter holes drilled vertically into the lunar surface. The electronics package contains the functional circuits of the experiment for decoding and executing commands and handling data. The heat flow experiment operates in three basic modes that can be selected and sequenced by commands from Earth: 1. Gradient mode (normal mode; gradient sensor excitation, no heater excitation) 2. Low conductivity mode (gradient sensor excitation, low heater excitation) 3. High conductivity mode (ring sensor excitation, high heater excitation) (Continued)	Temperature differentials (gradient): High sensitivity Range: ±2 degrees C Probable error: 0.003 degrees C Low sensitivity Range: ±20 degrees C Probable error: 0.03 degrees C Probe ambient temperatures Range: 200 to 250 degrees K Probable error: 0.1 degrees C Thermocouple reference junction temperature Range: -20 to 60 degrees C Probable error: 0.1 degrees C Probe cable ambient temperature Range: 90 to 350 degrees K Probable error: 0.3 degrees C (Continued)

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-037 Heat Flow Experiment (Continued)		The normal gradient mode is used to monitor the heat flow in and out of the lunar surface crust. Heat from solar radiation flows into the Moon during the lunar day and out during the night. This larger heat gradient in the near subsurface will be measured in order to differentiate it from the more steady but smaller heat flow outward from the interior of the Moon. The low and high conductivity modes are used to measure the thermal conductivity of lunar surface materials. A known quantity of heat is generated at a known location by exciting one of the eight probe heaters and temperatures at the various probe sensors are observed for a period of time. The low and high conductivity modes provide a wide range of conductivity measurement for loosely consolidated material and solid rock. Communication with Earth for commands and data return is via the ALSEP central station.	Probe heater power Low power excitation 2 milliwatts High power excitation 500 milliwatts
S-038 Charged Particles Lunar Environment	To measure the energy distribution, time variations, and direction of proton and electron fluxes at the lunar surface. The measurements will provide information on a variety of particle phenomena, including: a. Interaction of the solar wind with the magnetospheric tail of the Earth near full moon. b. Interaction of the solar wind with the Moon, including the possible existence of a standing front.	The charged particles experiment measures the flux levels and energy of protons and electrons separately, each in 18 different energy levels. The basic instrument consists of two detector packages oriented in different directions and with minimum exposure in the direction of the ecliptic. Each detector package has six particle detectors. Five of these detectors provide information about particle energy distribution, while the sixth provides high sensitivity at low particle fluxes. Particles entering the detector package are deflected by an electric field along curved paths which are a function of the energy-to-charge ratio of the particles and of the strength and polarity of the electric field. Particles of one sign will be detected in five discrete energy levels, while particles of opposite sign are detected simultaneously in one broad energy spectrum. (Continued)	Energy range 40 ev to 70 kev Flux range 10^5 to 10^{10} particles per sq cm/sec/steradian Particle counting rate Up to 10^6 per sec Discrete energy levels 18

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-038 Charged Particles Lunar Environment (Continued)		The electric field can be sequenced through three intensity levels and both polarities and through a nominal zero. With the field at zero background flux can be measured. Sequencing the direction of the electric field enables measurement of the flux and energy distribution of both positive and negative particles.	
S-058 Cold Cathode Gauge	To measure the density of the lunar atmosphere, including any temporal variations, either random or associated with lunar local time or solar activity. In addition the cold cathode gauge will measure the rate of loss of contaminants left in the landing area by the astronauts and the lunar module.	The cold cathode gauge measures neutral atom densities corresponding to atmospheric pressures of approximately 10^{-12} torr to 10^{-6} torr. Charged particles injected into the CCG aperture collide with neutral atoms entering the sensor from the atmosphere. Ions produced by these collisions and free ions are collected by the cathode by a pair of sensor electrodes which are maintained at a potential difference of 4500 volts. The ions resulting from collisions greatly outnumber the free ions and result in a minute current flow to an electrometer. The electrometer amplifies the current and generates an equivalent analog voltage as the output signal. The sensitivity of the measurement is automatically determined by a seven-position sensitivity range network. The CCG is connected to the ALSEP central station for commands and data return.	Pressure range 10^{-12} to 10^{-6} torr Accuracy Above 10^{-10} torr ±30 percent Below 10^{-10} torr ±50 percent
S-078 Laser Ranging Retroreflector	To enable precise ranging from the Earth to a point on the surface of the Moon. Precise range data will be useful for several purposes, including: a. Determination of lunar ephemeris and orientation b. Detecting tidal motion c. Detecting variations in Earth rotation rate	The laser retroreflector will consist of an array of 90 to 100 fused silica optical corner reflectors and a mounting and orientation device. It will serve as a reflecting target for active laser systems on the Earth.	The array is expected to reflect the transmitted pulse with a time spread of less than one nano-second and a return enhancement factor of 100.
S-080 Solar Wind Composition	To determine the heavier ion content of the solar wind. The primary objective is to determine the isotopic noble gas composition of the solar wind.	A sheet of aluminum foil of known area is unrolled from a spring-loaded roller and exposed to solar radiation on the lunar surface for a prescribed interval of time, after which it is rerolled and returned to Earth for analysis.	

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
S-151 Cosmic Ray Experiment	To obtain data from which to infer the origin, age, and probable storage volume (galactic disc, halo or intergalactic space) of heavy, energetic cosmic particles. High resolution measurements of charge, mass and energy of cosmic rays beyond the Earth's atmosphere and magnetic field will provide unique information on the origin of cosmic rays and thus on the origin of the elements and the nature of stellar nucleosynthesis. Tracks of heavily ionizing particles in the astronauts' helmets will be measured to establish the integrated exposure of their heads and faces to heavily ionizing particles.	The experiment equipment consists of plastic particle detectors and the astronauts' helmets. The detectors will be attached to the LM exterior and exposed for approximately 100 hours. Each detector stack will contain 40 sheets of Lexan polycarbonate resin (0.010 inch thick), which is the plastic detector material. The Lexan sheets measure 6 by 10 inches and are held in a frame. The astronaut will remove the stacks during EVA and place them in the LM for return to Earth for analysis. The Lexan helmets are the only equipment required for the helmet portion of the experiment. The helmets are analyzed for particle tracks after return to Earth, as are the plastic detectors.	Particle energy 10 to 200 mev/nucleon Atomic number $Z > 8$
Astronomy Radiometer	To survey the background radio noise at the lunar surface for use in evaluation of the Moon as a radio astronomy base. Impedance measurements possible with this instrument will also provide limited information on the properties of lunar material and will determine variations in the properties of the lunar ionosphere or local photoemission cloud. Long-term operation of the experiment would provide data concerning the long wavelength dynamic spectra of solar, jovian, and terrestrial radio bursts.	The astronomy radiometer consists of a multifrequency radiometer, an impedance meter, and an antenna. It will be emplaced on the lunar surface about 100 feet from the LM and operated during lunar surface stay. Long-term observations can be made if the instrument can be connected to the ALSEP before the astronauts leave.	Frequency range 50 kHz to 15 mHz
Electric Field Gradiometer	To measure the electric field strength immediately above the lunar surface and from this to infer the surface charge and its polarity. Knowledge of the near-surface electric field will also aid in theoretical and experimental analysis of the lunar atmosphere and of the solar wind interaction with the Moon.	The electric field gradiometer will utilize two parallel, oppositely directed electron beams passing over open lunar surface to avoid disturbing the electric charge environment. The deflection of these beams will be a measure of the existing electric and magnetic fields. An electric field will deflect the two beams in the same direction, while a magnetic field will deflect them oppositely. For each beam there is an electron gun and opposite it, a sectored target on which the (Continued)	Field strength range ±(0.2 to 500 v/m) Uncertainty ±2 percent or ±0.1 v/m whichever is larger Response time 0.1 sec or less (v/m ≡ volts per meter)

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Electric Field Gradiometer (Continued)		beam impinges. Any deflection of the beam by the lunar electric field will be detected and amplified, and a proportional voltage will be fed back to deflection plates at the gun to keep the beam centered on the target. This correction voltage will then be a measure of the electric field.	
Gravimeter	To measure the acceleration of gravity and its temporal variations at the lunar surface. Precise measurements over a period of months will establish the deformation of the Moon due to tidal forces, enabling conclusions to be drawn concerning the internal constitution of the Moon. The gravimeter will also detect free oscillations of the Moon and seismic waves, from which to infer additional information about the interior.	A La Coste and Romberg mass spring and level system will be used to measure absolute gravity, tidal variations, free oscillations, and seismic waves. Data transmission will be via the ALSEP central station.	Absolute gravity, Accuracy: Approx. 1 m gal Tidal variations, Accuracy: 1 μ gal or better Frequency range: 0 to 2 cpm Free oscillations Sensitivity: 0.1 μ gal or better Frequency range: 0.01 to 2 cpm Seismic waves Frequency range: 0 to 3 Hz
Mass Spectrometer	1. To determine the composition and concentration of any ambient lunar atmosphere, including temporal variations of random character or associated with lunar local time or solar activity 2. To determine the rate of loss of contaminants left in the landing area by the astronauts and the LM 3. To provide information of geochemical significance relating to any release of gas from volcanic activity or from other geological structures or materials on the Moon	The instrument to be used is essentially a Nier-type sector-field analyzer with three collectors, one for each of three mass ranges. Atmosphere constituent molecules are ionized by electric bombardment, accelerated by an electric field, and collimated into two separate magnetic analyzers at ground potential. The magnetic analyzers divide the ions according to their masses among three collectors, where they are counted. The spectrum is scanned by varying the ion accelerating voltage in steps.	Collector mass ranges Low: 1 to 4 amu Intermediate: 12 to 45 amu High: 40 to 150 amu Mass resolution (approximate) Low mass range: 1 part in 5 Intermediate range: 1 part in 50 High range: 1 part in 150 Partial pressures: As low as 10^{-14} torr

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Low Energy Nuclear Particle Detection	To obtain vital information for the interpretation of observations on returned lunar samples and some information on the flux, energy spectrum, and chemical composition of extremely low energy nuclear particles that are difficult to study by other means. The experiment will also give useful data on the radiation dose received by the spacecraft in the event of enhanced solar activity during the mission.	The inorganic low energy particle detectors will be sandwiches made up by stacking 20-micron mica sheets to a total thickness of 250 microns. Four of the detectors will have surface area of 10 cm^2 and one an area of 100 cm^2. Three of the smaller detectors will be covered with increasing thickness of evaporated aluminum. The fourth smaller detector and the larger detector will not be covered with aluminum. An additional detector will be an area of approximately 5 cm^2 containing samples of enstatite, albite, and hornblende minerals that have high probability of being found on the Moon. Two types of plastic detectors will be used to detect the lowest energy particles. The basic plastic detectors will consist of a 25-micron top layer of aluminized lexon plastic followed by two 250-micron layers of cellulose acetate. The second plastic detector will consist of a 2-micron top layer of aluminized makrofol followed by a 250-micron layer of cellulose acetate.	
Radiometer	To measure heat rates resulting from ascent engine exhaust.	Not available.	
Water Detector	To detect the presence of water in samples of lunar material and, if water is present, to determine whether it exists in the free or absorbed state or as water of hydration.	The water detector is based on the phenomenon of nuclear magnetic resonance absorption of radio frequency energy that is exhibited by many nuclei. When placed in a static magnetic field of known strength and simultaneously exposed to an oscillating electromagnetic field, such nuclei will absorb energy at characteristic frequencies proportional to the magnetic field strength. In particular, the hydrogen nuclei (protons) in water will absorb energy at a frequency of $4.257 \times 10^{-3}H$ mHz, where H is the field strength in gauss. The quantity and state of water in a sample can be determined simply by observing the proton absorption signal. (Continued)	The water content of lunar samples can be measured with this technique when it is 0.05 percent or greater.

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Water Detector (Continued)		The intensity of the signal is a measure of the quantity. The width and shape of the absorption line indicate whether the protons are present in water or in organic molecules and, if in water, the state in which the water is present.	
Cone Penetrometer	To probe the top one-half to one meter of the lunar surface for the following purposes: a. Determine the stratigraphy, or vertical variation of resistance to penetration b. Determine the presence and extent of a rock layer or rock fragments c. Determine the spacial variation of penetration resistance, rock layers and rock fragments d. Provide engineering data on the mechanical behavior of the lunar soil e. Provide correlation data to aid in the interpretation of the deposition of the lunar surface	The proposed cone penetrometer resembles a spear, the shaft of which is about 2.2 meters long by a maximum of 4 cm in diameter. On the impinging end is a 30-degree cone and a surface reference ring slides on the shaft. A magnetic tape recorder and electronics are mounted at the top of the shaft. The cone penetrometer will be manually forced into the lunar surface as far as possible at a rate of approximately 2 to 3 cm per second. The longitudinal force on the cone and the longitudinal displacement of the cone below the lunar surface will be measured as a function of time. The measured data are recorded on magnetic tape for subsequent removal and return to Earth. Each test takes about 30 seconds and is repeated about 10 times.	Longitudinal forces: 0 to 30 ± 0.1 lb Longitudinal displacement: 0 to 36 ± 1 inch Temperature, electronics and tape recorder: 40 to 100 ± 0.1 deg C
Hasselblad Camera	General still photography on the lunar surface.	The lunar surface Hasselblad will be a modified version of the commercial model. A ring sight will be substituted for the reflex viewing system, flash synchronization will be eliminated, and the leatherette covering will be removed for compatibility with the oxygen environment of the LM. The camera body and lens mounts will be anodized black. Lenses of 80 mm (normal) and 60 mm (wide angle) will be provided for lunar surface use. Interchangeable film magazines of 30- or 80-exposure capacity will be available.	Normal 80 mm lens Shutter speeds: 1 to 1/500 second Aperture: f/2.8 to f/22 Focusing range: 3 feet to infinity Field: 37.5 by 37.5 degrees

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Stereo Camera	To obtain imagery for photogrammatic, photometric, polarimetric, and colorimetric analyses of the lunar surface in support of geological exploration. The stereo camera will take high resolution, dimensionally stable, stereoscopic and survey photographs of lunar surface features in the near field (intermediate between the resolution of orbital photographs and the dimensions that can be obtained from returned samples).	The stereo camera is an essential element of the lunar surveying system that can be operated on the survey staff or as a hand-held instrument. It is a combined stereo and telephoto camera that will make simultaneous stereo pairs and a telephoto image on a single 35 mm film. A data annotation feature is provided for recording the following data on the film for each exposure: number, focus setting, filter position, lens aperture, camera orientation in pitch and roll, and time. When the camera is used on the lunar survey staff, the shutter operates synchronously with the PCM pulse. Film transport is motor driven, the power being provided by a self-contained battery.	Stereo / Telephoto Focal length: 25-40 mm / 100-140 mm Aperture range: f/4 to f/22 / f/4 to f/22 Format: 24 x 36 mm / 24 x 24 mm Exposure time: 8 milliseconds Focusing range: 1.5 meters to infinity Filters: Right stereo lens: Polarization / None Left stereo lens: Color separation Film magazine capacity: 100 exposures (minimum)
Closeup Camera	To obtain photographs of small scale features (between micro and macro) on the lunar surface in their natural structure and environment. The closeup camera will be especially configured to photograph details such as cracks or holes in rocks and other similar features of interest.	The closeup camera is a special hand-held, fixed-focus camera for making closeup stereo pictures. A hood mounted on the front of the camera extends forward to the object plane. Correct focus and field-of-view are obtained by holding the front edge of the hood against the object to be photographed. A stick extends upward from the camera with the camera controls grouped at the upper end, making it unnecessary for the astronaut to stoop or bend forward to operate the camera. The hood contains an electronic flash unit with self-contained battery.	Aperture: Fixed, between f/20 and f/40 Stereo convergence angle: Between 10 and 15 degrees Format: 35 x 35 mm Magazine capacity: 100 - 200 stereo pairs
Television Camera	Real time television coverage of lunar exploration.	Not available.	
Lunar Survey Staff	To provide data for mapping the immediate vicinity of the landing site and to provide communications between the roving astronaut and the lunar module during exploratory sorties.	The basic equipment items of the lunar survey system are the portable lunar survey staff and the laser tracker located at the lunar module. The staff has brackets for mounting a stereometric camera and a TV camera, a laser reflector, an FM communications system, orientation transducers, and self-contained batteries. (Continued)	Range: 700 yards Staff location accuracy Azimuth: ±21 minutes Elevation: ±21 minutes Range: ±0.5 meter Staff orientation accuracy Bearing: ±0.5 degree Tip: ±0.1 degree Tilt: ±0.1 degree

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Lunar Survey Staff (Continued)		Stereometric photographs taken from the staff, staff orientation data, and staff location relative to the LM constitute the data required to map the landing area. TV observations and voice communications provide documentation of the exploratory activities and findings.	
Apollo Lunar Hand Tools	To perform lunar surface observations and to collect samples of lunar material.	The tools and their purposes are: • Aseptic sampler - for collecting uncontaminated samples from a few inches beneath the surface • Extension handle - for use with several other tools to permit their use without requiring astronaut to kneel or bend down. The cap may be used as an anvil. • Core tubes - for collecting and storing unmixed samples of relatively soft material • Scoop - for use as a trowel or chisel • Sampling hammer - sampling, driving core tubes or scoop • Tongs - for retrieving small samples without stooping • Brush/scriber/hand lens - sampling • Spring scale • Surveying instrument - rangefinder, azimuth indicator, inclinometer • Instrument staff - for support of surveying instrument and cameras • Gnomon - vertical indicator • Color chart - photography calibration • Tool carrier • Field sample bags - for individual samples • Collection bag - for stowing and carrying field sample bags	

EXPERIMENT/EQUIPMENT	PURPOSE	DESCRIPTION	PERFORMANCE
Upgraded Hand Tools	To perform lunar surface observations and to collect samples of lunar material.	Not available.	
Drill (3-Meter)	To bore holes in the lunar surface for heat flow experiment probes and to collect core samples of lunar material to a depth of three meters.	The three-meter drill is a hand-held, battery powered, rotary percussion drill consisting of battery pack, power head, drill string, and accessories. The drill string consists of a tungsten-carbide core bit and eight extension tubes. Core samples are collected in the extension tubes, which can be individually capped and used as sample containers after drilling is completed. The accessories include hole casings for use in soft materials. Nominal hole diameter is one inch.	
Sample Return Container	To contain and protect samples of lunar material during return to Earth and delivery to the Lunar Receiving Laboratory, Manned Spacecraft Center.	The sample return container is a polished aluminum box approximately 19 x 11-1/2 x 8 inches in size. It has a hinged lid that can be vacuum sealed during translunar and transearth flight and delivery to the Lunar Receiving Laboratory. Six eutectics, having different melting points, are provided in the lid as temperature indicators and an electrical connector is provided on the front of the container for pressure readout equipment. The internal configuration may include packing materials and sampling tools consistent with the kinds of samples to be collected (contingency, core, aseptic, etc.).	

APPENDIX C

ALTERNATE NON-LUNAR LANDING MISSION DESCRIPTION (TYPE I)

If the potential scientific return from a non-landing lunar mission becomes sufficient to balance or to outweigh that from a landing mission, or if a contingency situation arises with the LM, an I-type mission may be flown.

Such a mission could be an alternate for any of the missions subsequent to J1. It would be a lunar orbit only flight for the purpose of mapping a significant area of the lunar surface or future landing sites and exploring it with remote sensors. The area over-flown would include as much as 200 degrees of longitude between 45 degrees south and 45 degrees north latitude. A hybrid translunar trajectory would be flown and the CSM would be inserted into a lunar orbit of high inclination, possibly using multiple-impulse techniques. Lunar orbit mapping and scientific activities would be conducted for not more than eight days, after which multiple-impulse techniques may again be used to inject the spacecraft into a trans-earth trajectory.

Primary objectives of an I-type mission would include:

- Perform a lunar orbital science survey in an orbit of high inclination
- Obtain metric and panoramic photographs for lunar mapping of candidate lunar exploration sites

The following table describes the more significant mission operations changes that would be required for a non-landing mission.

Spacecraft Operations - Non-Landing Mission

OPERATIONAL CHANGE FROM G MISSION	REMARKS/COMMENTS
PRELAUNCH THROUGH TLI	
Launch window will be defined by the requirements of the scientific activities to be performed.	
Crew training will be required for execution of experiments.	
	The free return trajectory (with multiple-impulse LOI) or hybrid trajectory option may be used to insert the spacecraft into a highly inclined orbit. Since the DPS abort capability does not exist on this mission, the free return option is used.
LUNAR ORBIT INSERTION	
Payload and launch window requirements may necessitate a multiple-impulse lunar orbit insertion sequence. The multiple-impulse sequence consists of an initial maneuver which inserts the spacecraft into a highly elliptical lunar orbit, apocynthion from 2,000 to 10,000 n mi and period up to 24 hours. At or near apocynthion a plane maneuver is executed. The third maneuver inserts the spacecraft into a 60 n mi circular lunar orbit.	The purpose of this mission is, at the maximum, to allow surveillance of the lunar surface from Littrow on the east to the Marius Hills on the west and between the maximum latitudes attainable. MPAD analysis indicates orbital inclinations up to 88 degrees are attainable.
LUNAR ORBIT SCIENCE	
The time available for lunar orbital experiments is 6 to 7 days. Mission conduct during this phase will be as indicated in paragraph 4.4, page 4-37.	The current SIM thermal design will not allow orbital inclinations in excess of ±45 degrees without changes and/or maneuvers and operational duty cycles for the instruments, i.e., surveillance of the terminator from highly inclined orbits is not possible.

OPERATIONAL CHANGE FROM G MISSION	REMARKS/COMMENTS
TRANSEARTH INJECTION	
Excess performance requirements and a near-earth equatorial return inclination (i.e. 40 degrees) may require a multiple impulse TEI. The first impulse inserts the spacecraft into a highly elliptical lunar orbit. At apocynthion, a plane change/pericynthion increase maneuver will be executed. The third maneuver will insert the spacecraft into a transearth trajectory.	
TRANSEARTH COAST	
EVA to recover scientific instruments may be accomplished during the transearth coast phase or during lunar orbit coast phase. Experiment activity may also be required during the transearth coast phase.	EVA for film retrieval must not be conducted in the presence of solar flare flux.
RECOVERY THROUGH MISSION COMPLETION	
Recovery operations will not require quarantine procedures.	Similar to Mission types C prime and F. (Apollo 8 and 10)

APPENDIX D

CONSUMABLES REVIEW AND MISSION TIMELINE SUMMARY

The purpose of this appendix is to present a current summary of the types of consumables data that were used in the development of the plans for the missions described in this document. The basic mission timelines that were used are also included. The prime source for these data is the Consumables Analysis Section of the Mission Planning and Analysis Division (References 27 and 28).

Table D-1 summarizes the consumables plan for mission type H1 and is considered to be representative of the subsequent H type missions. The expected consumables situation for the J type missions is shown in Table D-2. Table D-3 shows the summary of mission type timelines in terms of major mission events.

TABLE D-1. MISSION H-1 CONSUMABLES SUMMARY

CONSUMABLE	UNIT	CAPACITY OR LOADING	AVAILABLE FOR CONSUMPTION	NOMINAL MISSION REQUIREMENTS	DISPERSIONS AND BIASES	MARGIN	MARGIN AS A PERCENTAGE OF CAPACITY
RCS	LB						
CM		245.0	208.6	42.3	0	166.3	80
SM		1,344.4	1,222.0	641.0	0	581.0	48
LM		633.0	535.9	300.4	0	235.5	44
PROPELLANTS	LB						
SPS		40,796.0	40,194.0	38,027.6	1,946.7	219.7	0.3
DPS		18,429.2	18,436.7	16,734.7	810.6	591.4	3
APS		5,231.7	5,170.1	4,862.7	160.8	146.6	3
ELECTRICAL POWER	AMP HOURS						
CSM		120.0	120.0	104.0	5.0	11.0	9
LM DESCENT STAGE		1,600.0	1,600.0	1,039.0	107.3	453.7	28
LM ASCENT STAGE		592.0	592.0	220.0	12.1	359.9	61
OXYGEN	LB						
CSM		660.2	629.7	420.3	37.0	122.4	19
LM DESCENT STAGE		48.0	45.7	36.0	2.5	9.4	21
HYDROGEN	LB						
CSM		58.6	54.8	48.6	1.7	4.5	8
WATER	LB						
LM DESCENT STAGE		250.0	235.3	156.2	48.3	30.8	13
LM ASCENT STAGE		85.0	80.8	36.8	18.4	29.8	37

TABLE D-2. MISSIONS J1-J5 CONSUMABLES SUMMARY

CONSUMABLE	UNIT	CAPACITY OR LOADING	AVAILABLE FOR CONSUMPTION	NOMINAL MISSION REQUIREMENT	DISPERSIONS AND BIASES	MARGIN	MARGIN AS A PERCENTAGE OF CAPACITY
RCS	LB						
CM		245.0	208.6	39.3	0	169.3	81
SM		1,342.4	1,220.0	923.0	0	297.0	24
LM		633.0	535.9	295.6	0	240.3	45
PROPELLANTS	LB						
SPS		40,796.0	40,194.0	TBD	TBD	TBD	TBD
DPS		19,510.0	19,042.0	TBD	TBD	TBD	TBD
APS		5,230.0	5,170.0	TBD	TBD	TBD	TBD
ELECTRICAL POWER	AMP HOURS						
CSM		120.0	120.0	TBD	TBD	TBD	TBD
LM DESCENT STAGE		2,000.0	2,000.0	1,786.0	88.0	126.0	6
LM ASCENT STAGE		592.0	592.0	254.9	18.3	318.8	54
OXYGEN	LB						
CSM		990.3	944.6	716.9	43.0	184.7	19
LM DESCENT STAGE		96.0	91.3	39.8	2.0	49.5	52
HYDROGEN	LB						
CSM		87.9	82.1	73.0	3.0	5.3	6
WATER	LB						
LM DESCENT STAGE		666.0	633.4	342.4	58.6	232.4	35
LM ASCENT STAGE		85.0	80.8	35.5	5.8	39.5	46

TABLE D-3. MISSION TIMELINE SUMMARY

	G MISSION (ACTUAL-HOURS)	H-1 MISSION (NOMINAL-HOURS)	J MISSION (TYPICAL-HOURS)
EARTH LIFTOFF TO LOI1	76	83	110
LOI1 TO LANDING	27	27	34
LANDING TO LIFTOFF	22	32	54
LANDING TO LOPC1 (1)	(5)	(10)	(10)
LIFTOFF TO LOPC2 (2)	N/A	17	17
LOPC2 TO TEI	N/A	13	69
MAXIMUM PHOTOGRAPHIC AND SCIENCE TIME (3)	N/A	(9)	(61) (4)
TEI PREPARATIONS	10	(4)	(8)
TEI TO SPLASHDOWN	60	72	100
MISSION DURATION	195	244	384

(1) LOPC1 - CSM PLANE CHANGE PRIOR TO LM LIFTOFF.

(2) LOPC2 - CSM PLANE CHANGE TO OBTAIN DESIRED PHOTOGRAPHIC AND SCIENTIFIC COVERAGE.

(3) DOES NOT INCLUDE PHOTOGRAPHY FROM CM DURING LM LUNAR SURFACE STAY.

(4) INCLUDES APPROXIMATELY 4 HOURS FOR SIM DATA RETRIEVAL EVA UNLESS PERFORMED TRANSEARTH.

APPENDIX E

SURFACE COVERAGE FROM LUNAR ORBIT

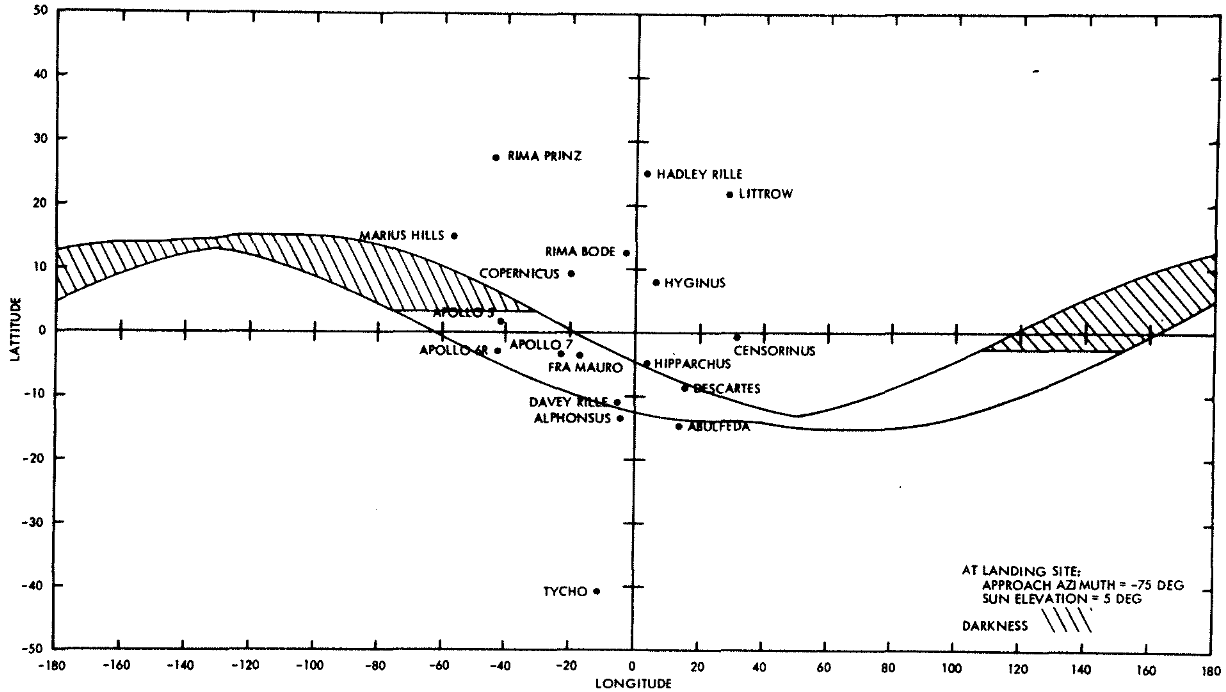
Spacecraft orbital tracks over the lunar surface must be considered in mission planning because of the requirements to perform photography of subsequent landing sites and to plan the orbital science program. The extent of nominal mission coverage is determined by the landing site location, the launch date dependent trajectory characteristics, and the nominal mission timeline. After LM/CSM docking, subsequent coverage is limited by the SPS ΔV which can be provided for plane change if LM rescue maneuvers are not required and by the amount of remaining consumables.

Lunar surface coverage charts for the H and J missions are presented in Figures E-1 through E-9, pages E-3 through E-11. The chart labeled (a) in each figure shows the area covered during a nominal mission, and the chart labeled (b) shows the additional area which can be covered by performing a CSM plane change (LOPC2). The maneuver is executed no earlier than 17 hours after LM ascent and no later than 4 hours before TEI. The following assumptions were used in generaging these charts:

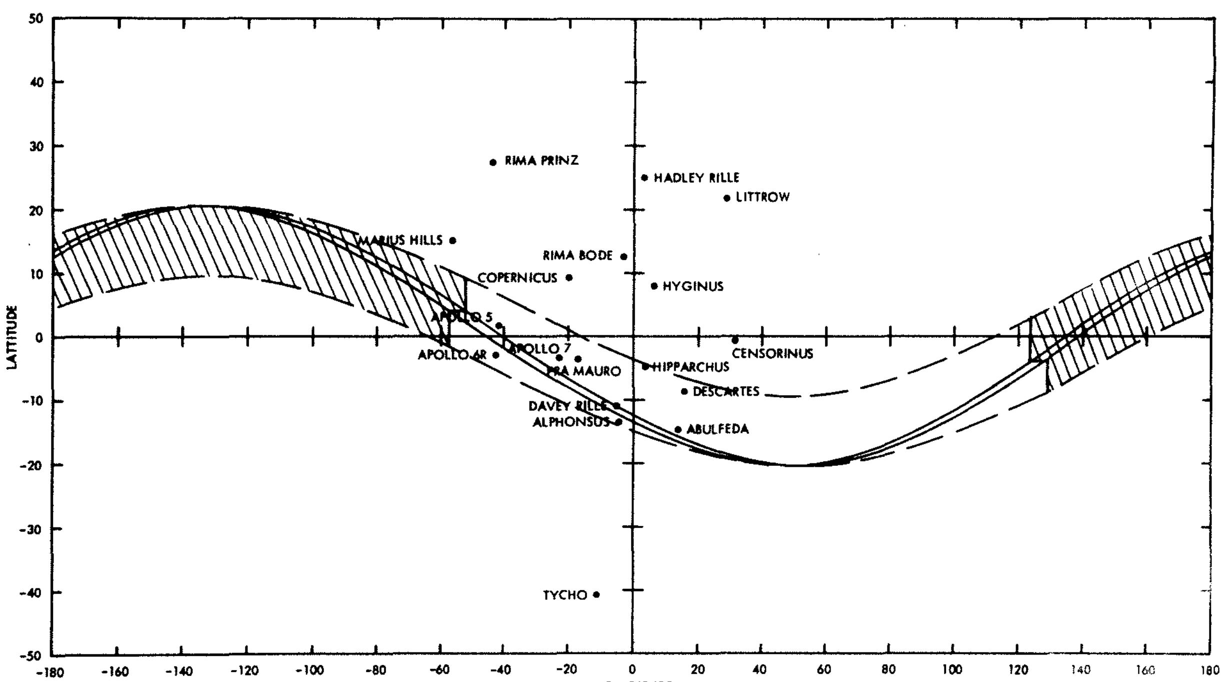
- The ΔV for LOPC2 is 500 feet per second. This maneuver can be performed at any point in the parking orbit and results in a plane change of about 5.5 degrees.
- TEI can be targeted to the originally planned flight time and inclination. Preliminary studies indicate that the maximum TEI ΔV penalty for high latitude landing sites is about 250 feet per second. It is usually less than 70 feet per second for equatorial sites.
- For plane changes of less than 5.5 degrees, the area covered, the ΔV required for plane change, and the maximum TEI ΔV penalty are all reduced proportionally.
- Time increments between major mission milestones are shown in Table D-3, page D-4 .

The locations of all candidate sites are shown in Figures E-1 through E-9. A site is covered during the nominal mission if it is within the area between the solid lines of an (a) chart. Additional coverage after LOPC2 is designated by the dashed lines of the (b) charts. Contained within this area are the targets of opportunity that can be selected for bootstrap photography and/or remote sensing. Not all of the area within the dashed lines can be covered, however, since this area represents all possible combinations of plane change position and magnitude. The solid lines on the (b) charts illustrate the combination of plane change position and magnitude which maximize the surface area covered during each mission. The purpose of the (b) charts are, therefore, to illustrate the targets of opportunity available with plane change after rendezvous and the area of maximum surface coverage on each mission.

The trajectory data used to generate the orbital coverage charts are preliminary and not approved for planning. These charts are therefore only reasonable approximations to the coverage that can be expected on each mission. Refined data will be developed by and should be obtained from MPAD, symbol FM5.

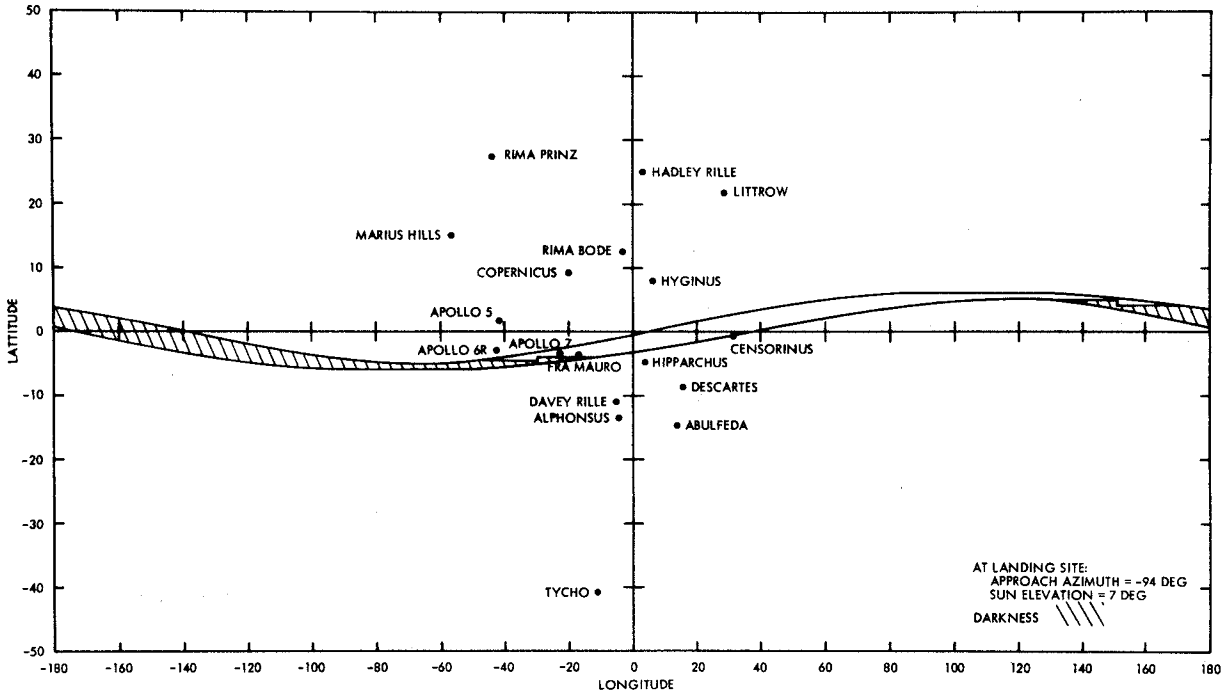


(a) Coverage During the Nominal Mission

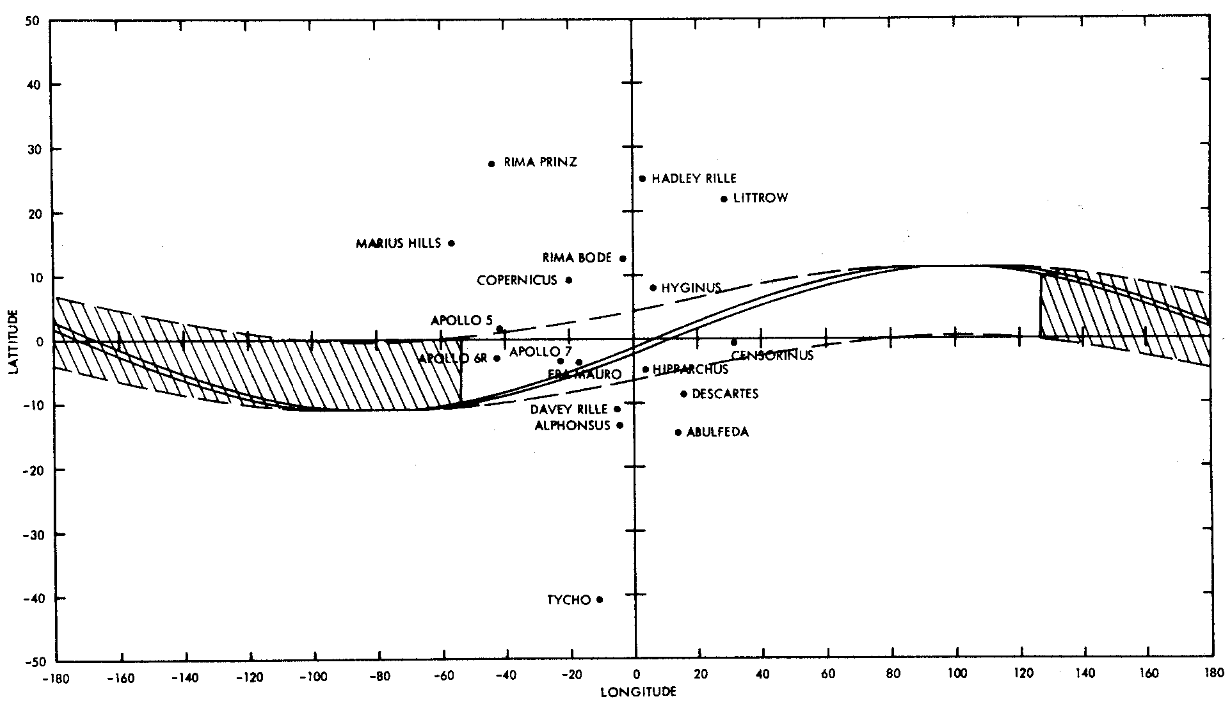


(b) Additional Coverage After LOPC2

Figure E-1 . Lunar Surface Coverage, Mission H1, Landing Site Apollo 7

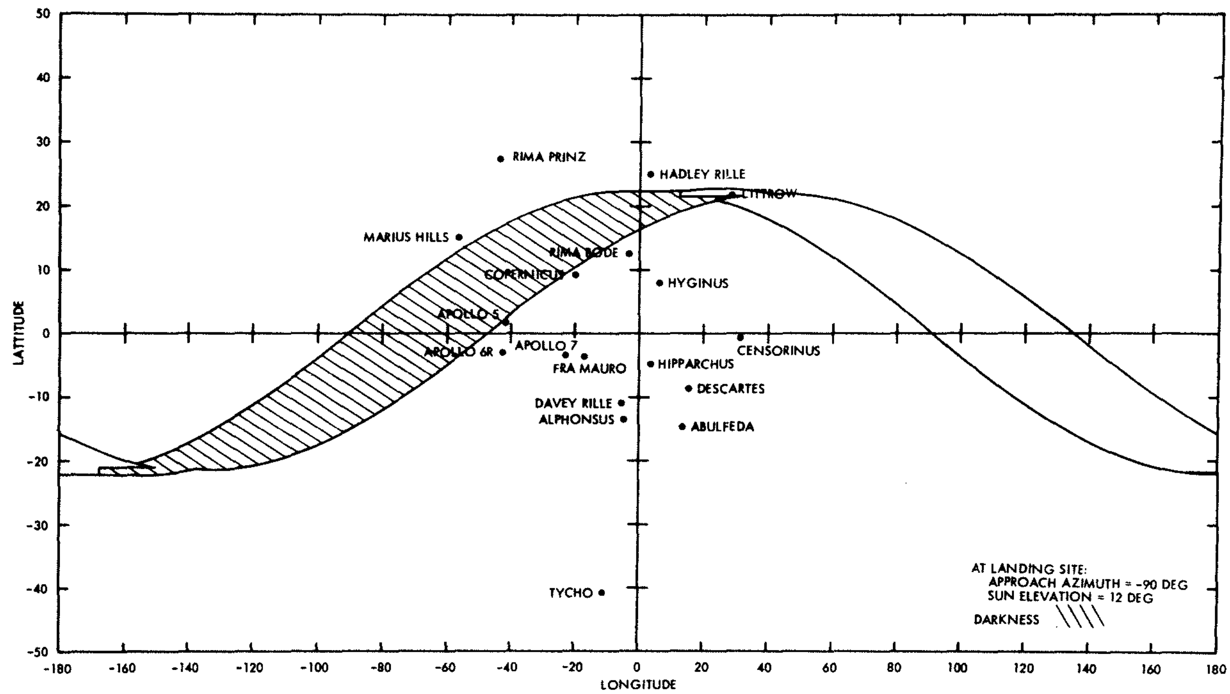


(a) Coverage During the Nominal Mission

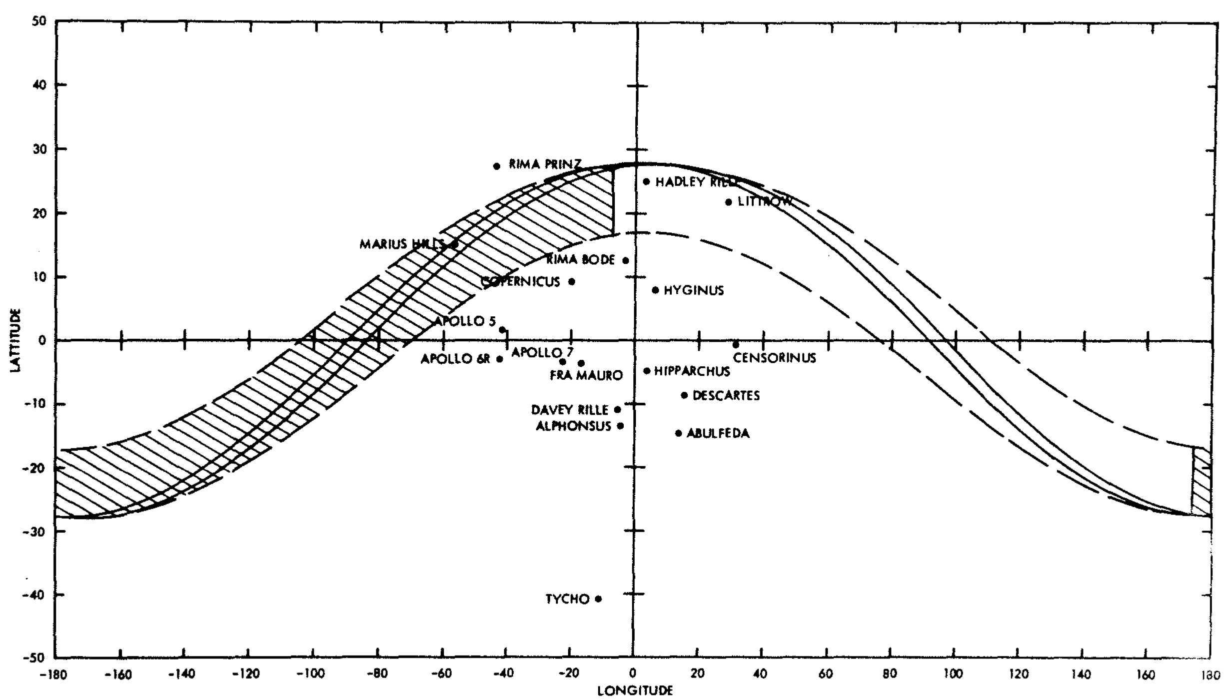


(b) Additional Coverage After LOPC2

Figure E-2. Lunar Surface Coverage, Mission H2, Landing Site Fra Mauro FM

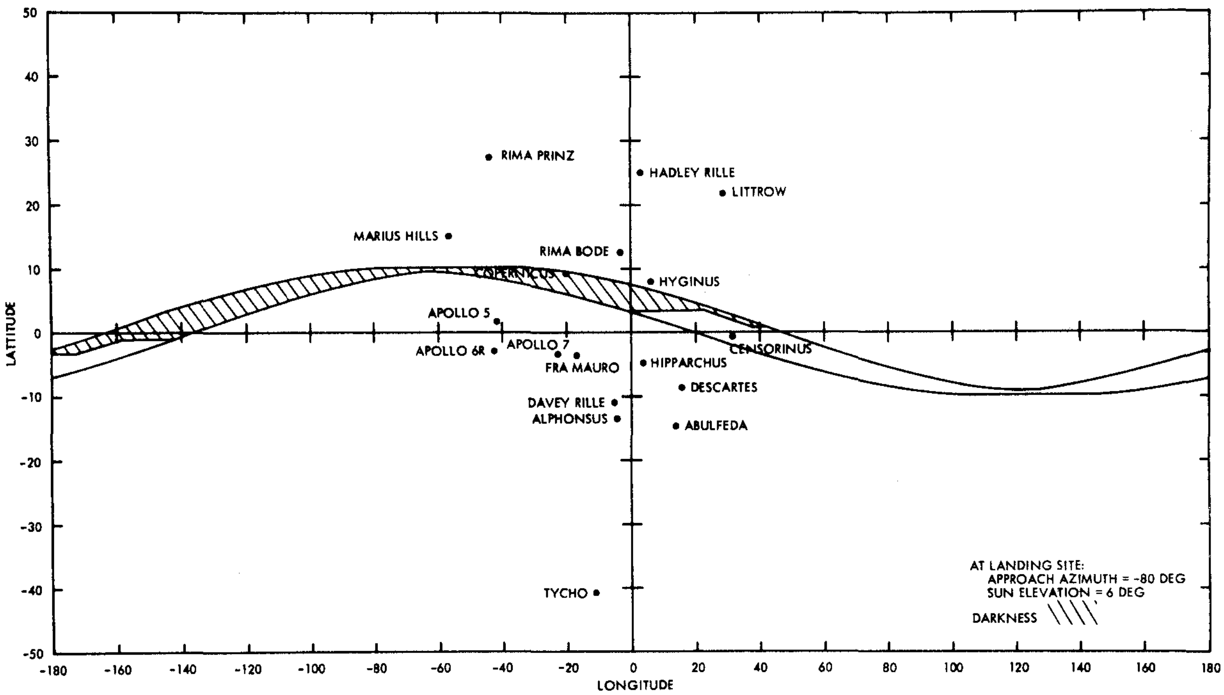


(a) Coverage During the Nominal Mission

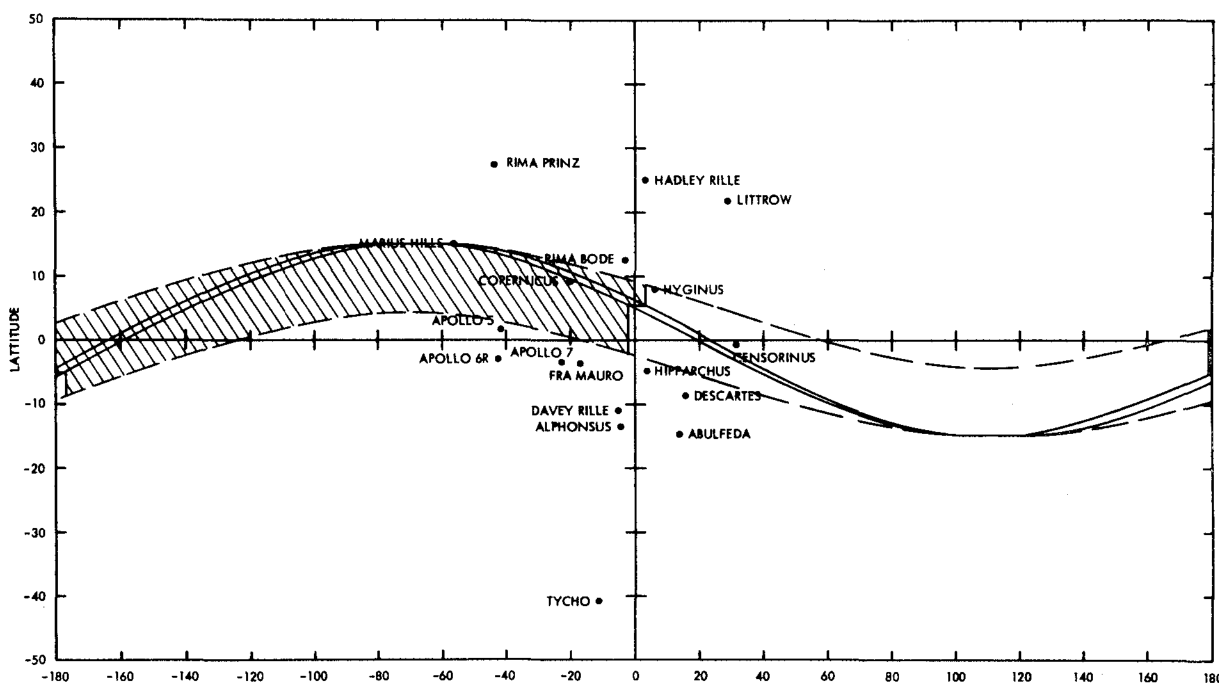


(b) Additional Coverage After LOPC2

Figure E-3. Lunar Surface Coverage, Mission H3
Landing Site Littrow

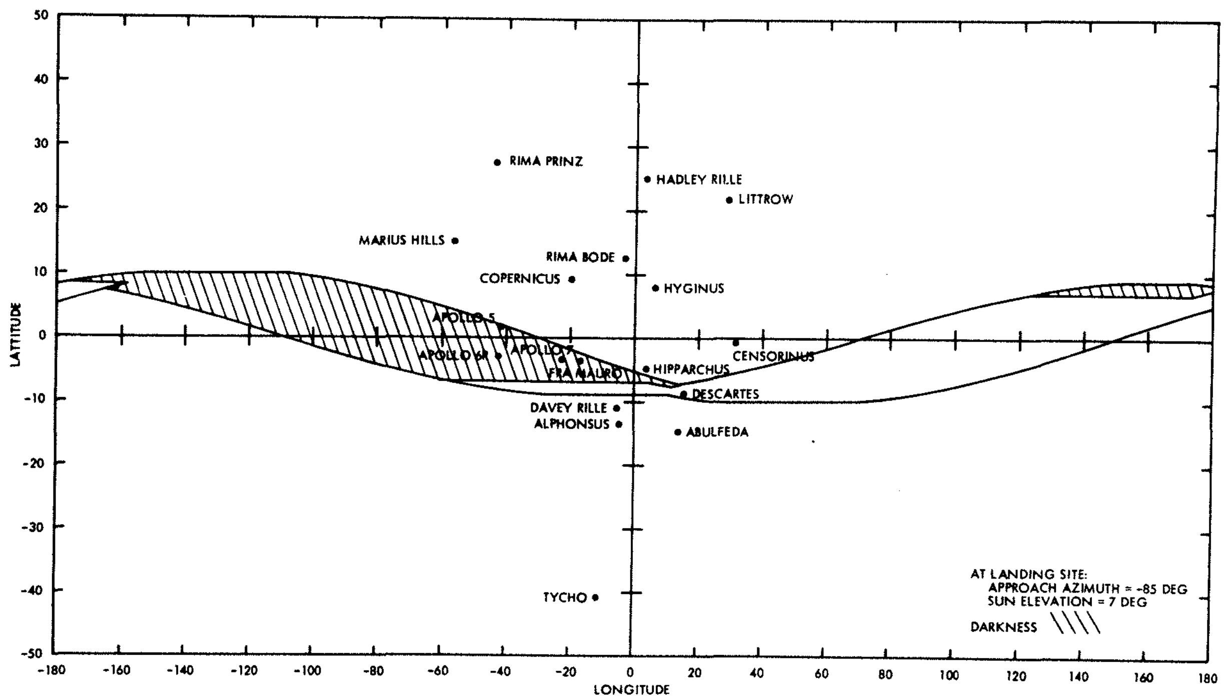


(a) Coverage During the Nominal Mission

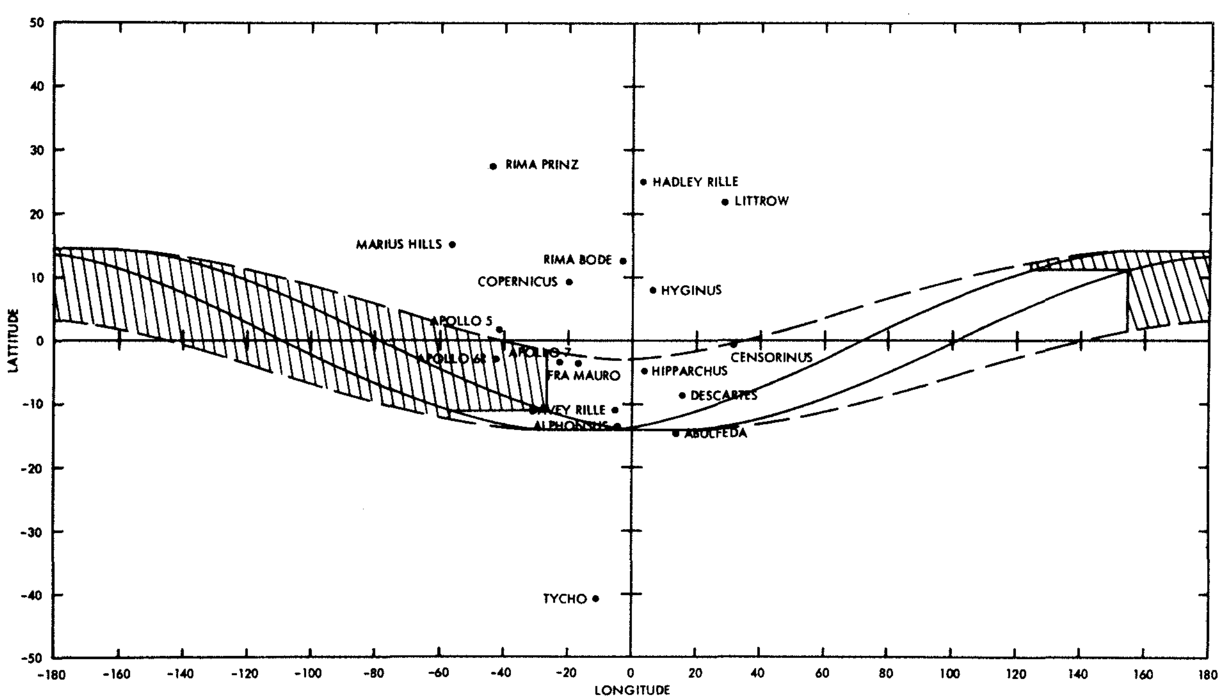


(b) Additional Coverage After LOPC2

Figure E-4. Lunar Surface Coverage, Mission H4
Landing Site Censorinus

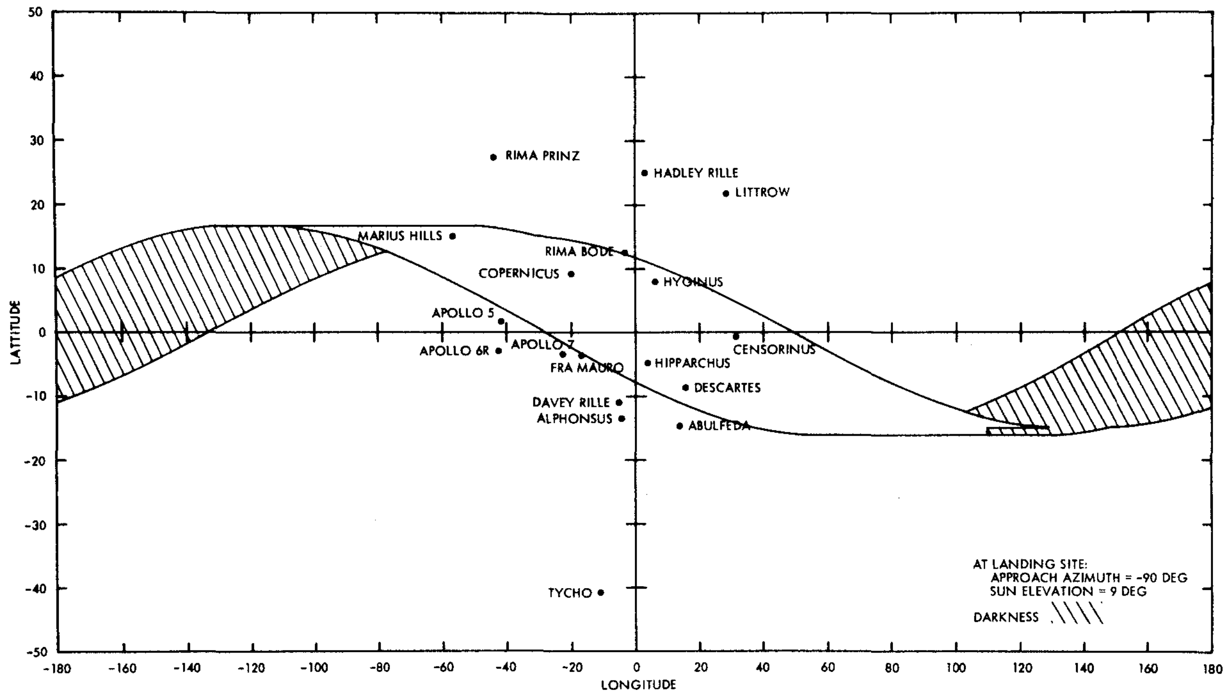


(a) Coverage During the Nominal Mission

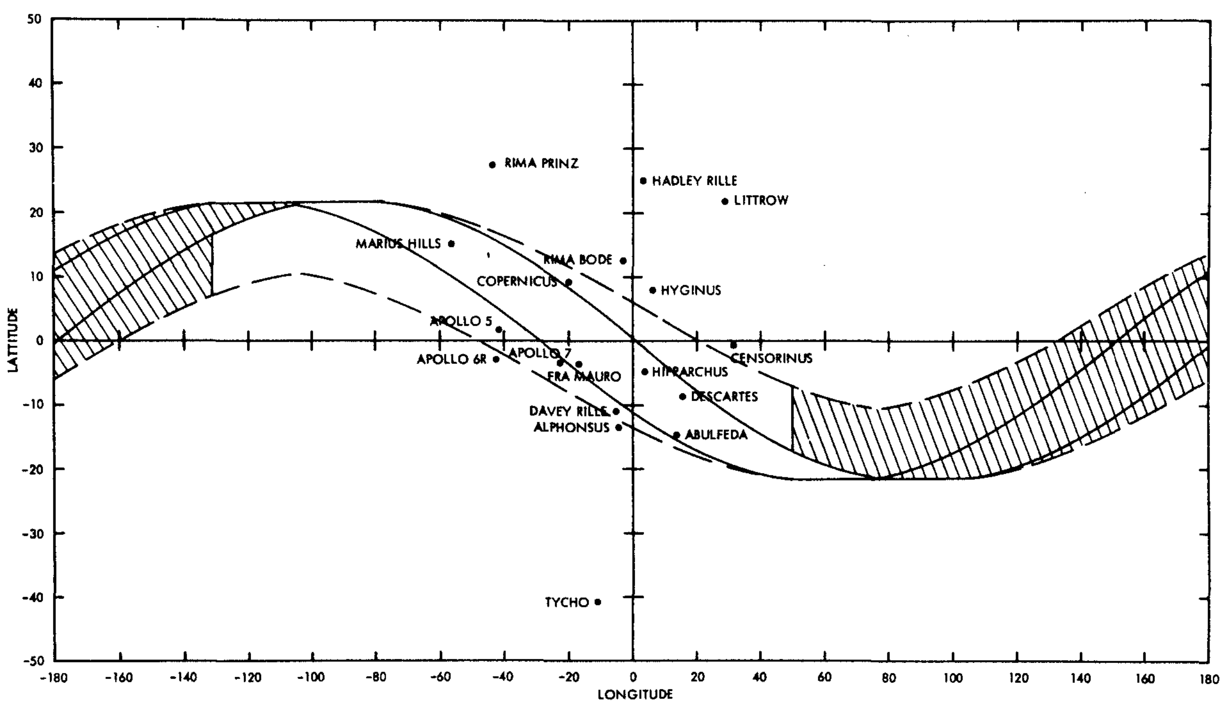


(b) Additional Coverage After LOPC2

Figure E-5. Lunar Surface Coverage, Mission J1
Landing Site Descartes

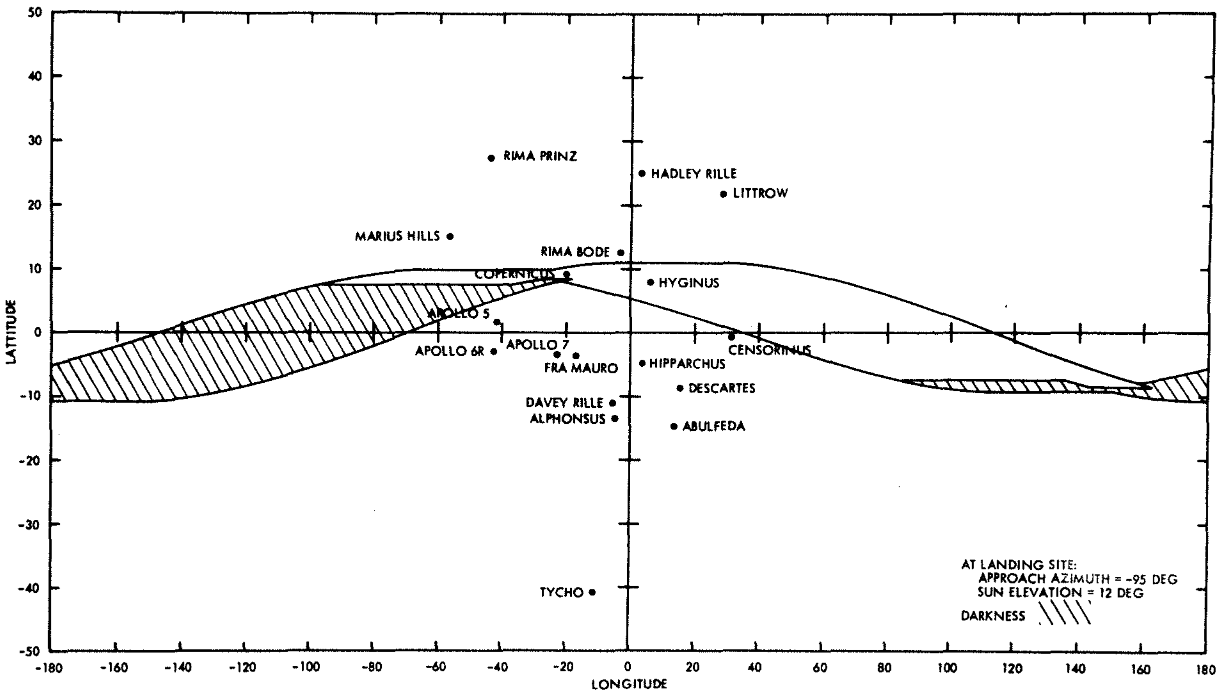


(a) Coverage During the Nominal Mission

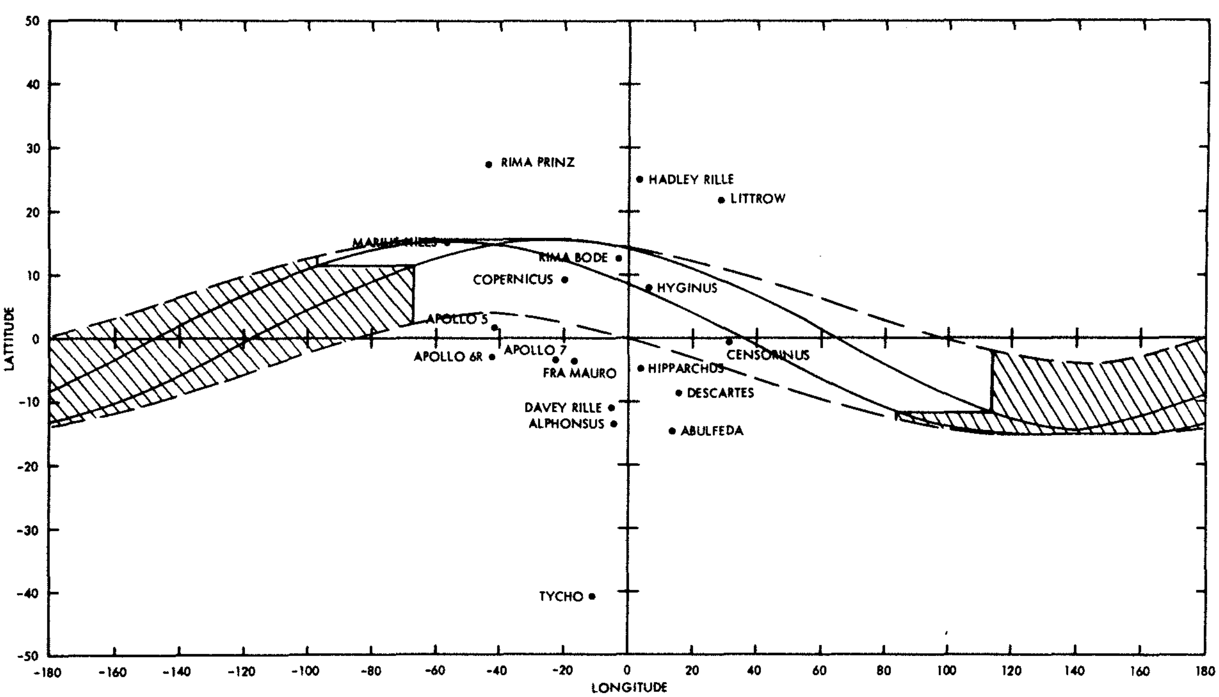


(b) Additional Coverage After LOPC2

Figure E-6. Lunar Surface Coverage, Mission J2
Landing Site Marius Hills

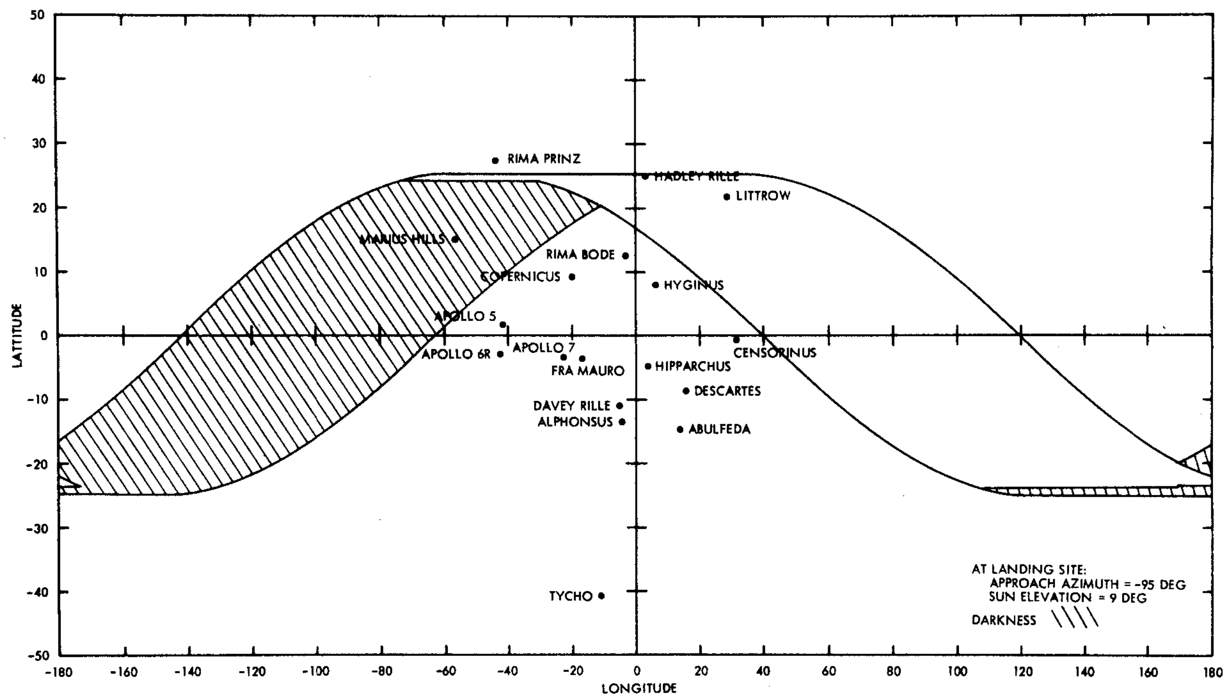


(a) Coverage During the Nominal Mission

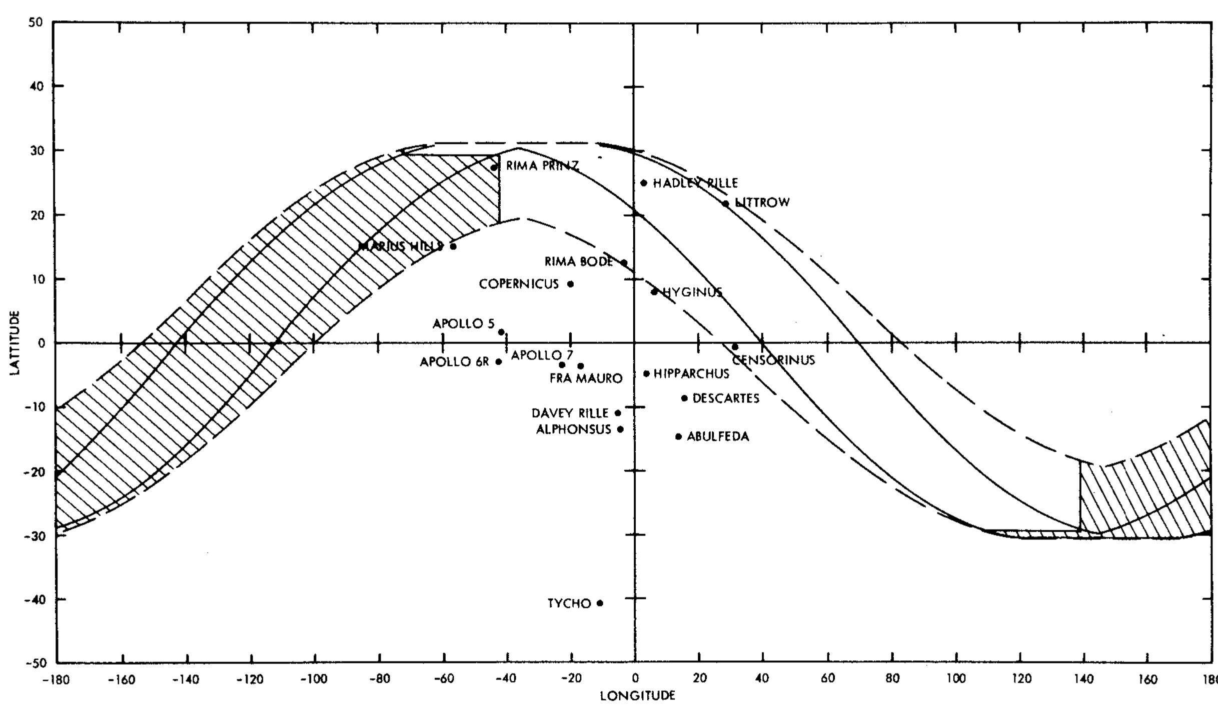


(b) Additional Coverage After LOPC2

Figure E-7. Lunar Surface Coverage, Mission J3 Landing Site Copernicus Peaks

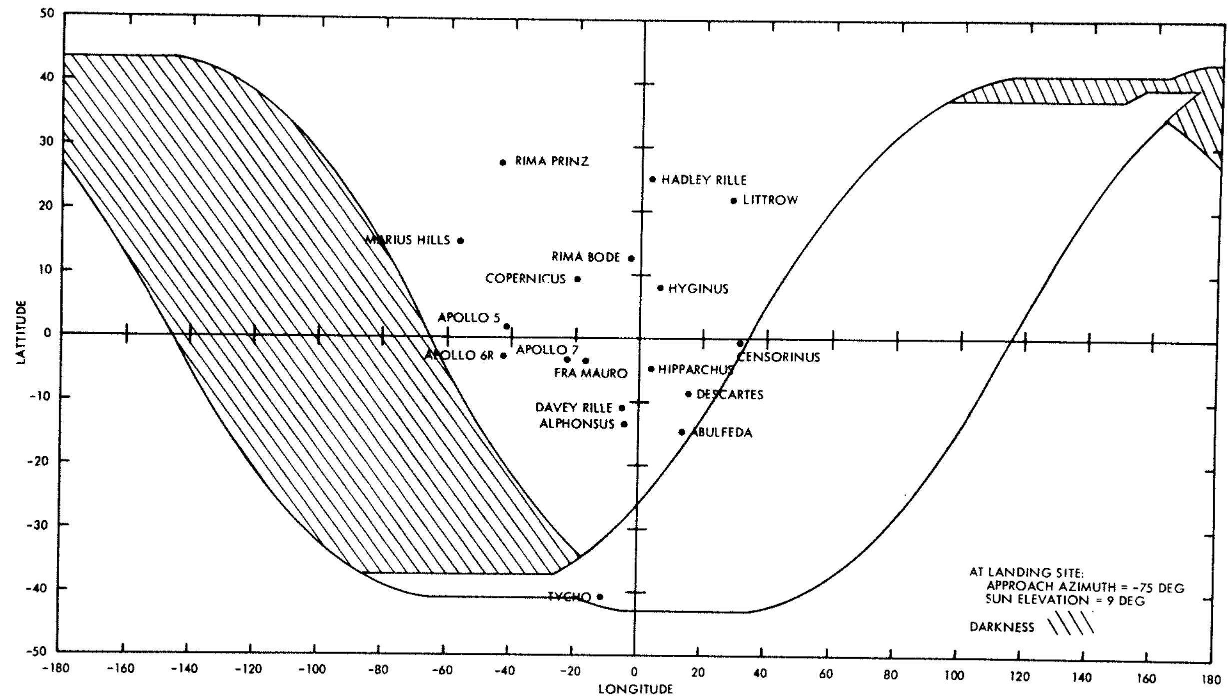


(a) Coverage During the Nominal Mission

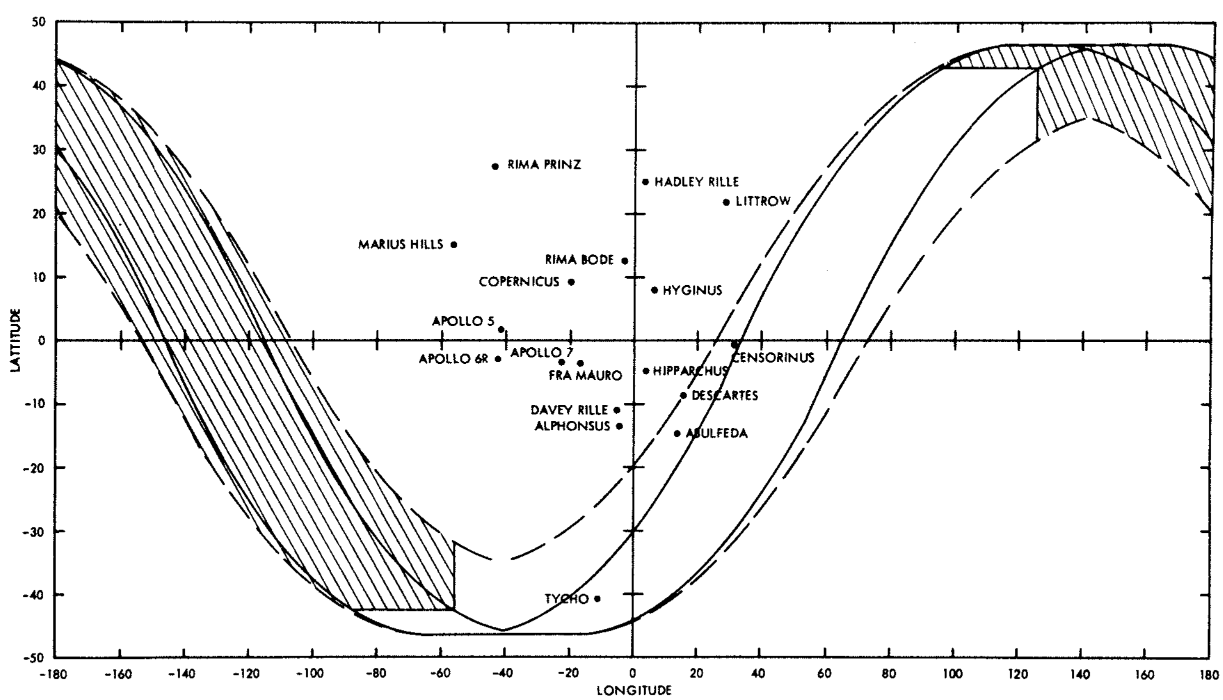


(b) Additional Coverage After LOPC2

Figure E-8. Lunar Surface Coverage, Mission J4
Landing Site Hadley Rille



(a) Coverage During the Nominal Mission



(b) Additional Coverage After LOPC2

Figure E-9. Lunar Surface Coverage, Mission J5
Landing Site Tycho

APPENDIX F

MSC ANNOUNCEMENTS

No.: 69-61

Date: May 6, 1969

File:

MANNED SPACECRAFT CENTER

ANNOUNCEMENT

DEFINITION OF MANAGEMENT RESPONSIBILITIES FOR THE APOLLO LUNAR EXPLORATION PROGRAM

The Advanced Missions Program Office has completed initial planning efforts for manned lunar missions after the first lunar landing. These missions generally fall into two categories : The first of these consists of several additional flights, utilizing Apollo spacecraft that are essentially unchanged. These flights will be used to perform a variety of lunar orbit and lunar surface experiments in what is generally known as the Apollo zone of the moon. Three or four such flights are planned; and they will be flown on 4- to 6-month launch intervals. The second category includes more advanced lunar missions. For these flights, additional flexibility may be provided in the Command and Service Modules and in the Lunar Modules to provide for landings in different areas on the lunar surface; to provide for larger payloads and/or longer lunar staytimes; and to provide for more sophisticated experiments to be performed, both from lunar orbit and on the lunar surface. Our immediate efforts on this second category of missions are limited to design definition studies and to detailed engineering work.

Responsibility for the first category of missions is hereby assigned to the Apollo Spacecraft Program Office. Responsibility for current activities on the second category of missions will remain with the Advanced Missions Program Office for the time being. However, as soon as the mission definition is complete and as soon as implementation decisions have been reached, responsibility for the later missions will also be transferred to the Apollo Spacecraft Program Office.

Robert R. Gilruth
Director

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No.: 69-138

Date: September 30, 1969

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MANNED SPACECRAFT CENTER

ANNOUNCEMENT

Assignment of Responsibility for Advanced Lunar Missions

MSC Announcement 69-61 assigned responsibility to the Apollo Spacecraft Program Office for manned lunar missions after the first lunar landing which utilize Apollo spacecraft that are essentially unchanged. These flights will perform lunar orbit and lunar surface experiments in what is generally known as the Apollo zone of the moon. The announcement indicated that the Advanced Missions Program Office would retain responsibility until mission definition and implementation decisions had been completed for a second, more advanced, category of lunar missions. These flights require additional flexibility for the Command and Service Modules and the Lunar Module to permit landings in different areas on the lunar surface, larger payloads and/or longer lunar staytimes, and more sophisticated experiments.

Mission definition for advanced lunar missions has now been completed, and responsibility for these missions is transferred to the Apollo Spacecraft Program Office.

Robert R. Gilruth
Director

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