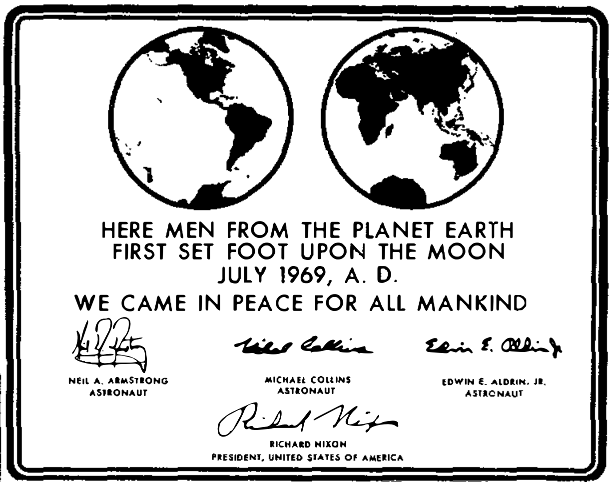
Report No. M-932-69-11

MISSION OPERATION REPORT

APOLLO 11 (AS-506) MISSION

OFFICE OF MANNED SPACE FLIGHT

Prepared by: Apollo Program Office - MAO



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Initial reports are prepared and issued for each flight project just prior to launch. Following launch, updating reports for each mission are issued to keep General Management currently informed of definitive mission results as provided in NASA Instruction 6-2-10.

Because of their sometimes highly technical orientation, distribution of these reports is provided to personnel having program-project management responsibilities. The Office of Public Affairs publishes a comprehensive series of prelaunch and postlaunch reports on NASA flight missions, which are available for general distribution.

APOLLO MISSION OPERATION REPORTS are published in two volumes: the MISSION OPERATION REPORT (MOR); and the MISSION OPERATION REPORT, APOLLO SUPPLEMENT. This format was designed to provide a mission-oriented document in the MOR, with supporting equipment and facility description in the MOR, APOLLO SUPPLEMENT. The MOR, APOLLO SUPPLEMENT is a program-oriented reference document with a broad technical description of the space vehicle and associated equipment; the launch complex; and mission control and support facilities.

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APOLLO 11 MISSION

The primary purpose of the Apollo 11 Mission is to perform a manned lunar landing and return. During the lunar stay, limited selenological inspection, photography, survey, evaluation, and sampling of the lunar soil will be performed. Data will be obtained to assess the capability and limitations of an astronaut and his equipment in the lunar environment. Figure 1 is a summary of the flight profile.

Apollo 11 will be launched from Pad A of Launch Complex 39 at Kennedy Space Center on 16 July 1969. The Saturn V Launch Vehicle and the Apollo Spacecraft will be the operational configurations. The Command Module (CM) equipment will include a color television camera with zoom lens, a 16mm Maurer camera with 5, 18, and 75mm lenses, and a Hasselblad camera with 80 and 250mm lenses. Lunar Module (LM) equipment will include a lunar television camera with wide angle and lunar day lenses, a 16mm Maurer camera with a 10mm lens, a Hasselblad camera with 80mm lens, a Lunar Surface Hasselblad camera with 60mm lens, and a close-up stereo camera. The nominal duration of the flight mission will be approximately 8 days 3 hours. Translunar flight time will be approximately 73 hours. Lunar touchdown is planned for Landing Site 2, located in the southwest corner of the moon's Sea of Tranquility. The LM crew will remain on the lunar surface for approximately 21.5 hours. During this period, the crew will accomplish postlanding and pre-ascent procedures and extravehicular activity (EVA).

The nominal EVA plan, as shown in Figure 2, will provide for an exploration period of open-ended duration up to 2 hours 40 minutes with maximum radius of operation limited to 300 feet. The planned lunar surface activities will include in the following order of priority: (1) photography through the LM window, (2) collection of a Contingency Sample, (3) assessment of astronaut capabilities and limitations, (4) LM inspection, (5) Bulk Sample collection, (6) experiment deployment, and (7) lunar field geology — including collection of a Documented Lunar Soil Sample. Priorities for activities associated with Documented Sample collection will be: (a) core sample, (b) bag samples with photography, (c) environmental sample, and (d) gas sample. Photographic records will be obtained and EVA will be televised. Assessment of astronaut capabilities and limitations during EVA will include quantitative measurements. There will be two rest and several eat periods. The total lunar stay time will be approximately 59.5 hours.

The transearth flight time will be approximately 60 hours. Earth landing will be in the Mid-Pacific recovery area with a target landing point located at 172°W longitude and 11°N latitude. Table 1 is a summary of mission events.

Following landing, the flotation collar will be attached to the CM, the CM hatch will be opened and the crew will don Biological Isolation Garments passed in to them by the recovery swimmer. The crew will then egress the CM, transfer to the recovery ship by helicopter, and will immediately enter the Mobile Quarantine Facility (MQF). They will be transported in the MQF to the Lunar Receiving Laboratory (LRL) at the Manned Spacecraft Center. The CM, Sample Return Containers, film, tapes, and astronaut logs will also be transported to the LRL under quarantine procedures.

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APOLLO 11 FLIGHT PROFILE

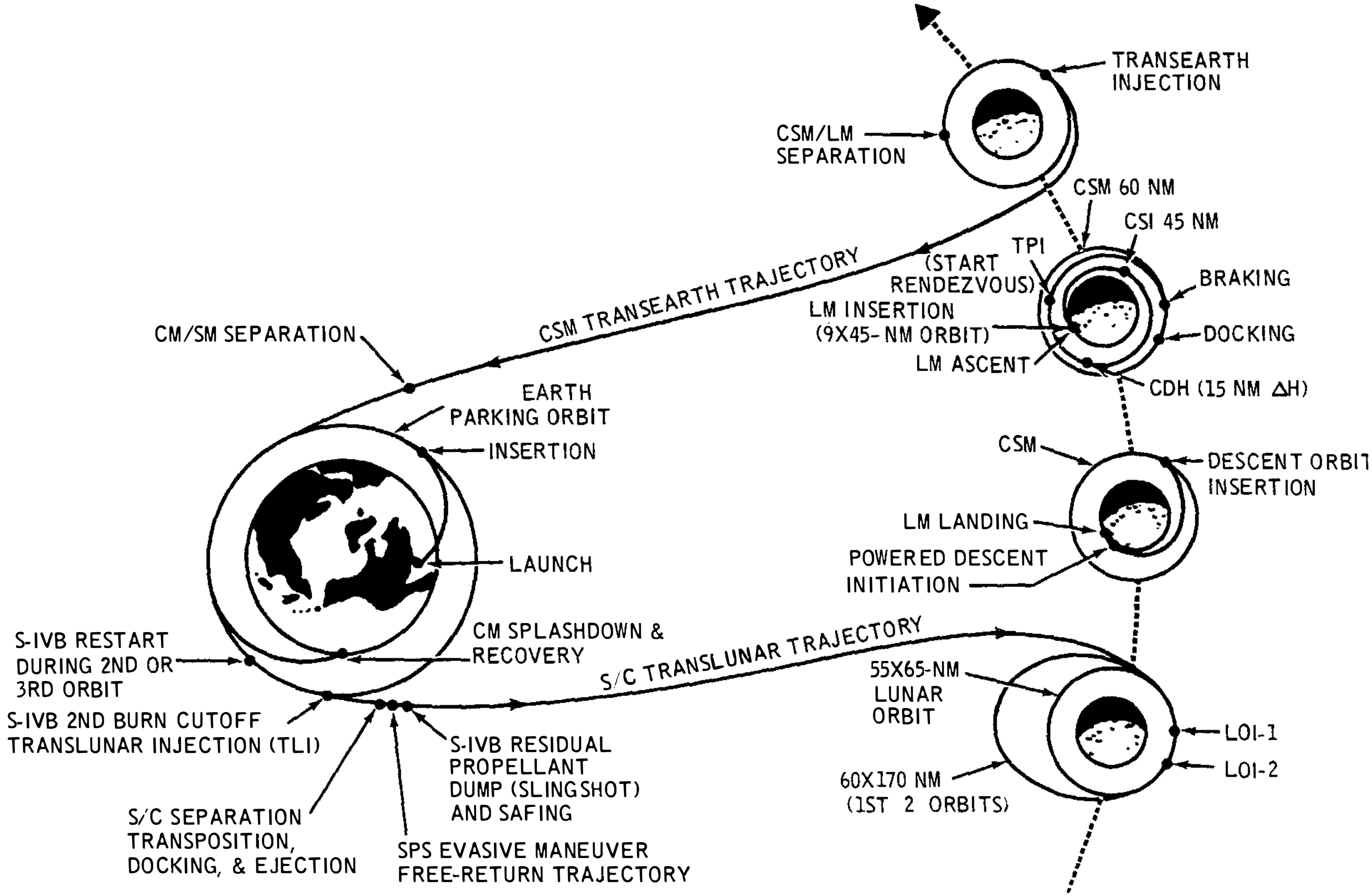

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Fig. 1

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SUMMARY TIMELINE

NOMINAL LUNAR SURFACE EVA

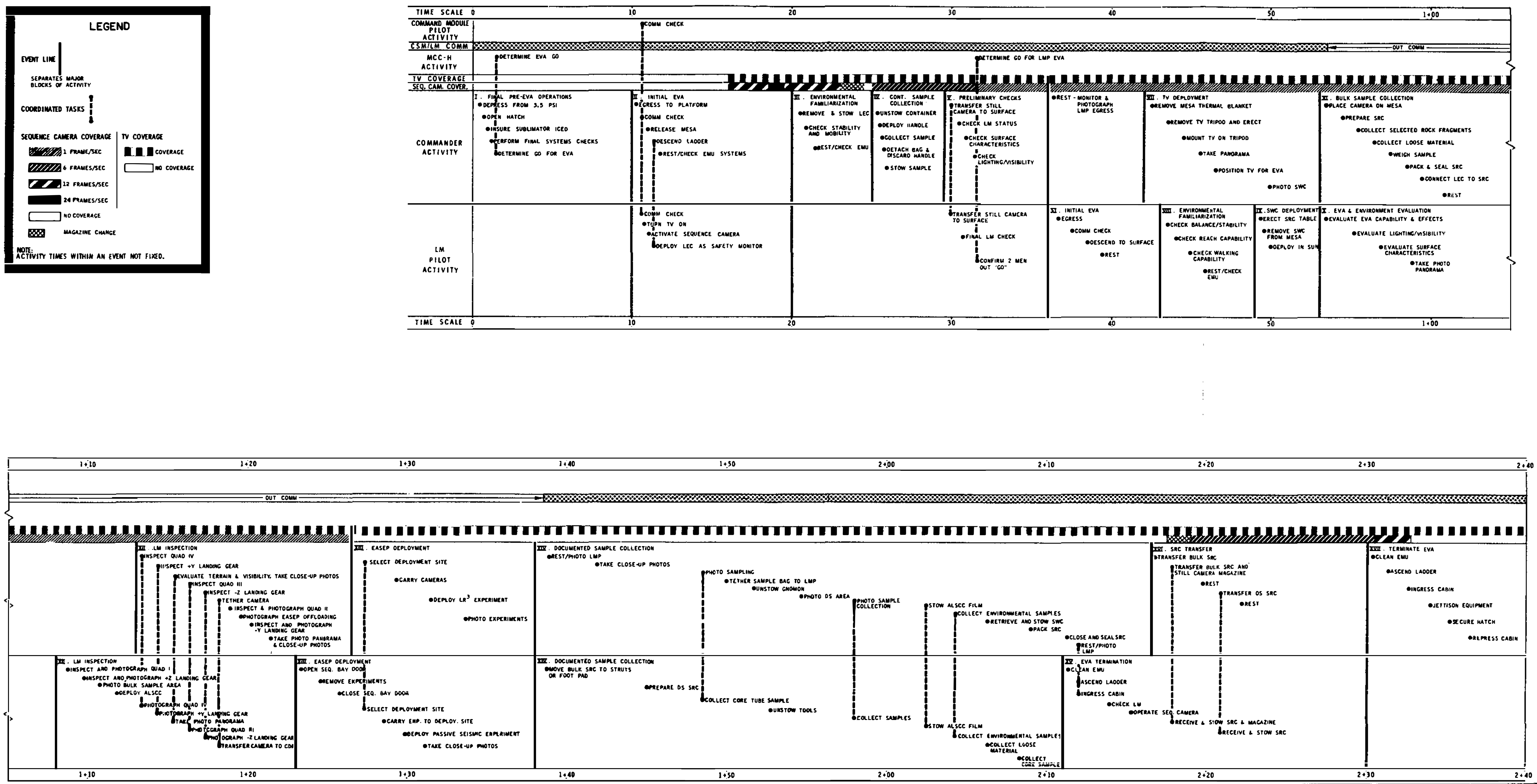


Fig. 2

TABLE 1

MISSION SUMMARY

16 JULY, 72° LAUNCH AZIMUTH, FIRST TRANSLUNAR INJECTION OPPORTUNITY

	DURATION (HR:MIN)	GET (DAYS:HR:MIN)	EDT (DAY:HR:MIN
LAUNCH		0:00:00	16:09:32
EARTH ORBIT COAST	2:32		
TRANSLUNAR INJECTION		0:02:44	16:12:16
TRANSLUNAR COAST	73:10		
LUNAR ORBIT INSERTION-1		3:03:54	19:13:26
LUNAR ORBIT INSERTION-2		3:08:09	19:17:41
DESCENT ORBIT INSERTION		4:05:39	20:15:11
LUNAR LANDING		4:06:47	20:16:19
LUNAR STAY	21:36		
EXTRAVEHICULAR ACTIVITY INITIATION		4:16:39	21:20:11
LUNAR EXTRAVEHICULAR ACTIVITY	2:40		
ASCENT		5:04:23	
DOCKING		5:08:00	21:17:32
LM JETTISON		5:11:53	21:21:25
TOTAL LUNAR ORBIT	59:30		
TRANSEARTH INJECTION		5:15:25	22:00:57
TRANSEARTH COAST	59:38		
EARTH LANDING		8:03:17	24:12:49

PROGRAM DEVELOPMENT

The first Saturn vehicle was successfully flown on 27 October 1961, initiating operations in the Saturn I Program. A total of 10 Saturn I vehicles (SA-1 to SA-10) was successfully flight tested to provide information on the integration of launch vehicle and spacecraft and to provide operational experience with large multiengined booster stages (S-I, S-IV).

The next generation of vehicles, developed under the Saturn IB Program, featured an uprated first stage (S-IB) and a more powerful new second stage (S-IVB). The first Saturn IB was launched on 26 February 1966. The first three Saturn IB missions (AS-201, AS-203, and AS-202) successfully tested the performance of the launch vehicle and spacecraft combination, separation of the stages, behavior of liquid hydrogen in a weightless environment, performance of the Command Module heat shield at low earth orbital entry conditions, and recovery operations.

The planned fourth Saturn IB mission (AS-204) scheduled for early 1967 was intended to be the first manned Apollo flight. This mission was not flown because of a spacecraft fire, during a manned prelaunch test, that took the lives of the prime flight crew and severely damaged the spacecraft. The SA-204 Launch Vehicle was later assigned to the Apollo 5 Mission.

The Apollo 4 Mission was successfully executed on 9 November 1967. This mission initiated the use of the Saturn V Launch Vehicle (SA-501) and required an orbital restart of the S-IVB third stage. The spacecraft for this mission consisted of an unmanned Command/Service Module (CSM) and a Lunar Module test article (LTA). The CSM Service Propulsion System (SPS) was exercised, including restart, and the Command Module Block II heat shield was subjected to the combination of high heat load, high heat rate, and aerodynamic loads representative of lunar return entry. All primary mission objectives were successfully accomplished.

The Apollo 5 Mission was successfully launched and completed on 22 January 1968. This was the fourth mission utilizing Saturn IB vehicles (SA-204). This flight provided for unmanned orbital testing of the Lunar Module (LM-1). The LM structure, staging, and proper operation of the Lunar Module Ascent Propulsion System (APS) and Descent Propulsion System (DPS), including restart, were verified. Satisfactory performance of the S-IVB/Instrument Unit (IU) in orbit was also demonstrated. All primary objectives were achieved.

The Apollo 6 Mission (second unmanned Saturn V) was successfully launched on 4 April 1968. Some flight anomalies were encountered, including oscillations reflecting propulsion-structural longitudinal coupling, an imperfection in the Spacecraft-LM Adapter (SLA) structural integrity, and malfunctions of the J-2 engines in the S-II and S-IVB stages. The spacecraft flew the planned trajectory, but preplanned high velocity reentry conditions were not achieved. A majority of the mission objectives for Apollo 6 was accomplished.

The Apollo 7 Mission (first manned Apollo) was successfully launched on 11 October 1968. This was the fifth and last planned Apollo mission utilizing a Saturn IB Launch Vehicle (SA-205). The 11-day mission provided the first orbital tests of the Block II Command/Service Module. All primary mission objectives were successfully accomplished. In addition, all planned detailed test objectives, plus three that were not originally scheduled, were satisfactorily accomplished.

The Apollo 8 Mission was successfully launched on 21 December and completed on 27 December 1968. This was the first manned flight of the Saturn V Launch Vehicle and the first manned flight to the vicinity of the moon. All primary mission objectives were successfully accomplished. In addition, all detailed test objectives plus four that were not originally scheduled, were successfully accomplished. Ten orbits of the moon were successfully performed, with the last eight at an altitude of approximately 60 NM. Television and photographic coverage was successfully carried out, with telecasts to the public being made in real time.

The Apollo 9 Mission was successfully launched on 3 March and completed on 13 March 1969. This was the second manned Saturn V flight, the third flight of a manned Apollo Command/Service Module, and the first flight of a manned Lunar Module. This flight provided the first manned LM systems performance demonstration. All primary mission objectives were successfully accomplished. All detailed test objectives were accomplished except two associated with S-band and VHF communications which were partially accomplished. The S-IVB second orbital restart, CSM transposition and docking, and LM rendezvous and docking were also successfully demonstrated.

The Apollo 10 Mission was successfully launched on 18 May 1969 and completed on 26 May 1969. This was the third manned Saturn V flight, the second flight of a manned Lunar Module, and the first mission to operate the complete Apollo Spacecraft around the moon. This mission provided operational experience for the crew, space vehicle, and mission-oriented facilities during a simulated lunar landing mission, which followed planned Apollo 11 mission operations and conditions as closely as possible without actually landing. All primary mission objectives and detailed test objectives were successfully accomplished. The manned navigational, visual, and excellent photographic coverage of Lunar Landing Sites 2 and 3 and of the range of possible landing sites in the Apollo belt highlands areas provided detailed support information for Apollo 11 and other future lunar landing missions.

NASA OMSF PRIMARY MISSION OBJECTIVES

FOR APOLLO 11

PRIMARY OBJECTIVE

- Perform a manned lunar landing and return.

Sam C. Phillips
Sam C. Phillips
Lt. General, USAF
Apollo Program Director

Date: June 26, 1969.

George E. Mueller
George E. Mueller
Associate Administrator for
Manned Space Flight

Date: June 26, 1969

DETAILED OBJECTIVES AND EXPERIMENTS

The detailed objectives and experiments listed below have been assigned to the Apollo 11 Mission. There are no launch vehicle detailed objectives or spacecraft mandatory and principal detailed objectives assigned to this mission.

	NASA CENTER IDENTIFICATION
• Collect a Contingency Sample.	A
• Egress from the LM to the lunar surface, perform lunar surface EVA operations, and ingress into the LM from the lunar surface.	B
• Perform lunar surface operations with the EMU.	C
• Obtain data on effects of DPS and RCS plume impingement on the LM and obtain data on the performance of the LM landing gear and descent engine skirt after touchdown.	D
• Obtain data on the lunar surface characteristics from the effects of the LM landing.	E
• Collect lunar Bulk Samples.	F
• Determine the position of the LM on the lunar surface.	G
• Obtain data on the effects of illumination and contrast conditions on crew visual perception.	H
• Demonstrate procedures and hardware used to prevent back contamination of the earth's biosphere.	I
• Passive Seismic Experiment.	S-031
• Laser Ranging Retro-Reflector.	S-078
• Solar Wind Composition.	S-080
• Lunar Field Geology.	S-059
• Obtain television coverage during the lunar stay period.	L
• Obtain photographic coverage during the lunar stay period.	M

LAUNCH COUNTDOWN AND TURNAROUND CAPABILITY, AS-506

COUNTDOWN

Countdown (CD) for launch of the AS-506 Space Vehicle (SV) for the Apollo 11 Mission will begin with a precount period starting at T-93 hours during which launch vehicle (LV) and spacecraft (S/C) CD activities will be conducted independently. Official coordinated S/C and LV CD will begin at T-28 hours and will contain two built-in holds; one of 11 hours 32 minutes at T-9 hours, and another of 1 hour at T-3 hours 30 minutes. Figure 3 shows the significant launch CD events.

SCRUB/TURNAROUND

A termination (scrub) of the SV CD could occur at any point in the CD when launch support facilities, SV conditions, or weather warrant. The process of recycling the SV and rescheduling the CD (turnaround) will begin immediately following a scrub. The turnaround time is the minimum time required to recycle and count down the SV to T-0 (liftoff) after a scrub, excluding built-in hold time for launch window synchronization. For a hold that results in a scrub prior to T-22 minutes, turnaround procedures are initiated from the point of hold. Should a hold occur from T-22 minutes (S-II start bottle chilldown) to T-16.2 seconds (S-IC forward umbilical disconnect), then a recycle to T-22 minutes, a hold, or a scrub is possible under the conditions stated in the Launch Mission Rules. A hold between T-16.2 seconds and T-8.9 seconds (ignition) could result in either a recycle or a scrub depending on circumstances. An automatic or manual cutoff after T-8.9 seconds will result in a scrub.

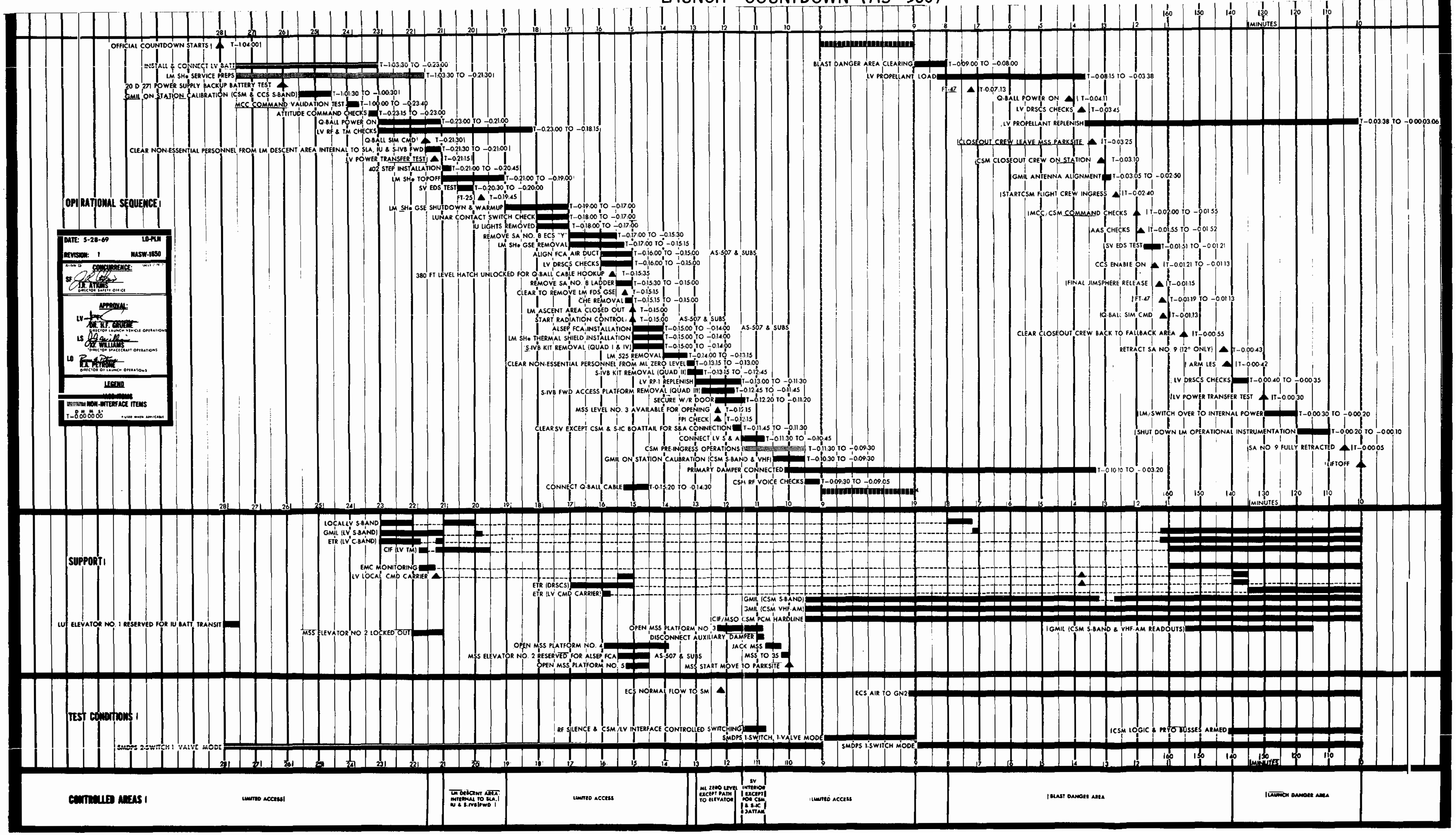
Although an indefinite number of scrub/turnaround cases could be identified, six baseline cases have been selected to provide the flexibility required to cover probable contingencies. These cases identify the turnaround activities necessary to maintain the same confidence for subsequent launch attempts as for the original attempt. The six cases, shown in Figure 4, are discussed below.

Case 1 - Scrub/Turnaround at Post-LV Cryogenic Loading - Command/Service Module (CSM)/Lunar Module (LM) Cryogenic Reservicing.

Condition: The scrub occurs during CD between T-16.2 and T-8.9 seconds and all SV ordnance items remain connected except the range safety destruct safe and arm (S&A) units. Reservicing of the CSM cryogenics and LM supercritical helium (SHe) is required in addition to the recycling of the LV.

Turnaround Time: Turnaround would require 65 hours consisting of 37 hours for recycle time and 28 hours for countdown time. The time required for a Case 1 turnaround results from flight crew egress, LV cryogenic unloading, LV ordnance operations and battery

LAUNCH COUNTDOWN (AS-506)



TURNAROUND FROM SCRUB, AS-506

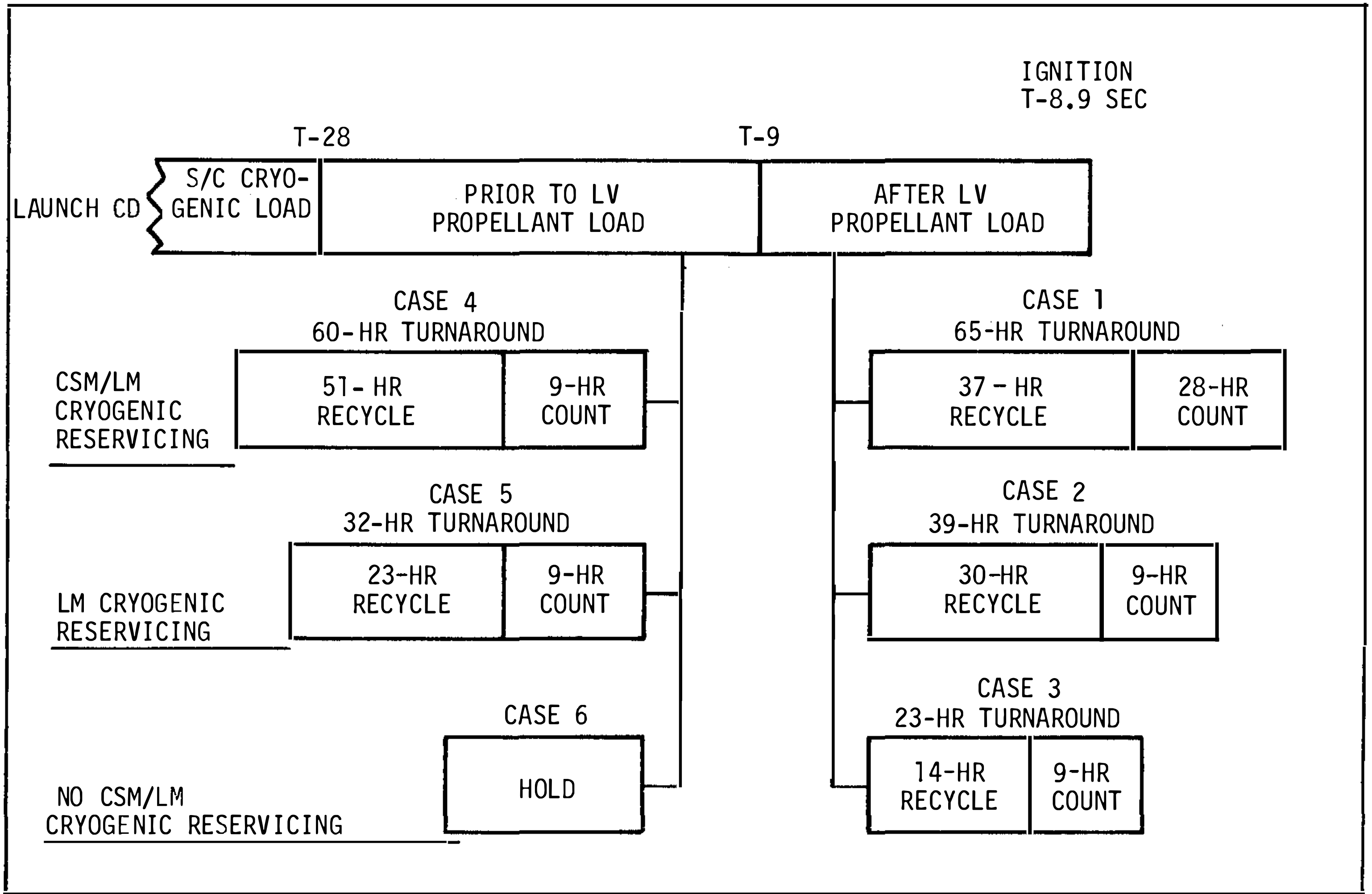


Fig. 4

removal, LM SHe reservicing, CSM cryogenic reservicing, CSM battery removal and installation, and CD resumption at T-28 hours.

Case 2 - Scrub/Turnaround at Post-LV Cryogenic Loading - LM Cryogenic Reservicing

Condition: The scrub occurs during CD between T-16.2 and T-8.9 seconds. Launch vehicle activities are minimized since they fall within allowable time constraints. Reservicing of the LM SHe is required.

Turnaround Time: Turnaround would require 39 hours 15 minutes, consisting of 30 hours 15 minutes for recycle time and 9 hours for CD time. The time requirement for this turnaround case results from flight crew egress, LV cryogenic unloading, LM SHe reservicing, LV loading preparations, and CD resumption at T-9 hours.

Case 3 - Scrub/Turnaround at Post-LV Cryogenic Loading - No CSM/LM Cryogenic Reservicing

Condition: The scrub occurs between T-16.2 and T-8.9 seconds in the CD. Launch vehicle recycle activities are minimized since they fall within allowable time constraints. LM SHe reservicing is not required.

Turnaround Time: Turnaround would require approximately 23 hours 15 minutes, consisting of 14 hours 15 minutes for recycle and 9 hours for CD time. The time required for this case results from flight crew egress, LV cryogenic unloading, S-IC forward umbilical installation and retest, LV propellant preparations, and CD resumption at T-9 hours.

Case 4 - Scrub/Turnaround at Pre-LV Cryogenic Loading - CSM/LM Cryogenic Reservicing

Condition: The scrub occurs at T-8 hours 15 minutes in the CD. The LV requires minimum recycle activities due to the point of scrub occurrence in the CD. The CSM cryogenics require reservicing and the CSM batteries require changing. The LM SHe cryogenics require reservicing. S-II servoactuator inspection is waived.

Turnaround Time: Turnaround would require approximately 59 hours 45 minutes, consisting of 50 hours 45 minutes for recycle and 9 hours for CD. The time required for this turnaround results from CSM cryogenic reservicing, CSM battery removal and installation, LM SHe reservicing, and CD resumption at T-9 hours.

Case 5 - Scrub/Turnaround at Pre-LV Cryogenic Loading - LM Cryogenic Reservicing

Condition: The scrub occurs at T-8 hours 15 minutes in the CD. The SV can remain closed out, except inspection of the S-II servoactuator is waived and the Mobile Service Structure is at the pad gate for reservicing of the LM SHe.

Turnaround Time: Turnaround would require approximately 32 hours, consisting of 23 hours for recycle time and 9 hours for CD. This case provides the capability for an approximate 1-day turnaround that exists at T-8 hours 15 minutes in the CD. This capability permits a launch attempt 24 hours after the original T-0. The time required for this turnaround results from LM SHe reservicing and CD resumption at T-9 hours.

Case 6 - Scrub/Turnaround at Pre-LV Cryogenic Loading - No LM/CSM Cryogenic Reservicing

Condition: A launch window opportunity exists 1 day after the original T-0. The LV, LM, and CSM can remain closed out.

Turnaround Time: Hold for the next launch window. The possibility for an approximate 1-day hold may exist at T-8 hours 15 minutes in the CD.

In the event of a scrub, the next possible attempt at a given launch window will depend on the following:

1. The type of scrub/turnaround case occurrence and its time duration.

2. Real-time factors that may alter turnaround time.

3. The number of successive scrubs and the case type of each scrub occurrence.

4. Specific mission launch window opportunities.

Figure 5 shows the scrub/turnaround possibilities in the Apollo 11 Mission for a July launch window. Since the turnaround time may fall short of or exceed a launch window, hold capabilities necessary to reach the closest possible launch window must be considered. Possible hold points are between recycle and CD, and at T-9 hours in the CD (as in the original CD).

In the event of two successive scrub/turnarounds, SV constraints may require that additional serial or parallel tasks be performed in the second scrub/turnaround case. The 36 possible combinations of the baseline cases and the constraints that may develop on the second turnaround case occurrence are shown in the second scrub/turnaround matrix (Figure 6). A second scrub/turnaround will require that real-time considerations be given either to additional task performance or to task waivers.

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SCRUB/TURNAROUND POSSIBILITIES, AS 506
JULY LAUNCH WINDOW

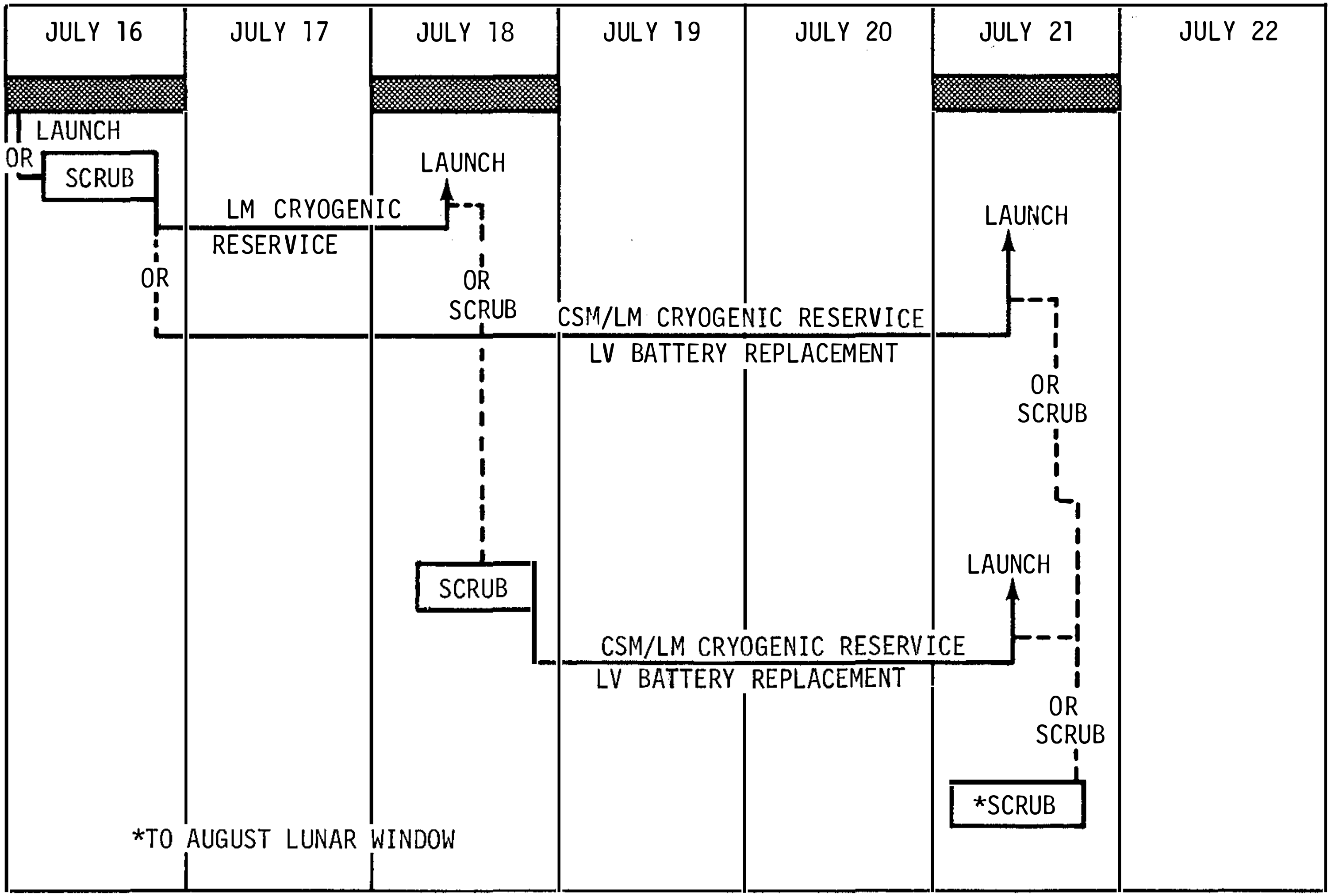

Fig. 5

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SECOND SCRUB/TURNAROUND MATRIX, AS-506

SECOND SCRUB/TURNAROUND	FIRST SCRUB/TURNAROUND: CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6
CASE 1	YES	YES	YES	YES	YES	YES
CASE 2	YES	NO A,C,D	NO A,C,D	NO A,C,D	NO A,C,D	NO A,C,D
CASE 3	YES	NO A,C,D	NO A,B,C	NO D	NO A,C	NO A,B,C
CASE 4	YES	NO D	NO D	NO D	NO D	NO D
CASE 5	YES	NO A,C,D	NO A,C	NO D	NO A,C	NO A,C
CASE 6	YES	NO A,C,D	NO A,B,C	NO D	NO A,C	NO A,B,C

LEGEND

A YES IN THE MATRIX BLOCK INDICATES NO IDENTIFIABLE CONSTRAINTS ARE APPARENT.

A NO FOLLOWED BY ONE OR MORE LETTERS IN THE MATRIX BLOCK INDICATES THAT SOME CONSTRAINT(S), AS IDENTIFIED BELOW, IS APPARENT:

A. THE CSM CRYOGENICS MAY REQUIRE RESERVICING.
B. THE LM SHE MAY REQUIRE RESERVICING.
C. THE CSM BATTERIES MAY REQUIRE CHANGING.
D. THE LV BATTERIES WILL REQUIRE CHANGING.

Fig. 6

DETAILED FLIGHT MISSION DESCRIPTION

LAUNCH WINDOWS

Apollo 11 has two types of launch windows. The first, a monthly launch window, defines the days of the month when launch can occur, and the second, a daily launch window, defines the hours of these days when launch can occur.

Monthly Launch Window

Since this mission includes a lunar landing, the flight is designed such that the sun is behind the Lunar Module (LM) and low on the eastern lunar horizon in order to optimize visibility during the LM approach to one of the three Apollo Lunar Landing Sites available during the July monthly launch window. Since a lunar cycle is approximately 28 earth days long, there are only certain days of the month when these landing sites are properly illuminated. Only one launch day is available for each site for each month. Therefore, the Apollo 11 launch must be timed so that the spacecraft will arrive at the moon during one of these days. For a July 1969 launch, the monthly launch window is open on the 16th, 18th, and 21st days of the month. The unequal periods between these dates are a result of the spacing between the selected landing sites on the moon. Table 2 shows the opening and closing of the monthly launch windows and the corresponding sun elevation angles. Figure 7 shows the impact of July launch windows on mission duration.

TABLE 2

MONTHLY LAUNCH WINDOWS

Site	Date	July (EDT) Open-Close**	SEA***	Date	August (EDT) Open-Close**	SEA
2	16	09:32-13:54	10.8°	14H	07:45-12:15	6.0°
3	18H*	11:32-14:02	11.0°	16H	07:55-12:25	6.0°
5	21H	12:09-14:39	9.1°	20H	09:55-14:35	10.0°

*Hybrid (H) trajectory used.
**Based on 108° launch azimuth upper limit.
***Sun Elevation Angle (SEA) - assumes launch at window opening and translunar injection at the first opportunity.

NOTE: A hybrid trajectory is required for a launch on 18 July to make it possible for the Goldstone tracking station 210-foot antenna to cover the LM powered descent phase.

MISSION DURATIONS, JULY LAUNCH WINDOWS

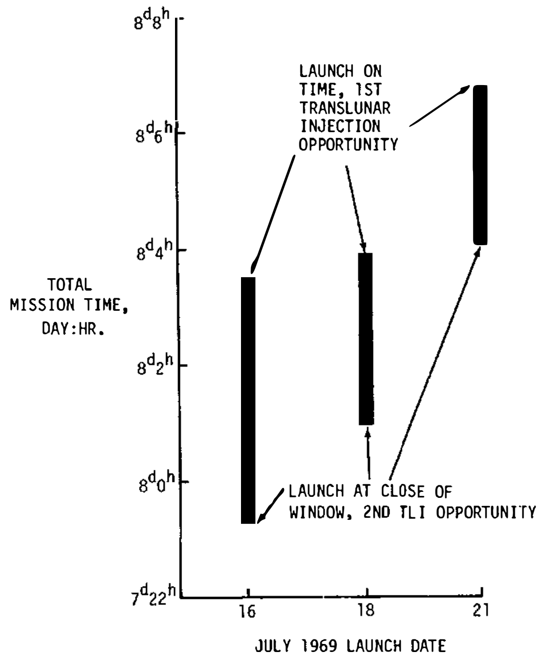

Fig. 7

Daily Launch Windows

The maneuver to transfer the S-IVB/spacecraft from earth parking orbit to a translunar trajectory must be performed over a point called the moon's antipode. This is a point on the earth's surface where an imaginary line, drawn from the moon's position (at expected spacecraft arrival time) through the center of the earth, will intersect the far side of the earth. In other words, it is the point on the earth that is exactly opposite the moon. Since the moon revolves around the earth and the earth is spinning on its axis, the antipode is constantly moving. This presents the problem of having the S-IVB/spacecraft rendezvous with a moving target, the antipode, before it can perform the translunar injection (TLI) burn. Additional constraints on the execution of this maneuver are: (1) it will be performed over the Pacific Ocean, (2) it can occur no earlier than revolution 3 because of S-IVB systems lifetime. These constraints, combined with a single fixed launch azimuth, allow only a very short period of time each day that launch can be performed.

To increase the amount of time available each day, and still maintain the capability to rendezvous with the antipode, a variable launch azimuth technique will be used. The launch azimuth increases approximately 8° per hour during the launch window, and the variation is limited by range safety considerations to between 72° and 106°. This extends the time when rendezvous with the projected antipode can be accomplished up to a maximum of approximately 4.5 hours. The minimum daily launch window for Apollo 11 is approximately 2.5 hours.

FREE-RETURN/HYBRID TRAJECTORY

A circumlunar free-return trajectory, by definition, is one which circumnavigates the moon and returns to earth. The perigee altitude of the return trajectory is of such a magnitude that by using negative lift the entering spacecraft can be prevented from skipping out of the earth's atmosphere, and the aerodynamic deceleration can be kept below 10 g's. Thus, even with a complete propulsion system failure following TLI, the spacecraft would return safely to earth. However, free-return trajectory severely limits the accessible area on the moon because of the very small variation in allowable lunar approach conditions and because the energy of the lunar approach trajectory is relatively high. The high approach energy causes the orbit insertion velocity change requirement (ΔV) to be relatively high.

Since the free-return flight plan is so constraining on the accessible lunar area, hybrid trajectories have been developed that retain most of the safety features of the free return, but do not suffer from the performance penalties. If a hybrid trajectory is used for Apollo 11, the spacecraft will be injected into a highly eccentric elliptical orbit which had the free-return characteristic; i.e., a return to the entry corridor without any further maneuvers. The spacecraft will not depart from the free-return ellipse until spacecraft ejection from the launch vehicle has been completed. After the Service Propulsion System (SPS) has been checked out, a midcourse maneuver will be performed by the SPS to place the spacecraft on a lunar approach trajectory. The resulting lunar approach will not be on a free-return trajectory, and hence will not be subject to the same limitations in trajectory geometry.

On future Apollo lunar missions, landing sites at higher latitudes will be achieved, with little or no plane change, by approaching the moon on a highly inclined trajectory.

LUNAR LANDING SITES

The following Lunar Landing Sites, as shown in Figure 8, are final choices for Apollo 11:

Site 2 latitude 0°41' North
longitude 23°43' East

Site 2 is located on the east central part of the moon in southwestern Mare Tranquillitatis.

Site 3 latitude 0°21' North
longitude 1°18' West

Site 3 is located near the center of the visible face of the moon in the southwestern part of Sinus Medii.

Site 5 latitude 1°41' North
longitude 41°54' West

Site 5 is located on the west central part of the visible face in southeastern Oceanus Procellarum.

APOLLO LUNAR LANDING SITES

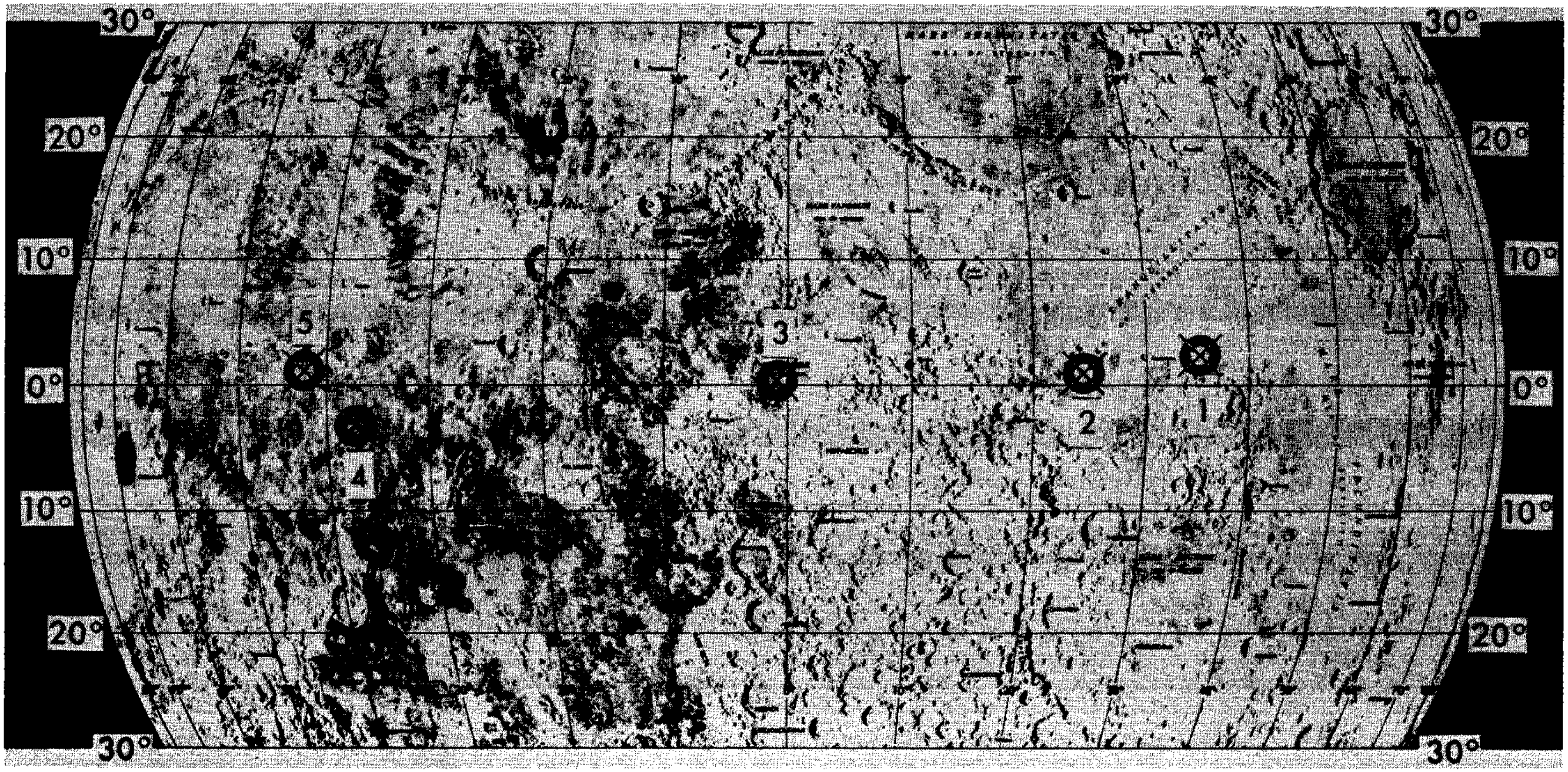

Fig. 8

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The final site choices were based on these factors:

- Smoothness (relatively few craters and boulders).
- Approach (no large hills, high cliffs, or deep craters that could cause incorrect altitude signals to the Lunar Module landing radar).
- Propellant requirements (selected sites require the least expenditure of spacecraft propellants).
- Recycle (selected sites allow effective launch preparation recycling if the Apollo/Saturn V countdown is delayed).
- Free-return (sites are within reach of the spacecraft launched on a free-return translunar trajectory).
- Slope (there is little slope — less than 2 degrees in the approach path and landing area).

FLIGHT PROFILE

Launch to Earth Parking Orbit

The Apollo 11 Space Vehicle is planned to be launched at 09:32 EDT from Complex 39A at the Kennedy Space Center, Florida, on a launch azimuth of 72°. The space vehicle (SV) launch weight breakdown is shown in Table 3. The Saturn V boost to earth parking orbit (EPO), shown in Figure 9, will consist of a full burn of the S-IC and S-II stages and a partial burn of the S-IVB stage of the Saturn V Launch Vehicle. Insertion into a 103-nautical mile (NM) EPO (inclined approximately 33 degrees from the earth's equator) will occur approximately 11.5 minutes ground elapsed time (GET) after liftoff. The vehicle combination placed in earth orbit consists of the S-IVB stage, the Instrument Unit (IU), the Lunar Module (LM), the Spacecraft-LM Adapter (SLA), and the Command/Service Module (CSM). While in EPO, the S-IVB and spacecraft will be readied for the second burn of the S-IVB to achieve the translunar injection (TLI) burn. The earth orbital configuration of the SV is shown in Figure 10.

Translunar Injection

The S-IVB J-2 engine will be reignited during the second parking orbit (first opportunity) to inject the SV combination into a translunar trajectory. The second opportunity for TLI will occur on the third parking orbit. The TLI burn will be biased for a small overburn to compensate for the Service Propulsion System (SPS) evasive maneuver that will be performed after ejection of the LM/CSM from the S-IVB/IU/SLA.

TABLE 3

APOLLO 11 WEIGHT SUMMARY

(Weight in Pounds)

STAGE/MODULE	INERT WEIGHT	TOTAL EXPENDABLES	TOTAL WEIGHT	FINAL SEPARATION WEIGHT
S-IC Stage	288,750	4,739,320	5,028,070	363,425
S-IC/S-II Interstage	11,465	-----	11,465	-----
S-II Stage	79,920	980,510	1,060,430	94,140
S-II/S-IVB Interstage	8,080	-----	8,080	-----
S-IVB Stage	25,000	237,155	262,155	28,275
Instrument Unit	4,305	-----	4,305	-----
Launch Vehicle at Ignition			6,374,505	
Spacecraft-LM Adapter	4,045	-----	4,045	-----
Lunar Module	9,520	23,680	33,200	*33,635
Service Module	10,555	40,605	51,160	11,280
Command Module	12,250	-----	12,250	11,020 (Landing)
Launch Escape System	8,910	-----	8,910	-----
Spacecraft At Ignition			109,565	
Space Vehicle at Ignition			6,484,070	
S-IC Thrust Buildup			(-)85,845	
Space Vehicle at Liftoff			6,398,325	
Space Vehicle at Orbit Insertion			292,865	

* CSM/LM Separation

ASCENT TRAJECTORY

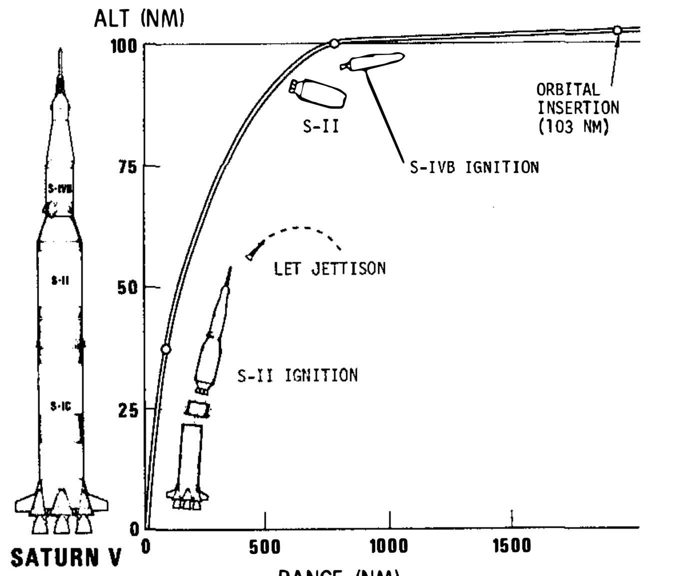


Fig. 9

TRANSPOSITION, DOCKING, EJECTION

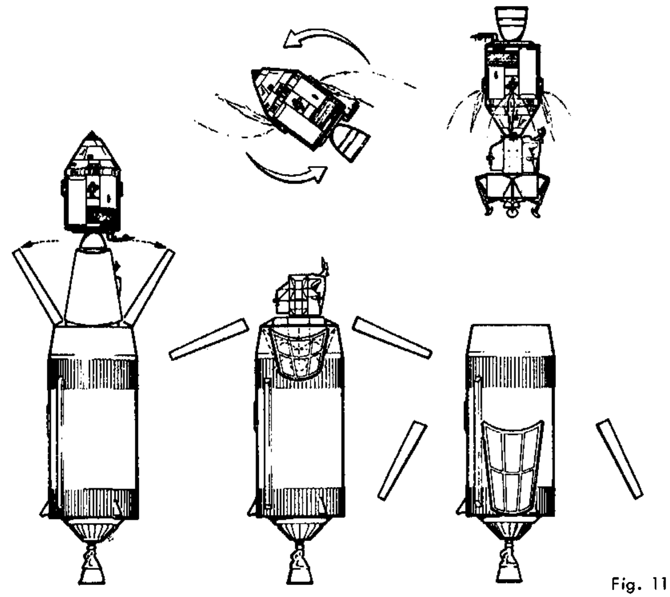


Fig. 11

EARTH ORBITAL CONFIGURATION

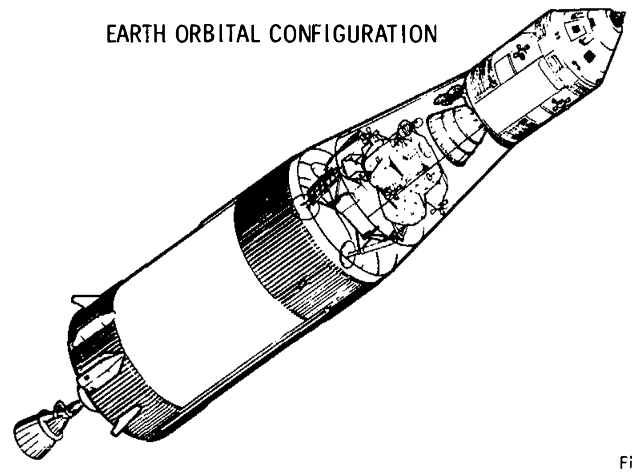


Fig. 10

TRANSLUNAR CONFIGURATION

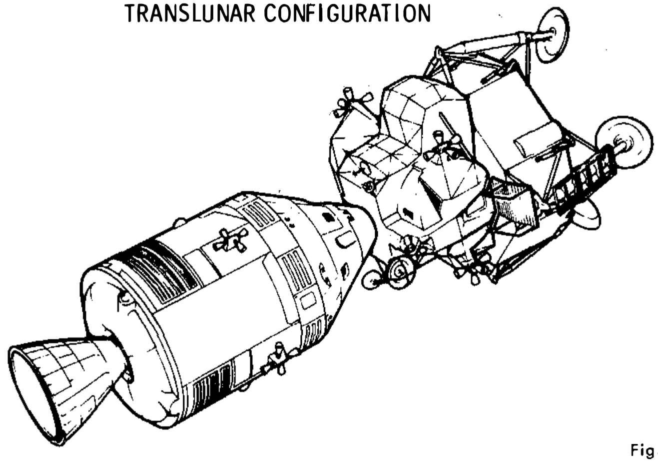


Fig. 12

Translunar Coast

Within 2.5 hours after TLI, the CSM will be separated from the remainder of the vehicle and will transpose, dock with the LM, and initiate ejection of the CSM/LM from the SLA/IU/S-IVB as shown in Figure 11. A pitchdown maneuver of a prescribed magnitude for this transposition, docking, and ejection (TD&E) phase is designed to place the sun over the shoulders of the crew, avoiding CSM shadow on the docking interface. The pitch maneuver also provides continuous tracking and communications during the inertial attitude hold during TD&E.

At approximately 1 hour 45 minutes after TLI, a spacecraft evasive maneuver will be performed using the SPS to decrease the probability of S-IVB recontact, to avoid ice particles expected to be expelled by the S-IVB during LOX dump, and to provide an early SPS confidence burn. This SPS burn will be performed in a direction and of a duration and magnitude that will compensate for the TLI bias mentioned before. The evasive maneuver will place the docked spacecraft, as shown in Figure 12, on a free return circumlunar trajectory. A free return to earth will be possible if the insertion into lunar parking orbit cannot be accomplished.

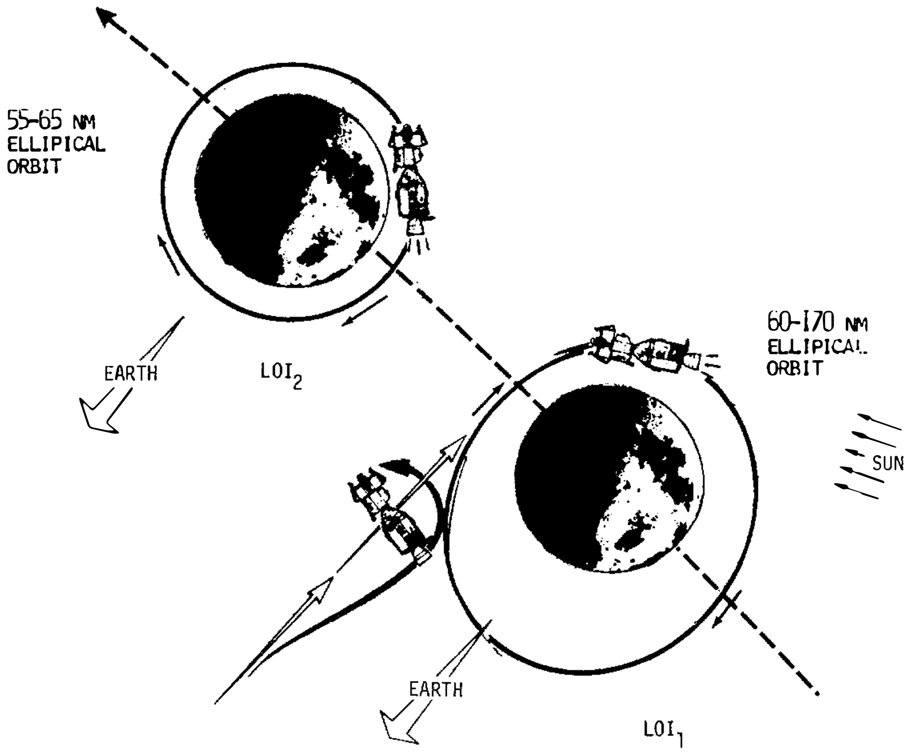
Approximately 2 hours after TLI, the residual propellants in the S-IVB are dumped to perform a retrograde maneuver. This "slingshot" maneuver reduces the probability of S-IVB recontact with the spacecraft and results in a trajectory that will take the S-IVB behind the trailing edge of the moon into solar orbit, thereby avoiding both lunar impact and earth impact.

Passive thermal control attitude will be maintained throughout most of the translunar coast period. Four midcourse correction maneuvers are planned and will be performed only if required. They are scheduled to occur at approximately TLI plus 9 hours, TLI plus 24 hours, lunar orbit insertion (LOI) minus 22 hours, and LOI minus 5 hours. These corrections will use the Manned Space Flight Network (MSFN) for navigation. The translunar coast phase will span approximately 73 hours.

Lunar Orbit Insertion

LOI will be performed in two separate maneuvers using the SPS of the CSM as shown in Figure 13. The first maneuver, LOI-1, will be initiated after the spacecraft has passed behind the moon and crosses the imaginary line through the centers of the earth and moon at approximately 80 NM above the lunar surface. The SPS burn is a retrograde maneuver that will place the spacecraft into an elliptical orbit that is approximately 60 x 170 NM. After two revolutions in the 60 x 170-NM orbit and a navigation update, a second SPS retrograde burn (LOI-2) will be made as the spacecraft crosses the antipode behind the moon to place the spacecraft in an elliptical orbit approximately 55 x 65 NM. This orbit will become circularized at 60 NM by the time of LM rendezvous due to the effect of variations in the lunar gravitational potential on the spacecraft as it orbits the moon.

LUNAR ORBIT INSERTION



CSM/LM Coast to LM Powered Descent

After LOI-2, some housekeeping will be accomplished in both the CSM and the LM. Subsequently, a simultaneous rest and eat period of approximately 10 hours will be provided for the three astronauts prior to checkout of the LM. Then the Commander (CDR) and Lunar Module Pilot (LMP) will enter the LM, perform a thorough check of all systems, and undock from the CSM. During the 13th revolution after LOI-2 and approximately 2.5 hours before landing, the LM and CSM will undock in preparation for descent. The undocking is a physical unlatching of a spring-loaded mechanism that imparts a relative velocity of approximately 0.5 feet per second (fps) between the vehicles. Station-keeping is initiated at a distance of 40 feet, and the LM is rotated about its yaw axis for CM Pilot observation of the deployed landing gear. Approximately one-half hour after undocking, the SM Reaction Control System (RCS) will be used to perform a separation maneuver of approximately 2.5 fps directed radially downward toward the center of the moon. This maneuver increases the LM/CSM separation distance to approximately 2.2 NM at descent orbit insertion (DOI). The DOI maneuver will be performed by a LM DPS retrograde burn, as shown in Figure 14, one-half revolution after LM/CSM separation. This maneuver places the LM in an elliptical orbit that is approximately 60 NM by 50,000 feet. The descent orbit events are shown in Figure 15.

DESCENT ORBIT INSERTION

Fig. 14

LUNAR MODULE DESCENT

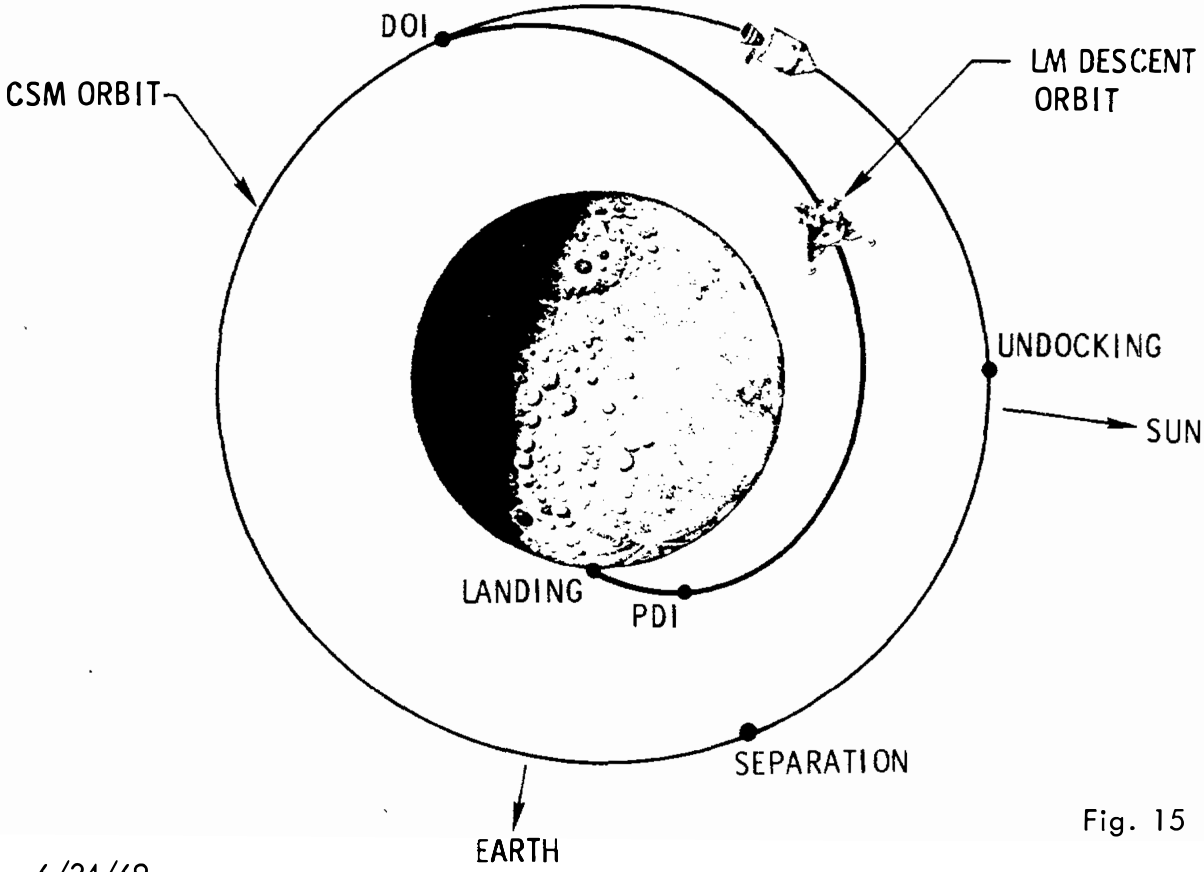


Fig. 15

Lunar Module Powered Descent

The LM powered descent maneuver will be initiated at the 50,000-foot altitude point of the descent orbit and approximately 14° prior to the landing site. This maneuver will consist of a braking phase, an approach phase, and a landing phase. The braking phase will use maximum thrust from the DPS for most of this phase to reduce the LM's orbital velocity. The LM will be rotated to a windows-up attitude at an altitude of 45,000 feet. The use of the landing radar can begin at an altitude of about 39,000 feet, as depicted in Figure 16. The approach phase, as shown in Figure 17, will begin at approximately 7600 feet (high gate) from the lunar surface. Vehicle attitudes during this phase will permit crew visibility of the landing area through the forward window. The crew can redesignate to an improved lunar surface area in the event the targeted landing point appears excessively rough. The landing phase will begin at an altitude of 500 feet (low gate) and has been designed to provide continued visual assessment of the landing site. The crew will take control of the spacecraft attitude and make minor adjustments as required in the rate of descent during this period.

The vertical descent portion of the landing phase will start at an altitude of 125 feet and continue at a rate of 3 fps until the probes on the foot pads of the LM contact the lunar surface. The CDR will cut off the descent engine within 1 second after the probes, which extend 68 inches beyond the LM footpad, contact the lunar surface although the descent engine can be left on until the footpads contact the lunar surface. The lunar surface contact sequence is shown in Figure 18.

LANDING RADAR-ANTENNA BEAM CONFIGURATION

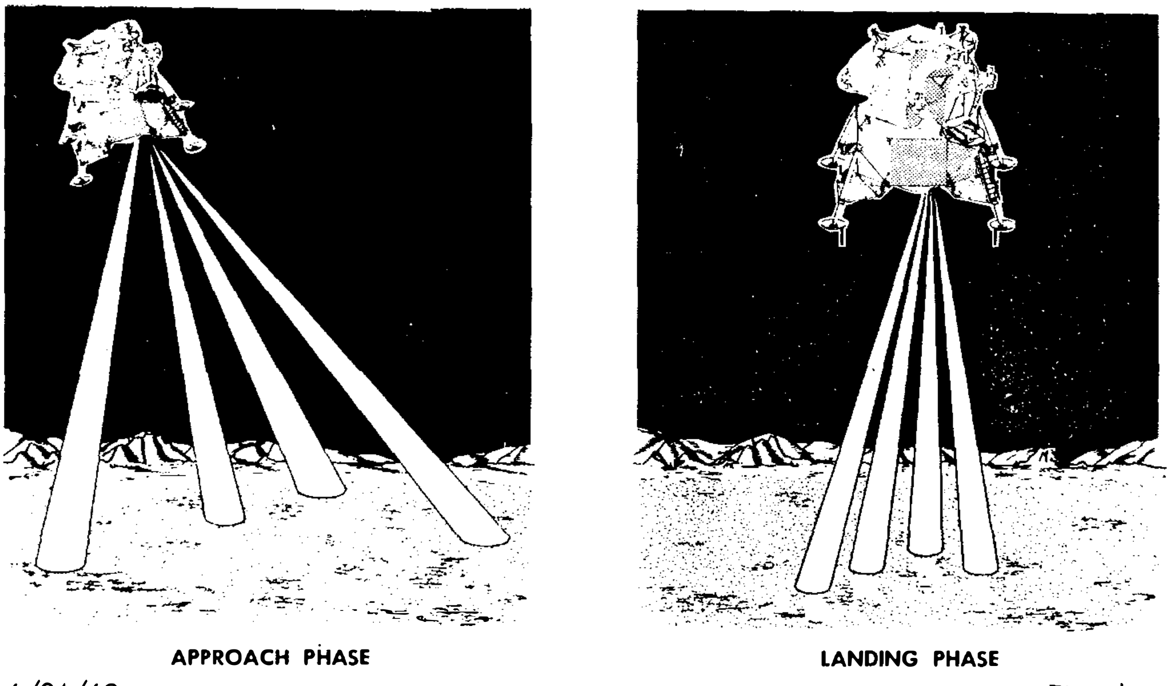


 Fig. 16

LANDING APPROACH PHASE

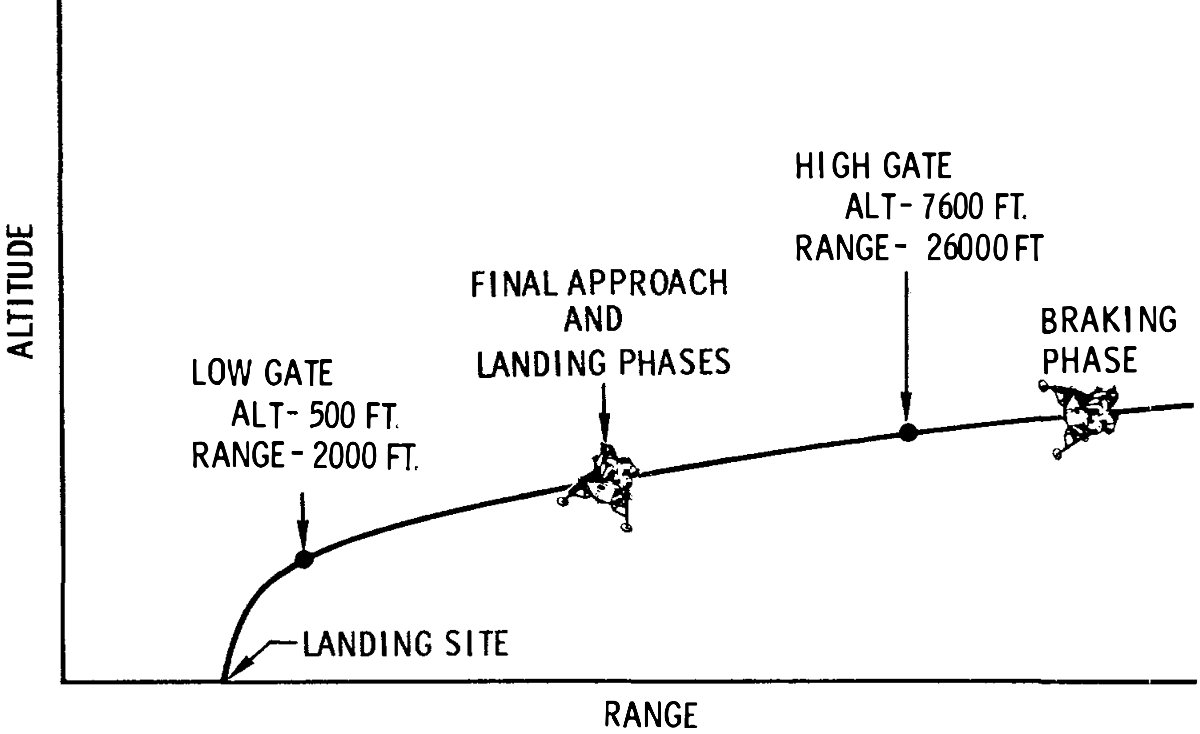


Fig. 17

LUNAR CONTACT SEQUENCE

- PROBE CONTACTS LUNAR SURFACE
- 'LUNAR CONTACT' INDICATOR ON CONTROL PANEL LIGHTS
- DESCENT ENGINE IS SHUT DOWN BY CREW AFTER 1 SECOND
- LM SETTLES TO LUNAR SURFACE

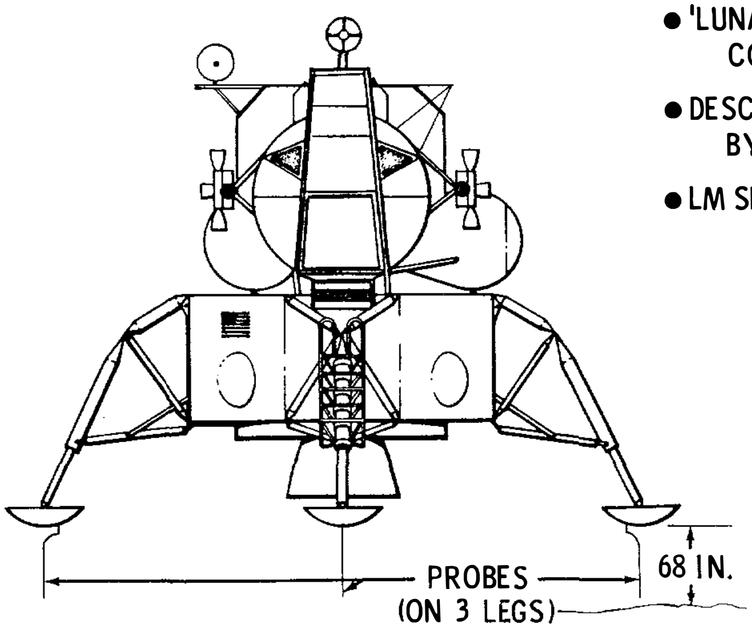


Fig. 18

Lunar Surface Activities

Immediately after landing, the LM will be checked to assess its launch capability. After the postlanding checks and prior to preparation for extravehicular activity (EVA), there will be a 4-hour rest period, with eat periods before and after. A timeline for the lunar surface activity is shown in Figure 19. Each crewman will then don a "back-pack" consisting of a Portable Life Support System (PLSS) and an Oxygen Purge System (OPS). The LM Environmental Control System (ECS) and the Extravehicular Mobility Unit (EMU) will be checked out, and the LM will be depressurized to allow the CDR to egress to the lunar surface. As the CDR begins to descend the LM ladder, he will pull a "D" ring which will lower the Modularized Equipment Stowage Assembly (MESA). This allows the TV camera mounted on the MESA access panel to record his descent to the lunar surface. The LMP will remain inside the LM Ascent Stage during the early part of the EVA to monitor the CDR's surface activity (including photography through the LM window) and the LM systems in the depressurized state.

Commander Environmental Familiarization

Once on the surface, the CDR will move slowly from the footpad to check his balance and determine his ability to continue with the EVA — the ability to move and to see or, specifically, to perform the surface operations within the constraints of the EMU and the lunar environment. Although a more thorough evaluation and documentation of a crewman's capabilities will occur later in the timeline, this initial familiarization will assure the CDR that he and the LMP are capable of accomplishing the assigned EVA tasks. A brief check of the LM status will be made to extend the CDR's environment familiarization and, at the same time, provide an important contribution to the postflight assessment of the LM landing should a full or nominal LM inspection not be accomplished later.

Contingency Sample Collection

A Contingency Sample of lunar surface material will be collected. This will assure the return of a small sample in a contingency situation where a crewman may remain on the surface for only a short period of time. One to four pounds of loose material will be collected in a sample container assembly which the CDR carries to the surface in his suit pocket. The sample will be collected near the LM ladder and the sample bag restowed in the suit pocket to be carried into the Ascent Stage when the CDR ingresses at the end of the EVA. Figure 20 shows the relative location of the Contingency Sample collection and the other lunar surface activities.

LUNAR SURFACE ACTIVITY TIMELINE FOR 22-HOUR STAY

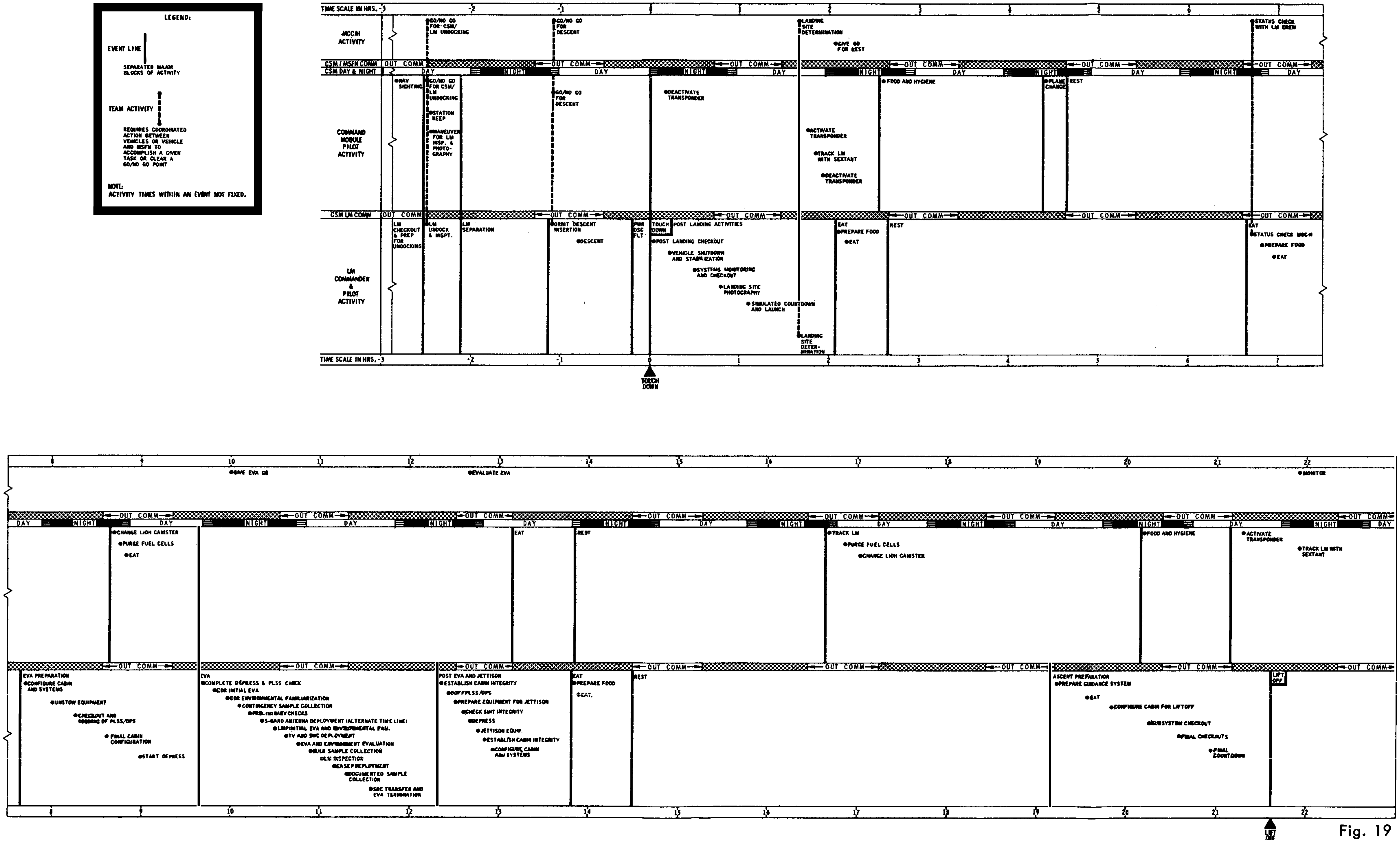


Fig. 19

LUNAR SURFACE ACTIVITY

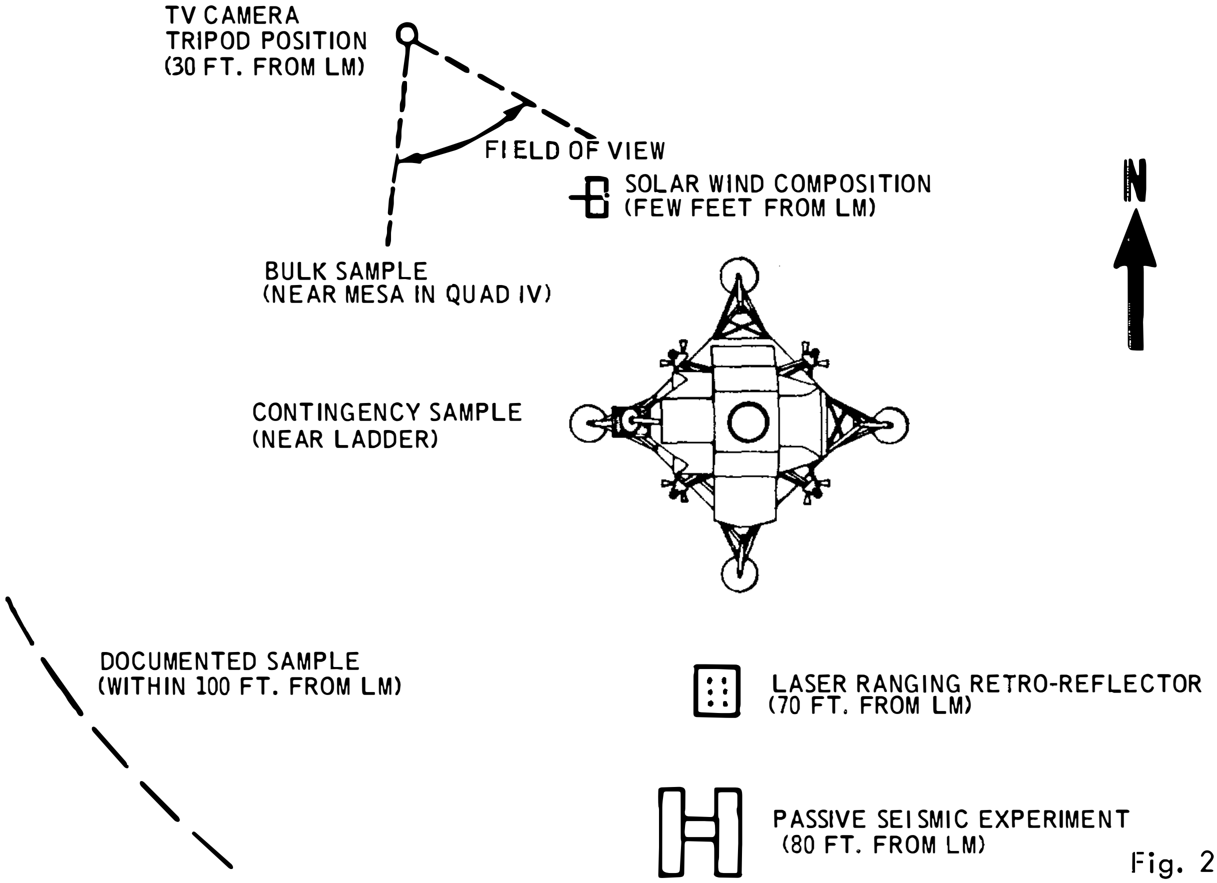


Fig. 20

S-Band Erectable Antenna Deployment

In the event that adequate margins do not exist with the steerable antenna for the entire communications spectrum (including television) during the EVA period, the S-band erectable antenna may be deployed to improve these margins. This would require approximately 19 minutes and will probably reduce the time allocated to other EVA events.

Lunar Module Pilot Environmental Familiarization

After the CDR accomplishes the preliminary EVA task, the LMP will descend to the surface and spend a few minutes in the familiarization and evaluation of his capability or limitations to conduct further operations in the lunar environment.

Television Camera Deployment

The CDR, after photographing the LMP's egress and descent to the surface, will remove the TV camera from the Descent Stage MESA, obtain a panorama, and place the camera on its tripod in a position to view the subsequent surface EVA operations. The TV camera will remain in this position.

Extravehicular Activity and Environmental Evaluation

The LMP will proceed to conduct the environmental evaluation. This involves a detailed investigation and documentation of a crewman's capability within the constraints of the EMU; the PLSS/EMU performance under varying conditions of sunlight, shadow, crewman activity or inactivity; and the characteristics of the lunar environment which influence operations on the surface.

Flag Deployment

Early in the LMP EVA period the astronauts will erect a 3 by 5-foot Americal flag. It will be on an 8-foot aluminum staff and a spring-like wire along its top edge will keep it unfurled in the airless environment of the moon. The event will be recorded on television and transmitted live to earth. The flag will be placed a sufficient distance from the LM to avoid damage by the ascent engine exhaust at lunar takeoff.

Bulk Sample Collection

The CDR will collect a Bulk Sample of lunar surface material. In the Bulk Sample collection at least 22 pounds, but as much as 50 pounds, of unsorted surface material and selected rock chunks will be placed in a special container, a lunar Sample Return Container (SRC), to provide a near vacuum environment for its return to the Lunar Receiving Laboratory (LRL). Apollo Lunar Handtools (ALHT), stowed in the MESA with the SRC, will be used to collect this large sample of loose lunar material from the surface near the MESA in Quad IV of the LM. Figure 21 shows the removal of tools stowed in the MESA. Figure 22 shows the preparation of a handtool for use. As each rock sample or scoop of loose material is collected, it will be placed into a large sample bag. Placing the sealed bag, rather than the loose material. directly into the SRC prevents contamination and possible damage to the container seals.

Solar Wind Composition Experiment Deployment

The LMP will deploy the Solar Wind Composition (SWC) experiment. The SWC experiment consists of a panel of very thin aluminum foil rolled and assembled into a combination handling and deployment container. It is stowed in the MESA. Once the thermal blanket is removed from around the MESA equipment it is a simple task to remove the SWC, deploy the staff and the foil "window shade," and place it in direct sunlight where the foil will be exposed to the sun's rays, as shown in Figure 23. The SWC experiment is designed to entrap noble gas constituents of the solar wind, such as helium, neon, argon, krypton, and xenon. It is deployed early in the EVA period for maximum exposure time. At the conclusion of the EVA, the foil is rolled up, removed from the staff, and placed in a SRC. At the time the foil is recovered, the astronaut will push the staff into the lunar surface to determine, for postflight soil mechanics analysis, the depth of penetration.

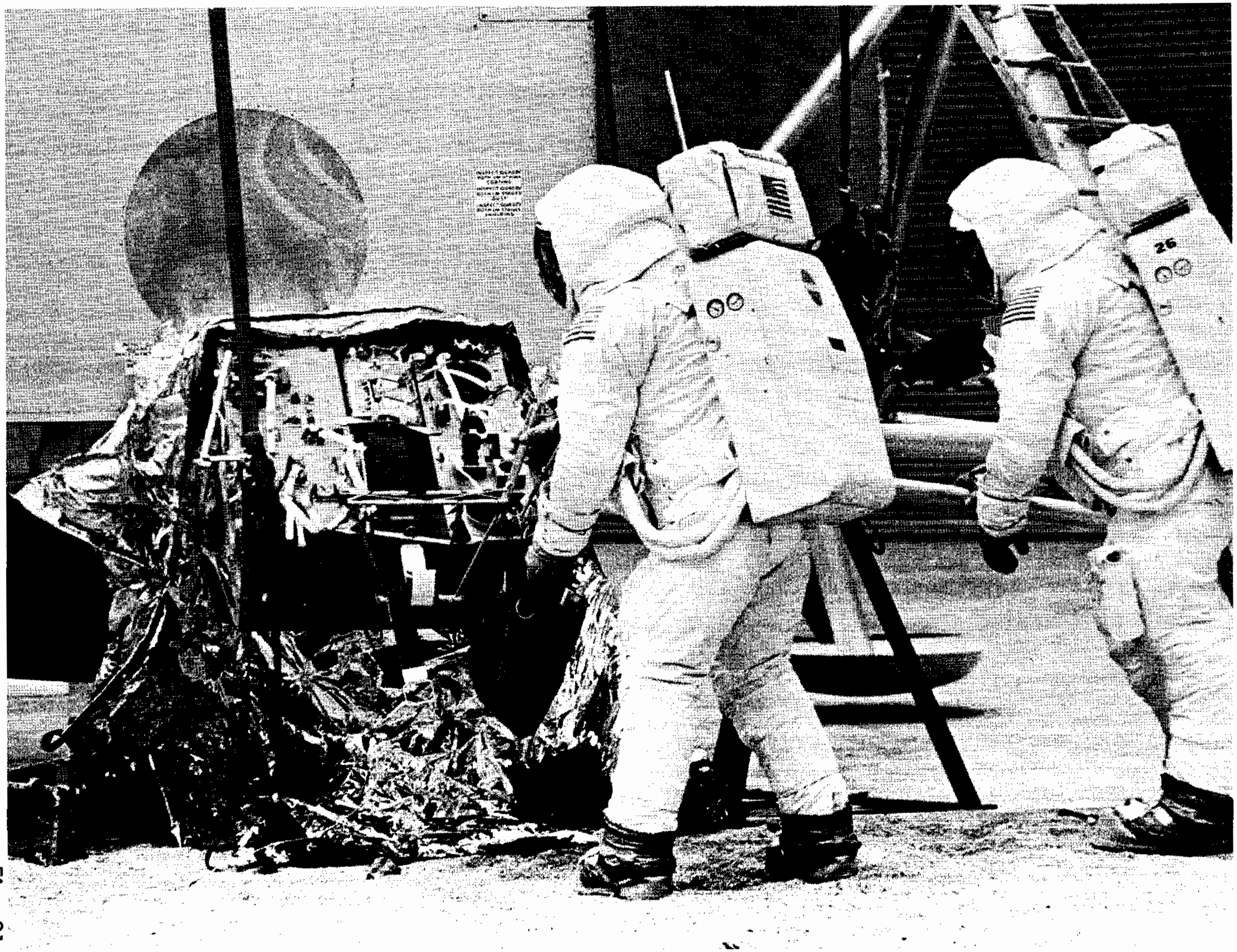
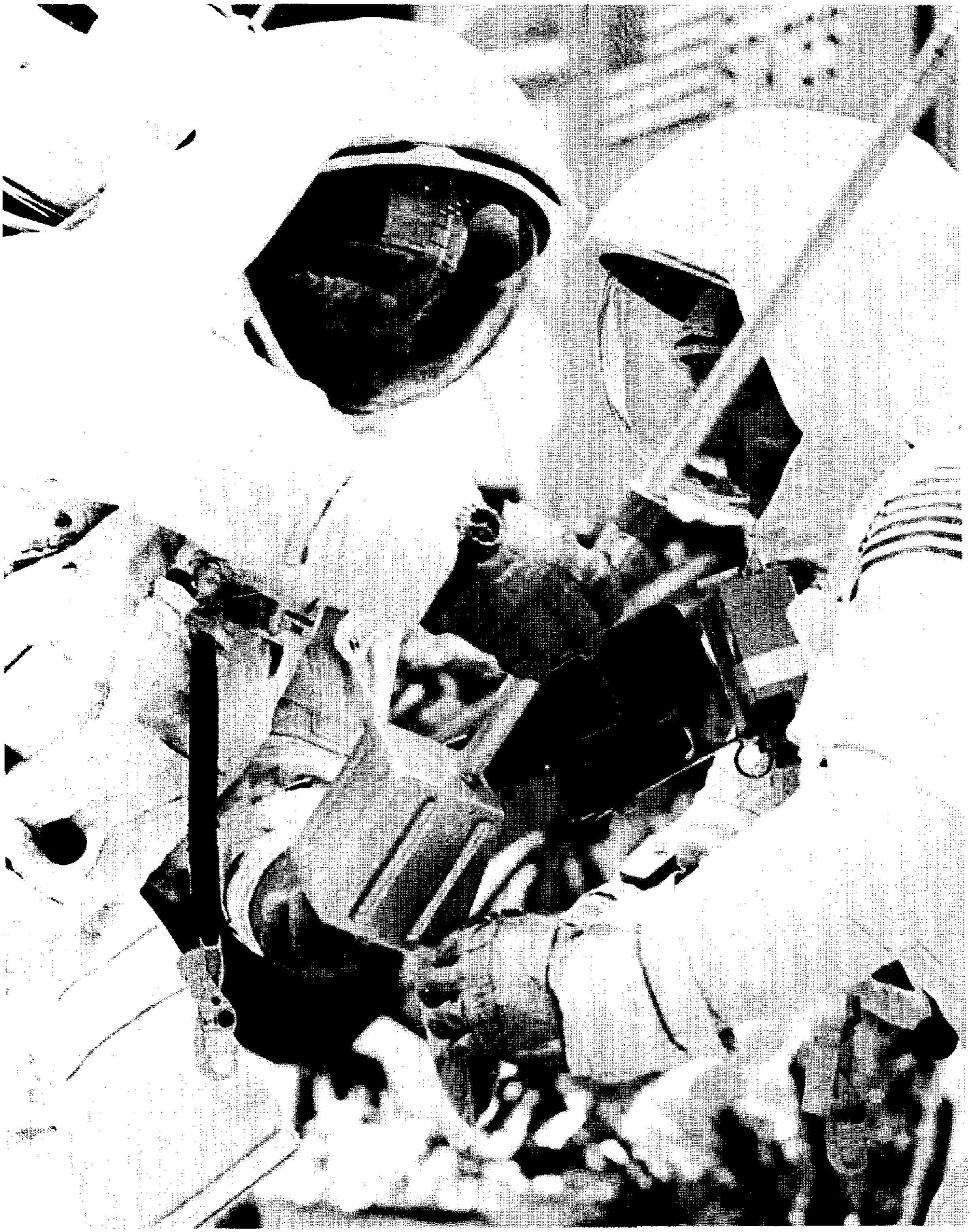


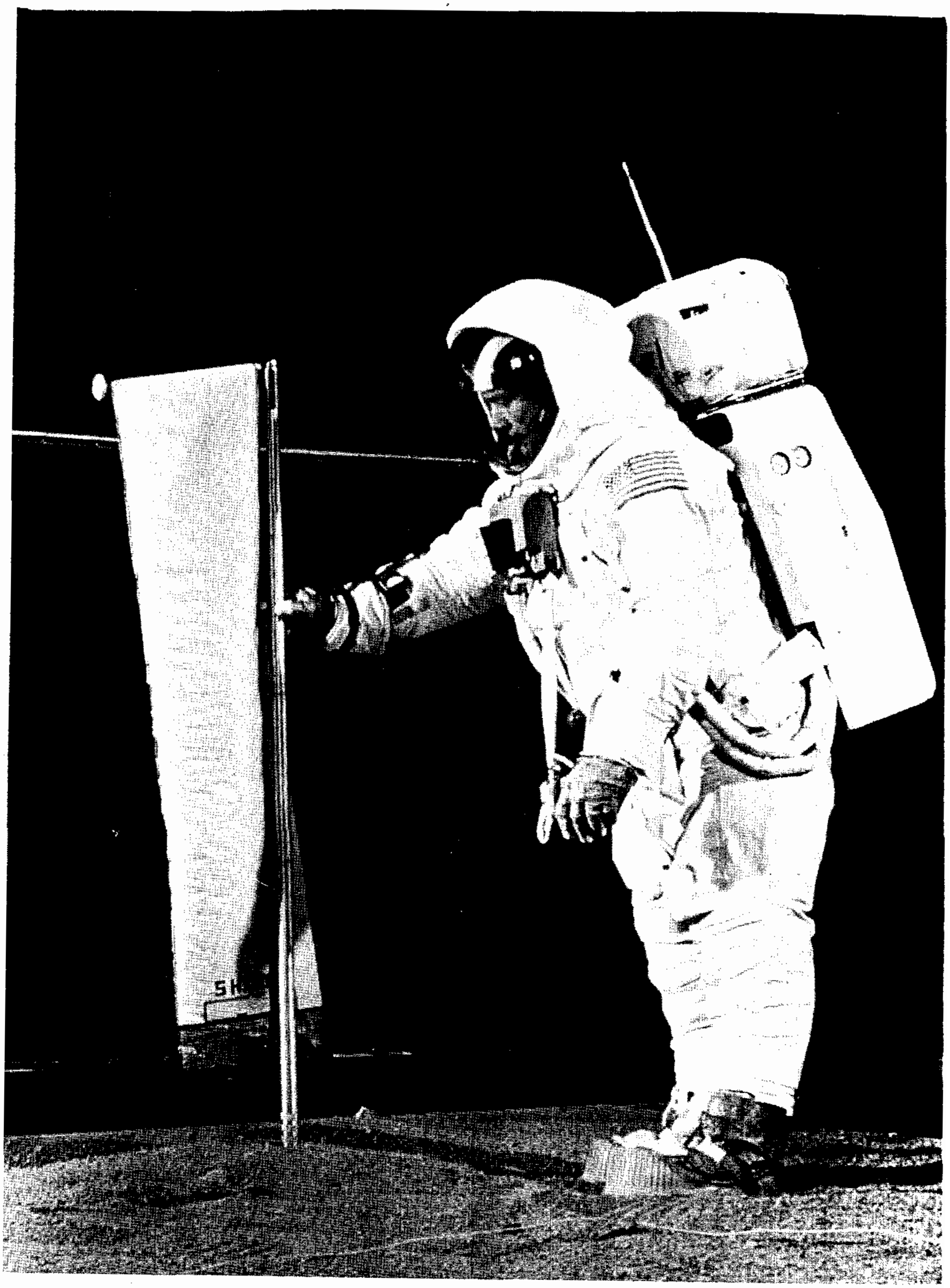
Fig. 21

REMOVAL OF STOWED TOOLS FROM MESA



PREPARATION OF HAND TOOL

Fig. 22



DEPLOYED SOLAR WIND COMPOSITION EXPERIMENT Fig. 23

Lunar Module Inspection

The LMP will begin the LM inspection and will be joined by the CDR after the Bulk Samples have been collected. The purpose of the LM inspection is to visually check and photographically document the external condition of the LM landing on the lunar surface. The inspection data will be used to verify the LM as a safe and effective vehicle for lunar landings. The data will also be used to gain more knowledge of the lunar surface characteristics. In general the results of the inspection will serve to advance the equipment design and the understanding of the environment in which it operates. The crewmen will methodically inspect and report the status of all external parts and surfaces of the LM which are visible to them. The still color photographs will supplement their visual documentation for postflight engineering analysis and design verification. They will observe and photograph the RCS effects on the LM, the interactions of the surface and footpads, and the DPS effects on the surface as well as the general condition of all quadrants and landing struts.

Early Apollo Scientific Experiments Package

When the crewmen reach the scientific equipment bay in Quad II, the LMP will open it and remove the Early Apollo Scientific Experiments Package (EASEP) using prerigged straps and pulleys as the CDR completes the LM inspection and photographically documents the LMP's activity. EASEP consists of two basic experiments: the Passive Seismic Experiment (PSE) and the Laser Ranging Retro-Reflector (LRRR). Both experiments are independent , self-contained packages weighing a total of about 170 pounds and occupying 12 cubic feet of space.

The PSE uses three long-period seismometers and one short-period vertical seismometer for measuring meteoroid impacts and moonquakes as well as to gather information on the moon's interior such as the existence of a core and mantle. The Passive Seismic Experiment Package (PSEP) has four basic subsystems: the structure/thermal subsystem provides shock, vibration, and thermal protection; the electrical power subsystem generates 34 to 46 watts by solar panel array; the data subsystem receives and decodes MSFN uplink commands and downlinks experiment data, handles power switching tasks; and the Passive Seismic Experiment subsystem measures lunar seismic activity with long-period and short-period seismometers which detect inertial mass displacement. Also included in this package are 15-watt radioisotope heaters to maintain the electronic package at a minimum of 60°F during the lunar night.

The LRRR experiment is a retro-reflector array with a folding support structure for aiming and aligning the array toward earth. The array is built of cubes of fused silica. Laser ranging beams from earth will be reflected back to their point of origin for precise measurement of earth-moon distances, center of moon's mass motion, lunar radius, earth geophysical information, and development of space communication technology.

Earth stations that will beam lasers to the LRRR include the McDonald Observatory at Fort Davis, Texas; the Lick Observatory in Mount Hamilton, California; and the Catalina Station of the University of Arizona. Scientists in other countries also plan to bounce laser beams off the LRRR.

In nominal deployment, as shown in Figures 24 through 26, the EASEP packages are removed individually from the storage receptacle and carried to the deployment site simultaneously. The crewmen will select a level site, nominally within ±15° of the LM -Y axis and at least 70 feet from the LM. The selection of the site is based on a compromise between a site which minimizes the effects of the LM ascent engine during liftoff, heat and contamination by dust and insulation debris (kapton) from the LM Descent Stage, and a convenient site near the scientific equipment bay.

Documented Sample Collection

After the astronauts deploy the EASEP, they will select, describe as necessary, and collect lunar samples, as shown in Figure 27, until they terminate the EVA. The Documented Sample will provide a more detailed and selective variety of lunar material than will be obtained from the Contingency and Bulk Samples. It will include a core sample collected with a drive tube provided in the Sample Return Container, a gas analysis sample collected by placing a representative sample of the lunar surface material in a special gas analysis container, lunar geologic samples, and descriptive photographic coverage of lunar topographic features.

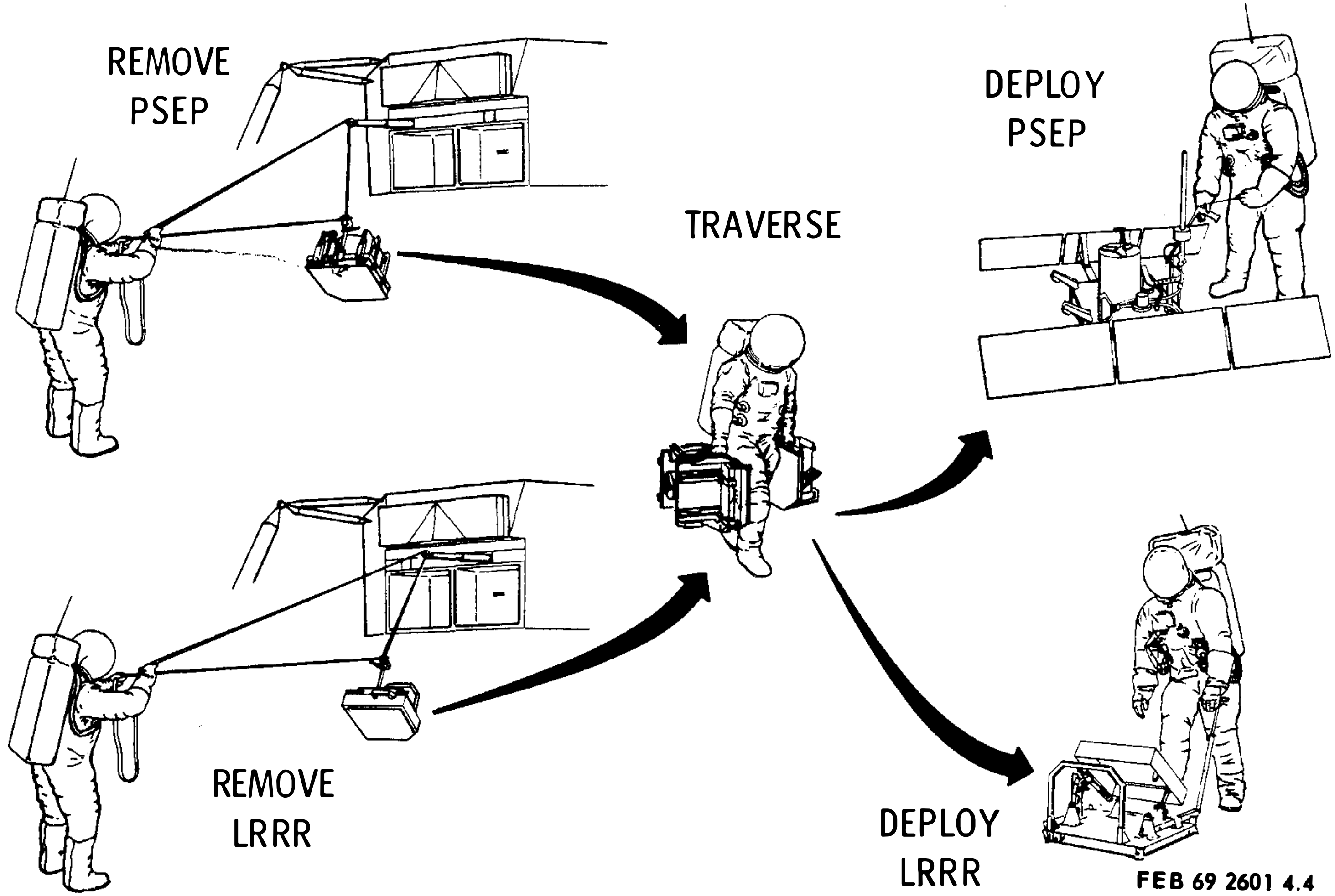
Samples will be collected using tools stored in the MESA and will be documented by photographs. Samples will be placed individually in prenumbered bags and the bags placed in the Sample Return Container.

Television and Photographic Coverage

The primary purpose of the TV is to provide a supplemental real-time data source to assure or enhance the scientific and operational data return. It may be an aid in determining the exact LM location on the lunar surface, in evaluating the EMU and man's capabilities in the lunar environment, and in documenting the sample collections. The TV will be useful in providing continuous observation for time correlation of crew activity with telemetered data, voice comments, and photographic coverage.

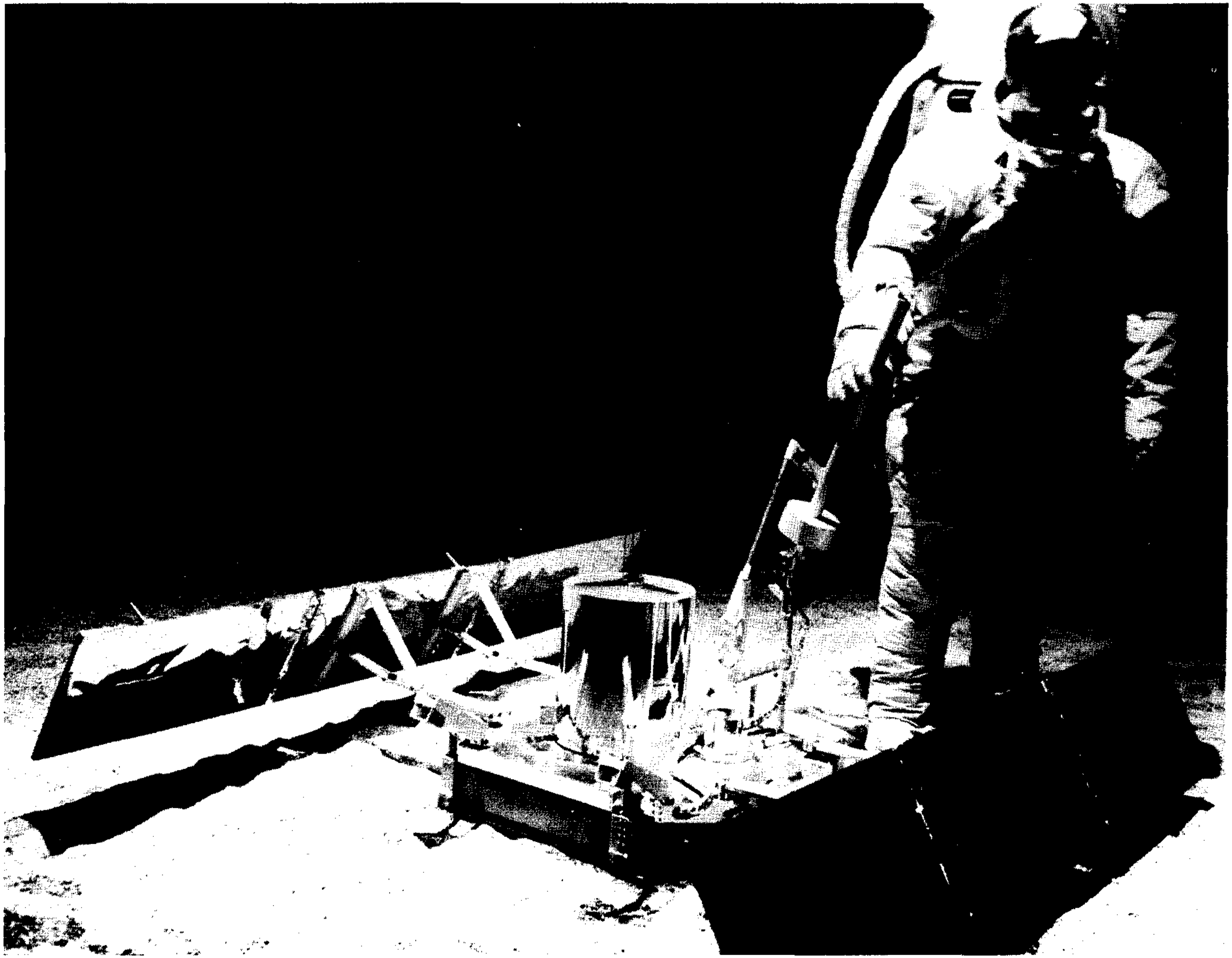
Photography consists of both still and sequence coverage using the Hasselblad camera, the Maurer data acquisition camera, and the Apollo Lunar Surface Close-Up Camera (ALSCC). The crewmen will use the Hasselblad extensively on the surface to document each major task which they accomplish. Additional photography, such as panoramas and scientific documentation, will supplement other data in the postflight analysis of the lunar environment and the astronauts'

EARLY APOLLO SCIENTIFIC EXPERIMENTS PACKAGE DEPLOYMENT

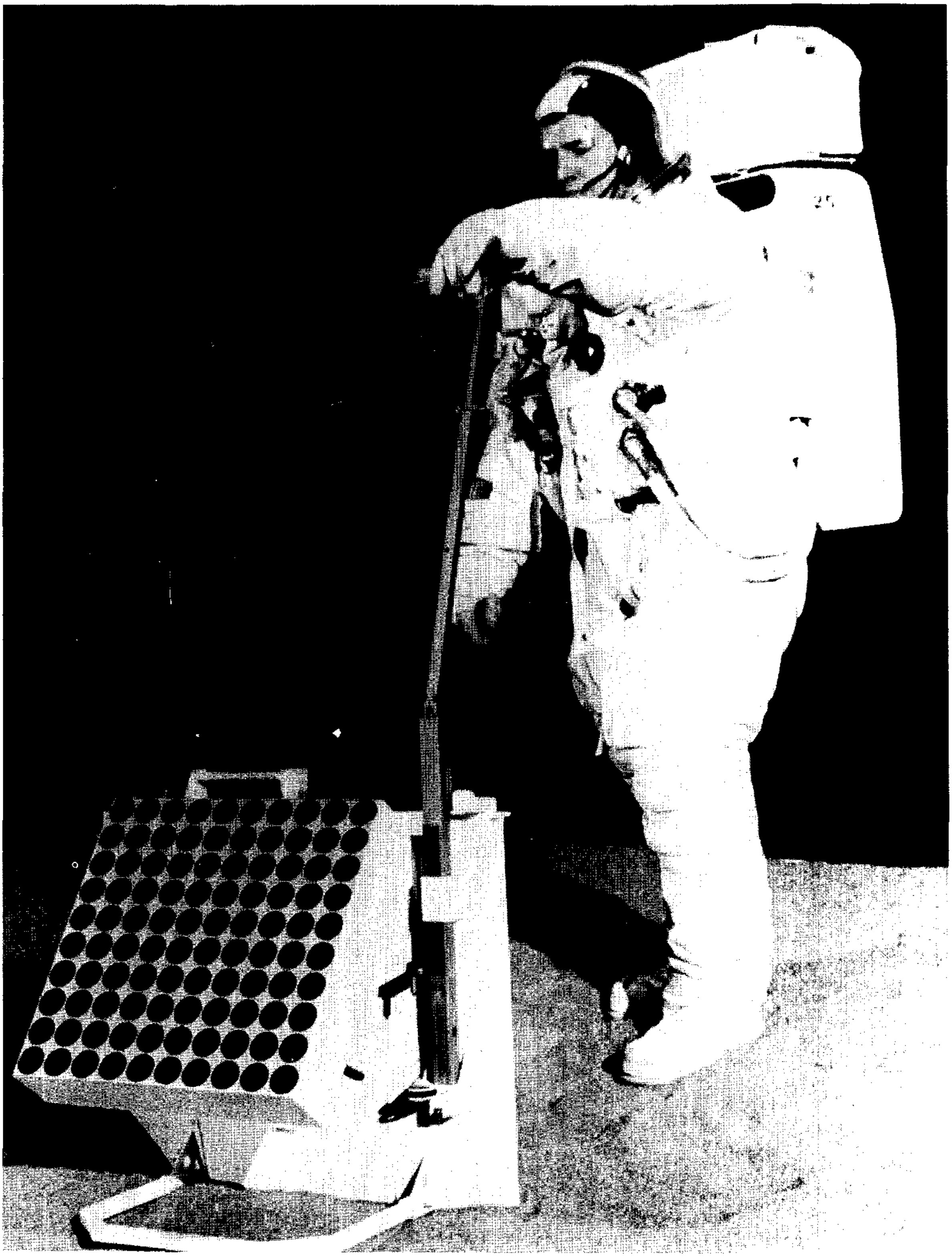


PSEP- PASSIVE SEISMIC EXPERIMENTS PACKAGE
LRRR= LASER RANGING RETRO REFLECTOR

Fig. 25



DEPLOYED PASSIVE SEISMIC EXPERIMENT



DEPLOYED LASER RANGING RETRO-REFLECTOR

Fig. 26

Fig. 27 DOCUMENTED SAMPLE COLLECTION

capabilities or limitations in conducting lunar surface operations. The ALSCC is a stereo camera and will be used for recording the fine textural details of the lunar surface material. The data acquisition camera (sequence camera) view from the LM Ascent Stage window will provide almost continuous coverage of the surface activity. The LMP, who remains inside the Ascent Stage for the first few minutes of the EVA, will use the sequence camera to document the CDR's initial surface activities. Then, before he egresses, the LMP will position the camera for optimum surface coverage while both crewmen are on the surface. After the first crewman (LMP) ingresses he can use the sequence camera to provide coverage of the remaining surface activity.

Extravehicular Activity Termination

The LMP will ingress before the SRC's are transferred to the LM. He will assist during the SRC transfer and will also make a LM systems check, change the sequence camera film magazine, and reposition the camera to cover the SRC transfer and the CDR's ladder ascent.

As each man begins his EVA termination he will clean the EMU. Although the crew will have a very limited capability to remove lunar material from their EMU's they will attempt to brush off any dust or particles from the portions of the suit which they can reach and from the boots on the footpad and ladder.

In the EVA termination there are two tasks that will require some increased effort. The first is the ascent from the footpad to the lowest ladder rung. In the unstroked position the vertical distance from the top of the footpad to the lowest ladder rung is 31 inches. In a nominal level landing this distance will be decreased only about 4 inches. Thus, unless the strut is stroked significantly the crewman is required to spring up using his legs and arms to best advantage to reach the bottom rung of the ladder from the footpad.

The second task will be the ingress or the crewmen's movement through the hatch opening to a standing position inside the LM. The hatch opening and the space inside the LM are small. Therefore, the crewmen must move slowly to prevent possible damage to their EMU's or to the exposed LM equipment.

After the crewmen enter the LM, they will jettison the equipment they no longer need. The items to be jettisoned are the used ECS canister and bracket, OPS brackets (adapters), and three armrests. The crewmen will then close the hatch and pressurize the LM. The EVA is considered to be terminated after the crewmen start this initial cabin pressurization. After the cabin pressure has stabilized, the crewmen will doff their PLSS's, connect to the LM ECS, and prepare to jettison more equipment they no longer need. The equipment, such as the PLSS's, lunar boots, and cameras, will be stowed in two containers. The LM will again be depressurized, the hatch opened, the containers jettisoned, and the cabin repressurized. Table 4 shows the loose equipment left on the lunar surface.

TABLE 4

LOOSE EQUIPMENT LEFT ON LUNAR SURFACE

During EVA

- TV equipment
  - camera
  - tripod
  - handle/cable assembly
  - MESA bracket
- Solar Wind Composition staff
- Apollo Lunar Handtools -
  - scoop
  - tongs
  - extension handle
  - hammer
  - gnomon
- Equipment stowed in Sample Return Containers (outbound) -
  - extra York mesh packing material
  - SWC bag (extra)
  - spring scale
  - unused small sample bags
  - two core tube bits
  - two SRC seal protectors
  - environmental sample containers O rings

- Apollo Lunar Surface Close-up Camera (film casette returned)
- Hasselblad EL Data Camera (magazine returned)

EVA termination

- Lunar equipment conveyor
- ECS canister and bracket
- OPS brackets
- Three armrests

Post-EVA equipment jettison

- Two Portable Life Support Systems
- Left hand side stowage compartment (with equipment - such as lunar boots - inside)
- One armrest

Following the EVA and post-EVA activities, there will be another rest period of 4 hours 40 minutes duration, prior to preparation for liftoff.

Command/Service Module Plane Change

The CSM will perform a plane change of 0.18° approximately 2.25 revolutions after LM touchdown. This maneuver will permit a nominally coplanar rendezvous by the LM.

Lunar Module Ascent to Docking

After completion of crew rest and ascent preparations, the LM Ascent Propulsion System (APS) and the LM RCS will be used for powered ascent, rendezvous, and docking with the CSM.

Powered ascent will be performed in two phases during a single continuous burn of the ascent engine. The first phase will be a vertical rise, as shown in Figure 28, required for the Ascent Stage to clear the lunar terrain. The second will be an orbital insertion maneuver which will place the LM in an orbit approximately 9 x 45 NM. Figure 29 shows the LM ascent through orbit insertion. Figure 30 shows the complete rendezvous maneuver sequence and the coverage capability of the rendezvous radar (RR) and the MSFN tracking. After insertion into orbit, the LM will compute and execute the coelliptic rendezvous sequence which nominally consists of four major maneuvers: concentric sequence initiation (CSI), constant delta height (CDH), terminal phase initiation (TPI), and terminal phase finalization (TPF). The CSI maneuver will be performed to establish the proper phasing conditions at CDH so that, after CDH is performed, TPI will occur at the desired time and elevation angle. CSI will nominally circularize the LM orbit 15 NM below that of the CSM. CSI is a posigrade maneuver that is scheduled to occur approximately at apolune. CDH nominally would be a small radial burn to make the LM orbit coelliptic with the orbit of the CSM. The CDH maneuver would be zero if both the CSM and LM orbits are perfectly circular at the time of CDH. The LM will maintain RR track attitude after CDH and continue to track the CSM. Meanwhile the CSM will maintain sextant/VHF ranging tracking of the LM. The TPI maneuver will be performed with the LM RCS thrusters approximately 38 minutes after CDH. Two midcourse corrections (MCC-1 and MCC-2) are scheduled between TPI and TPF, but are nominally zero. TPF braking will begin approximately 42 minutes after TPI and end with docking to complete approximately 3.5 hours of rendezvous activities. One lunar revolution, recently added to the flight plan, will allow LM housekeeping activities primarily associated with back contamination control procedures. Afterward, the LM crewmen will transfer to the CSM with the lunar samples and exposed film.

LUNAR MODULE VERTICAL RISE PHASE

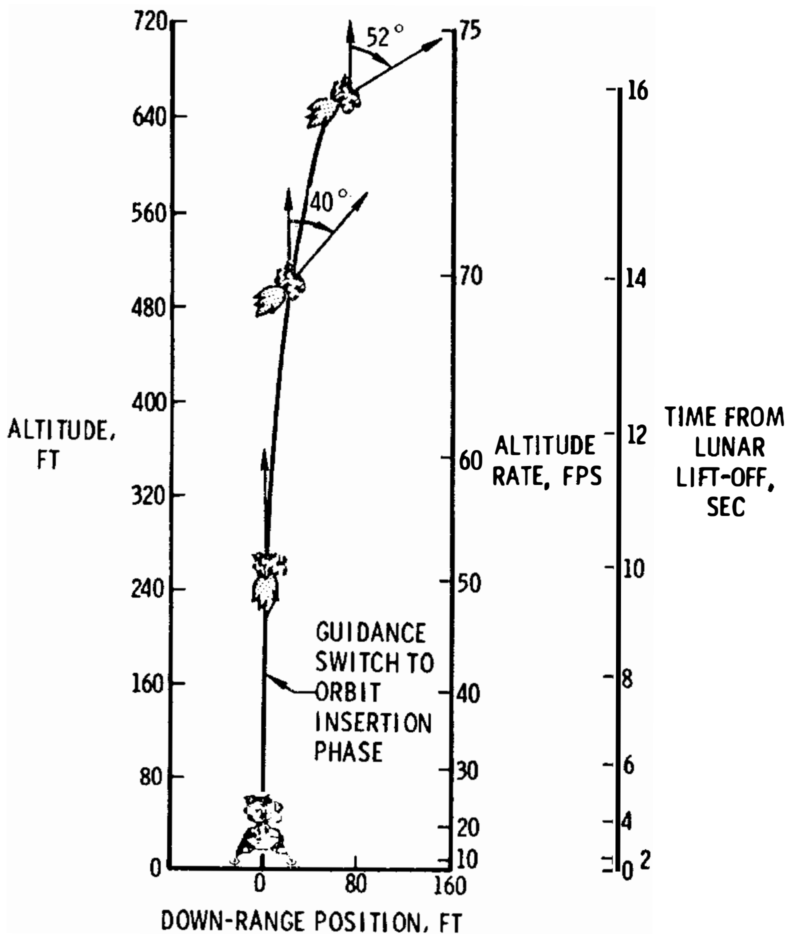
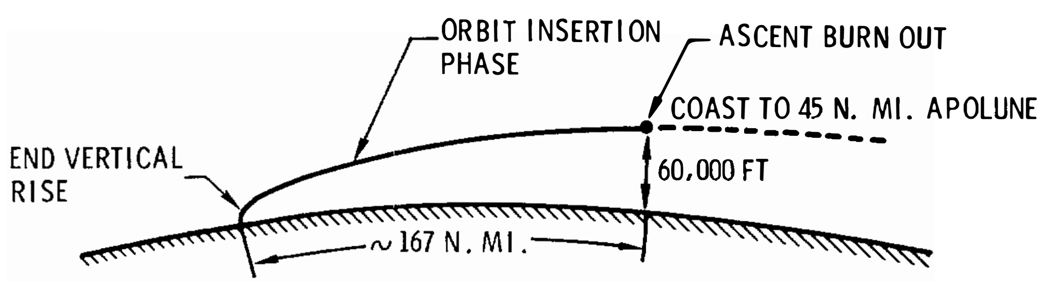


Fig. 28

ORBIT INSERTION PHASE



TOTAL ASCENT:
BURN TIME = 7:15 MIN:SEC
ΔV REQUIRED = 6,056 FPS
PROPELLANT REQUIRED = 4,980 LBS

Fig. 29

RENDEZVOUS MANEUVERS/RADAR COVERAGE

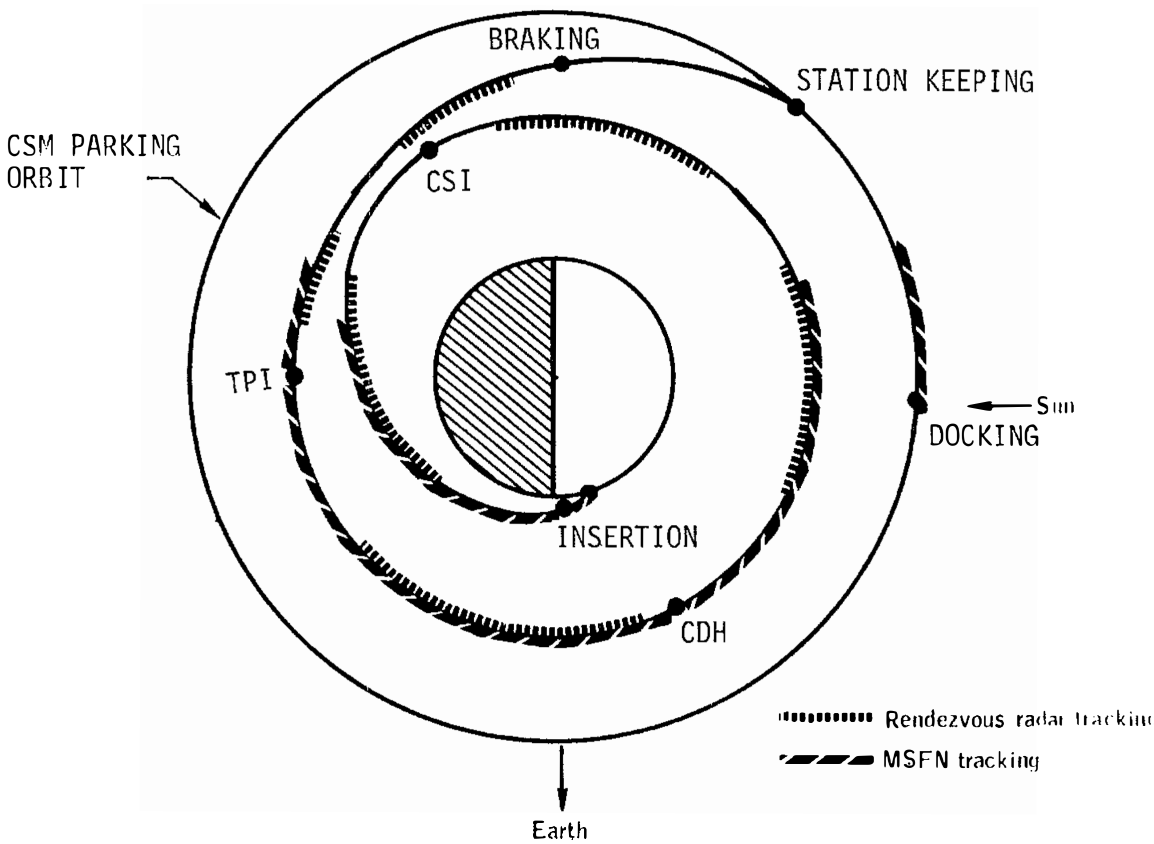


Fig. 30

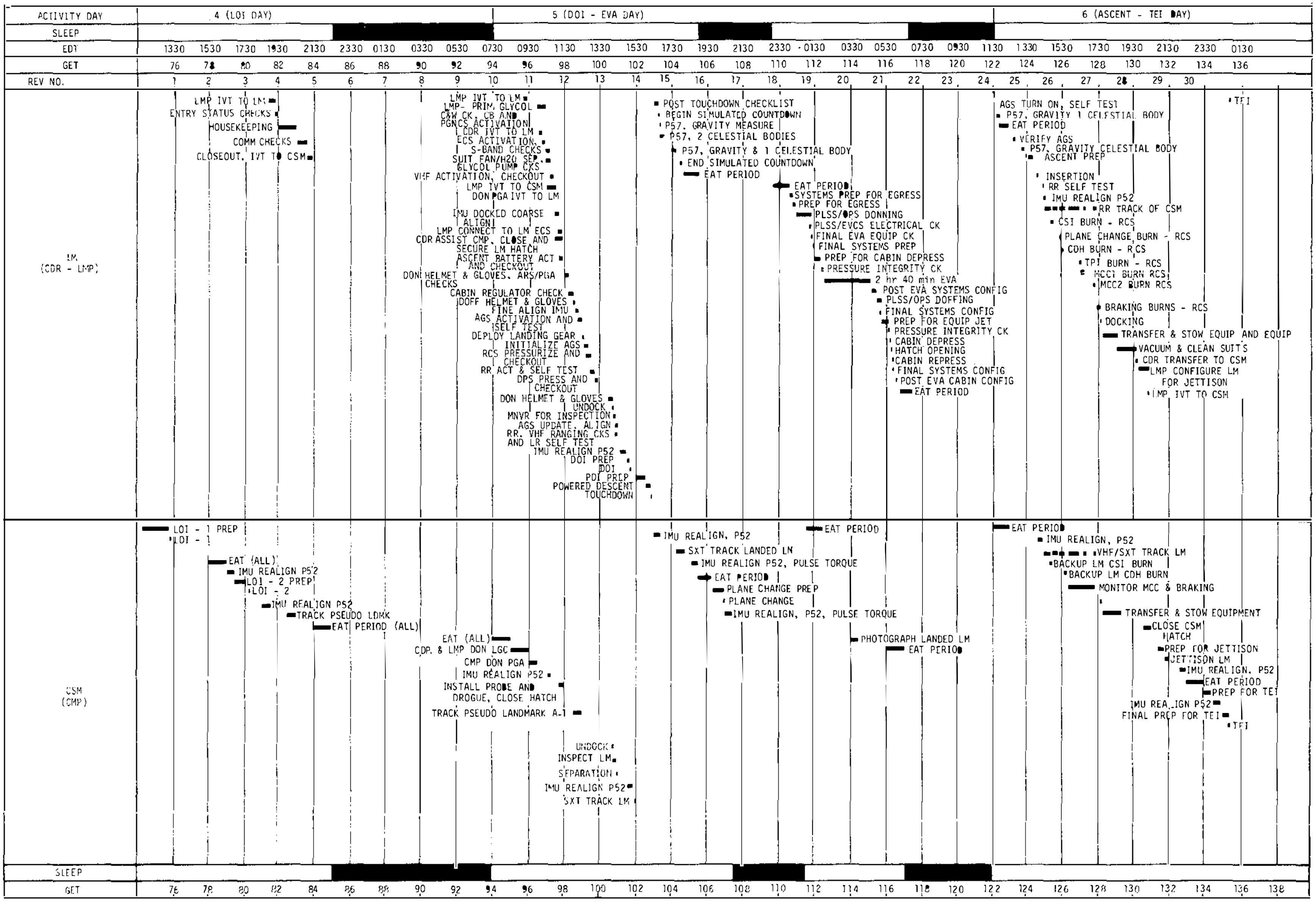
Lunar Module Jettison to Transearth Injection

Approximately 2 hours after hard docking, the CSM will jettison the LM and then separate from the LM by performing a 1-fps RCS maneuver. The crew will then eat, photograph targets of opportunity, and prepare for transearth injection (TEI). Figure 31 presents a summary of activities from lunar orbit insertion through transearth injection.

Transearth Injection

The burn will occur 59.5 hours after LOI-1 as the CSM crosses the antipode on the far side of the moon. The spacecraft configuration for transearth injection and transearth coast is shown in Figure 32.

LUNAR ACTIVITIES SUMMARY



Transearth Coast

During transearth coast, three midcourse correction (MCC) decision points have been defined, as shown in Figure 33. The maneuvers will be targeted for corridor control only and will be made at the following times if required:

MCC-5 - TEI plus 15 hours
MCC-6 - Entry interface (EI) minus 15 hours
MCC-7 - EI minus 3 hours.

TRANSEARTH CONFIGURATION

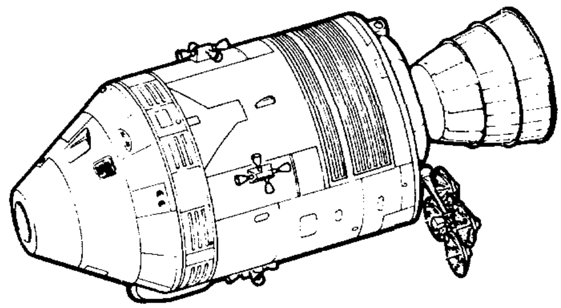


Fig. 32

These corrections will utilize the MSFN for navigation. In the transearth phase there will be continuous communications coverage from the time the spacecraft appears from behind the moon until about 1 minute prior to entry. The constraints influencing the spacecraft attitude timeline are thermal control, communications, crew rest cycle, and preferred times of MCC's. The attitude profile for the transearth phase is complicated by more severe fuel slosh problems than for the other phases of the mission.

Entry Through Landing

Prior to atmospheric entry, the final MCC will be made and the CM will be separated from the SM using the SM RCS. The spacecraft will reach entry interface (EI) at 400,000 feet, as shown in Figure 34, with a velocity of 36,194 fps. The S-band communication blackout will begin 18 seconds later followed by C-band communication blackout 28 seconds from EI. The rate of heating will reach a maximum 1 minute 10 seconds after EI. The spacecraft will exit from C-band blackout 3 minutes 4 seconds after entry and from S-band blackout 3 minutes 30 seconds after entry. Drogue parachute deployment will occur 8 minutes 19 seconds after entry at an altitude of 23,000 feet, followed by main parachute deployment at EI plus 9 minutes 7 seconds. Landing will occur approximately 14 minutes 2 seconds after and 1285 NM downrange from EI.

Landing will be in the Pacific Ocean at 172°W longitude, 11°N latitude and will occur approximately 8 days 3 hours after launch.

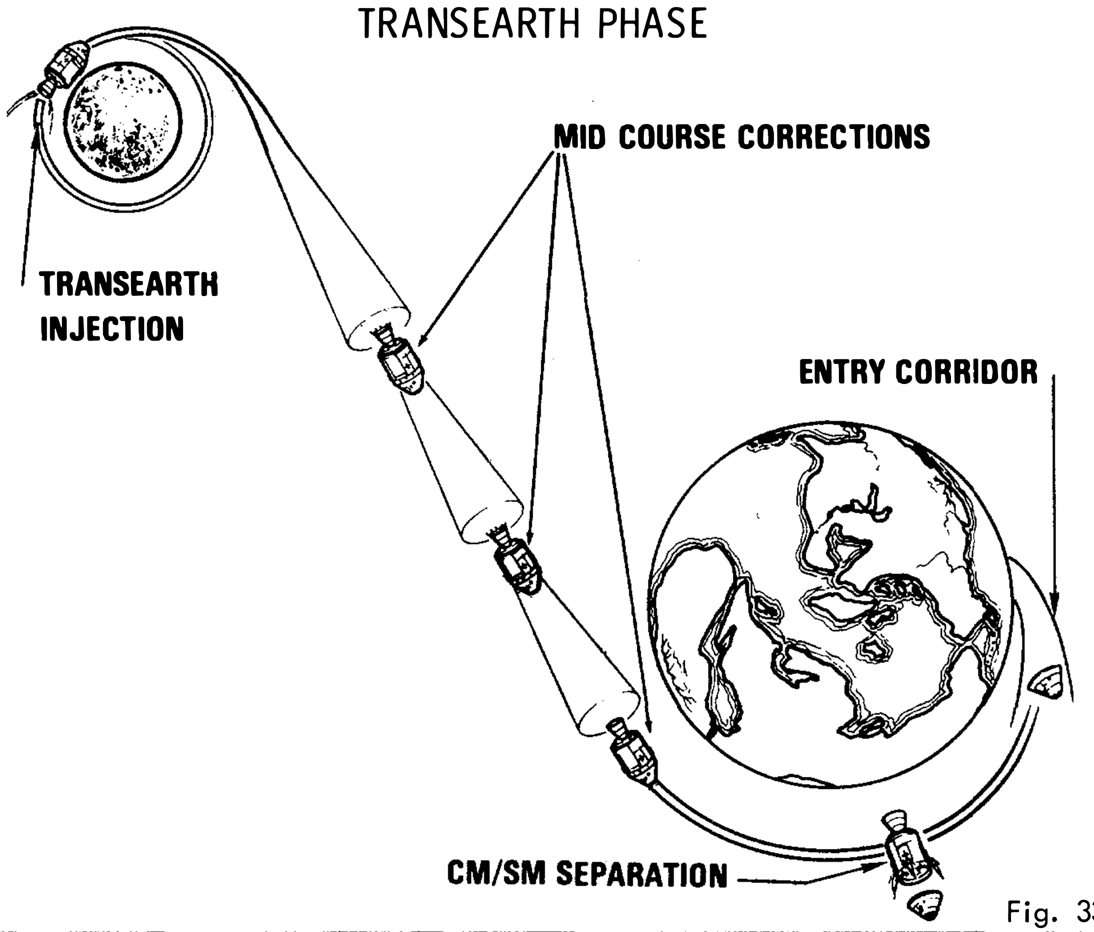

TRANSEARTH PHASE
MID COURSE CORRECTIONS
TRANSEARTH INJECTION
ENTRY CORRIDOR
CM/SM SEPARATION

Fig. 33

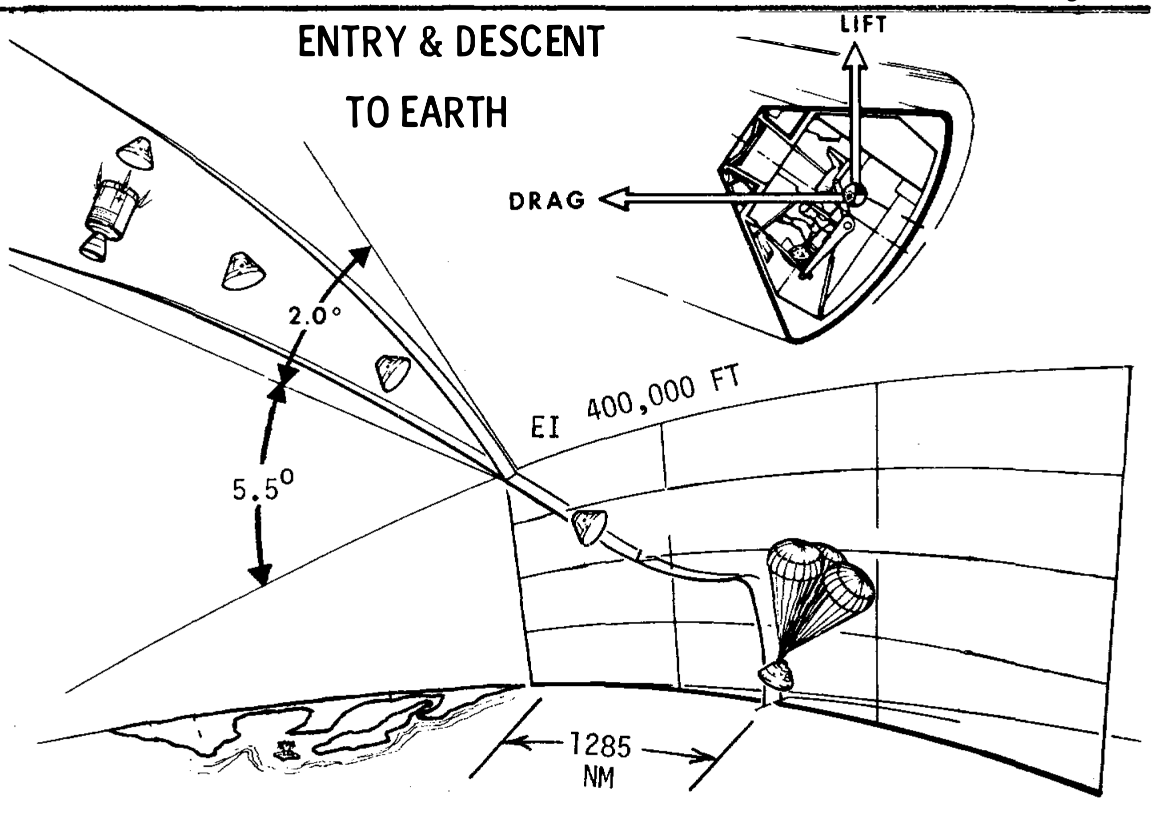

ENTRY & DESCENT TO EARTH
LIFT
DRAG
2.0°
5.5°
EI 400,000 FT
1285 NM

Fig. 34

Postlanding Operations

Following landing, the recovery helicopter will drop swimmers who will install the flotation collar to the CM. A large, 7-man liferaft will be deployed and attached to the flotation collar. Biological Isolation Garments (BIG's) will be lowered into the raft, and one swimmer will don a BIG while the astronauts don BIG's inside the CM. Two other swimmers will move upwind of the CM on a second large raft. The post-landing ventilation fan will be turned off, the CM will be powered down, and the astronauts will egress to the raft. The swimmer will then decontaminate all garments, the hatch area, and the collar.

The helicopter will recover the astronauts and the recovery physician riding in the helicopter will provide any required assistance. After landing on the recovery carrier, the helicopter will be towed to the hanger deck. The astronauts and the physician will then enter the Mobile Quarantine Facility (MQF). The flight crew, recovery physician and recovery technician will remain inside the MQF until it is delivered to the Lunar Receiving Laboratory (LRL) at the Manned Spacecraft Center (MSC) in Houston, Texas.

After flight crew pickup by the helicopter, the auxiliary recovery loop will be attached to the CM. The CM will be retrieved and placed in a dolly aboard the recovery ship. It will then be moved to the MQF and mated to the Transfer Tunnel. From inside the MQF/CM containment envelope, the MQF engineer will begin post-retrieval procedures (removal of lunar samples, data, equipment, etc.), passing the removed items through the decontamination lock. The CM will remain sealed during RCS deactivation and delivery to the LRL. The SRC, film, data, etc. will be flown to the nearest airport from the recovery ship for transport to MSC. The MQF and spacecraft will be off-loaded from the ship at Pearl Harbor and then transported by air to the LRL.

In order to minimize the risk of contamination of the earth's biosphere by lunar material, quarantine measures will be enforced. The crew will be quarantined for approximately 21 days after liftoff from the lunar surface. In addition, the CM will be quarantined after landing. Termination of the CM quarantine period will be dependent on the results of the lunar sample analysis and observations of the crew.

BACK CONTAMINATION PROGRAM

The Apollo Back Contamination Program can be divided into three phases, as shown in Figure 35. The first phase covers the procedures which are followed by the crew while in flight to minimize the return of lunar surface contaminants in the Command Module.

The second phase includes spacecraft and crew recovery and the provisions for isolation and transport of the crew, spacecraft, and lunar samples to the Manned Spacecraft Center. The third phase encompasses the quarantine operations and preliminary sample analysis in the Lunar Receiving Laboratory (LRL).

A primary step in preventing back contamination is careful attention to spacecraft cleanliness following lunar surface operations. This includes use of special cleaning equipment, stowage provisions for lunar-exposed equipment, and crew procedures for proper "housekeeping."

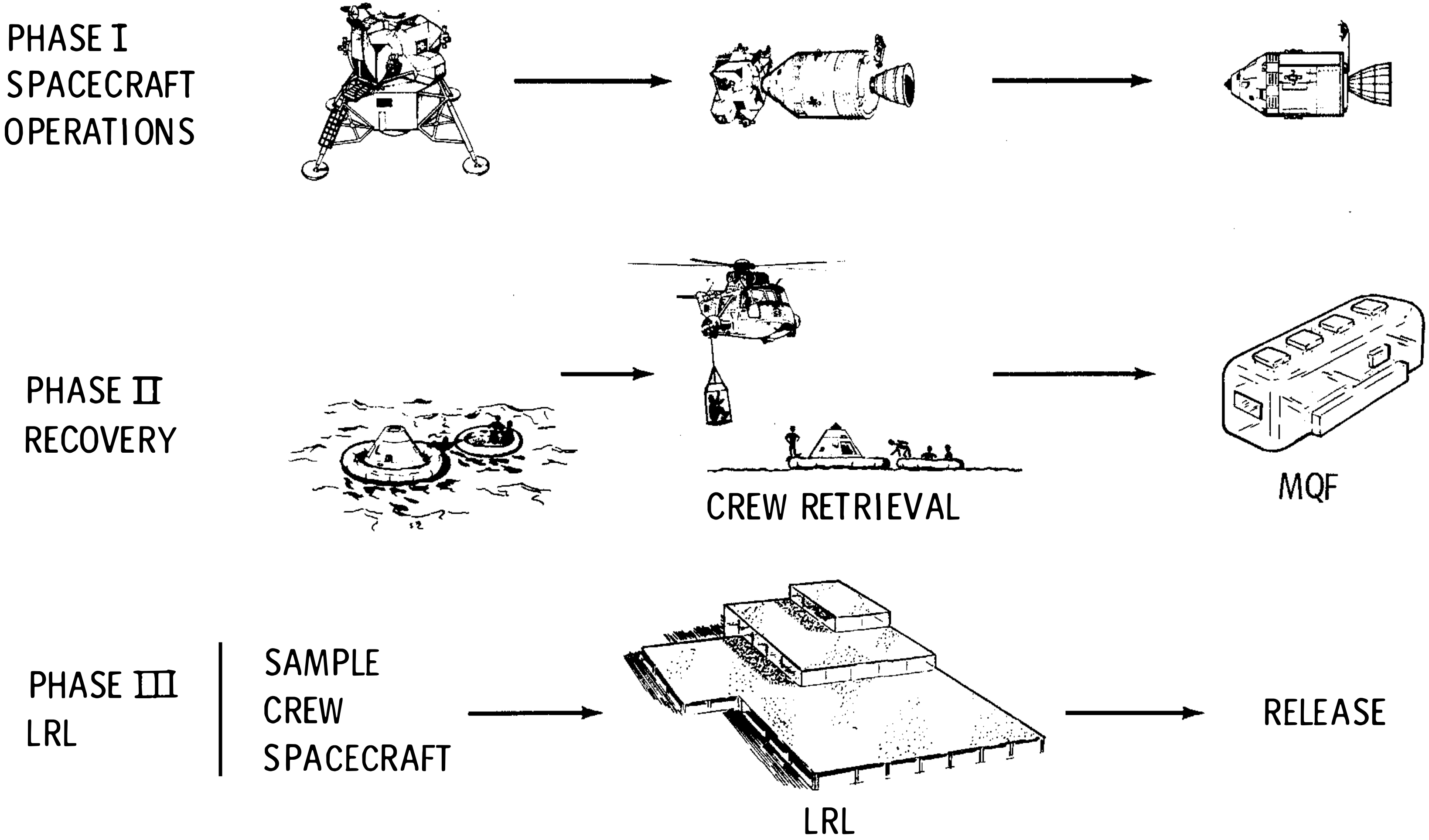
LUNAR MODULE OPERATIONS

The Lunar Module (LM) has been designed with a bacterial filter system to prevent contamination of the lunar surface when the cabin atmosphere is released at the start of lunar exploration. Prior to reentering the LM after lunar surface exploration, the crewmen will brush any lunar surface dust or dirt from the space suit using the suit gloves. They will scrape their overboots on the LM footpad and while ascending the LM ladder dislodge any clinging particles by a kicking action.. After entering the LM and pressurizing the cabin, the crew will doff their Portable Life Support System, Oxygen Purge System, lunar boots, EVA gloves, etc. The equipment to be jettisoned will be assembled and bagged to be subsequently left on the lunar surface. The lunar boots, likely the most contaminated items, will be placed in a bag as early as possible to minimize the spread of lunar particles. Following LM rendezvous and docking with the Command Module (CM), the CM tunnel will be pressurized and checks made to insure that an adequate pressurized seal has been made. During this period, the LM, space suits, and lunar surface equipment will be vacuumed. To accomplish this, one additional lunar orbit has been added to the mission.

The LM cabin atmosphere will be circulated through the Environmental Control System (ECS) suit circuit lithium hydroxide canister to filter particles from the atmosphere. A minimum of 5 hours of weightless operation and filtering will reduce the original airborne contamination to about 10^{-15} percent.

To prevent dust particles from being transferred from the LM atmosphere to the CM, a constant flow of 0.8 lb/hr oxygen will be initiated in the CM at the start of combined LM/CM operation. Oxygen will flow from the CM into the LM then overboard through the LM cabin relief valve or through spacecraft leakage. Since the flow of gas is always from the CM to the LM, diffusion and flow of dust contamination into the CM will be minimized. After this positive gas flow has been established from the CM, the tunnel hatch will be removed.

APOLLO BACK CONTAMINATION PROGRAM



The CM Pilot will transfer the lunar surface equipment stowage bags into the LM one at a time. The equipment transferred will then be bagged using the "buddy system" and transferred back into the CM where the equipment will be stowed. The only equipment that will not be bagged at this time are the crewmen's space suits and flight logs.

Following the transfer of the LM crew and equipment, the spacecraft will be separated and the three crewmen will start the return to earth. The separated LM contains the remainder of the lunar exposed equipment.

COMMAND MODULE OPERATIONS

Through the use of operational and housekeeping procedures the CM cabin will be purged of lunar surface and/or other particulate contamination prior to earth atmosphere entry. These procedures start while the LM is docked with the CM and continue through entry into the earth's atmosphere.

The LM crewmen will doff their space suits immediately upon separation of the LM and CM. The space suits will be stowed and will not be used again during the transearth phase unless an emergency occurs.

Specific periods for cleaning the spacecraft using the vacuum brush have been established. Visible liquids will be removed by the liquid dump system. Towels will be used by the crew to wipe surfaces clean of liquids and dirt particles. The three ECS suit hoses will be located at random positions around the spacecraft to insure positive ventilation, cabin atmosphere filtration, and avoid partitioning. During the transearth phase, the CM atmosphere will be continually filtered through the ECS lithium hydroxide canister. After about 63 hours operation, essentially none (10^{-90} percent) of the original contaminates will remain.

RECOVERY OPERATIONS

Following landing and the attachment of the flotation collar to the CM, the swimmer in a Biological Isolation Garment (BIG) will open the spacecraft hatch, pass three BIG's into the spacecraft, and close the hatch.

The crew will don the BIG's and then egress into the liferaft. The hatch will be closed immediately after egress. Tests have shown that the crew can don their BIG's in less than 5 minutes under ideal sea conditions. The spacecraft hatch will be open only for a few minutes. The spacecraft and crew will be decontaminated by the swimmer using a liquid agent. Crew retrieval will be accomplished by helicopter transport to the carrier. Subsequently, the crew will transfer to the Mobile Quarantine Facility. The spacecraft will be retrieved by the aircraft carrier.

BIOLOGICAL ISOLATION GARMENT

The BIG's will be donned in the CM just prior to egress and helicopter pickup and will be worn until the crew enters the Mobile Quarantine Facility aboard the primary recovery ship.

The suit is fabricated of a light weight cloth fabric which completely covers the wearer and serves as a biological barrier. Built into the hood area is a face mask with a plastic visor, air inlet flapper valve, and an air outlet biological filter.

Two types of BIG's are used in the recovery operation. One is worn by the recovery swimmer. In this type garment, the inflow air (inspired) is filtered by a biological filter to preclude possible contamination of support personnel. The second type is worn by the astronauts. The inflow gas is not filtered, but the outflow gas (respired) is passed through a biological filter to preclude contamination of the air.

MOBILE QUARANTINE FACILITY

The Mobile Quarantine Facility (MQF) is equipped to house six people for a period up to 10 days. The interior is divided into three sections — lounge area, galley, and sleep/bath area. The facility is powered through several systems to interface with various ships, aircraft, and transportation vehicles. The shell is air and water tight. The principal method of assuring quarantine is to filter effluent air and provide a negative pressure differential for biological containment in the event of leaks.

Non-fecal liquids from the trailer are chemically treated and stored in special containers. Fecal wastes will be contained until after the quarantine period. Items are passed in or out of the MQF through a submersible transfer lock. A complete communications system is provided for intercom and external communications to land bases from ship or aircraft. Emergency alarms are provided for oxygen alerts while in transport by aircraft, for fire, loss of power, and loss of negative pressure.

Specially packaged and controlled meals will be passed into the facility where they will be prepared in a microwave oven. Medical equipment to complete immediate postlanding crew examination and tests are provided.

LUNAR RECEIVING LABORATORY

The final phase of the Back Contamination Program is completed in the Manned Spacecraft Center Lunar Receiving Laboratory (LRL). The crew and spacecraft are quarantined for a minimum of 21 days after lunar liftoff and are released based upon the completion of prescribed test requirements and results. During this time the CM will be disinfected. The lunar samples will be quarantined for a period of 50 to 80 days depending upon the results of extensive biological tests. The LRL serves four basic purposes:

- The quarantine of the lunar mission crew and spacecraft, the containment of lunar and lunar-exposed materials, and quarantine testing to search for adverse effects of lunar material upon terrestrial life.

- The preservation and protection of the lunar samples.

- The performance of time-critical investigation.

- The preliminary examination of returned samples to assist in an intelligent distribution of samples to principal investigators.

The LRL has a vacuum system with manually operated space gloves leading directly into a vacuum chamber at pressures of 10^{-7} torr (mm of mercury). It has a low-level counting facility with a background count an order of magnitude better than other known counters. Additionally, it is a facility that can handle cabinets to contain extremely hazardous pathogenic material.

The LRL covers 83,000 square feet of floor space and includes several distinct areas. These are the Crew Reception Area (CRA), Vacuum Laboratory, Sample Laboratories (Physical and Bioscience), and an administrative and support area. Special building systems are employed to maintain air flow into sample handling areas and the CRA to sterilize liquid waste and to incinerate contamination air from the primary containment systems.

The CRA provides biological containment for the flight crew and 12 support personnel. The nominal occupancy is about 14 days but the facility is designed and equipped to operate for considerably longer if necessary.

The biomedical laboratories provide for the required quarantine tests to determine the effect of lunar samples on terrestrial life. These tests are designed to provide data upon which to base the decision to release lunar material from quarantine.

Among the tests:

A. Germ-free mice will be exposed to lunar materials and observed continuously for 21 days for any abnormal changes. Periodically, groups will be sacrificed for pathologic observation.

B. Lunar material will be applied to 12 different culture media and maintained under several environmental conditions. The media will then be observed for bacterial or fungal growth. Detailed inventories of the microbiol flora of the spacecraft and crew have been maintained so that any living material found in the sample testing can be compared against this list of potential contaminants taken to the moon by the crew or spacecraft.

C. Six types of human and animal tissue culture cells will be maintained in the laboratory and, together with embryonated eggs, will be exposed to the lunar material. Based on cellular and/or other changes, the presence of viral material can be established so that special tests can be conducted to identify and isolate the type of virus present.

D. Thirty-three species of plants and seedlings will be exposed to lunar material. Seed germination, growth of plant cells, or the health of seedlings will then be observed, and histological, microbiological, and biochemical techniques will be used to determine the cause of any suspected abnormality.

E. A number of lower animals will be exposed to lunar material. These specimens include fish, birds, oysters, shrimp, cockroaches, houseflies, planaria, paramecia, and euglena. If abnormalities are noted, further tests will be conducted to determine if the condition is transmissible from one group to another.

STERILIZATION AND RELEASE OF THE SPACECRAFT

Postflight testing and inspection of the spacecraft is presently limited to investigation of anomalies which happened during the flight. Generally, this entails some specific testing of the spacecraft and removal of certain components of systems for further analysis. The timing of postflight testing is important so that corrective action may be taken for subsequent flights.

The schedule calls for the spacecraft to be returned to port where a team will deactivate pyrotechnics, flush and drain fluid systems (except water). This operation will be confined to the exterior of the spacecraft. The spacecraft will then be flown to the LRL and placed in a special room for storage, sterilization, and postflight checkout.

CONTINGENCY OPERATIONS

GENERAL

If an anomaly occurs after liftoff that would prevent the space vehicle from following its nominal flight plan, an abort or an alternate mission will be initiated. Aborts will provide for an acceptable flight crew and CM recovery while alternate missions will attempt to maximize the accomplishment of mission objectives as well as providing for an acceptable flight crew and CM recovery. Figure 36 shows the Apollo 11 contingency options.

ABORTS

The following sections describe the abort procedures that may be used to return the CM to earth safely following emergencies that would prevent the space vehicle from following its normal flight plan. The abort descriptions are presented in the order of mission phase in which they could occur.

Launch

There are six launch abort modes. The first three would result in the termination of the launch sequence and a CM landing in the launch abort areas.

Mode I - The Mode 1 abort procedure is designed for safe recovery of the CM following an abort initiated between Launch Escape System arming and Launch Escape Tower jettison. The procedure would consist of the Launch Escape Tower pulling the CM off the launch vehicle and propelling it a safe distance downrange. The resulting landing point would lie between the launch site and approximately 520 NM downrange.

Mode II - The Mode II abort could be performed from the time the Launch Escape Tower is jettisoned early during second-stage burn until the full-lift CM landing point reaches 3200 NM downrange. The procedure would consist of separating the CSM from the launch vehicle, separating the CM from the SM, and then letting the CM free fall to entry. The entry would be a full-lift, or maximum range trajectory, with a landing on the ground track between 440 and 3200 NM downrange.

Mode III - The Mode III abort procedure could be performed from the time the full-lift CM landing range reaches 3200 NM downrange until orbital insertion is achieved. The procedure would consist of separating the CSM from the launch vehicle and then, if necessary, performing a retrograde burn with the SPS so that the half-lift CM landing point is no farther than 3350 NM downrange. Since a half-lift entry would be flown, the CM landing point would be approximately 70° NM south of the ground track between 3000 and 3350 NM downrange.

APOLLO 11 NOMINAL MISSION EVENTS AND CONTINGENCY OPTIONS

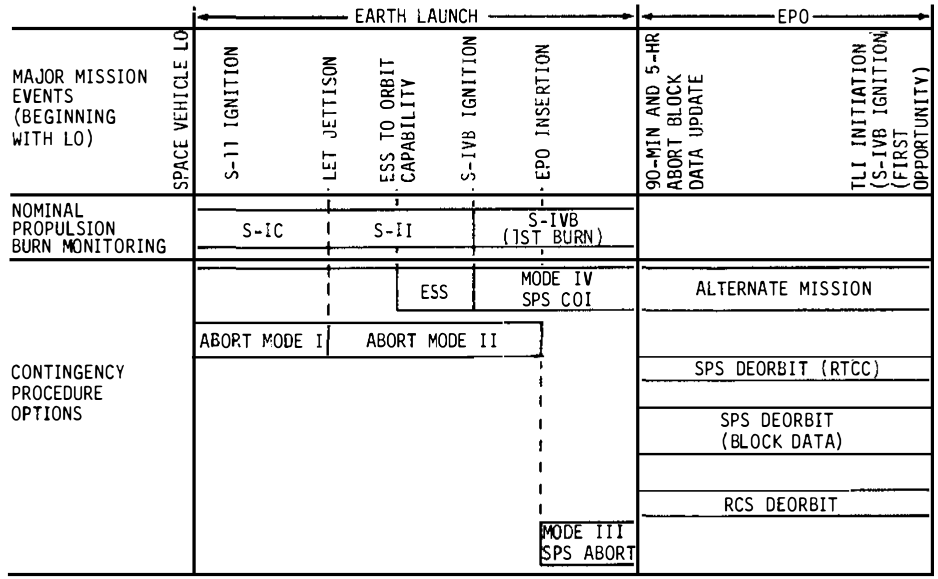


Fig. 36

APOLLO 11 NOMINAL MISSION EVENTS AND CONTINGENCY OPTIONS (CONTINUED)

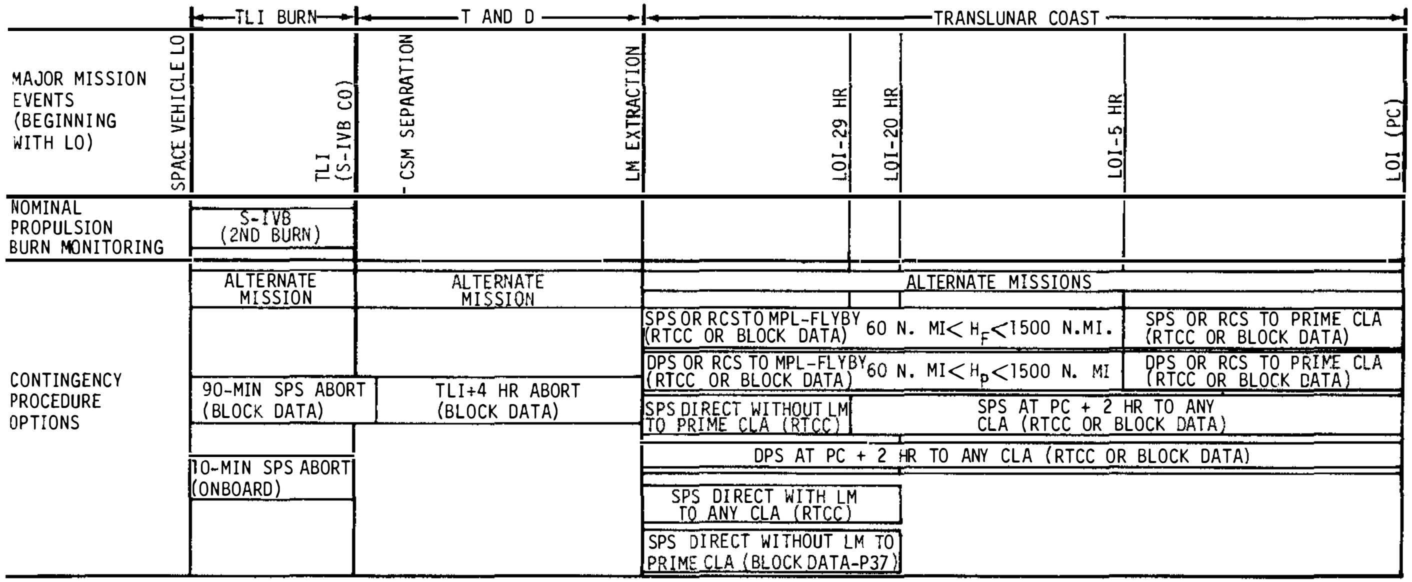


Fig. 36(continued)

APOLLO 11 NOMINAL MISSION EVENTS AND CONTINGENCY OPTIONS (CONTINUED)

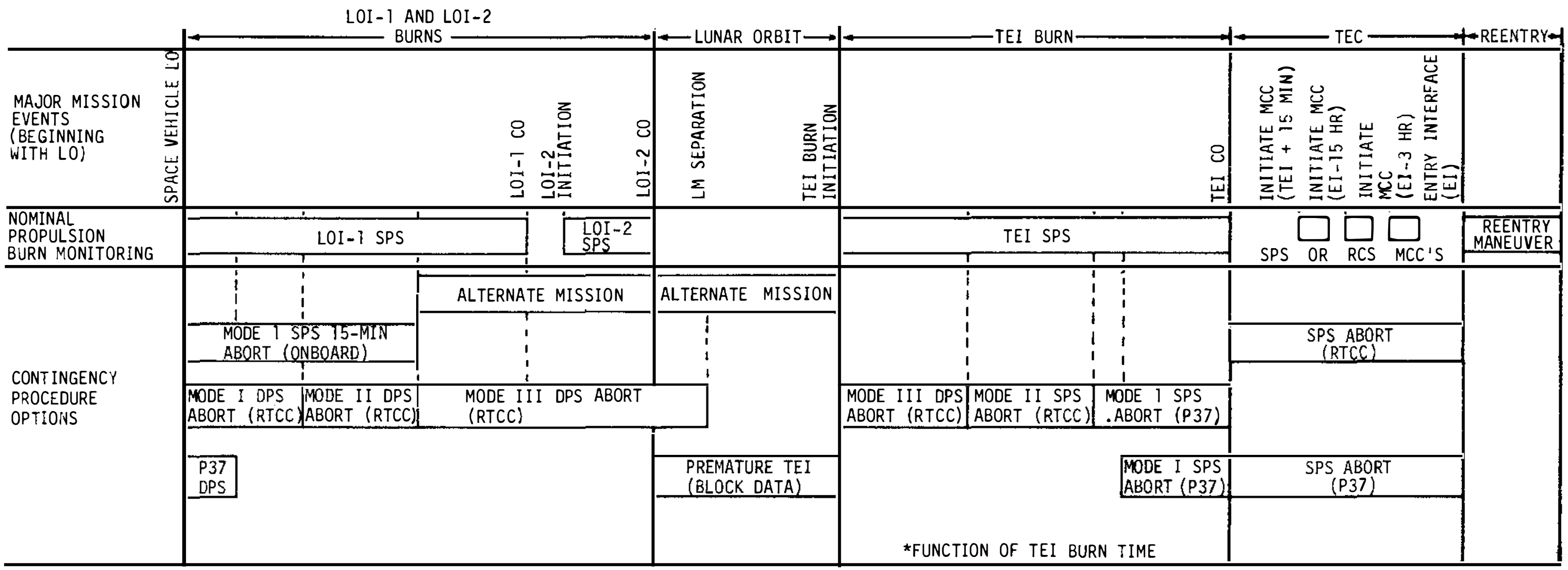


Fig. 36(continued)

M-932-69-11

These three descriptions are based on aborts initiated from the nominal launch trajectory. Aborts from a dispersed trajectory will consist of the same procedures, but the times at which the various modes become possible and the resultant landing points may vary.

The following launch abort procedures are essentially alternate launch procedures and result in insertion of the spacecraft into a safe earth orbit. These procedures would be used in preference to Modes II and III above unless immediate return to earth is necessary during the launch phase.

Mode IV and Apogee Kick - The Mode IV abort procedure is an abort to earth parking orbit and could be performed any time after the SPS has the capability to insert the CSM into orbit. This capability begins approximately 8 minutes 30 seconds GET. The procedure consists of separating the CSM from the launch vehicle and, shortly afterwards, performing a posigrade SPS burn to insert the CSM into earth orbit. This means that any time during the S-IVB burn portion of the launch phase the CSM has the capability to insert itself into orbit if the S-IVB should fail. Apogee kick is a variation of the Mode IV abort wherein the SPS burn to orbit would be performed at, or near, the first spacecraft apogee. The main difference between the two is the time at which the posigrade SPS burn is performed.

S-IVB Early Staging - Under normal conditions, the S-IVB is inserted into orbit with enough fuel to perform the TLI maneuver. This capability can be used, if necessary, during the launch phase to insure that the spacecraft is inserted into a safe parking orbit. After approximately 6 minutes 30 seconds GET, the S-IVB has the capability to be staged early and achieve orbit. The CSM/LM could then remain in earth orbit to carry out an alternate mission, or, if necessary, return to the West Atlantic Ocean after one revolution.

S-IVB Early Staging to Mode IV - Should it become necessary to separate from a malfunctioning S-II stage, the S-IVB could impart sufficient velocity and altitude to the CSM to allow the SPS to be used to place the CSM into an acceptable earth orbit. The procedure is a combination of S-IVB early staging and Mode IV procedures. This means that at any time after 5 minutes 30 seconds GET the S-IVB/SPS combination may be utilized to boost the CSM into a safe earth orbit.

Earth Parking Orbit

Once the S-IVB/CSM is safely inserted into earth parking orbit, a return-to-earth abort would be performed by separating the CSM from the S-IVB and then utilizing the SPS for a retrograde burn to place the CM on an atmosphere-intersecting trajectory. After entry, the CM would be guided to a preselected target point, if available. This procedure would be similar to the deorbit and entry procedure performed on the Apollo 7 and Apollo 9 flights.

Translunar Injection

Ten-Minute Abort — There is only a remote possibility that an immediate return-to-earth will become necessary during the relatively short period of the TLI maneuver. However, if it should become necessary the S-IVB burn would be cut off early and the crew would initiate an onboard-calculated retrograde SPS abort burn. The SPS burn would be performed approximately 10 minutes after TLI cutoff and would ensure a safe CM entry. The elapsed time from abort initiation to landing would vary from approximately 20 minutes to 5 hours, depending on the length of the TLI maneuver performed prior to S-IVB cutoff. For aborts initiated during the latter portion of TLI, a second SPS burn called a midcourse correction would be necessary to correct for dispersed entry conditions. Since this abort would be used only in extreme emergencies with respect to crew survival, the landing point would not be considered in executing the abort. No meaningful landing point predictions can be made because of the multiple variables involved including launch azimuth, location of TLI, the duration of the TLI burn prior to cutoff, and execution errors of the abort maneuvers.

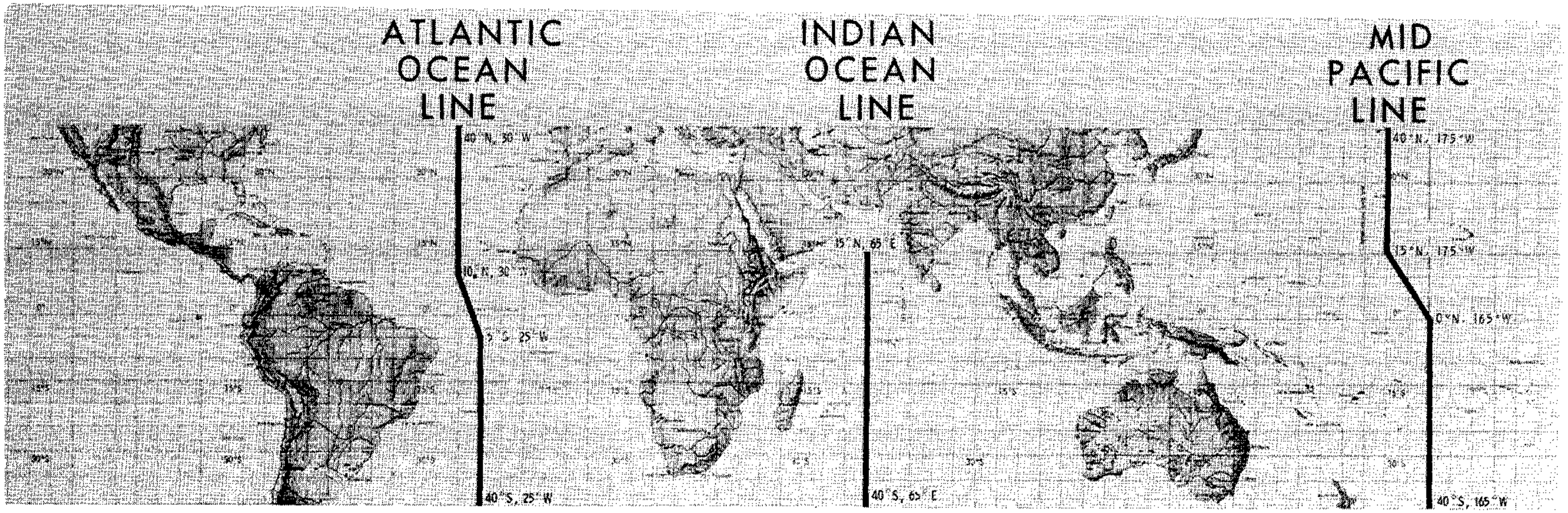
Ninety-Minute Abort — A more probable situation than the previous case is that the TLI maneuver would be completed and then the crew would begin checking any malfunctions that may have been evident during the burn. If, after the check, it becomes apparent that it is necessary to return to earth, an abort would be initiated at approximately TLI cutoff plus 90 minutes. Unlike the previous procedure, this abort would be targeted to a preselected landing location called a recovery line. There are three recovery lines spaced around the earth as shown in Figure 37. This abort would be targeted to either the Mid-Pacific or the Atlantic Ocean recovery line. The abort maneuver would be a retrograde SPS burn followed by a midcourse correction, if necessary, to provide the proper CM entry conditions.

Translunar Coast

The CSM/LM will be in the translunar coast phase of the mission for approximately 3 days. The abort procedure during this time would be similar to the 90-minute abort. Abort information specifying a combination of SPS burn time and CSM attitude would be sent to the crew to be performed at a specific time. The longitude of the landing is determined by the time of abort and the abort trajectory. Therefore, fixed times of abort that will result in a landing on the Mid-Pacific recovery line will be selected during translunar coast. Because of the earth's rotation, a landing on the Mid-Pacific line can be accomplished only during one time interval for each 24-hour period. For this reason, a time critical situation may dictate targeting the abort to one of the other two recovery lines in order to minimize the elapsed time from abort to landing. The order of priority for the recovery lines is: (1) Mid-Pacific line, (2) Atlantic Ocean line, and (3) Indian Ocean line. Although the longitudes of the recovery lines are different, the latitude of landing will remain at approximately the latitude at which TLI occurred.

Fig. 37

RECOVERY LINES



As the distance between the spacecraft and the moon decreases, the capability for return to earth increases. This continues until some time after the spacecraft reaches the moon's sphere of influence (basically, the point in the trajectory where the moon's influence on the spacecraft equals that of the earth) after which the return to earth becomes less for a circumlunar abort than for a direct return-to-earth abort.

Lunar Orbit Insertion

Should early termination of the LOI burn occur, the resulting abort procedure would be one of three modes classified according to length of burn before termination. Each abort mode would normally result in return of the CM to the Mid-Pacific recovery line. These modes are briefly discussed below.

Mode I - The Mode I procedure would be used for aborts following SPS cutoffs from ignition to approximately 1.5 minutes into the LOI burn. This procedure would consist of performing a posigrade DPS burn approximately 2 hours after cutoff to put the spacecraft back on a return-to-earth trajectory.

Mode II - The Mode II procedure would be used for aborts following SPS shutdown during the interval approximately between LOI ignition plus 1.5 minutes and LOI ignition plus 3 minutes. This abort maneuver is performed in two stages. First, a DPS burn would be executed to reduce the lunar orbital period and to insure that the spacecraft does not impact on the lunar surface. After one orbit, a second DPS burn would place the spacecraft on a return-to-earth trajectory.

Mode III - The Mode III procedure would be used for aborts following shutdowns from approximately 3 minutes into the burn until nominal cutoff. After 3 minutes of LOI burn, the spacecraft will have been inserted into an acceptable lunar orbit. Therefore, the abort procedure would be to let the spacecraft go through one or two lunar revolutions prior to doing a posigrade DPS burn at pericynthion. This would place the spacecraft on a return-to-earth trajectory targeted to the Mid-Pacific recovery line.

Lunar Orbit

An abort from lunar orbit would be accomplished by performing the TEI burn early. Should an abort become necessary during the LM descent, ascent, or rendezvous phases of the mission, the LM would make the burns necessary to rendezvous with the CSM. If the LM were unable to complete the rendezvous, the CSM would, if possible, perform a rescue of the LM. In any case, the early TEI would normally target the CM to the Mid-Pacific recovery line.

Lunar Module Powered Descent

Aborts for the powered descent phase are controlled by the Primary Guidance and Navigation System (PGNS) abort program or the Abort Guidance System (AGS), depending on the operational status of the DPS and the PGNS. If both the PGNS and DPS are operational, the abort is initiated by pushing the "Abort" button. The DPS abort will continue under PGNS control until either orbit insertion or engine cutoff due to DPS failure or propellant depletion. If DPS cutoff occurs and the velocity-to-be-gained (V_G) is less than 30 fps, the DPS will be staged manually and the RCS will be used to complete the orbit insertion of the LM. If V_G is greater than 30 fps, the "Abort Stage" button is pushed. This stages the Descent Stage, and ignites the APS engine. The desired insertion orbit will then be obtained using the APS.

If the DPS has failed, the abort will be performed using the APS. As above, the procedure is to push the "Abort Stage" button.

If the PGNS is not operational, the abort is controlled by the AGS. For an operational DPS, the thrust level is controlled manually, and the steering is controlled by the AGS. If the DPS is not operational or becomes inoperative with a V_G greater than 30 fps, the DPS will be staged manually, and the RCS will be used to insert the LM.

If both the PGNS and AGS have failed, a manual abort technique, using the horizon angle for a reference, will be used.

Lunar Stay

After LM touchdown if an early abort is required there are two preferred liftoff times. The first is actually a 15-minute span of time beginning at PDI (touchdown to touchdown plus 3 minutes). The second is at PDI plus 21.5 minutes (touchdown plus about 9.5 minutes). Both of these aborts will place the LM into a 9 x 30-NM orbit acceptable for LM-active rendezvous. Here again, an extra orbit and CSM dwell orbit are used to improve the rendezvous phasing and conditions in the former case and two revolutions are added in the latter case.

The above times may be adjusted somewhat in real-time to account for possible variations in the CSM orbit. Subsequently during the lunar stay, the preferred liftoff time is whenever the phasing is optimum for rendezvous. This occurs once each revolution shortly after the CM has passed over the site. The nominal rendezvous is performed with this phasing.

In the unlikely event of a catastrophic APS failure calling for an immediate liftoff, rendezvous following liftoff at any time could be performed within performance and time constraints. However, this contingency is considered highly unlikely and the rendezvous phasing is fairly poor during some periods. Due to the low probability of such an abort, highly developed operational plans for such are not being promulgated.

Aborts will proceed under the control of the PGNS, if operating, otherwise under control of AGS. A manual guidance scheme is being developed to provide backup in the event of both PGNS and AGS failure. This backup uses the Flight Director Attitude Indicator, if available, for attitude reference; otherwise, the horizon is used for reference.

Lunar Module Powered Ascent

Three types of aborts are available for the powered ascent phase. If the PGNS fails, the abort will require switching to the AGS. If the APS fails, the abort will be performed using the RCS for insertion provided the engine failure occurs within the RCS insertion capability. If both the PGNS and AGS fail, the abort will be performed by the crew using manual control.

Transearth Injection

The abort procedures for early cutoff of the SPS during the TEI burn are the inverse of the LOI abort procedures except that the abort would be performed by attempting to reignite the SPS. For SPS cutoff during the interval between TEI ignition and ignition plus 1.5 minutes, the Mode III LOI abort procedure would be used. For SPS cutoff between TEI ignition plus 1.5 minutes and TEI ignition plus 2 minutes, the Mode II LOI abort procedure would be used. If the SPS should be shut down from TEI ignition plus 2 minutes to nominal end of TEI, abort Mode I would be performed, except that the 2-hour coast period would be deleted.

Transearth Coast

From TEI until entry minus 24 hours, the only abort procedure that could be performed is to use the SPS or the SM RCS for a posigrade or retrograde burn that would respectively decrease or increase the transearth flight time and change the longitude of landing. After entry minus 24 hours, no further burns to change the landing point will be performed. This is to ensure that the CM maintains the desired entry velocity and flight path angle combination that will allow a safe entry.

Entry

If during entry, the Guidance, Navigation, and Control System (GNCS) fails, a guided entry to the end-of-mission target point cannot be flown. In this case, the crew would use their Entry Monitor System (EMS) to fly a 1285-NM range. The landing point would be approximately 39 NM uprange of the guided target point and 75 NM north of the ground track. If both the GNCS and EMS fail, a "constant g" (constant deceleration) entry would be flown. The landing point would be approximately 240 NM uprange of the guided target point and 75 NM north of the ground track.

ALTERNATE MISSION SUMMARY

The two general categories of alternate missions that can be performed during the Apollo 11 Mission are (1) earth orbital, and (2) lunar. Both of these categories have several variations which depend upon the nature of the anomaly causing the alternate mission and the resulting systems status of the LM and CSM. A brief description of these alternate missions is contained in the following paragraphs.

Earth Orbital Alternate Missions

Alternate 1 - CSM-Only Low Earth Orbit

Condition/Malfunction: LM not extracted, or S-IVB failed prior to 25,000-NM apogee, or SPS used to achieve earth orbit.

Perform: SPS LOI simulation (100 x 400-NM orbit), MCC's to approximate lunar timeline and for an approximate 10-day mission with landing in 150°W Pacific recovery area.

Alternate 2 - CSM-Only Semisynchronous

Conditon/Malfunction: S-IVB fails during TLI with apogee ≥25,000 NM, LM cannot be extracted.

Perform: SPS phasing maneuver for LOI tracking, LOI simulation, SPS phasing maneuver to place perigee over Pacific recovery zone at later time, SPS semi-synchronous orbit, and further MCC's to approximate lunar timeline.

Alternate 3 - CSM/LM Earth Orbit Combined Operations with SPS Deboost

Condition/Malfunction: TLI does not occur or TLI apogee <4000 NM, TD&E successful.

Perform: SPS maneuver to raise or lower apogee for orbit lifetime requirements if necessary, simulated LOI to raise or lower apogee to 400 NM, simulated DOI (in docked configuration), simulated PDI, SPS maneuver to circularize at 150 NM, a limited rendezvous (possibly CSM-active), and further SPS MCC's to complete lunar mission timeline.

Alternate 4 - CSM/LM Earth Orbit Combined Operations with DPS/SPS Deboost

Condition/Malfunction: S-IVB fails during TLI, SPS and DPS in combination can return CSM/LM to low earth orbit without sacrificing LM rescue (4000 NM < apogee ≤ 10,000 NM).

Perform: SPS phasing maneuver, simulated DOI, PDI to lower apogee to about 4000 NM, SPS phasing (simulated MCC) maneuver to insure tracking for LOI, SPS maneuver to circularize at 150 NM, a limited rendezvous (possibly CSM-active), SPS maneuver to complete lunar mission, timeline, and achieve nominal 90 x 240-NM, end-of-mission orbit for an approximate 10-day mission with landing in 150°W Pacific recovery area.

Alternate 5 - CSM/LM Semisynchronous

Condition/Malfunction: SPS and DPS in combination cannot place CSM/LM in low earth orbit without sacrificing LM rescue, SPS propellant not sufficient for CSM/LM circumlunar mission.

Perform: SPS phasing maneuver (to place a later perigee over an MSFN site), SPS LOI (approximately semisynchronous), SPS phasing maneuver if necessary to adjust semisynchronous orbit, docked DPS DOI, docked DPS PDI simulation, SPS phasing to put perigee over or opposite recovery zone, SPS to semisynchronous orbit, and further MCC's to approximate lunar mission timeline.

Lunar Alternate Missions

Alternate 1a - DPS LOI

Condition/Malfunction: Non-nominal TLI such that: continuation of nominal mission, including CSM/LM LOI and TEI with SPS, is No-Go; but CSM/LM LOI Go with DPS LOI-1.

Perform: TD&E, SPS free-return CSM/LM, DPS LOI-1, and SPS LOI-2, after LOI-2, plane change for site coverage, photography and tracking of future landing sites, high-inclination orbit determination, SPS DOI with CSM/LM for three revolutions.

Alternate 1b - CSM Solo Lunar Orbit

Condition/Malfunction: Non-nominal TLI such that: CSM/LM LOI No-Go, CSM-only LOI Go.

Perform: TD&E, SPS free-return CSM/LM, LM testing during TLC and DPS staging, SPS plane changes in lunar orbit for additional site coverage, photography and tracking of future landing sites, high-inclination orbit determination, SPS to 60 x 8-NM orbit for three revolutions.

Alternate 1c - CSM/LM Flyby

Condition/Malfunction: Non-nominal TLI, such that: CSM/LM Flyby Go, CSM/LM LOI No-Go, CSM-only LOI No-Go.

Perform: TD&E, LM testing near pericynthion, docked DPS maneuver to raise pericynthion, DPS staging, and SPS for fast return.

Alternate 2 - CSM-Only Lunar Orbit

Condition/Malfunction: Failure to TD&E.

Perform: CSM-only lunar orbit mission, SPS plane change in lunar orbit for additional site coverage, photography and tracking of future landing sites, high-inclination orbit determination, SPS to 60 x 8-NM orbit for three revolutions.

Alternate 3a - DPS TEI

Condition/Malfunction: LM No-Go for landing, but DPS Go for a burn.

Perform: SPS DOI to place CSM/LM in 60 x 8-NM orbit, three revolutions of tracking and photography, SPS circularization in 60 x 60-NM orbit, DPS TEI, SPS MCC for fast return.

Alternate 3b - DPS No-Go for Burn

Condition/Malfunction: LM No-Go for landing, and DPS No-Go for a burn.

Perform: CSM-only plane change for site coverage. Then follow same profile as Alternate 1b, above.

Alternate 4 - TEI With Docked Ascent Stage

Condition/Malfunction: CSM communications failure in lunar orbit.

Perform: TEI and keep LM as communication system. If DPS available, perform DPS TEI as in Alternate 3a. If Descent Stage jettisoned, perform SPS TEI with Ascent Stage attached.

CONFIGURATION DIFFERENCES

The space vehicle for Apollo 11 varies in its configuration from that flown on Apollo 10 and those to be flown on subsequent missions because of normal growth, planned changes, and experience gained on previous missions. Following is a list of the major configuration differences between AS-505 and AS-506.

SPACE VEHICLE	REMARKS
Command/Service Module (CSM-107)	
• Provided a short SPS main propellant sump tank.	To overcome potential delay in availability of scheduled tank.
• Changed insulation on hatch tunnel.	
Lunar Module (Ascent Stage) (LM-5)	
• Provided for first usage of EVA antenna (VHF).	Required for lunar landing mission.
• Incorporated Extravehicular Communication System (EVCS) into the PLSS.	Provides simultaneous and continuous telemetry from two extravehicular members, duplex voice communication between earth and one or both of the two extravehicular members, and uninterruptable voice communications between the crew members.
• Provided a Liquid Cooling Garment (LCG) heat removal subsystem.	Enhances mission success.
• Modified 22 critical stress corrosion fittings.	Enhances mission success.
Lunar Module (Descent Stage)	
• Modified the base heat shield.	Reduces the lunar landing fire-to-touchdown problem. Enhances mission success.
• Modified 11 critical stress corrosion fittings.	Enhances mission success.
• Added RCS plume deflectors for each of the lower four RCS thrusters.	To withstand increased firing time for RCS thrusters.

• Provided for first mission usage of erectable antenna (S-band).	Lunar landing mission requirement.
• Provided a modified gimbal drive actuator (polarizer and armature removed, added a new brake material and sleeve).	Enhances system performance.

Spacecraft-LM Adapter (SLA-14)

• (No significant differences.)

LAUNCH VEHICLE	REMARKS
Instrument Unit (S-IU-506)	
• (No significant differences.)	
S-IVB Stage (SA-506)	
• (No significant differences.)	
S-II Stage (S-II-506)	
• Deleted research and development (R&D) instrumentation and retained operational instrumentation only.	Basic requirement.
S-IC Stage (SA-506)	
• Retained operational instrumentation only.	Weight reduction of 5900 pounds results from deletion of R&D instrumentation.

MISSION SUPPORT

GENERAL

Mission support is provided by the Launch Control Center (LCC), the Mission Control Center (MCC), the Manned Space Flight Network (MSFN), and the recovery forces. The LCC is essentially concerned with prelaunch checkout, countdown, and with launching the SV, while MCC located at Houston, Texas, provides centralized mission control from liftoff through recovery. The MCC functions within the framework of a Communications, Command, and Telemetry System (CCATS); Real-Time Computer Complex (RTCC); Voice Communications System; Display/Control System; and a Mission Operations Control Room (MOCR) supported by Staff Support Rooms (SSR's). These systems allow the flight control personnel to remain in contact with the spacecraft, receive telemetry and operational data which can be processed by the CCATS and RTCC for verification of a safe mission, or compute alternatives. The MOCR is staffed with specialists in all aspects of the mission who provide the Mission Director and Flight Director with real-time evaluation of mission progress.

MANNED SPACE FLIGHT NETWORK

The MSFN is a worldwide communications and tracking network which is controlled by the MCC during Apollo missions. The network is composed of fixed stations (Figure 38) and is supplemented by mobile stations (Table 5) which are optimally located within a global band extending from approximately 40° south latitude to 40° north latitude. Station capabilities are summarized in Table 6. Figure 39 depicts communications during lunar surface operations.

The functions of these stations are to provide tracking, telemetry, updata, and voice communications both on an uplink to the spacecraft and on a downlink to the MCC. Connection between these many MSFN stations and the MCC is provided by NASA Communications Network (NASCOM). More detail on mission support is in the MOR Supplement.

TABLE 5

MSFN MOBILE FACILITIES

Ships	Location	Support
USNS VANGUARD	25°N 49°W	Insertion
USNS MERCURY	10°N 175.2°W	Injection
USNS REDSTONE	2.25°S 166.8°E	Injection
USNS HUNTSVILLE	3.0°N 154°E	Entry (tentative)

APOLLO RANGE INSTRUMENTATION AIRCRAFT

Eight Apollo Range Instrumentation Aircraft (ARIA) will be available to support the Apollo 11 Mission in the Pacific sector. The mission plan calls for ARIA support of translunar injection on revolution 2 or 3 and from entry (400,000-foot altitude) to recovery of the spacecraft and crew after landing.

TABLE 6

MSFN CONFIGURATION, APOLLO 11 MISSION

STATION TYPE AND NAME	B	PAFB	CNV	MLA	CIF	MIL	GBI	GBM	GTK	ANT	ANG	BDA	CYI	MAD	MADX	ASC	ACN
	C																
TYPE EQUIPMENT	A																
TRACKING																	
C-Band Radar		X	X	X					X	X		X				X	
USB						X		X			X	X	X	X	X		X
TELEMETRY																	
VHF Links					X	X	X	X			X	X	X				X
USB					X	X		X			X	X	X	X	X		X
Data Processor					X	X		X			X	X	X	X	X		X
Data Remoting					X	X		X			X	X	X	X	X		X
Bio-Med Remoting						X		X			X	X	X	X	X		X
Display																	
COMMAND																	
USB Updata						X		X			X		X	X	X		X
Cmd Processor						X		X			X	X	X	X	X		X
Cmd Remoting						X		X			X	X	X	X	X		X
Cmd Destruct			X				X		X	X		X					
A/G VOICE																	
VHF						X		X			X	X	X				
USB						X		X			X	X	X	X	X		X
TV																	
USB						X		X			X	X	X	*X	X		X
SPAN													X				

STATION TYPE AND NAME	PRE	TAN	CRO	HSK	HSKX	GWM	PARKES 210 ft.	HAW	CAL	GDS	GDSX	GYM	TEX	GDS 210 ft.	INS.	INJ.	INJ.	RE-EN.	A/RIA
TRACKING																			
C-Band Radar	X	X	X					X	X						X	X	X	X	
USB			X	X	X	X		X		X	X	X	X		X	X	X	X	
TELEMETRY																			
VHF Links		X	X			X		X				X	X		X	X	X	X	X
USB			X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Data Processor			X	X	X	X		X		X	X	X	X		X	X	X		
Data Remoting			X	X	X	X		X		X	X	X	X		X	X	X	X	
Bio-Med Remoting			X	X	X	X		X		X	X	X	X		X	X	X		
Display																		X	
COMMAND																			
USB Updata			X	X	X	X		X		X	X	X	X		X	X	X		
Cmd Processor			X	X	X	X		X		X	X	X	X		X	X	X		
Cmd Remoting			X	X	X	X		X		X	X	X	X		X	X	X		
Cmd Destruct																			
A/G VOICE																			
VHF		X	X			X		X	X			X	X		X	X	X	X	X
USB			X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
TV																			
USB			X	*X	X	X	*X	X		*X	X	X	X	*X		X	X		
SPAN			X																

6/24/69

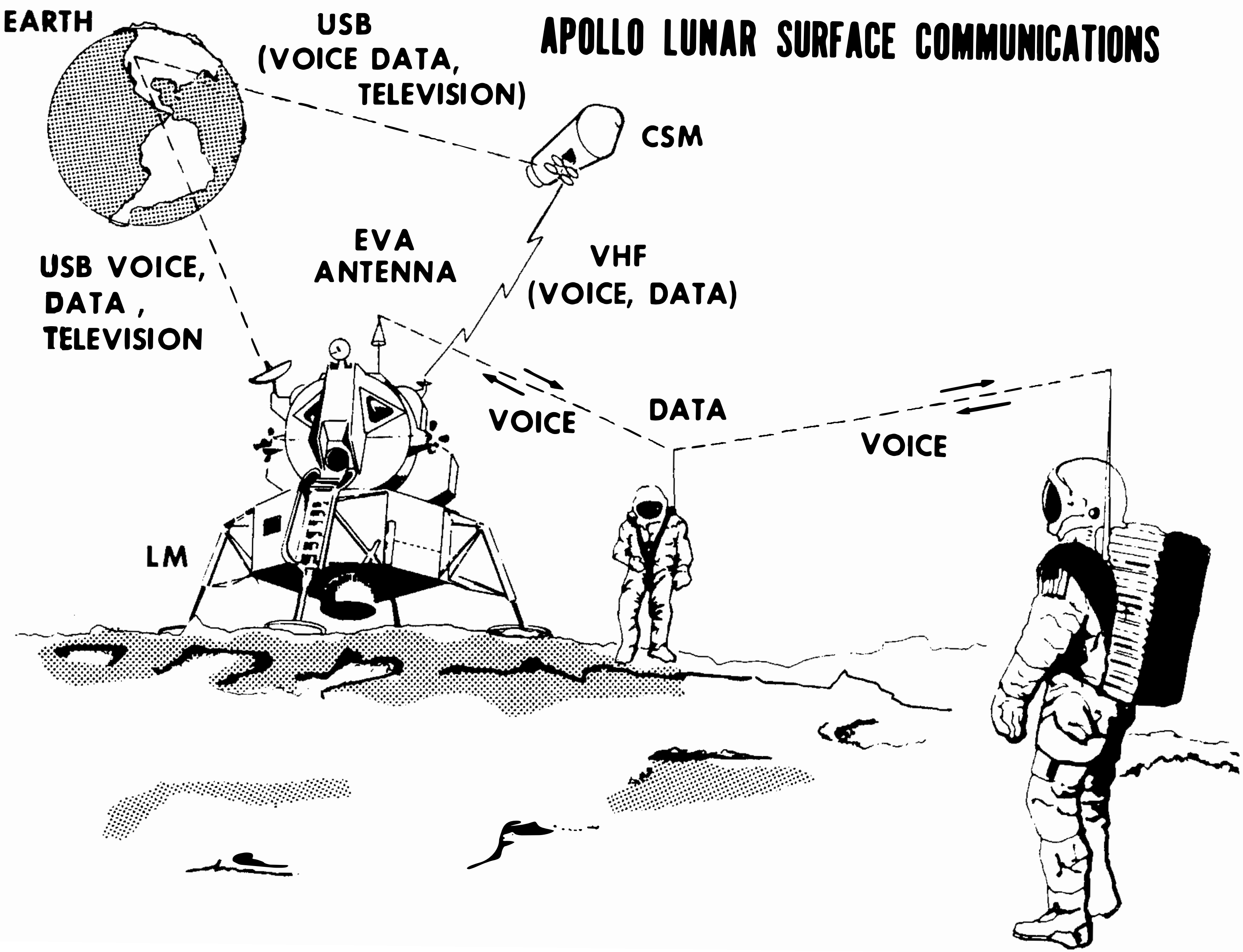


Fig. 39

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RADAR COVERAGE DURING LUNAR ORBIT PERIODS FOR LAUNCH DATE OF JULY 16

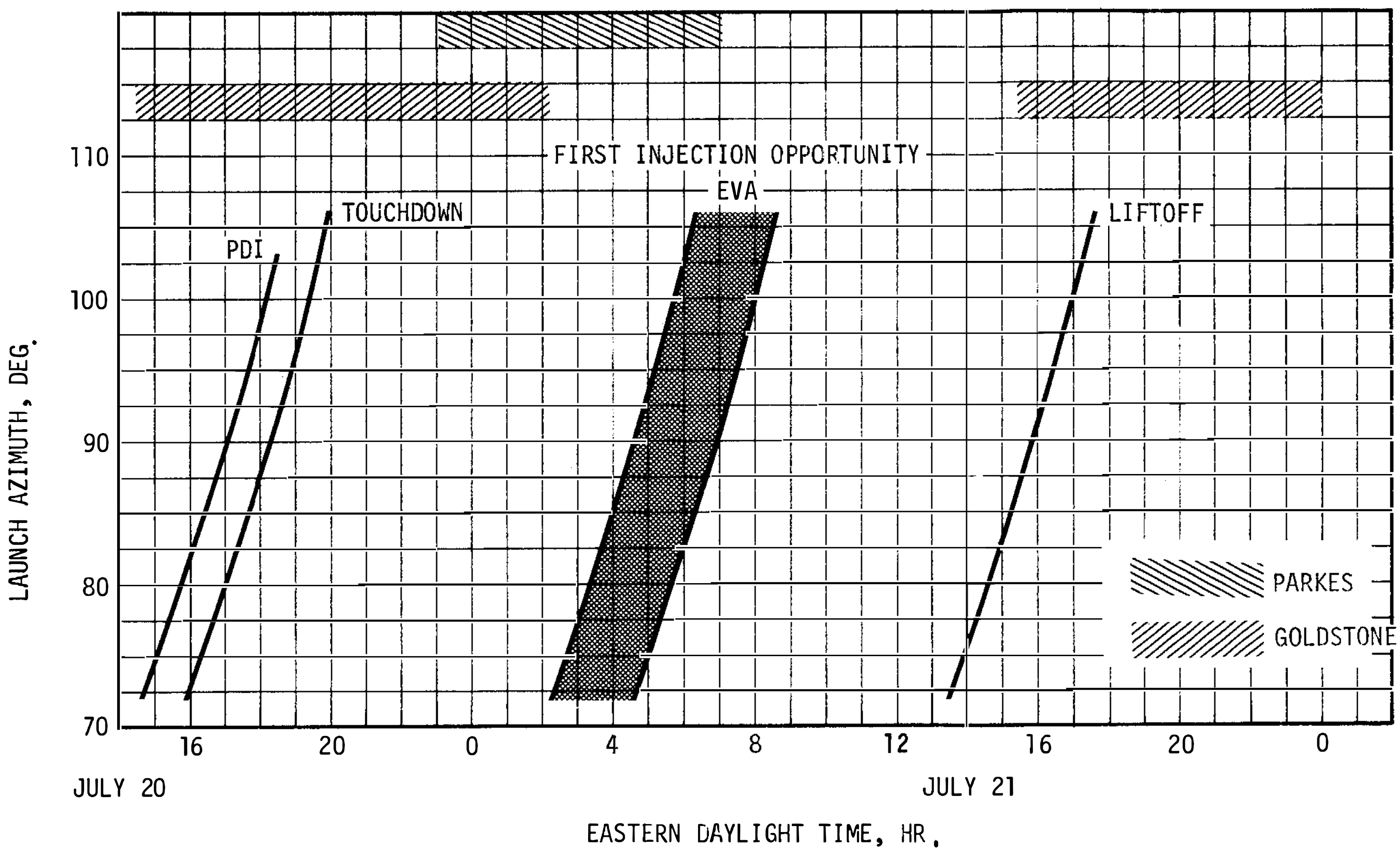

Fig. 40

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RECOVERY SUPPORT PLAN

GENERAL

The Apollo 11 flight crew and Command Module (CM) will be recovered as soon as possible after landing, while observing the constraints required to maintain biological isolation of the flight crew, CM, and materials removed from the CM. After locating the CM, first consideration will be given to determining the condition of the astronauts and to providing first-level medical aid when required. The second consideration will be the recovery of the astronauts and CM. Retrieval of the CM main parachutes, apex cover, and drogue parachutes, in that order, is highly desirable if feasible and practical. Special clothing, procedures, and the Mobile Quarantine Facility (MQF) will be used to provide biological isolation of the astronauts and CM. The lunar sample rocks will also be isolated and returned to the Manned Spacecraft Center within 30 hours as specified by NASA.

The recovery forces will also be capable of salvaging portions of the space vehicle in case of a catastrophic failure in the vicinity of the launch site. Specific components to be recovered will be identified after the fact. After a normal launch, if items such as portions of the first stage of the launch vehicle or the Launch Escape System (LES) are found, they should be recovered if possible. If it appears that the items are too large or unsafe for retrieval, the Mission Control Center will be contacted for guidance before recovery is attempted.

LAUNCH PHASE

During the time between LES arming and parking orbit insertion, the recovery forces are required to provide support for landings that would follow a Mode I, II, or III launch abort

Launch Site Area

The launch site area includes all possible CM landing points which would occur following aborts initiated between LES arming and approximately 90 seconds GET. Figure 41 shows the launch site area and recovery force deployment. Recovery forces in the launch site area will be capable of meeting a maximum access time of 30 minutes to any point in the area. This support is required from the time the LES is armed until 90 seconds after liftoff. However, prior to LES arming, the launch site forces are required to be ready to provide assistance, if needed, to the Pad Egress Team, and, after T plus 90 seconds, they are required to be prepared to provide assistance to the launch abort area recovery forces. In addition to the 30-minute access time, the launch site recovery forces are required to have the capability to:

APOLLO 11 LAUNCH SITE AREA AND FORCE DEPLOYMENT

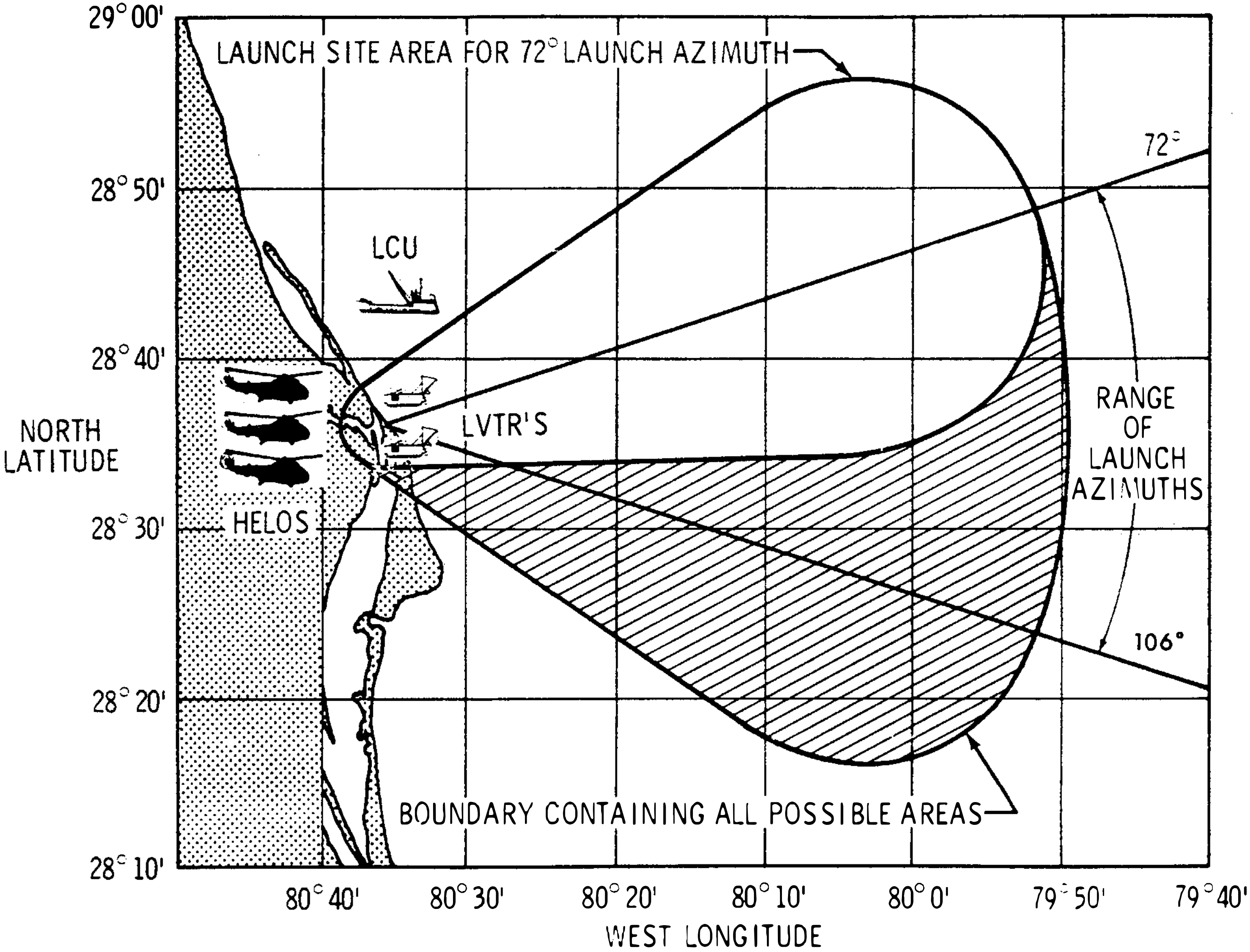


Fig. 41

a. Provide firefighting units that are capable of containing hypergolic fuel fires.

b. Upright the CM.

c. Transport the flight crew from any point in the area to the Patrick AFB hospital.

d. Transport the CM to a deactivation site.

e. Provide debris location, mapping, and recording assistance for a salvage operation.

Launch Abort Area

The launch abort area is the area in which the CM would land following an abort initiated during the launch phase of flight, after approximately 90 seconds GET. The launch abort area shown in Figure 42 includes all possible CM landing points following a launch abort from any launch azimuth. The launch abort landing area is divided into two sectors: A and B. These sectors are used to differentiate the level of recovery support available in the area. Sector A is all the area in the launch abort area that is between 41 and 1000 nautical miles (NM) downrange of the launch site. Sector B is all the area in the launch abort area that is between 1000 and 3400 NM downrange of the launch site.

The primary responsibility of launch abort forces is to locate and recover the astronauts and retrieve the CM within the required access and retrieval times should a landing occur in the launch abort area. The forces required, their staging bases, and access times are listed in Table 7.

Two secondary recovery ships and three search and rescue aircraft will be positioned in the launch abort area as shown in Figure 42. Ship and aircraft stations in the launch abort area will sweep to the south each day during the launch window as the launch azimuth changes from 72° to 106°. Recovery ships and aircraft are positioned for optimum coverage of the 72° launch azimuth. Launch abort aircraft are required to provide a 4-hour access time to any launch azimuth. Retrieval time in Sector A will be 24 hours. Sector B will be considered as a contingency retrieval area; therefore, retrieval will be as soon as possible. HC-130 aircraft will be on station ten minutes prior to predicted landing time. Recovery forces providing immediate launch abort support will be released after translunar injection (TLI).

EARTH PARKING ORBIT PHASE

Earth parking orbit (EPO) secondary landing areas (SLA's) are configured to include target points and associated dispersion areas with low-speed entries from near-earth orbits. These areas are selected to provide recovery support at suitable time intervals throughout the EPO phase of the mission. The SLA is a 210-NM long by 80-NM wide

LAUNCH ABORT AREA AND FORCE DEPLOYMENT

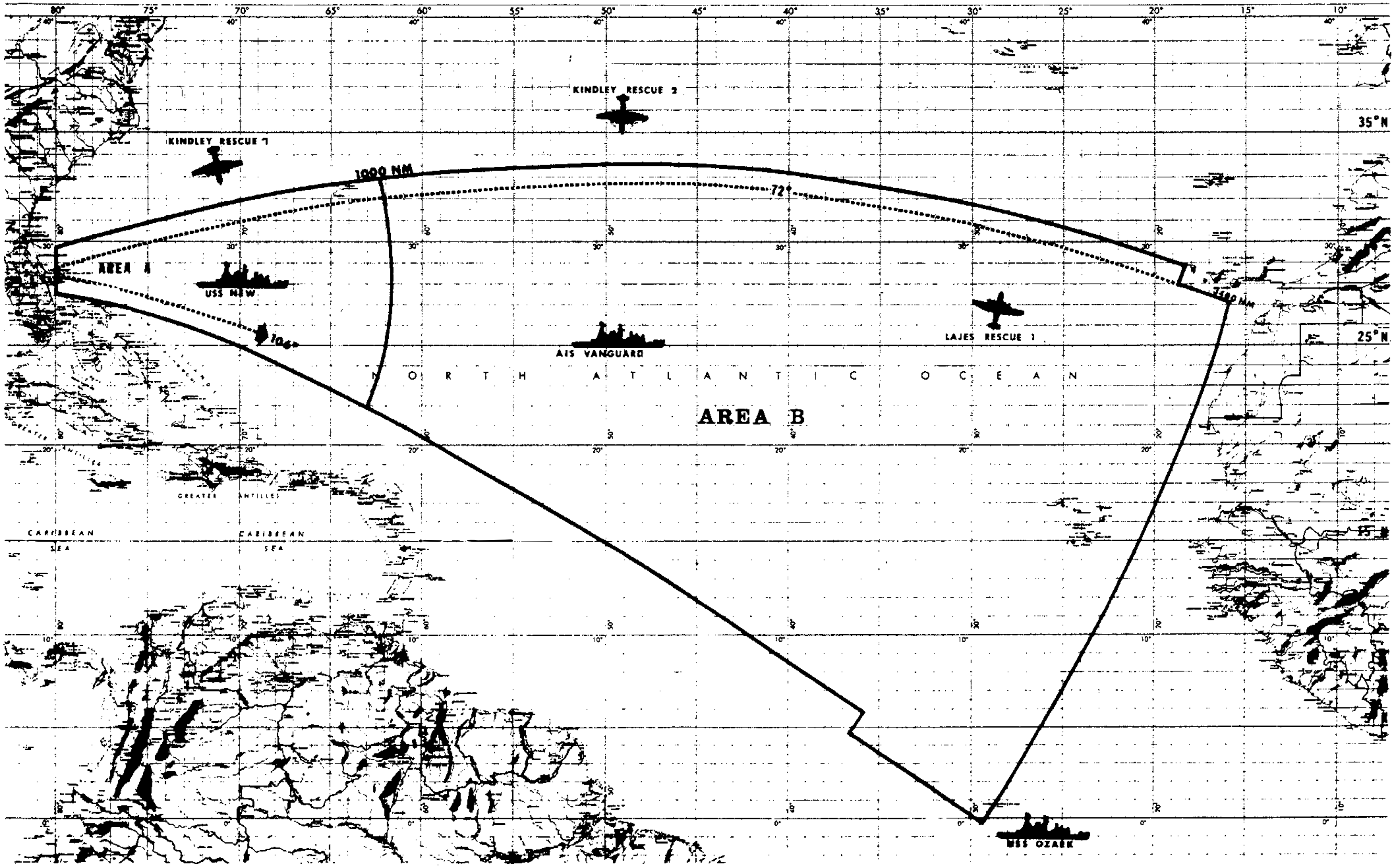


Fig. 42

TABLE 7

RECOVERY FORCE REQUIREMENTS

LAUNCH ABORT AREA

AREA OR ZONE	DESCRIPTION	RETRIEVAL TIME (HR) SHIP	ACCESS TIME (HR) A/C	SHIP			HC-130 AIRCRAFT		
				STA	POSITION	TYPE	STA	NO	POSITION
LAUNCH ABORT	Sector A: From launch site to 1000 NM downrange. 50 NM north of 072° azimuth and 50 NM south of 106° azimuth.	24	4	1	28°00'N 70°00'W	DD	A1	1	32°35'N 71°00'W
	Sector B: From 1000 NM to 3400 NM downrange. 50 NM north of 072° azimuth and 50 NM south of 106° azimuth.	ASAP	4	2	25°00'N 49°00'W	AIS	B1	1	35°00'N 49°05'W
							C1	1	27°35'N 28°25'W

NOTE 1: Ship positions shown are for 072° azimuth launch on 16 July. As launch azimuth increases, ships will proceed south.

NOTE 2: Aircraft positions shown are for 072° azimuth launch on 16 July. As launch azimuth increases, aircraft will proceed south and maintain their relative position to the changing ground track.

dispersion ellipse oriented along the entry ground track and centered on the target point. For the Apollo 11 Mission, EPO SLA's will be required for four revolutions and are selected in two general locations called recovery zones. See Figure 43 for locations and Table 8 for access and retrieval times and forces required. If the TLI maneuver is not completed and a long duration earth orbital mission is flown, Zone 2, located in the East Atlantic Ocean, will also be activated. For landings during this phase of the mission, one HC-130 aircraft will be stationed 50 NM abeam of the target point.

The contingency landing area for this phase includes all the earth's surface between 34°N and 34°S latitude, except the launch abort, earth orbital, and deep space SLA's, and the end-of-mission planned landing area. The forces required, their staging bases, and access times are listed in Table 8.

DEEP SPACE PHASE

Deep space SLA's are designed to include the target point and dispersion area associated with a high-speed entry from space. These areas are selected to provide recovery support at suitable time intervals throughout the translunar, lunar orbit, and transearth phases of the mission. Deep space SLA's are located along or near ship-supported recovery lines which are spaced to provide varying return times as shown in Figure 44.

For the Apollo 11 Mission, these areas are defined as the areas where a landing could occur following translunar coast aborts targeted to the Mid Pacific Line (MPL) (line 4), and any abort after TLI targeted to the Atlantic Ocean Line (AOL) (line 1). USS HORNET and two aircraft (HC-130's) are required to provide secondary landing area support for the MPL, and USS OZARK and two aircraft (HC-130's) are required for the AOL. The two ships will move along lines 1 and 4 to maintain the latitude of the moon's declination in the opposite hemisphere. Table 9 shows the approximate location of this point for each day's launch window. Actual positions required for each day will be published in the appropriate task force operations order.

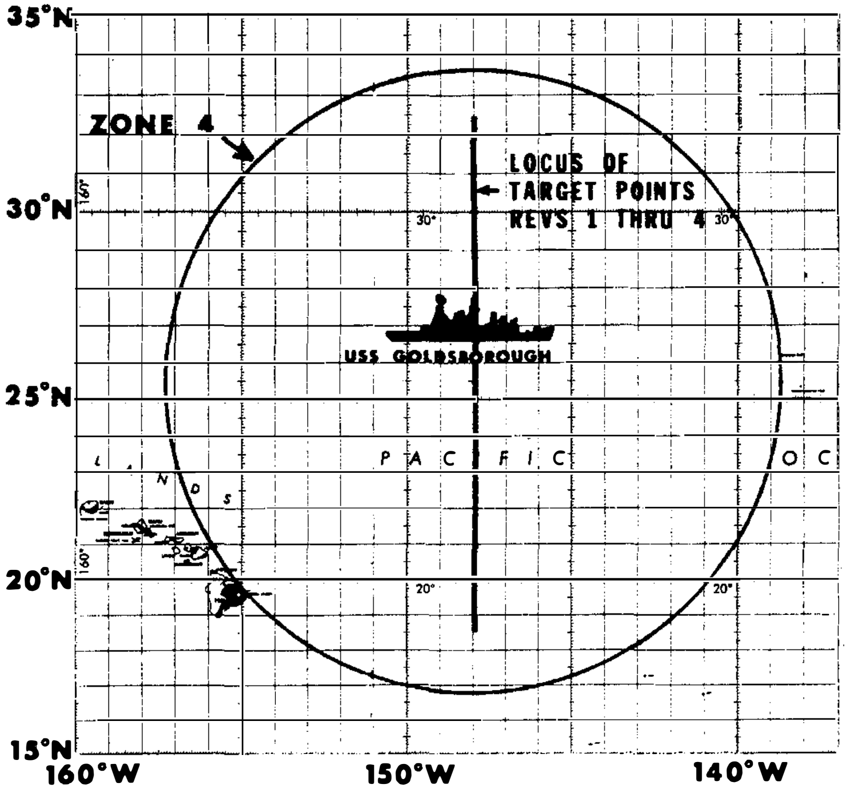
The only time the ship's position is critical is during the first few hours after TLI. The minimum time between abort initiation and landing for these aborts will be approximately 11 hours for the AOL and 13 hours for the MPL. After these times, the return time becomes greater leaving sufficient time to position the ship at the CM target point. At entry minus 35 hours, if the CM is still targeted to the MPL, USS OZARK will be released.

Aborts made to the MPL or AOL after TLI require, within the high-speed entry footprint, an access time of 14 hours and retrieval time of 24 hours to any point in the area.

For deep space aborts to the MPL, one HC-130 aircraft will be stationed 200 NM up-range and 100 NM north of the ground track, one 200 NM north of ground track, and one abeam of the target point and 50 NM north of the ground track. Minimum alert

APOLLO 11 EARTH PARKING ORBIT RECOVERY ZONES

PACIFIC



ATLANTIC

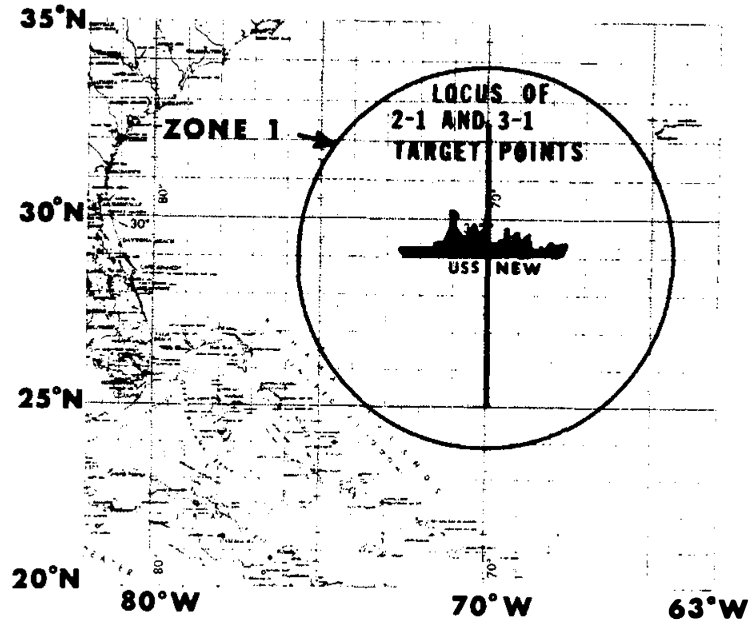


Fig. 43

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TABLE 8

RECOVERY FORCE REQUIREMENTS

EARTH ORBITAL PHASE

SECONDARY LANDING AREAS

RECOVERY ZONES	RETRIEVAL TIME (HR) SHIP	ACCESS TIME (HR) A/C	SHIP TYPE	SHIP POSITION	HC-130 AIRCRAFT NO	HC-130 AIRCRAFT STAGING BASES
1. 300 NM radius of 29°00'N, 70°00'W	24	6	DD	32°31'N 70°00'W	2	Kindley AFB, Bermuda
4. 510 NM radius of 25°30'N, 148°00'W	24	6	DD	25°30'N 148°00'W	2	Hickam AFB, Hawaii

EARTH ORBITAL AND DEEP SPACE

CONTINGENCY LANDING AREA

DESCRIPTION	ACCESS TIME HR A/C	A/C READINESS	A/C NO.	STAGING BASES
All area outside the launch site, launch abort, primary and secondary landing areas between 40°N 15°S. For earth orbital phase, latitude limits are 34°N and 34°S.	18	See Tab A to Appendix VII	2 2 2 2 2 1 2	Bermuda (May be released after TLI) Ascension Island Lajes/Moron (May be released after TLI) Mauritius Island Hickam AFB, Hawaii Andersen AFB, Guam (SAR Alert) Howard AFB, Canal Zone

DEEP SPACE TYPICAL SECONDARY LANDING AREA AND FORCE DEPLOYMENT

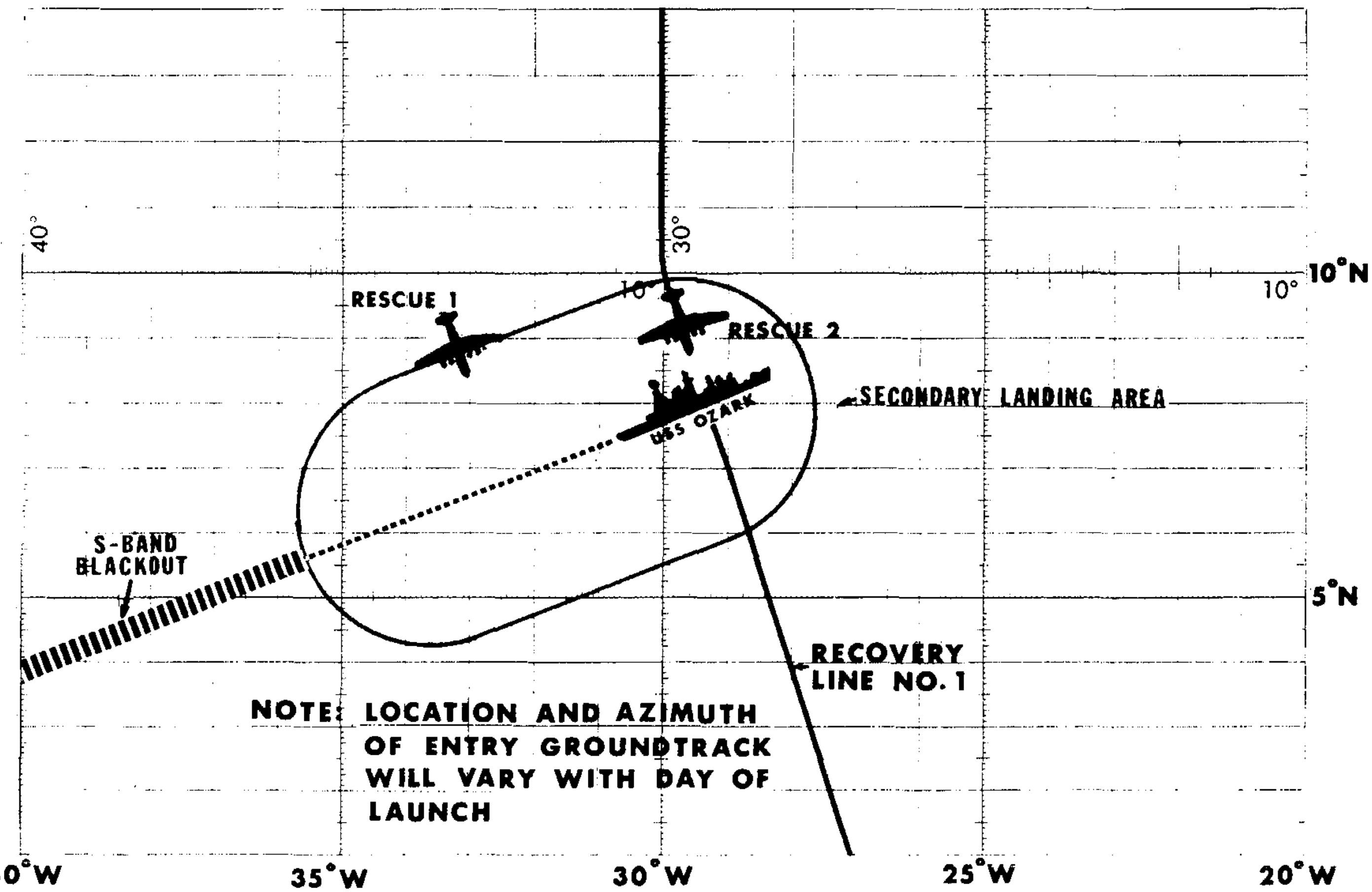

Fig. 44

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posture for HC-130 aircraft is listed in Table 10. Table 11 shows the access and retrieval times and forces required to support the deep space SLA's.

The contingency landing area for the deep space phase of the mission is associated with very low probability of a CM landing and requires land-based recovery aircraft support only. For Apollo 11, the deep space contingency landing area is all the area in a band around the earth between 40°N and 15°S outside the primary and secondary landing areas. The forces required, their staging bases, and access times are shown in Table 8.

TABLE 9

RECOVERY SHIP LOCATIONS, DEEP SPACE PHASE

Launch Date	Mid-Pacific Line USS HORNET	Atlantic Ocean Line USS OZARK
16 July	03°00'S, 165°00'W	01°00'S, 26°25'W
18 July	09°30'N, 171°10'W	11°00'N, 30°00'W
21 July	25°30'N, 175°00'W	24°00'N, 30°00'W

END-OF-MISSION PHASE

The normal end-of-mission (EOM) landing area will be selected on or near the MPL (line 4) located in the Mid-Pacific Ocean as shown in Figure 45. The latitude of the target point will depend on the declination of the moon at transearth injection and will be in the general range of 11° N to 29°N for the July launch window. The target point will normally be 1285 NM downrange of the entry point. Forces will be assigned to this area, as listed in Table 11, to meet the specified access and retrieval times. These forces will be on station not later than 10 minutes prior to predicted CM landing time.

If the entry range is increased to avoid bad weather, the area moves along with the target point and contains all the high probability landing points as long as the entry range does not exceed 2000 NM. Access and retrieval times quoted for the primary landing area will not apply if entry ranges greater than 2000 NM are flown during the mission.

TABLE 10

HC-130 MINIMUM ALERT POSTURE

STAGING BASE	LAUNCH TO PARKING ORBIT INSERTION	PARKING ORBIT INSERTION TO TLI	AFTER TLI*	REMARKS
Pease	Aircraft A airborne in Launch Abort Area	1 aircraft with 1/2 hr reaction time. Aircraft A or B can provide support while returning to home base	Aircraft can be released after TLI	
Kindley	Aircraft B airborne in Launch Abort Area		Aircraft can be released after TLI	
Lajes	Aircraft C airborne in Launch Abort Area	Aircraft returning to home base	Aircraft can be released after TLI	
Ascension	Not Required	1 aircraft with 2 hr reaction time	2 aircraft with 1/2 hr reaction time until TLI + 4 hrs	Aircraft can return to home base after TLI + 35 hours. Aircraft can be released at entry minus 37 hours if CM is still targeted to MPL.
Mauritius	Not Required	1 aircraft with 2 hr reaction time	1 aircraft with 6 hr reaction time until TLI plus 14 hrs	Aircraft can be released at entry minus 56 hours if CM still targeted to MPL.

*Reaction times are designed to provide required support during first few hours after TLI for any possible mission launched during the July launch window. After TLI the mission trajectory will have been established and more relaxed reaction times will be possible based on the minimum return time. These minimum return times will be passed to recovery forces as they are identified.

TABLE 11

RECOVERY FORCE REQUIREMENTS

DEEP SPACE PHASE

MID-PACIFIC LINE 4

RECOVERY ZONES	RETRIEVAL TIME (HR) SHIP	ACCESS TIME (HR) A/C	SHIP TYPE	SHIP POSITION	HC-130 AIRCRAFT NO	HC-130 AIRCRAFT STAGING BASES
A 125 NM circle centered 275 NM uprange A 125 NM circle centered 25 NM uprange from the target point connected by two tangential lines	24	14	CVS	At TP, latitude dependent on launch day	2	Hickam AFB, Hawaii. One A/C 200 NM uprange and 100 NM north of ground track. One A/C 200 NM downrange of TP and 100 NM north of ground track.
ATLANTIC OCEAN LINE 1						
Same as Mid-Pacific Line	24	14	MCS-2	Same as Mid-Pacific Line	2	Ascension. One HC-130 200 NM uprange at TP and 100 NM north of ground track. One HC-130 abeam of TP and 50 NM north of ground track.

DEEP SPACE PRIMARY LANDING AREA

MPL DESCRIPTION	RETRIEVAL TIME (HR) SHIP	ACCESS TIME (HR) A/C	DEPLOYMENT SHIP NO.	SHIP TYPE	SHIP POSITION	AIRCRAFT NO.	AIRCRAFT POSITION
Same as Mid-Pacific line	Crew 16 CM 24	2	1	CVS	At TP, latitude dependent on launch day (as updated)	4 2 1 1	Helos (*) HC-130 (*) E-1B (AIR BOSS) EC-135 (ARIA)

TYPICAL PRIMARY LANDING AREA AND FORCE DEPLOYMENT

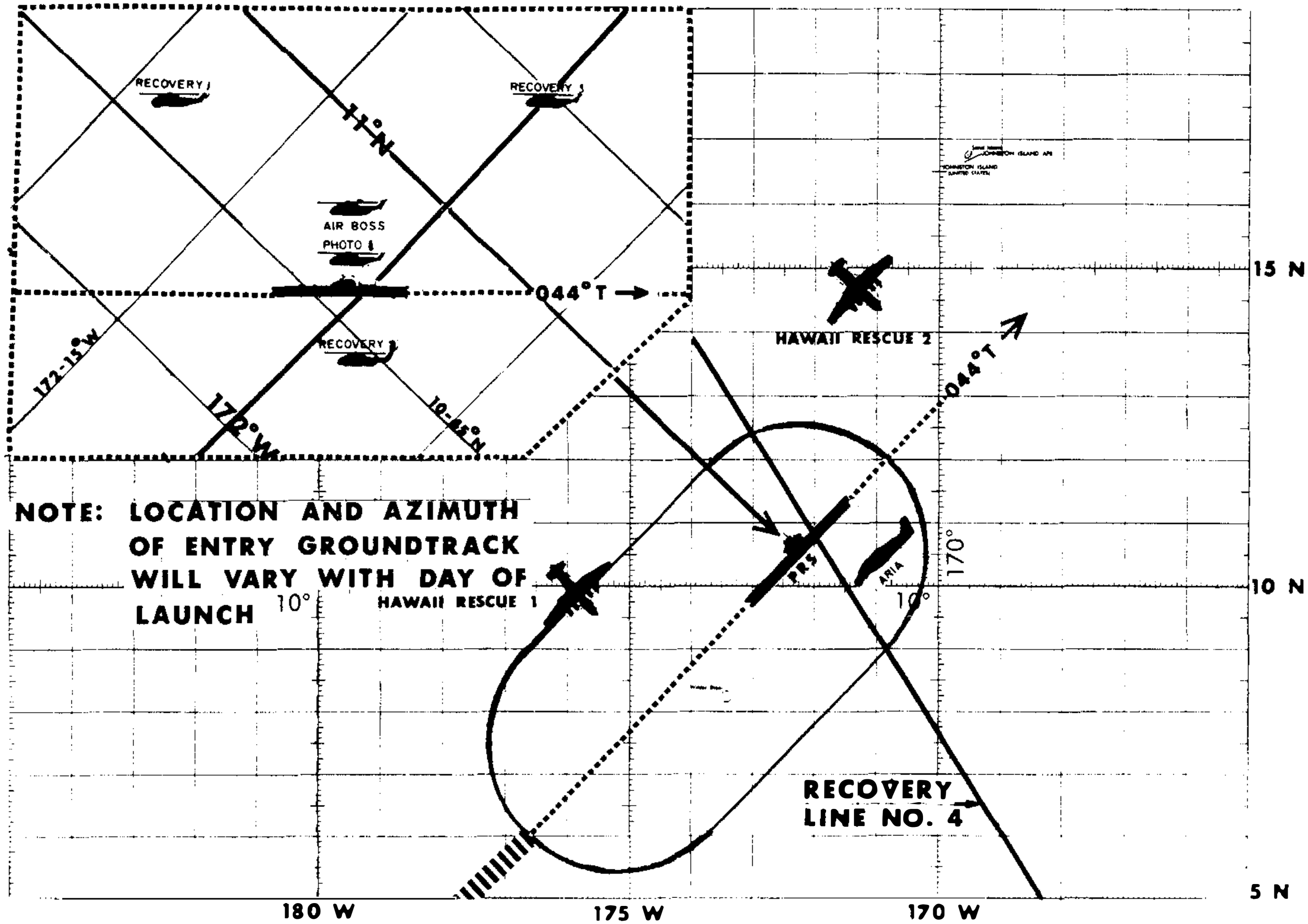


Fig. 45

The recovery forces in the primary landing area will be capable of meeting:

- A maximum access time of 2 hours to any point in the area.
- A maximum crew retrieval time of 16 hours to any point in the area.
- A maximum CM retrieval time of 24 hours to any point in the area.

The recovery forces assigned to the primary landing area are:

- USS HORNET will be on the EOM target point.
- Three SARAH-equipped helicopters, each carring a three-man swimmer team, to conduct electronic search are required. At least one of the swimmers on each team will be equipped with an underwater (Calypso) 35mm camera. NASA will furnish the equipment and film and will brief the swimmers concerning employment and coverage required.
- One helicopter to carry photographers as designated by the NASA Recovery Team Leader assigned to USS HORNET in the vicinity of the target point.
- One aircraft to function as communications relay, stationed overhead at the scene of action.
- One fixed-wing or rotary-wing aircraft over USS HORNET to function as on-scene commander.
- One HC-130 aircraft with operational AN/ARD-17 (Cook Tracker), 3-man pararescue team, and complete Apollo recovery equipment will be stationed 200 NM uprange from the target point and 100 NM north of the CM ground track at 25,000 feet.
- One HC-130 aircraft with operational AN/ARD-17, 3-man pararescue team, and complete Apollo recovery equipment will be stationed 200 NM downrange from the target point and 100 NM north of the CM ground track at 25,000 feet.
- Prior to CM reentry, one EC-135 Apollo Range Instrumentation Aircraft will be on station near the primary landing area for network support.

FLIGHT CREW

FLIGHT CREW ASSIGNMENTS

Prime Crew (Figure 46)

Commander (CDR) - Neil A. Armstrong (Civilian)
Command Module Pilot (CMP) - Michael Collins (Lt. Colonel, USAF)
Lunar Module Pilot (LMP) - Edwin E. Aldrin, Jr. (Colonel, USAF)

Backup Crew (Figure 47)

Commander (CDR) - James A. Lovell, Jr. (Captain, USN)
Command Module Pilot (CMP) - William A. Anders (Lt. Colonel, USAF)
Lunar Module Pilot (LMP) - Fred Wallace Haise, Jr. (Civilian)

The backup crew follows closely the training schedule for the prime crew and functions in three significant categories. One, they are fully informed assistants who help the prime crew organize the mission and check out the hardware. Two, they receive nearly complete mission training which becomes a valuable foundation for later assignments as a prime crew. Three, should the prime crew become unavailable, they are prepared to fly as prime crew up until the last few weeks prior to launch. During the final weeks before launch, the flight hardware and software, ground hardware and software, and flight crew and ground crews work as an integrated team to perform ground simulations and other tests of the upcoming mission. It is necessary that the flight crew that will conduct the mission take part in these activities, which are not repeated for the benefit of the backup crew. To do so would add an additional costly and time consuming period to the prelaunch schedule, which for a lunar mission would require rescheduling for a later lunar launch window.

PRIME CREW BIOGRAPHICAL DATA

Commander (CDR)

NAME: Neil A. Armstrong (Mr.)

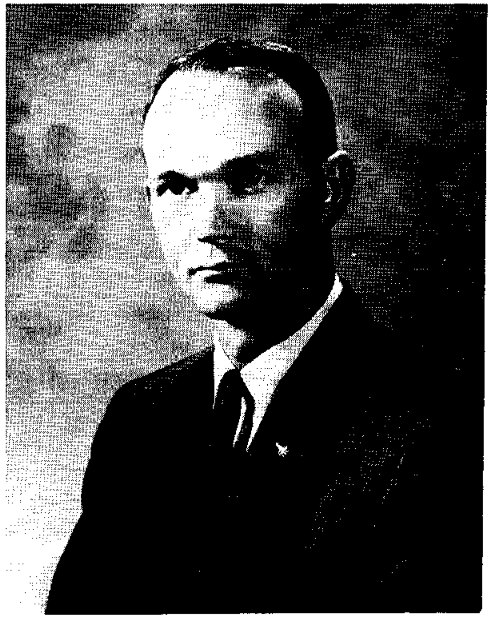
BIRTHPLACE AND DATE: Wapakoneta, Ohio; 5 August 1930.

PHYSICAL DESCRIPTION: Blond hair; blue eyes; height: 5 ft. 11 in.; weight: 165 lb.

EDUCATION: Received a Bachelor of Science degree in Aeronautical Engineering from Purdue University in 1955. Graduate School - University of Southern California.

APOLLO 11 PRIME CREW

NEIL A. ARMSTRONG



MICHAEL COLLINS

EDWIN E. ALDRIN JR.

Fig. 46

APOLLO 11 BACK-UP CREW

JAMES A. LOVELL JR.

WILLIAM A. ANDERS

FRED W. HAISE JR.

Fig. 47

M-932-69-11

ORGANIZATIONS: Associate Fellow of the Society of Experimental Test Pilots; Associate Fellow of the American Institute of Aeronautics and Astronautics; and member of the Soaring Society of America.

SPECIAL HONORS: Recipient of the 1962 Institute of Aerospace Sciences Octave Chanute Award; the 1966 AIAA Astronautics Award; the NASA Exceptional Service Medal; and the 1962 John J. Montgomery Award.

EXPERIENCE: Armstrong was a naval aviator from 1949 to 1952. In 1955 he joined NASA's Lewis Research Center (then NACA Lewis Flight Propulsion Laboratory) and later transferred to the NASA High Speed Flight Station (now Flight Research Center) at Edwards Air Force Base, California, as an aeronautical research pilot for NACA and NASA. In this capacity, he performed as an X-15 project pilot, flying that aircraft to over 200,000 feet and approximately 4000 miles per hour. Other flight test work included piloting the X-1 rocket airplane, the F-100, F-101, F-102, F-104, F-5D, B-47, the paraglider, the B-29 "drop" airplane, and others.

CURRENT ASSIGNMENT: Mr. Armstrong was selected as an astronaut by NASA in September 1962. He served as the backup Command Pilot for the Gemini 5 flight.

As Command Pilot for the Gemini 8 Mission, which was launched on 16 March 1966, he performed the first successful docking of two vehicles in space. The flight, originally scheduled to last 3 days, was terminated early due to a malfunctioning attitude system thruster, but the crew demonstrated exceptional piloting skill in overcoming this problem and bringing the spacecraft to a safe landing.

He subsequently served as backup Command Pilot for the Gemini 11 Mission and backup Commander for the Apollo 8 Mission. In his current assignment as Commander for the Apollo 11 Mission, he will probably be the first human to set foot on the moon.

Command Module Pilot (CMP)

NAME: Michael Collins (Lieutenant Colonel, USAF)

BIRTHPLACE AND DATE: Rome, Italy; 31 October 1930.

PHYSICAL DESCRIPTION: Brown hair; brown eyes; height: 5 ft. 11 in.; weight: 165 lb.

EDUCATION: Received a Bachelor of Science degree from the United States Military Academy at West Point, New York, in 1952.

ORGANIZATIONS: Member of the Society of Experimental Test Pilots.

SPECIAL HONORS: Awarded the NASA Exceptional Service Medal, the Air Force Command Pilot Wings, and the Air Force Distinguished Flying Cross.

EXPERIENCE: Collins chose an Air Force career following graduation from West Point. He served as an experimental flight test officer at the Air Force Flight Test Center, Edwards Air Force Base, California. In that capacity, he tested performance, stability, and control characteristics of Air Force aircraft — primarily jet fighters.

CURRENT ASSIGNMENT: Lt. Colonel Collins was one of the third group of astronauts named by NASA in October 1963. His first assignment was as backup Pilot for the Gemini 7 Mission.

As Pilot of the 3-day, 44-revolution Gemini 10 Mission, launched 18 July 1966, Collins shares with Command Pilot John Young in the accomplishments of that record-setting flight — a successful rendezvous and docking with a separately launched Agena target vehicle and, using the power of the Agena, maneuvering the Gemini spacecraft into another orbit for a rendezvous with a second, passive Agena. The spacecraft landed 2.6 miles from the USS GUADALCANAL and became the second in the Gemini Program to land within eye and camera range of a primary recovery ship.

He was assigned as Command Module Pilot on the prime crew for the Apollo 8 Mission but was replaced when spinal surgery forced a lengthy recuperation.

Lunar Module Pilot (LMP)

NAME: Edwin E. Aldrin, Jr. (Colonel, USAF)

BIRTHPLACE AND DATE: Montclair, New Jersey; 20 January 1930.

PHYSICAL DESCRIPTION: Blond hair; blue eyes; height: 5 ft. 10 in.; weight: 165 lb.

EDUCATION: Received a Bachelor of Science degree from the United States Military Academy at West Point, New York, in 1951 and a Doctor of Science degree in Astronautics from the Massachusetts Institute of Technology in 1963; recipient of an Honorary Doctorate of Science degree from Gustavus Adolphus College in 1967.

ORGANIZATIONS: Fellow of the American Institute of Aeronautics and Astronautics; member of the Society of Experimental Test Pilots, Sigma Gamma Tau (aeronautical engineering society), Tau Beta Pi (national engineering society), and Sigma Xi (national science research society); and a 32nd Degree Mason advanced through the Commandery and Shrine.

SPECIAL HONORS: Awarded the Distinguished Flying Cross with one Oak Leaf Cluster, the Air Medal with two Oak Leaf Clusters, the Air Force Commendation Medal, the NASA Exceptional Service Medal and Air Force Command Pilot Astronaut Wings, the NASA Group Achievement Award for Rendezvous Operations Planning Team, an Honorary Life Membership in the International Association of Machinists and Aerospace Workers, and an Honorary Membership in the Aerospace Medical Association.

EXPERIENCE: Aldrin was graduated third in a class of 475 from the United States Military Academy at West Point in 1951 and subsequently received his wings at Bryan, Texas in 1952.

He flew combat missions in F-86 aircraft while on duty in Korea with the 51st Fighter Interceptor Wing. At Nellis Air Force Base, Nevada, he served as an aerial gunnery instructor and then attended the Squadron Officers' School at the Air University, Maxwell Air Force Base, Alabama.

Following his assignment as Aide to the Dean of Faculty at the United States Air Force Academy, Aldrin flew F-100 aircraft as a flight commander with the 36th Tactical Fighter Wing at Bitburg, Germany. He attended MIT, receiving a doctorate after completing his thesis concerning guidance for manned orbital rendezvous, and was then assigned to the Gemini Target Office of the Air Force Space Division, Los Angeles, California. He was later transferred to the USAF Field Office at the Manned Spacecraft Center which was responsible for integrating DOD experiments into the NASA Gemini flights.

CURRENT ASSIGNMENT: Colonel Aldrin was one of the third group of astronauts named by NASA in October 1963. He has since served as backup Pilot for the Gemini 9 Mission, prime Pilot for the Gemini 12 Mission, and backup Command Module Pilot for the Apollo 8 Mission.

BACKUP CREW BIOGRAPHICAL DATA

Commander (CDR)

NAME: James A. Lovell, Jr. (Captain, USN)

BIRTHPLACE AND DATE: Cleveland, Ohio; 25 March 1928

PHYSICAL DESCRIPTION: Blond hair; blue eyes; height: 5 ft. 11 in.; weight: 170 lb.

EDUCATION: Attended the University of Wisconsin for 2 years; received a Bachelor of Science degree from the United States Naval Academy in 1952.

ORGANIZATIONS: Member of the Society of Experimental Test Pilots and the Explorers Club.

SPECIAL HONORS: Awarded the NASA Distinguished Service Medal, two NASA Exceptional Service Medals, the Navy Astronaut Wings, two Navy Distinguished Flying Crosses, and the 1957 FAI Delavauly and Gold Space Medals (Athens, Greece); co-recipient of the 1966 American Astronautical Society Flight Achievement Award and the Harmon International Aviation Trophy in 1966 and 1967; and recipient of the American Academy of Achievement Gold Plate Award and the New York State Medal for Valor in 1969.

EXPERIENCE: Lovell received flight training following graduation from Annapolis. He has had numerous assignments including a 4-year tour as a test pilot at the Naval Air Test Center, Patuxent River, Maryland. While there he served as program manager for the F4H weapon system evaluation. A graduate of the Aviation Safety School of the University of Southern California, he also served as a flight instructor and safety officer with Fighter Squadron 101 at the Naval Air Station, Oceana, Virginia.

CURRENT ASSIGNMENT: Captain Lovell was selected as an astronaut by NASA in September 1962. He has served as backup Pilot for the Gemini 4 flight and as backup Command Pilot for Gemini 9.

On 4 December 1965, he and Command Pilot Frank Borman were launched into space on the history-making Gemini 7 Mission. The flight lasted 330 hours 35 minutes, during which the following space "firsts" were accomplished: longest manned space flight; first rendezvous of two manned maneuverable spacecraft, as Gemini 7 was joined by Gemini 6; and longest multimanned space flight.

The Gemini 12 Mission, with Command Pilot Lovell and Pilot Edwin Aldrin, began on 11 November 1966. This 4-day 59-revolution flight brought the Gemini Program to a successful close.

Lovell served as Command Module Pilot for the epic 6-day journey of Apollo 8 — man's maiden voyage to the moon — 21-27 December 1968. Apollo 8 was the first "manned spacecraft" to be lifted into near-earth orbit by a 7.5 million pound thrust Saturn V Launch Vehicle, and every aspect of the mission went smoothly from liftoff to landing.

Having completed three space flights, Captain Lovell holds the endurance record for time in space with a total of 572 hours 10 minutes.

Command Module Pilot (CMP)

NAME: William A. Anders (Lieutenant Colonel, USAF)

BIRTHPLACE AND DATE: Hong Kong; 17 October 1933.

PHYSICAL DESCRIPTION: Brown hair; blue eyes; height: 5 ft. 8 in.; weight: 145 lb.

EDUCATION: Received a Bachelor of Science degree from the United States Naval Academy in 1955 and a Master of Science degree in Nuclear Engineering from the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio, in 1962.

ORGANIZATIONS: Member of the American Nuclear Society and Tau Beta Pi.

SPECIAL HONORS: Awarded the Air Force Commendation Medal, Air Force Astronaut Wings, the NASA Distinguished Service Medal, and the New York State Medal for Valor.

EXPERIENCE: Anders was commissioned in the Air Force upon graduation from the Naval Academy. After Air Force flight training, he served as a fighter pilot in all-weather interceptor squadrons of the Air Defense Command.

After his graduate training, he served as a nuclear engineer and instructor pilot at the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, where he was responsible for technical management of radiation nuclear power reactor shielding and radiation effects programs.

CURRENT ASSIGNMENT: Lt. Colonel Anders was one of the third group of astronauts selected by NASA in October 1963. He has since served as back-up Pilot for the Gemini 11 Mission.

Anders served as Lunar Module Pilot for the Apollo 8 Mission, which was launched 21 December 1968 and returned from its voyage around the moon on 27 December 1968. This epic 6-day flight was man's maiden voyage to the moon.

Lt. Colonel Anders has recently been nominated by the President to be Executive Secretary of the National Aeronautics and Space Council.

Lunar Module Pilot (LMP)

NAME: Fred Wallace Haise, Jr. (Mr.)

BIRTHPLACE AND DATE: Biloxi, Mississippi; 14 November 1933.

PHYSICAL DESCRIPTION: Brown hair; brown eyes; height: 5 ft. 9.5 in.; weight: 150 lb.

EDUCATION: Attended Perkinston Junior College (Association of Arts); received a Bachelor of Science with honors in Aeronautical Engineering from the University of Oklahoma.

ORGANIZATIONS: Member of the Society of Experimental Test Pilots, Tau Beta Pi, Sigma Gamma Tau, and Phi Theta Kappa.

SPECIAL HONORS: Recipient of the A. B. Honts Trophy as the outstanding graduate of class 64A from the Aerospace Research Pilot School in 1964; awarded the American Defense Ribbon and the Society of Experimental Test Pilots Ray E. Tenhoff Award for 1966.

EXPERIENCE: Mr. Haise began his military career in October 1952 as a Naval Aviation Cadet at the Naval Air Station in Pensacola, Florida.

He served as a tactics and all-weather flight instructor in the U.S. Navy Advanced Training Command at NAAS Kingsville, Texas, and was assigned as a U.S. Marine Corps fighter pilot to VMF-533 and 114 at MCAS Cherry Point, North Carolina, from March 1954 to September 1956. From March 1957 to September 1959, he was a fighter-interceptor pilot with the 185th Fighter Interceptor Squadron in the Oklahoma Air National Guard.

He served with the U.S. Air Force from October 1961 to August 1962 as a tactical fighter pilot and as Chief of the 164th Standardization-Evaluation Flight of the 164th Tactical Fighter Squadron at Mansfield, Ohio.

Haise was a research pilot at the NASA Flight Research Center at Edwards, California, before coming to Houston and the Manned Spacecraft Center; and from September 1959 to March 1963, he was a research pilot at the NASA Lewis Research Center in Cleveland, Ohio. During this time he authored the following papers which have been published: a NASA TND, entitled "An Evaluation of the Flying Qualities of Seven General-Aviation Aircraft;" NASA TND 3380, "Use of Aircraft for Zero Gravity Environment, May 1966;" SAE Business Aircraft Conference Paper, entitled "An Evaluation of General-Aviation Aircraft Flying Qualities," 30 March-1 April 1966; and a paper delivered at the tenth symposium of the Society of Experimental Test Pilots, entitled "A Quantitative/Qualitative Handling Qualities Evaluation of Seven General-Aviation Aircraft," 1966.

CURRENT ASSIGNMENT: Mr. Haise is one of the 19 astronauts selected by NASA in April 1966. Haise served as backup Lunar Module Pilot for Apollo 8.

MISSION MANAGEMENT RESPONSIBILITY

Title	Name	Organization
Director, Apollo Program	Lt. Gen. Sam C. Phillips	NASA/OMSF
Director, Mission Operations	Maj. Gen. John D. Stevenson (Ret)	NASA/OMSF
Saturn V Vehicle Prog. Mgr.	Mr. Lee B. James	NASA/MSFC
Apollo Spacecraft Prog. Mgr.	Mr. George M. Low	NASA/MSC
Apollo Prog. Manager KSC	R. Adm. Roderick O. Middleton	NASA/KSC
Mission Director	Mr. George H. Hage	NASA/OMSF
Assistant Mission Director	Capt. Chester M. Lee (Ret)	NASA/OMSF
Assistant Mission Director	Col. Thomas H. McMullen	NASA/OMSF
Director of Launch Operations	Mr. Rocco Petrone	NASA/KSC
Director of Flight Operations	Mr. Christopher C. Kraft	NASA/MSC
Launch Operations Manager	Mr. Paul C. Donnelly	NASA/KSC
Flight Directors	Mr. Clifford E. Charlesworth Mr. Eugene F. Kranz Mr. Glynn S. Lunney Mr. Milton L. Windler	NASA/MSC
Spacecraft Commander (Prime)	Mr. Neil A. Armstrong	NASA/MSC
Spacecraft Commander (Backup)	Captain James A. Lovell, Jr.	NASA/MSC

PROGRAM MANAGEMENT

NASA HEADQUARTERS

Office of Manned Space Flight

Manned Spacecraft Center

Marshall Space Flight Center

Kennedy Space Center

LAUNCH VEHICLE	SPACECRAFT	TRACKING AND DATA ACQUISITION
Marshall Space Flight Center The Boeing Co. (S-IC) North American Rockwell Corp. (S-II) McDonnell Douglas Corp. (S-IVB) IBM Corp. (IU)	Manned Spacecraft Center North American Rockwell (LES, CSM, SLA) Grumman Aircraft Engineering Corp. (LM)	Kennedy Space Center Goddard Space Flight Center Department of Defense MSFN

ABBREVIATIONS AND ACRONYMS

AGS	Abort Guidance System
ALHT	Apollo Lunar Handtools
ALSCC	Apollo Lunar Surface Close-up Camera
AOL	Atlantic Ocean Line
AOS	Acquisition of Signal
APS	Ascent Propulsion System (LM)
APS	Auxiliary Propulsion System (S-IVB)
ARIA	Apollo Range Instrumentation Aircraft
AS	Ascent Stage
AS	Apollo/Saturn
BIG	Biological Isolation Garment
BPC	Boost Protection Cover
CCATS	Communications, Command, and Telemetry System
CD	Countdown
CDH	Constant Delta Height
CDR	Commander
CES	Control Electronics System
CM	Command Module
CMP	Command Module Pilot
COI	Contingency Orbit Insertion
CRA	Crew Reception Area
CSI	Concentric Sequence Initiation
CSM	Command/Service Module
DOI	Descent Orbit Insertion
DPS	Descent Propulsion System
DS	Descent Stage
EASEP	Early Apollo Scientific Experiments Package
ECS	Environmental Control System
EDS	Emergency Detection System
EDT	Eastern Daylight Time
EI	Entry Interface
EMU	Extravehicular Mobility Unit
EMS	Entry Monitor System
EOM	End-of-Mission
EPS	Electrical Power System
EPO	Earth Parking Orbit
EVA	Extravehicular Activity
EVCS	Extravehicular Communication System
GET	Ground Elapsed Time
GHe	Gaseous Helium
GNCS	Guidance, Navigation, and Control System
GOX	Gaseous Oxygen
H	Hybrid Trajectory
IMU	Inertial Measurement Unit
IS	Instrumentation System
IU	Instrument Unit
KSC	Kennedy Space Center

LC	Launch Complex
LCC	Launch Control Center
LCG	Liquid Cooling Garment
LES	Launch Escape System
LET	Launch Escape Tower
LH_2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LM	Lunar Module
LMP	Lunar Module Pilot
LOI	Lunar Orbit Insertion
LOX	Liquid Oxygen
LPO	Lunar Parking Orbit
LRL	Lunar Receiving Laboratory
LRRR	Laser Ranging Retro-Reflector
LTA	Lunar Module Test Article
LV	Launch Vehicle
MCC	Midcourse Correction
MCC	Mission Control Center
MESA	Modularized Equipment Stowage Assembly
MOCR	Mission Operations Control Room
MOR	Mission Operation Report
MPL	Mid-Pacific Line
MQF	Mobile Quarantine Facility
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSS	Mobile Service Structure
NASCOM	NASA Communications Network
NM	Nautical Mile
OPS	Oxygen Purge System
PC	Plane Change
PDI	Powered Descent Initiation
PGNS	Primary Guidance and Navigation System
PLSS	Portable Life Support System
PRS	Primary Recovery Ship
PSE	Passive Seismic Experiment
PTP	Preferred Target Point
RCS	Reaction Control System
RR	Rendezvous Radar
R&D	Research and Development
RTCC	Real-Time Computer Complex
S&A	Safe and Arm
SAR	Search and Rescue
S/C	Spacecraft
SCS	Stabilization and Control System
SEA	Sun Elevation Angle
SEQ	Sequential System
SEQ	Scientific Equipment
SHe	Supercritical Helium
S-IC	First Stage

S-II	Second Stage
S-IVB	Third Stage
SLA	Spacecraft-LM Adapter
SLA	Secondary Landing Area
SM	Service Module
SPS	Service Propulsion System
SRC	Sample Return Container
SRS	Secondary Recovery Ship
SSR	Staff Support Room
SV	Space Vehicle
SXT	Sextant
SWC	Solar Wind Composition
TB	Time Base
TD&E	Transposition, Docking, and Ejection
T/C	Telecommunications
TEC	Transearth Coast
TEI	Transearth Injection
TLC	Translunar Coast
TLI	Translunar Injection
TPF	Terminal Phase Finalization
TPI	Terminal Phase Initiation
T-time	Countdown time (referenced to liftoff time)
TV	Television
USB	Uniform S-band
VAB	Vehicle Assembly Building
VG	Velocity-to-be-Gained
VHF	Very High Frequency

GPO 878-246