LM-5 SPACECRAFT BRIEFING

CDDT/RECONFIGURE

AS-506/LM-5

TCP-KL-0007

PREPARED BY:

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

KENNEDY SPACE CENTER, FLORIDA

I. PROCEDURE DEVELOPMENT

THE BASIC ISSUE OF TCP-KL-0007 WAS PUBLISHED AS FOLLOWS:

VOLUME I RELEASED	6/17/69	321 PAGES
VOLUME II RELEASED	6/16/69	1220 PAGES

DURING THE PERIOD SINCE THE REVIEW MEETING AND THE CLOSE OUT OF INPUTS TO THE BASIC ISSUE (5/22/69), VOLUMES I AND II HAVE HAD ONE CHANGE EACH RELEASED ON 6/23/69.

THIS UPDATE AFFECTED SIXTEEN PERCENT (16%) OF VOLUME I AND TWELVE PERCENT (12%) OF VOLUME II. MAJOR FACTORS CONTRIBUTING TO THIS CHANGE WERE:

1. PROPULSION GSE UPLINK COMMAND CHANGES.
2. RCS PLUME DEFLECTOR INSTALLATION.
3. ENGINEERING OVERSIGHT AND PUBLICATION PROCESSING ERRORS.
4. CHANGE IN H_2O LOADING REQUIREMENTS.
5. MESA STOWAGE CHANGES.
6. DETAILING ACE CABLE DEMATE PRIOR TO MSS MOVE.
7. INTEGRATION OF SYSTEMS INPUTS.

II. TEST OBJECTIVES:

A. To PERFORM ALL COUNTDOWN DEMONSTRATION OPERATIONS

B. To PROVIDE OPERATIONAL PLANS TO RECONFIGURE FROM CDDT TO CD.

III. <u>GENERAL TEST DESCRIPTION</u>:

THE LM CDDT/RECONFIGURE PROCEDURE PROVIDES THE OPERATIONAL CONTROL OF THE WET COUNTDOWN DEMONSTRATION FROM T-113 HOURS THROUGH ZERO. IT ALSO PROVIDES CONTROL DURING DRY CDDT AND RECONFIGURE FOR COUNTDOWN. COUNTDOWN DEMONSTRATION TEST WILL BEGIN AFTER HYPERGOLICS ARE SERVICED. CREW STOWAGE FUNCTIONS AND EXPLOSIVE DEVICE CHECKS PERFORMED DURING CDDT/RECONFIGURE WILL BE CONTAINED IN SUPPLEMENTAL DOCUMENTS.

DURING THE COUNTDOWN DEMONSTRATION, LIMITED INTERFACE VERIFICATIONS OF THE LM SUBSYSTEMS WILL BE MADE. EXPLOSIVE DEVICES POWER-OFF STRAY VOLTAGE CHECKS AND INITIATOR HOOK-UP WILL BE DONE IN PARALLEL BY LM, CSM, AND LV. (CSM AND LV HEAVY ORDNANCE SIMULATED).

THE PRIMARY GUIDANCE SYSTEM AND THE ABORT GUIDANCE SYSTEM FINAL VERIFICATION WILL BE PERFORMED AND THE SYSTEMS POWERED DOWN TO STANDBY AND REMAIN IN THIS CONFIGURATION FOR LAUNCH.

COMMUNICATION CHECKS OF THE FLIGHT UMBILICAL WILL BE PERFORMED DURING CDDT.

SUPERCRITICAL HELIUM WILL BE INITIALLY LOADED FOLLOWED BY A COLD SOAK PERIOD AND THEN TOPPED OFF FOR LAUNCH. SHE WILL BE VENTED IN THE RECONFIGURE PERIOD AND THE LOADING OPERATION REPEATED IN COUNTDOWN.

III. GENERAL TEST DESCRIPTION: (CONTINUED)

THE LM CABIN WILL BE CLOSED OUT. PARTIAL SLA INTERNAL PLATFORMS WILL BE REMOVED. THE CABIN CLOSEOUT WILL LIMIT ACE-S/C DATA AND CONTROL TO UMBILICAL FUNCTIONS.

AFTER THE SERVICE STRUCTURE HAS BEEN MOVED AND THE PAD CLEARED, NO FURTHER LM PAD ACTIVITY IS PLANNED UNTIL COMPLETION OF DRY CDDT.

EPS WILL SWITCH TO INTERNAL POWER AT T-30 MINUTES. OPERATIONAL INSTRUMENTATION WILL BE SHUTDOWN AT T-10 MINUTES.

DURING THE RECONFIGURATION PERIOD, SLA PLATFORMS REMOVED DURING CDDT WILL BE INSTALLED AND THE REQUIRED SLA PENETRATIONS WILL BE OPENED. EPS AND ED GROUND TEST BATTERIES WILL BE REMOVED AND FLIGHT EPS AND ED BATTERIES INSTALLED. A SHE BURST DISC CHECK WILL BE PERFORMED AND THE SHE TANK WILL BE VENTED. THE LM WATER MANAGEMENT SYSTEM WILL BE SERVICED DURING THIS PERIOD. GHE AND SHE GSE WILL BE SET UP AND VERIFIED. THE GOX TRANSFER UNIT WILL BE SERVICED, TRANSPORTED TO LEVEL 3C, CONNECTED TO THE SPACECRAFT, AND LEAKED CHECKED.

IV. TEST SCHEDULE:

THE FOLLOWING IS A NARRATIVE OF THE LM ACTIVITIES DURING CDDT/RECONFIGURE:

A. CDDT:

1. T-113 HOURS TO T-93 HOURS
   A. LM SUBSYSTEM VERIFICATION CHECKS
2. T-92 HOURS 30 MINUTES TO T-80 HOURS 30 MINUTES
   A. LM POWER-OFF STRAY VOLTAGE CHECKS AND INITIATOR HOOK-UP.
   B. ED TEST BATTERY CONNECTIONS AND VERIFICATION.
3. T-80 HOURS TO T-41 HOURS
   A. LM MECHANICAL BUILDUP
4. T-80 TO T-64 HOURS
   A. PRIMARY GUIDANCE AND ABORT GUIDANCE VERIFICATION AND FINAL CLOSE OUT OPERATION.
5. T-80 HOURS TO T-69 HOURS
   A. SHE TANK LOADING PREPS
6. T-80 HOURS TO T-68 HOURS
   A. INSTALLATION AND COMMUNICATION CHECKS OF FLIGHT UMBILICAL.
7. T-63 HOURS TO T-58 HOURS 30 MINUTES
   A. CABIN DUMP VALVE AND CABIN LEAK CHECK.
8. T-48 HOURS TO T-44 HOURS
   A. SHE TANK FILL
9. T-38 HOURS TO T-34 HOURS
   A. PLSS CHECKS IN ECS BUILDING
10. T-29 HOURS 30 MINUTES TO T-21 HOURS
    A. FINAL CABIN CLOSE OUT INCLUDING CABIN STOWAGE, SWITCH SETTING, HATCH INSTALLATION.

IV. TEST SCHEDULE: (CONTINUED)

A. 11. T-27 HOURS 30 MINUTES TO T-13 HOURS 30 MINUTES

A. SHE TANK TOP-OFF OPERATION; GSE REMOVAL.

B. SHE TANK TOP-OFF AT T-21 HOURS TO T-19 HOURS.

12. T-29 HOURS 30 MINUTES TO T-12 HOURS 15 MINUTES

A. FINAL MECHANICAL CLOSEOUT OF THERMAL SHIELDS AND SLA CUTTER AND FREON/WATER DELUGE SYSTEM WILL BE REMOVED. LEVEL 3 AVAILABLE FOR OPENING AT T-12 HOURS AND 15 MINUTES.

13. T-11 HOURS TO T-10 HOURS 55 MINUTES

A. EPS SWITCHOVER TO INTERNAL BATTERY CHECKS.

14. T-30 MINUTES

A. SWITCHOVER TO INTERNAL BATTERY POWER.

15. T-10 MINUTES

A. TURN OFF OPERATIONS INSTRUMENTATION.

16. T-8 MINUTES

FINAL STATUS

B. LV DESERVICE AND DRY CDDT:

1. A. SWITCHOVER LM TO LUT POWER

B. OPERATIONAL INSTRUMENTATION TURN-ON.

2. PICK UP COUNT AT T-6:00 AFTER +17:00 OF RECONFIGURE (NO LM PAD ACTIVITY).

3. T-30 MINUTES

EPS SWITCHOVER TO INTERNAL POWER.

IV. TEST SCHEDULE: (CONTINUED)

B. 4. T-10 MINUTES

OPERATIONAL INSTRUMENTATION TURN-OFF.

C. RECONFIGURE FOR COUNTDOWN:

1. OPERATIONAL INSTRUMENTATION TURN-ON
2. SWITCHOVER TO LUT POWER
3. T + 6 HOURS 45 MINUTES

   PREPS FOR SHE BURST CHECK AND VENTING.
4. T + 6 HOURS 45 MINUTES TO T + 11 HOURS 15 MINUTES

   SHE TANK BURST LEAK CHECK AND SHE TANK VENTING.
5. T + 9 HOURS 45 MINUTES TO T + 22 HOURS
   - A. INSTALL WORK PLATFORMS
   - B. INSTALL SLA CUTTERS
   - C. REMOVE THERMAL SHIELD
   - D. INSTALL CLEAN TENT
   - E. REMOVE ED AND EPS TEST BATTERIES
   - F. REMOVE CREW PROVISIONS
6. T + 14 HOURS TO T + 23 HOURS WQMD CHECKS
7. T + 23 HOURS TO T + 54 HOURS LCG LEAK CHECKS AND FUNCTIONAL VERIFICATION.
8. T + 54 HOURS INDEFINITE HOLD
9. T - 128 HOURS TO T - 108 HOURS WMS SERVICING
10. T - 128 HOURS TO T - 118 HOURS INSTALL ED AND EPS FLIGHT BATTERIES.

IV. TEST SCHEDULE: (CONTINUED)

11. T - 128 HOURS TO T - 107 HOURS SHE GSE PREPS
12. T - 108 HOURS TO T - 105 HOURS SCA LEAK CHECKS
13. T - 108 HOURS TO T - 93 HOURS GOX GTU SERVICING AND GSE CONNECTION.
14. T - 107 HOURS TO T - 96 HOURS 15 MINUTES GHE GSE SETUP AND LEAK CHECKS.
15. T - 96 HOURS TO T - 93 HOURS OXID AND FUEL HOSE ROUTING AND LEAK CHECK.

V. SUPPORT SUMMARY:

THE FOLLOWING SUPPORT IS REQUIRED FOR LM ACTIVITIES DURING CDDT/RECONFIGURE:

A. 1. T-111 HOURS TO T-107 HOURS: GO_2 SAMPLING SUPPORT REQUIRED ON MSS LEVEL 3A (CDDT ONLY).

2. T-107 HOURS TO T-106 HOURS: TRANSFER LO_2 DEWAR FROM LEVEL 3C TO CCF.

B. T-110 HOURS TO T-101 HOURS: LM OPERATIONAL VHF FREQUENCY CLEARANCE (CDDT ONLY).

C. T-108 HOURS TO T-100 HOURS: LM S-BAND FREQUENCY CLEARANCE. USB STATION REQUIRED TO SUPPORT S-BAND TESTING AND DUA CHECKS. (CDDT ONLY).

D. T-99 HOURS TO T-98 HOURS: LM X-BAND FREQUENCY CLEARANCE REQUIRED FOR RADAR TESTING (CDDT ONLY).

E. T-97 HOURS TO T-96 HOURS: LM S-BAND AND OPER. VHF FREQUENCY CLEARANCE AND USB STATION REQUIRED FOR LM LOW BIT RATE CHECKS (CDDT ONLY).

F. T-80 HOURS TO T-19 HOURS LHE TANKER

G. T-73 HOURS TO T-72 HOURS: LM S-BAND FREQUENCY CLEARANCE USB STATION SUPPORT REQUIRED FLIGHT UMBILICAL ELECTRICAL TEST (CDDT ONLY).

H. T-76 HOURS TO T-69 HOURS: GHE SAMPLING SUPPORT REQUIRED IN IU AREA.

I. T-100 HOURS TO T-51.5 HOURS: T-26.5 HOURS TO T-14 HOURS: (CDDT) T-118 HOURS TO T-106 HOURS (RECONFIGURE): PHOTOGRAPHY SUPPORT REQUIRED FOR MECHANICAL CLOSEOUT.

J. T-63 HOURS TO T-58 HOURS 30 MINUTES: ENVIRONMENTAL HEALTH SUPPORT FOR OXYGEN CONTENT CHECKS IN CABIN AFTER LEAK CHECKS.

V. SUPPORT SUMMARY: (CONTINUED)

K. T-38 HOURS TO T-34 HOURS: LM OPERATIONAL VHF FREQUENCY CLEARANCE FOR PLSS TESTING FROM ECS BUILDING (CDDT & CD).

L. T-30 HOURS TO T-29.5 HOURS: ENVIRONMENTAL HEALTH SUPPORT FOR OXYGEN CONTENT CHECKS IN SLA REQUIRED PRIOR TO BEING OPEN FOR WORK.

M. T-117 TO T-113 HOURS 30 MINUTES AND T-110.5 TO T-109.5 HOURS (RECONFIGURE) H_2O SAMPLING SUPPORT ON MSS LEVEL 3A.

N. T-107 HOURS TO T-103 HOURS: (RECONFIGURE) GHE SAMPLING SUPPORT REQUIRED ON MSS LEVEL 3A.

O. SYSTEM SAFETY SUPPORT: REQUIRED FOR ALL LM HAZARDOUS OPERATIONS.

P. STANDBY SCAPE SUPPORT (2 X 2) FROM START OF CDDT UNTIL LAUNCH.

VI. HAZARDOUS SUMMARY:

A. T-93 HOURS TO T-80 HOURS 30 MINUTES: POWER OFF STRAY VOLTAGE CHECKS AND FLIGHT CONNECTOR MATING. LM REQUIRES SA 7, INTERNAL SLA, MSS LEVELS 3A, 3B, 3C, EXCEPT FOR ESSENTIAL PERSONNEL AS LISTED IN PROCEDURE (CDDT ONLY).

B. T-48 HOURS TO T-44 HOURS: CLEAR INTERNAL SLA IN IU AND LM D/S AREA EXCEPT ESSENTIAL PERSONNEL AS LISTED IN PROCEDURE FOR SHE FILL.

C. T-21 HOURS TO T-19 HOURS: CLEAR INTERNAL SLA IN IU AND LM D/S AREA EXCEPT ESSENTIAL PERSONNEL AS LISTED IN PROCEDURE FOR SHE TOP-OFF.

D. T + 10 HOURS 15 MINUTES TO T + 11 HOURS 15 MINUTES: CLEAR INTERNAL SLA IN IU AND LM D/S AREA EXCEPT ESSENTIAL PERSONNEL AS LISTED IN PROCEDURE FOR SHE TANK VENTING.

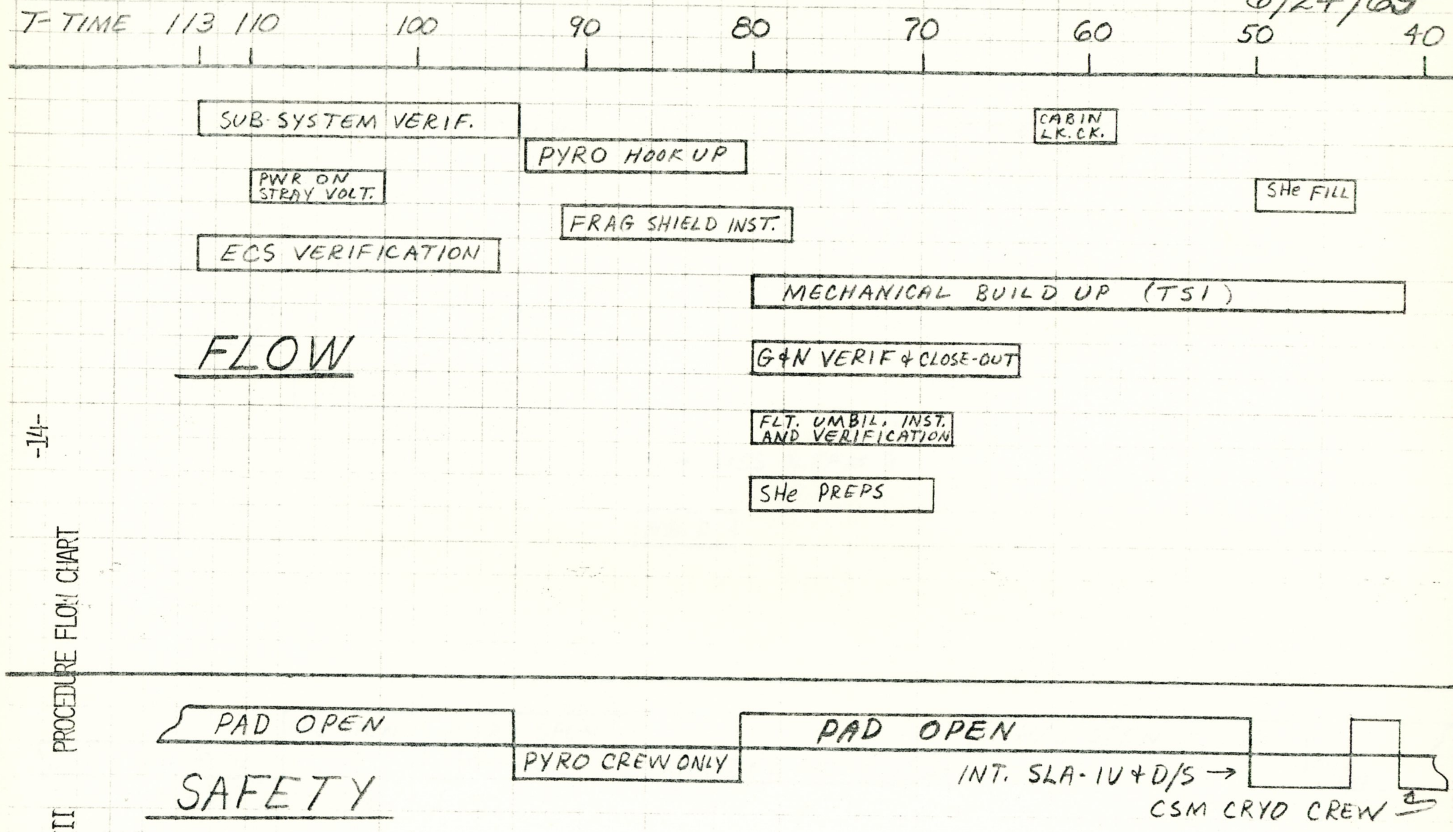
E. T - 97 HOURS 45 MINUTES TO T - 93 HOURS: CLEAR SLA INT., SIV B FORWARD AND IU EXCEPT LM PROPELLANT HOSE ROUTING, EM AND LEAK CHECKS.

VII. TEST CONSTRAINTS:

CONSTRAINTS TO THIS TEST ARE AS INDICATED IN THE LETTER TO THE CHIEF, OPERATIONS DIVISION, LLR-670-1441, DATED 24 JUNE 1969

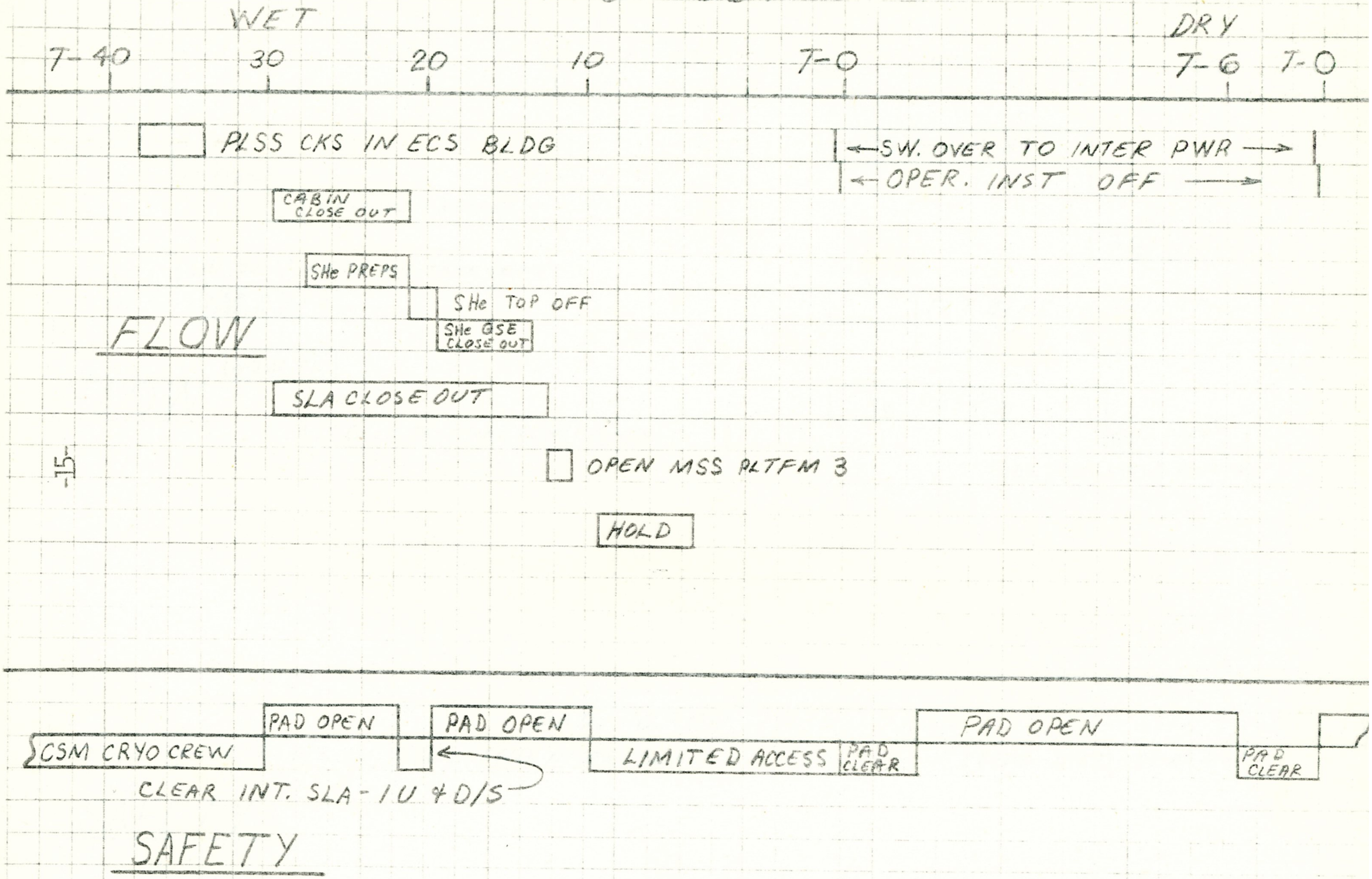
LM-5 CDDT

6/24/69



VIII PROCEDURE FLOW CHART

LM 5 CDDT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PLSS CKS IN ECS BLDG
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CABIN CLOSE OUT
SHe PREPS
SHe TOP OFF
SHe GSE CLOSE OUT
FLOW
SLA CLOSE OUT
OPEN MSS PLTFM 3
HOLD
CSM CRYO CREW
PAD OPEN
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CLEAR INT. SLA-IU & D/S
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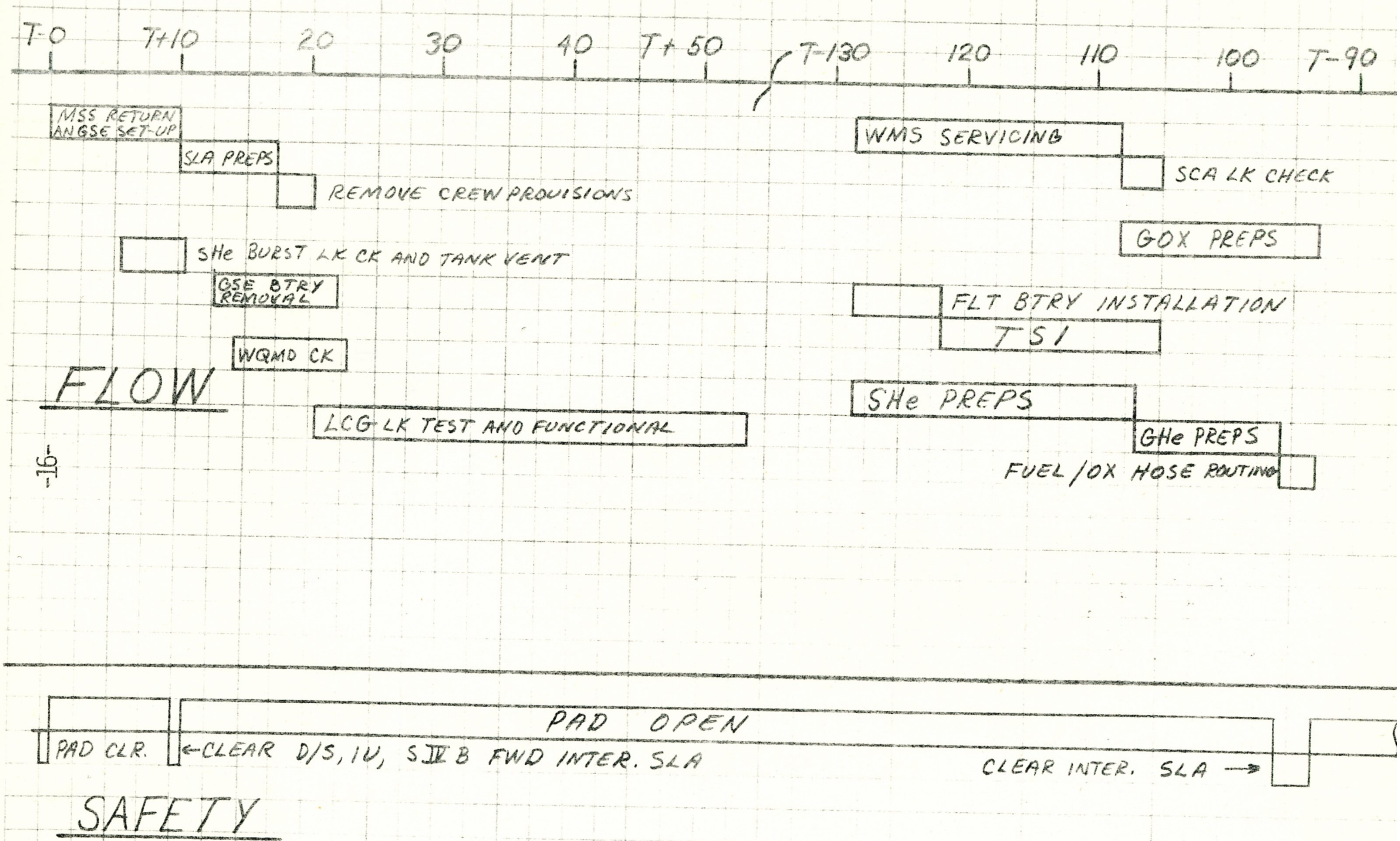
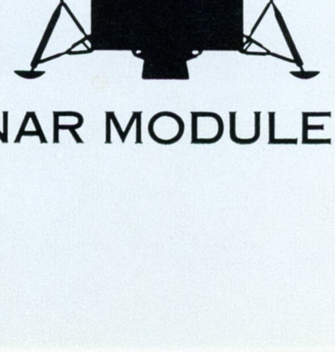
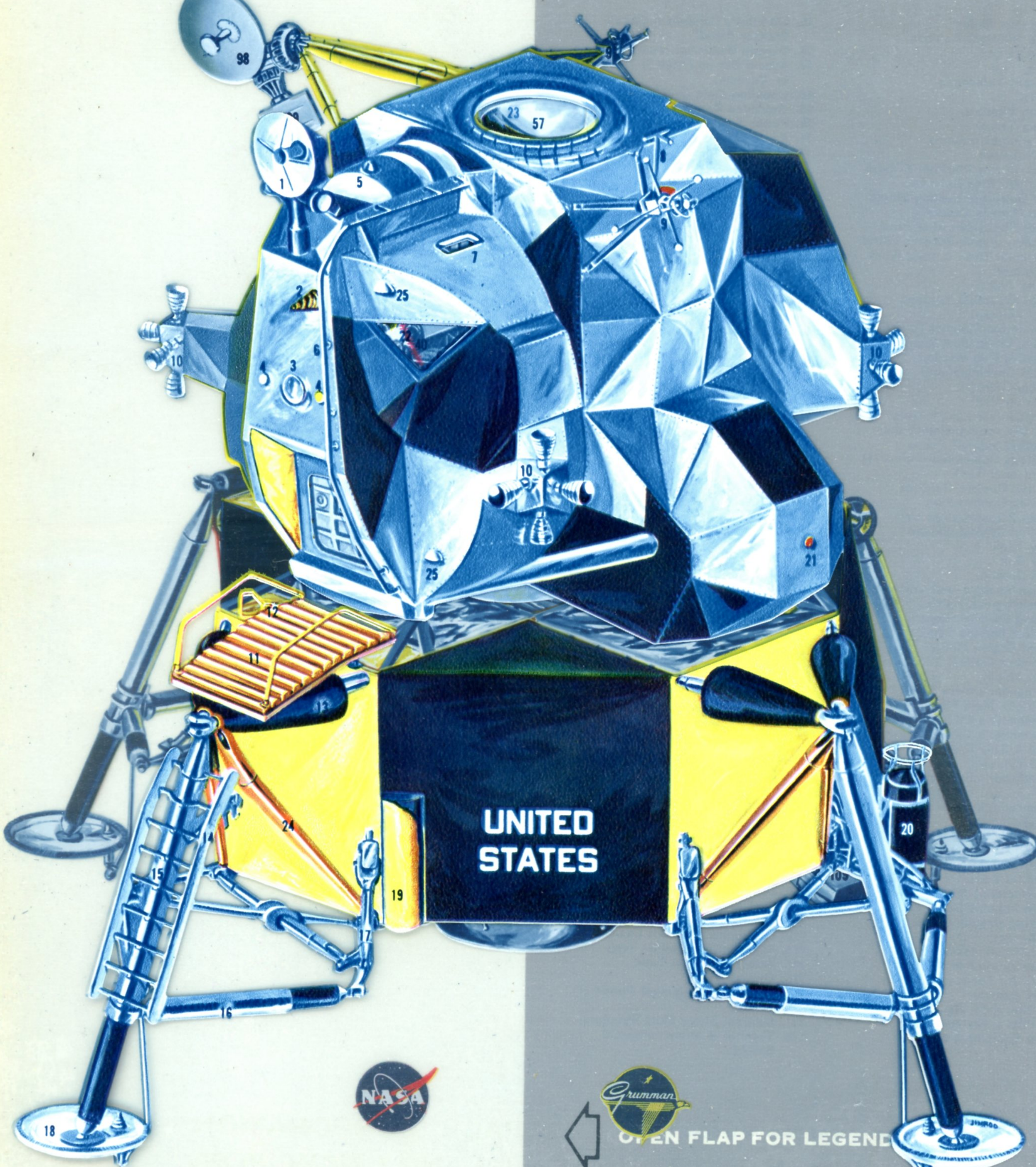
SAFETY

LM-5 RECONFIGURE FOR COUNTDOWN





NASA/GRUMMAN APOLLO LUNAR MODULE



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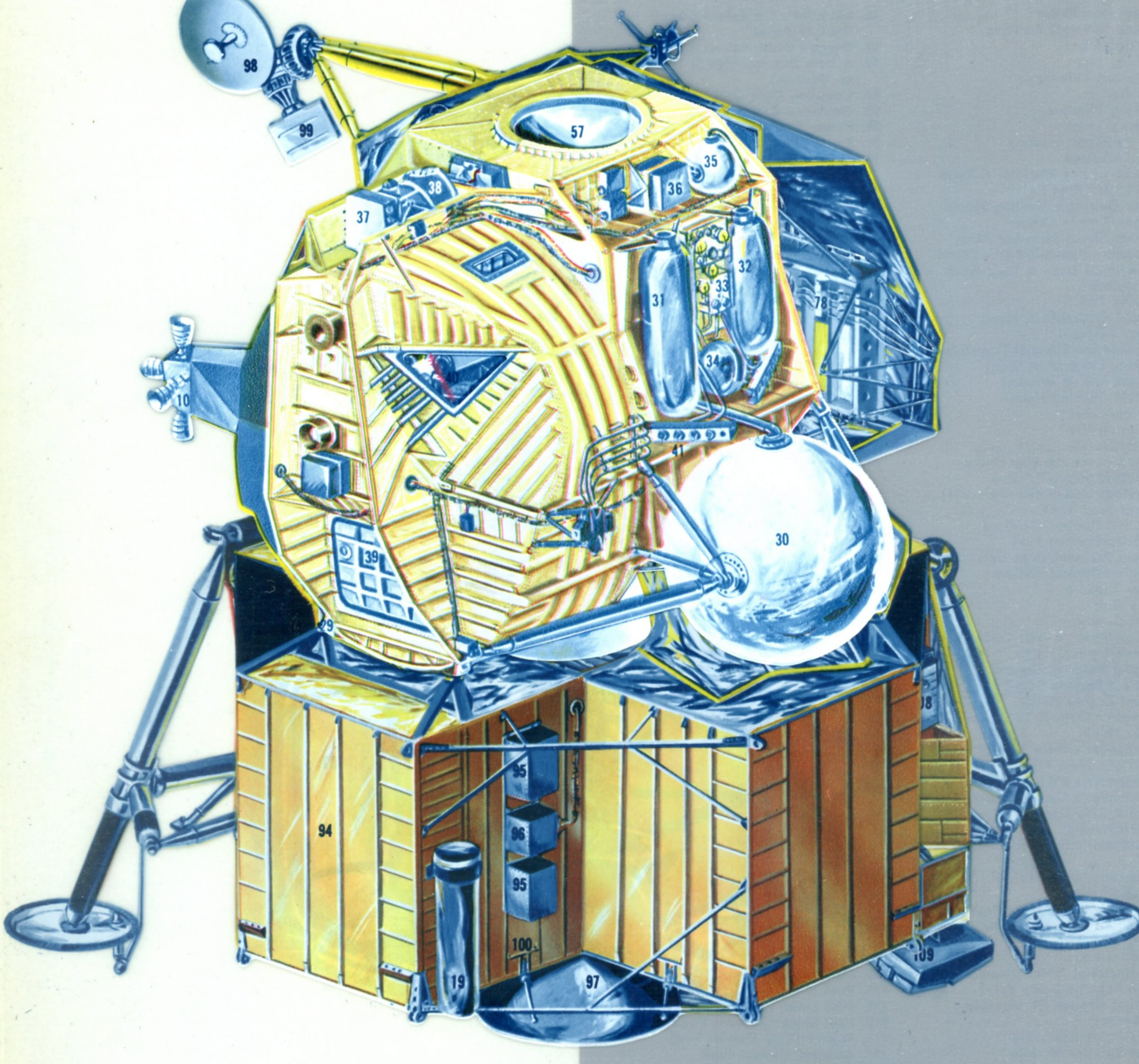

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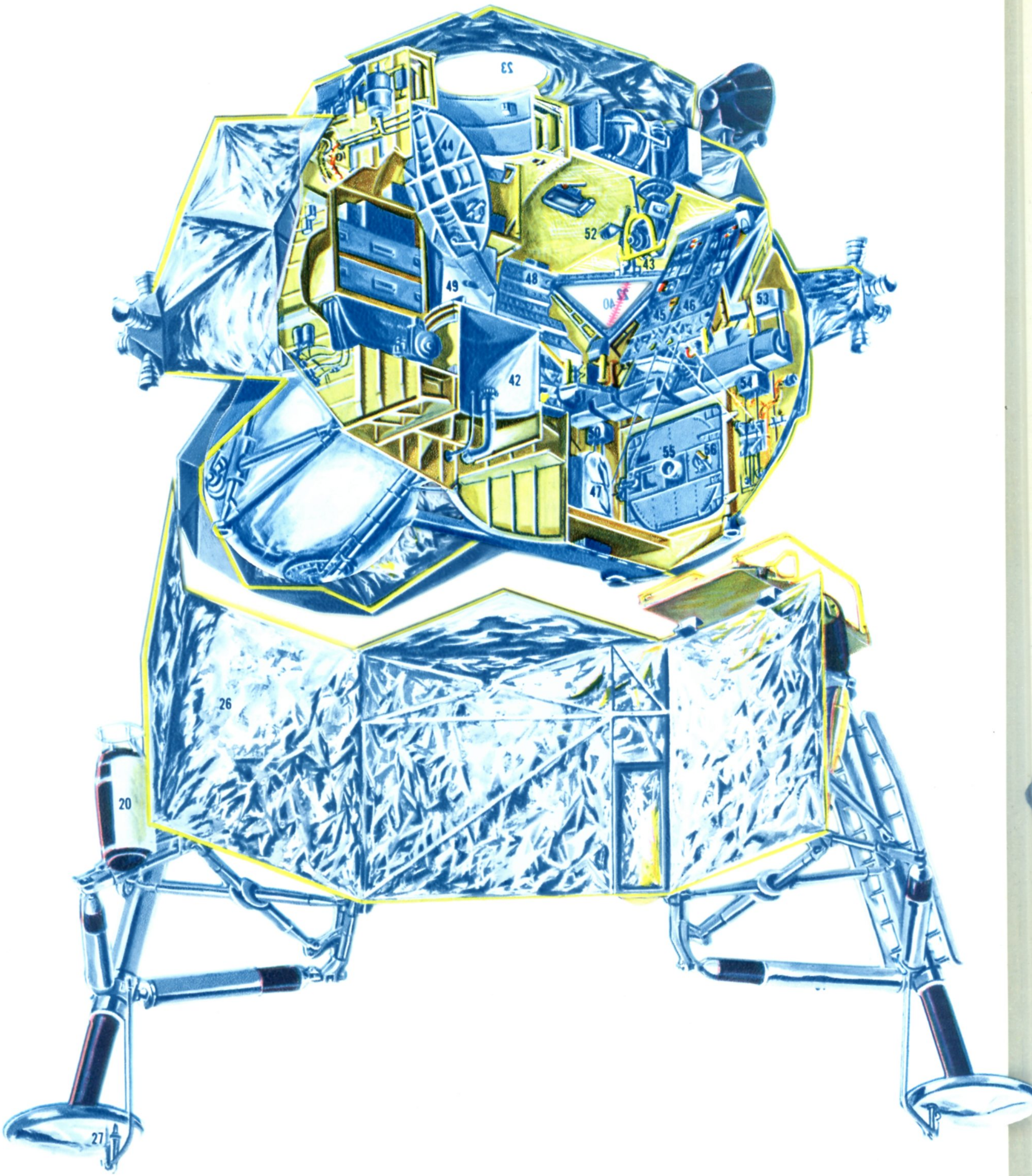
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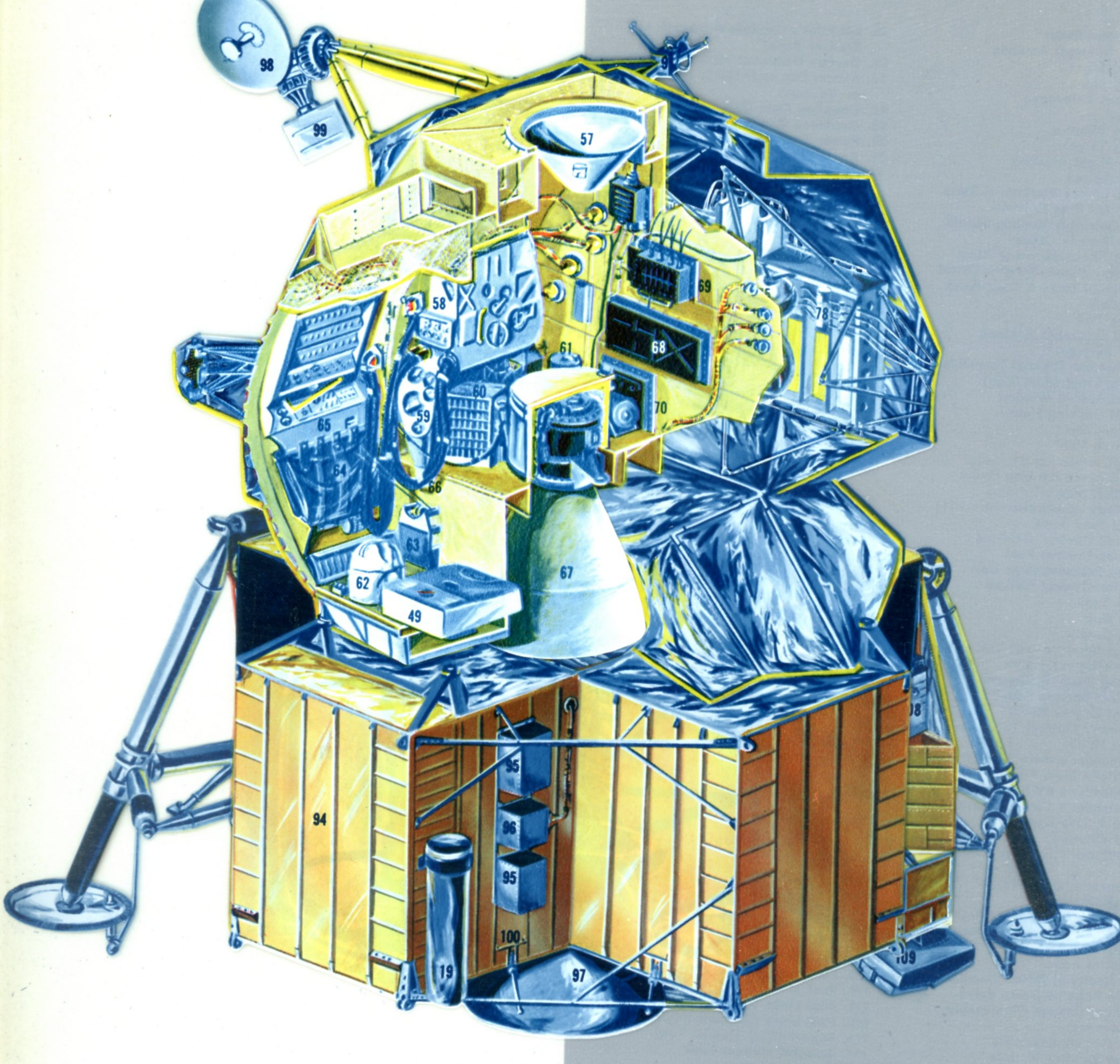

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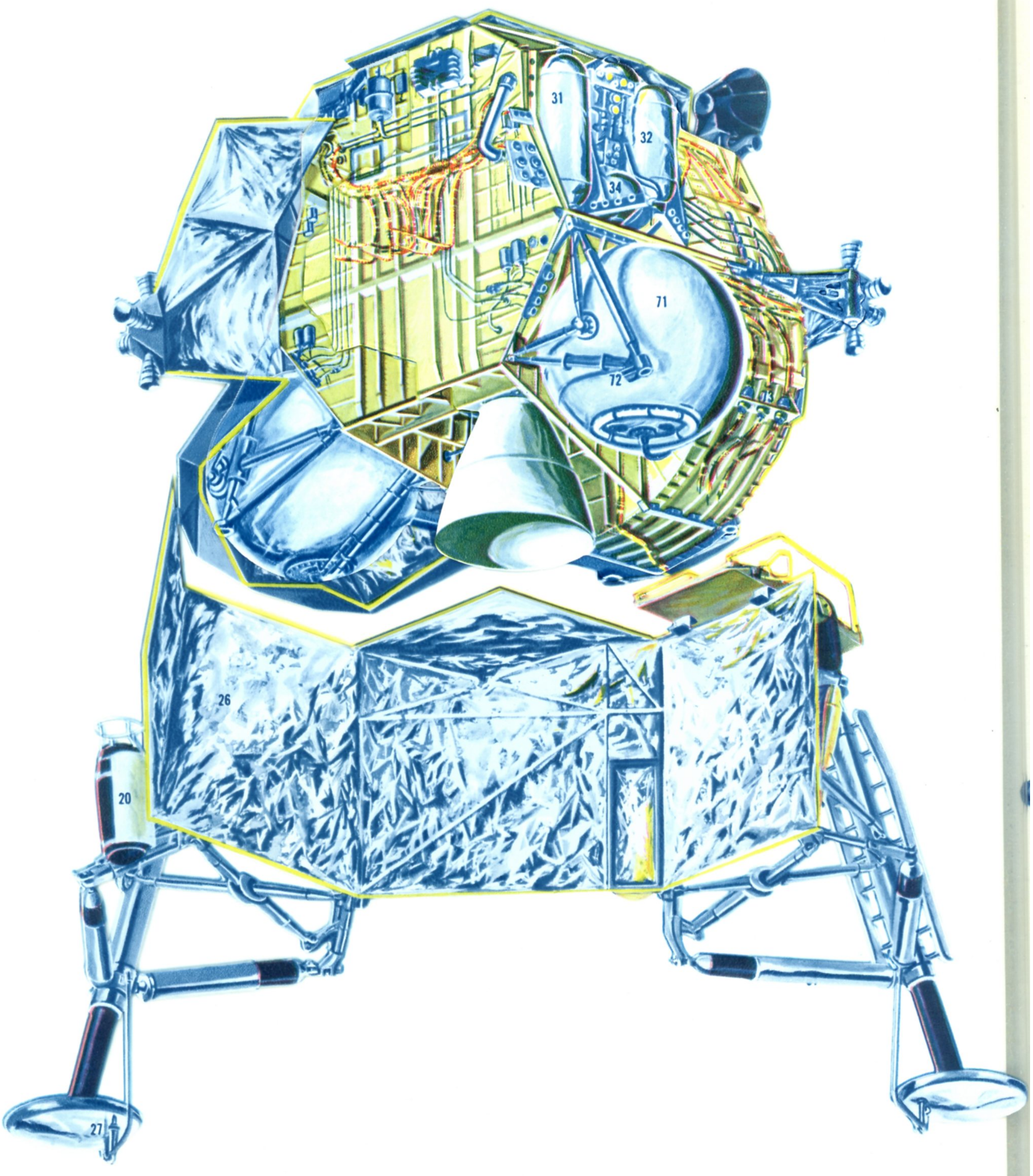

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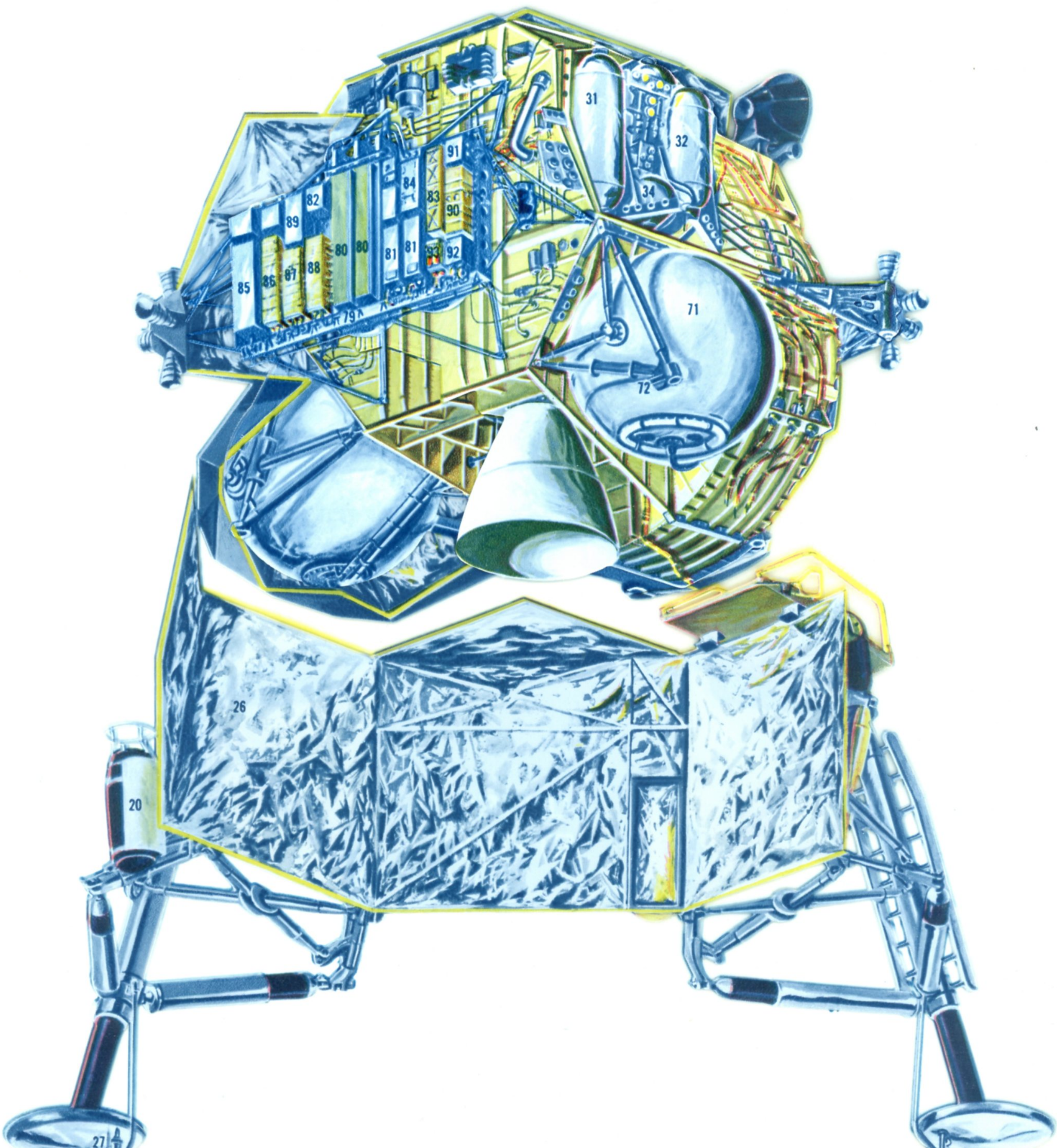

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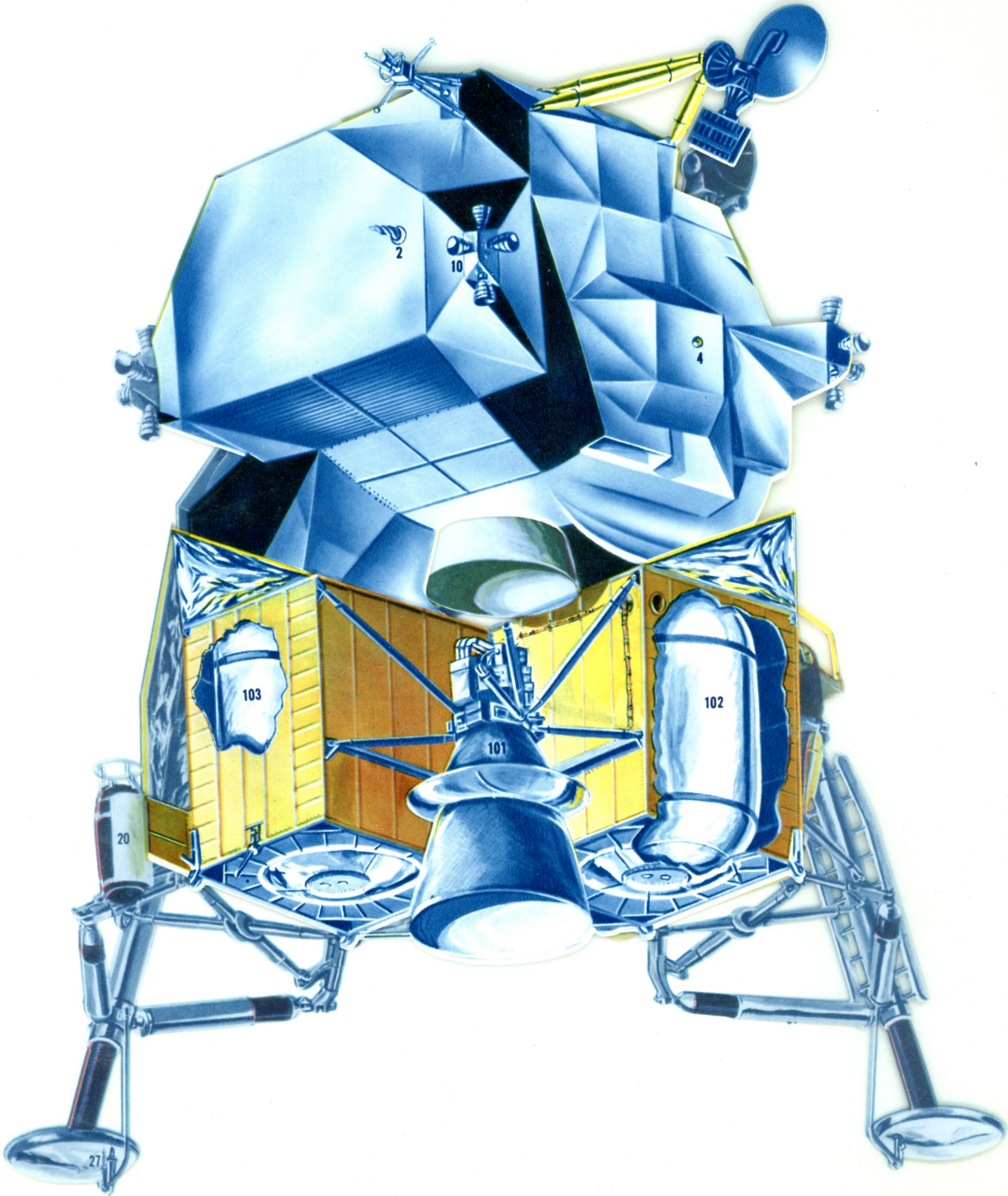
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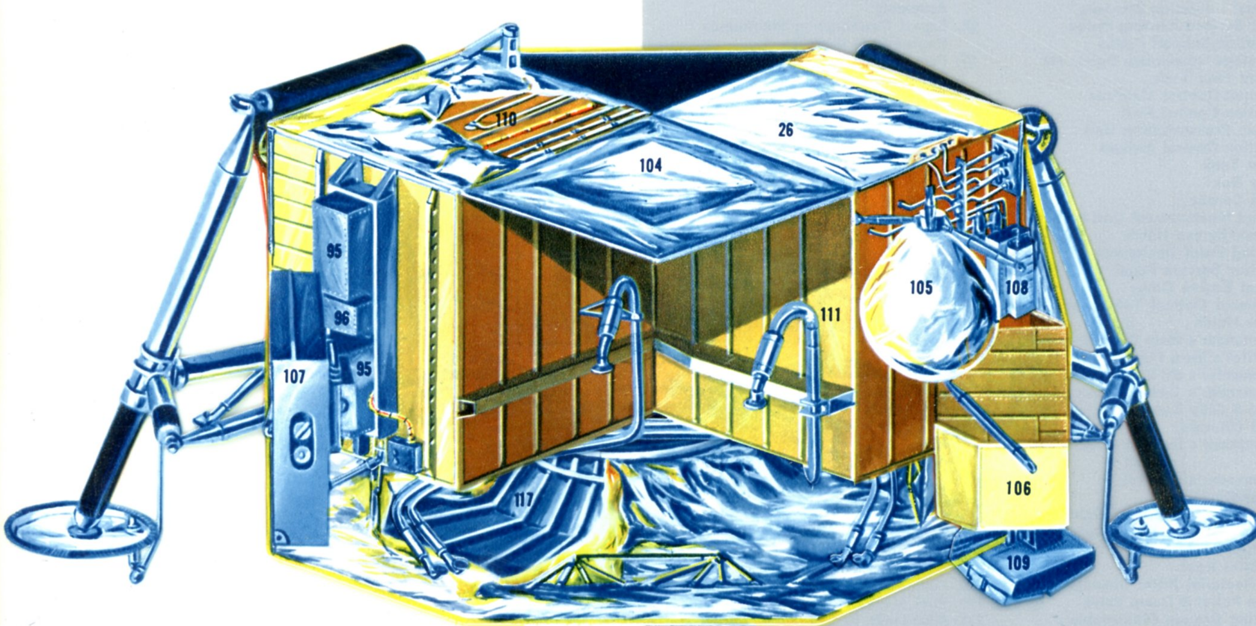

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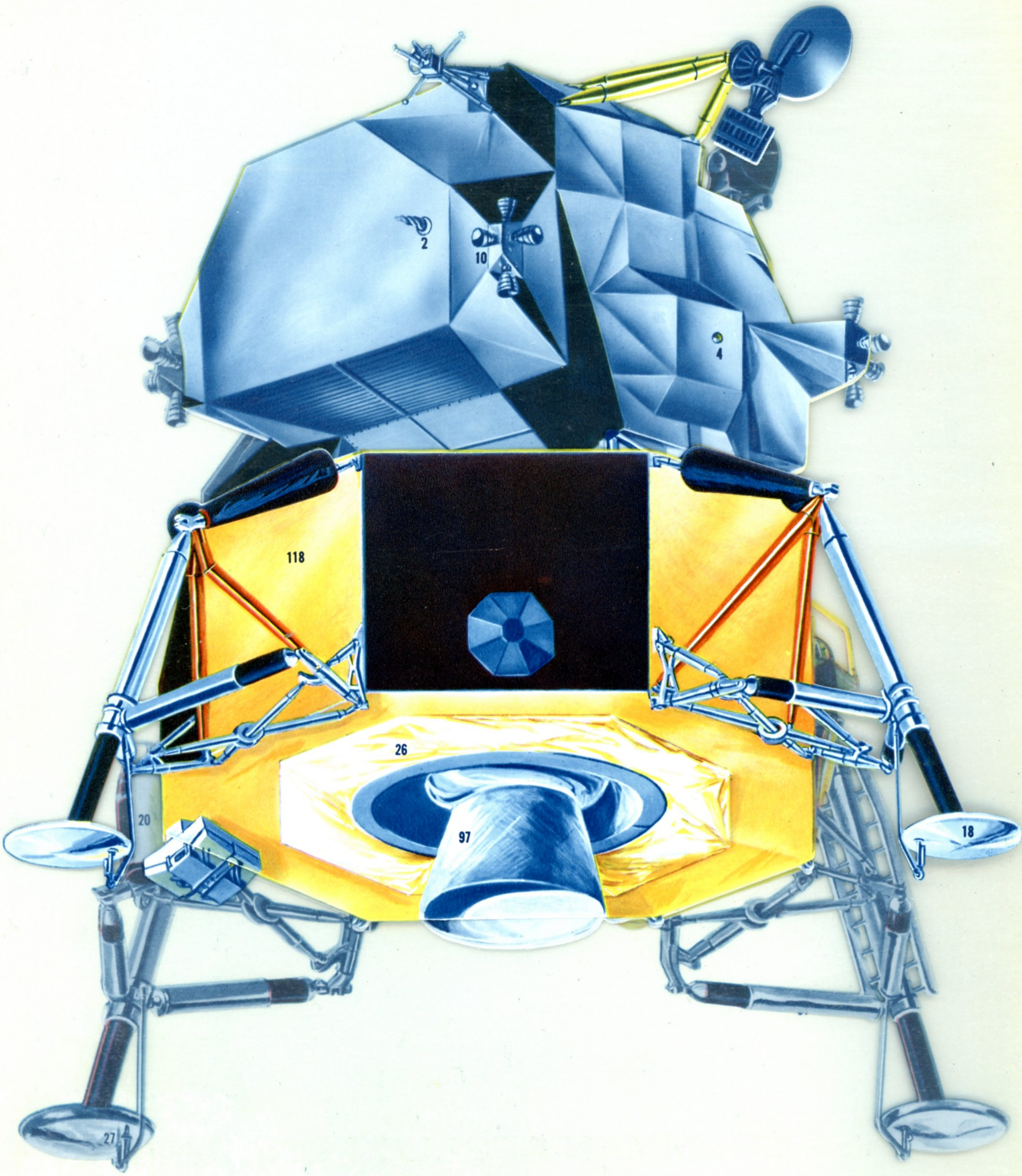

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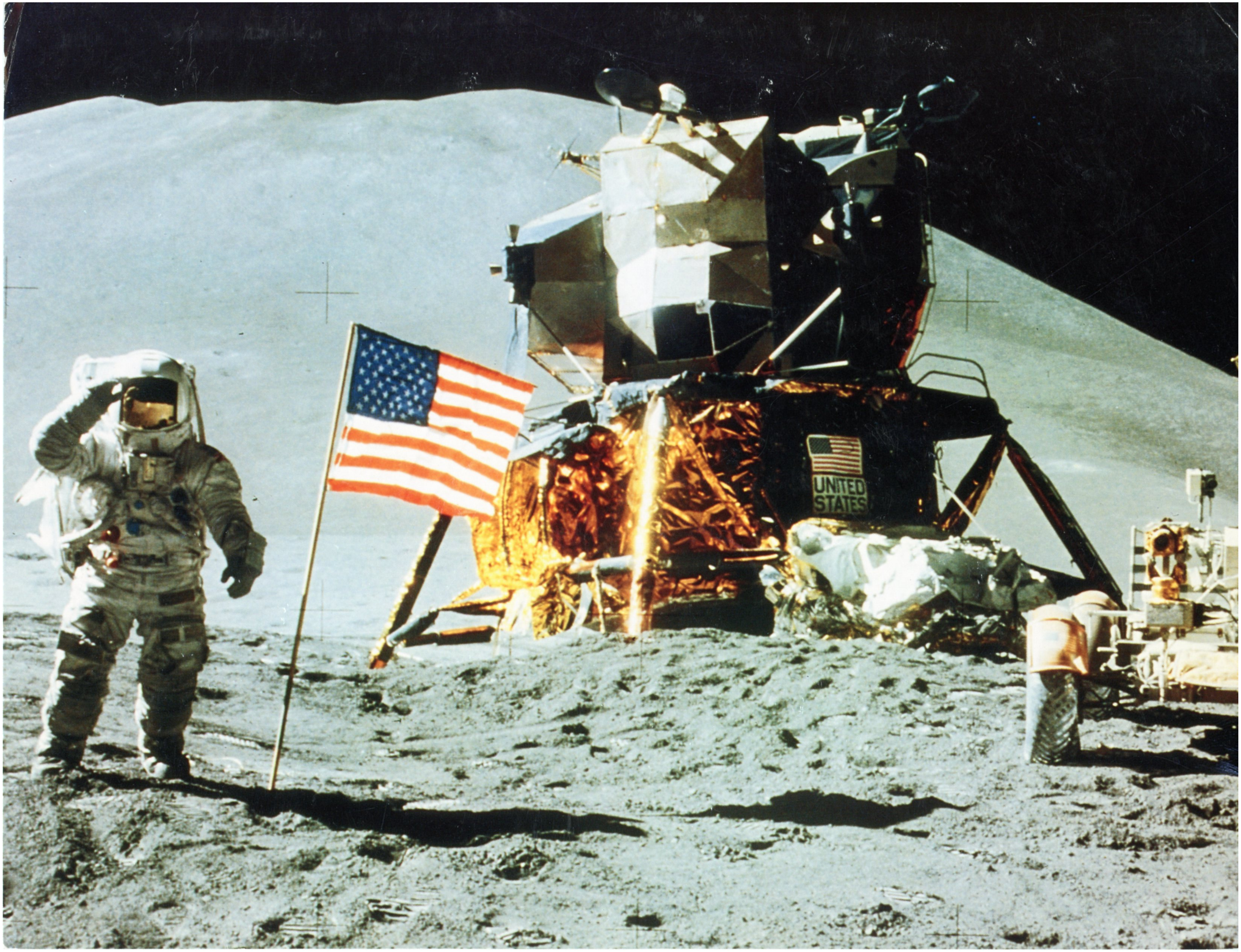
LEGEND

1. Rendezvous Radar
2. S-Band In-Flight Antenna
3. Tracking Light
4. Docking Light
5. Alignment Telescope
6. EVA Rail
7. Docking Window
8. Docking Target
9. VHF In-Flight Antenna
10. RCS Thrusters
11. Ingress/Egress Platform & Rails
12. MESA "O" Ring Release
13. Upper Outrigger Venting Shield
14. Ingress/Egress Ladder
15. Primary Shock-Absorber Strut
16. Secondary Shock-Absorber Strut
17. Deployment Truss & Down-Lock Mechanism
18. Landing Pad
19. S-Band Erectable Antenna (Lunar Surface)
20. Radioisotope Thermal Generator
21. Docking Light (Port Side)
22. Forward-Vision Window
23. LM/CM Docking Hatch
24. Outrigger Strut
25. Insulation Vent
26. Thermal Insulation Blankets
27. Lunar Surface Sensing Probe
28. Insulation Support Frame
29. Interstage Connection Points (4)
30. Ascent Fuel Tank
31. Reaction-Control Oxidizer
32. Reaction-Control Fuel
33. Helium Pressurization Unit
34. Reaction-Control Helium
35. Water Tank
36. Relay Box
37. Abort Sensor
38. Inertial Measurement Unit (IMU)
39. Ingress/Egress Hatch
40. Landing Point Designator
41. Oxidizer Service Panel
42. Ascent Engine Cover
43. Alignment Optical Telescope
44. Upper Hatch
45. Commander's Main Flight Panel
46. LM Pilot's Main Flight Panel
47. Commander's EV Visors (Stowed)
48. Commander's Circuit Breaker Panel & Side Console
49. PLSS (Stowed)
50. Commander's Support & Restraint Reel
51. Commander's Armrest & Thrust Control
52. Main Panel/Cabin Floodlights (2)
53. LM Pilot's Armrest (Stowed)
54. LM Pilot's Support & Restraint Reel
55. Anti-Bacterial Filter Stowage
56. Cabin Relief & Dump Valve
57. Docking Drogue (Removable for Access)
58. Suit Circuit Assembly
59. Water Control Module
60. Cabin Air Recirculation Fan
61. LiOH Canister
62. LM Pilot's EV Visor (Stowed)
63. LM Pilot's Restraint Reel
64. Crew Equipment Storage
65. LM Pilot's Console & Circuit Breaker Panel
66. Oxygen Umbilical Hoses
67. Ascent Engine (3,500 lb Thrust in Vacuum)
68. Coupling Data Unit
69. Guidance Computer & Cold Plate
70. Power Servo Assembly
71. Ascent Oxidizer Tank
72. Descent/Ascent Section Explosive Attachment
73. Interrupt Connector Assembly & Wiring
74. Aft Equipment Bay
75. Gaseous Oxygen Tank
76. Helium Tank
77. Helium Pressurization Control Modules
78. Thrust Chamber Isolation Valves
79. Electronic Replaceable Assembly Rack
80. Batteries
81. Inverter
82. Electrical Control Assembly
83. Abort Electronics Assembly
84. Attitude & Translation Control Assy
85. Rendezvous Radar Electronic Assembly
86. Signal Conditioning Electronics Replaceable Assy No. 1
87. Pulse Code Modulation & Timing Equip. Assy
88. Signal Conditioning Electronics Replaceable Assy No. 2
89. Caution & Warning Electronics Assembly
90. S-Band Transceivers
91. S-Band Power Amplifier & Diplexer
92. Signal Processor
93. VHF Transceivers & Diplexer
94. Descent Structure
95. Batteries
96. Electrical Control Assembly
97. Descent Engine Skirt
98. S-Band Steerable Antenna
99. Electronics Package
100. Landing Gear Chock Mount
101. Descent Engine Throttleable (10,000 lb Approx Thrust)
102. Descent Oxidizer Tank (Fore & Aft)
103. Descent Fuel Tank (Port & Starboard)
104. Ascent Engine Blast Deflector
105. Water Tank
106. Scientific Equipment Boxes (2)
107. Specimen Return Container Assembly (MESA)
108. Landing Radar Electronics
109. Landing Radar
110. Fuel & Electrical Line Runs
111. Fuel Lines To Descent Engine
112. Fuel Lines (Descent Engine)
113. Supercritical Helium Tank
114. Ambient Helium Tank
115. Oxygen Tank
116. Scientific Equipment Power Outlets
117. Descent Stage Skirt Structure
118. Thermal & Micrometeoroid Shield

ABBREVIATIONS USED IN LEGEND

EVA: Extravehicular Activity
VHF: Very High Frequency
MESA: Modularized Equipment Stowage Assembly
RCS: Reaction Control Subsystem
LM/CM: Lunar Module/Command Module
PLSS: Portable Life Support System


UNITED
STATES

APOLLO LUNAR MODULE

Built by Grumman for the Apollo program, the Lunar Module (LM) was the first and only vehicle designed solely for manned extra-terrestrial operation. On six successful moon landings, LMs carried astronauts and scientific payloads from the orbiting Apollo command module to the surface of the moon and back. On one mission, aborted because of damage to the command module, the LM provided the power to return the crippled vehicle and its crew safely back to earth.

The LM consisted of two stages joined by four interstage fittings. The ascent stage carried two astronauts along with navigation, guidance, control, communications, life support, environmental control, electrical power, and propulsion systems. The descent stage carried scientific equipment, a propulsion system, and additional electric power, water, and oxygen for the ascent unit.

At the end of a lunar stay, the interstage fittings were explosively severed, allowing the ascent stage to lift off and return the crew to the orbiting command module. The descent unit remained on the moon.

The Apollo missions greatly exceeded expectations. Lunar stay time increased from 21 hr 36 min and one EVA on the first landing to 75 hr and three extensive EVAs on the last. The LM payload also increased, from 48 lb on the first mission to 243 lb on the last.

The history and typical specifications of the twelve LMs produced by Grumman for the Apollo program are outlined below:

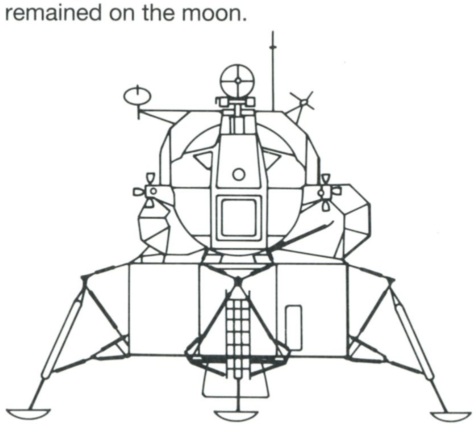
LM-1	Unmanned, earth orbit mission
LM-2	Unmanned backup, not flown
LM-3	Manned, earth orbit mission
LM-4	Manned, lunar orbit mission
LM-5	1st lunar landing - 20 July 1969
LM-6	2nd lunar landing - 20 Nov 1969
LM-7	Mission aborted in trans-lunar phase due to loss of service module electrical power. LM served as rescue "lifeboat"
LM-8	3rd lunar landing - 5 Feb 1971
LM-9	Manned backup, not flown
LM-10	4th lunar landing - 30 July 1971 (Carried lunar roving vehicle)
LM-11	5th lunar landing - 20 April 1972 (Carried lunar roving vehicle)
LM-12	6th lunar landing - 11 Dec 1972 (Carried lunar roving vehicle)

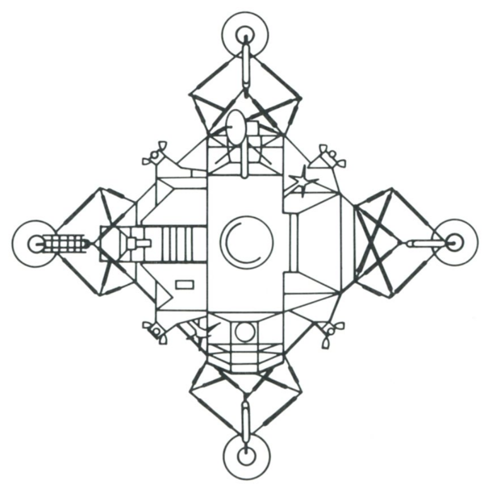
WEIGHT

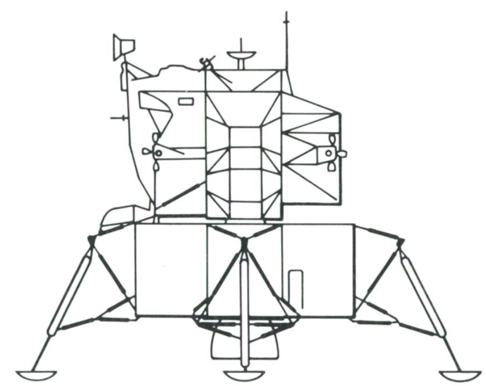
Ascent stage, inert	4,341 lb
Scientific equipment	406 lb
Propellants	5,835 lb
Total ascent stage	10,582 lb
Descent stage, inert	4,921 lb
Scientific equipment	1,212 lb
Propellants	19,507 lb
Total descent stage	25,640 lb
Overall orbital spacecraft	36,222 lb

PROPULSION, NOMINAL THRUST

Ascent engine	3,500 lb
Descent engine	
Full throttle	9,900 lb
Low stop	1,280 lb
Reaction control	
(16) System engines	(each) 100 lb







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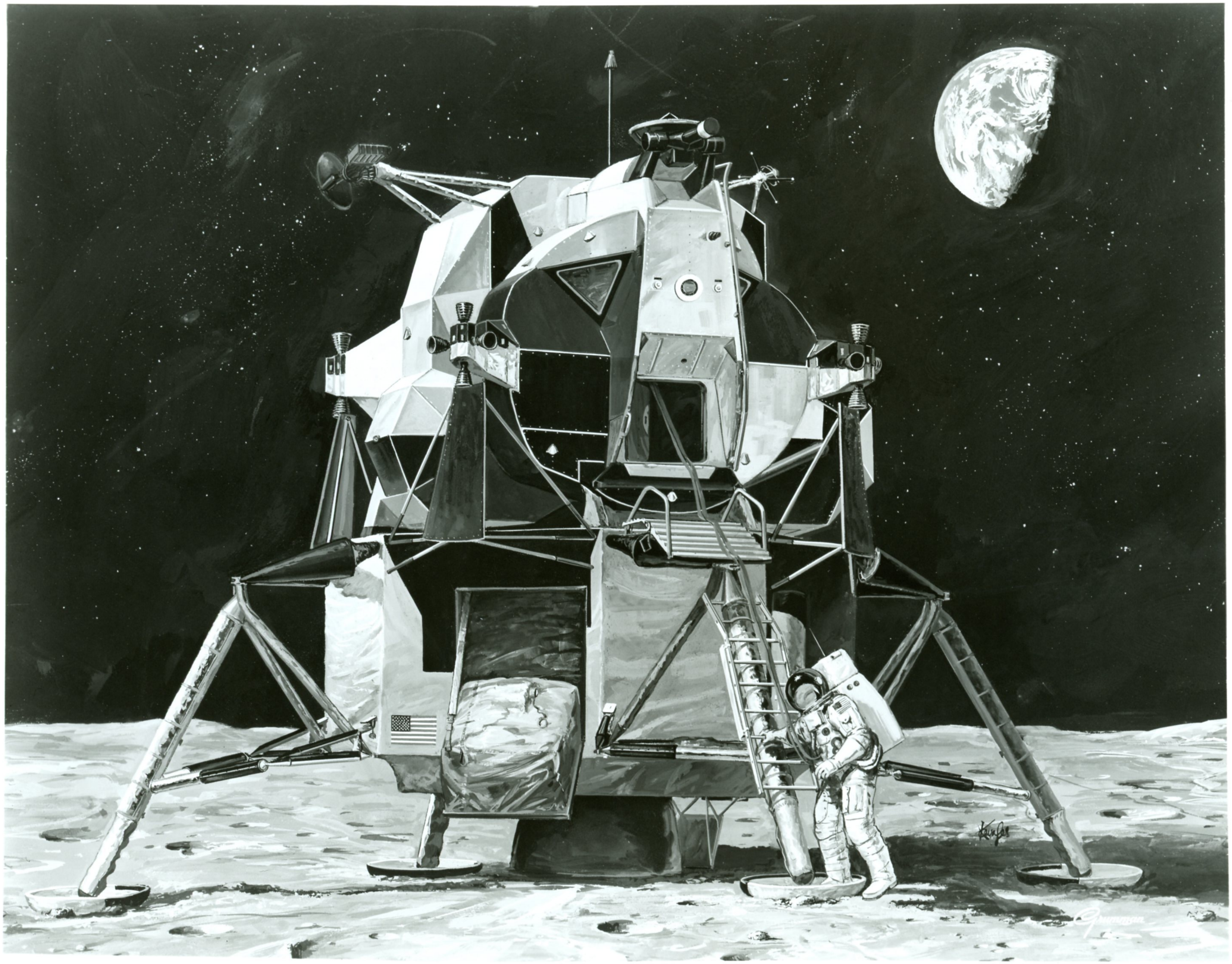


NASA/Grumman Apollo Lunar Module

PUBLIC AFFAIRS, SPACE
GRUMMAN AIRCRAFT ENGINEERING CORPORATION
BETHPAGE, LONG ISLAND, NEW YORK

WHAT IS GRUMMAN?

A leading aerospace manufacturer for over 39 years, Grumman currently employs over 35,000 people and is in the top 14 percent of the 500 leading industrial firms. Today, Grumman is turning out ever more versatile vehicles and systems: airborne platforms with the most advanced all-weather avionics; computerized flying command posts; aerial surveillance stations; high performance vehicles with variable wing and engine geometry; new military and commercial ocean-going hydrofoils; and undersea research submersibles. We are system managers and producers. We design the complete system and integrate the subsystems - our own and those of our suppliers. And we assemble, build and support the operational system.

In the space area, Grumman became the nation's second largest space contractor when NASA added the important Apollo Lunar Module contract to our existing one for the Orbiting Astronomical Observatory. While fulfilling our prime responsibility on the Apollo Program, we are working on various types of LM derivatives, meteorological satellites, and advanced lunar and planetary exploration systems.

Whether for use in space or in the atmosphere, Grumman products will continue to reflect a genuine concern for the men who will operate and fly them. We are dedicated to building systems that enable men to perform effectively and with safety in difficult and hostile environments. With all the automation, complexity and sophistication of today's aerospace vehicles, man is still the heart of the system. Grumman never forgets it.

PROJECT APOLLO

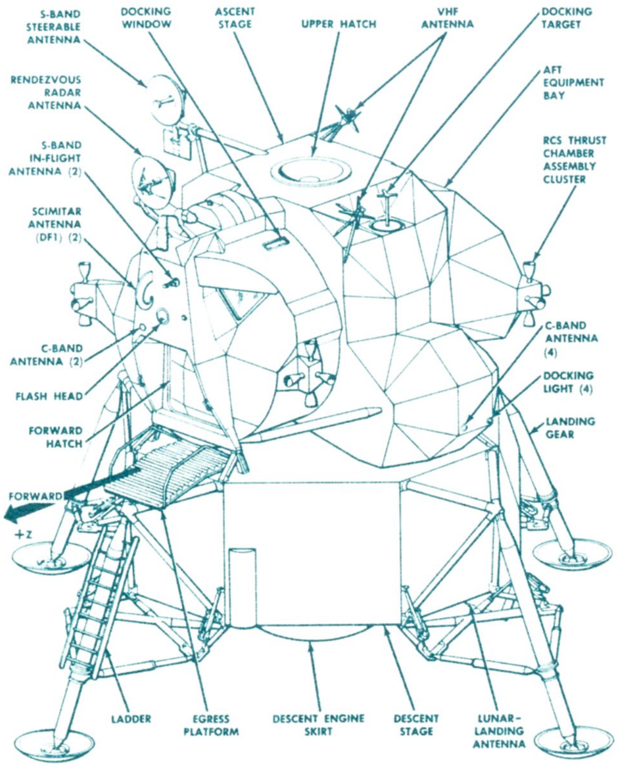
Project Apollo will reach its major objective with the landing of two United States astronauts on the moon and their safe return. This historic manned landing will be made in a spacecraft known as the Lunar Module whose design and development represents a tremendous feat by many thousands of engineers and technicians in hundreds of firms throughout the nation. It is a great source of pride to the Grumman Aircraft Engineering Corporation to be serving as the prime contractor to the National Aeronautics and Space Administration for the Lunar Module.

THE LM MISSION

A two-stage Lunar Module (LM) will function as a space ferry - transporting two astronauts from a lunar-orbiting Apollo Command/Service Module (CSM) to the moon's surface and back. The two astronauts land the entire spacecraft on the moon. When they leave, the descent (lower) stage remains on the moon and serves as the launching platform. The astronauts fly the ascent (upper) stage back to lunar orbit and rendezvous with the CSM for their return to earth.

THE LUNAR MODULE

The upper stage consists of a pressurized crew compartment, equipment areas, and ascent rocket engine. The lower stage, to which the landing gear is attached, contains a gimballed, throttleable, descent rocket engine. The LM, a completely self-sufficient spacecraft, is equipped with the subsystems necessary for life support, navigation and guidance, attitude control, communications and instrumentation. Two crewmembers stand side-by-side facing two triangular, forward-slanted windows that afford both a forward and downward line of sight. A large center panel permits the LM crew to share the displays and controls necessary for flight monitoring.



LUNAR MODULE GENERAL CHARACTERISTICS

DIMENSIONS (Legs Extended)

Overall height:	22 feet, 11 inches
Overall width:	14 feet, 1 inch
Diameter (diagonally across landing gear):	31 feet
Ascent Stage height:	12 feet, 4 inches
Descent Stage height:	10 feet, 7 inches

GENERAL DATA

Earth launch weight:	32,000 pounds
Pressurized cabin volume:	235 cubic feet
Cabin environment:	75°F 100% oxygen at 4.8 ± 0.2 psia

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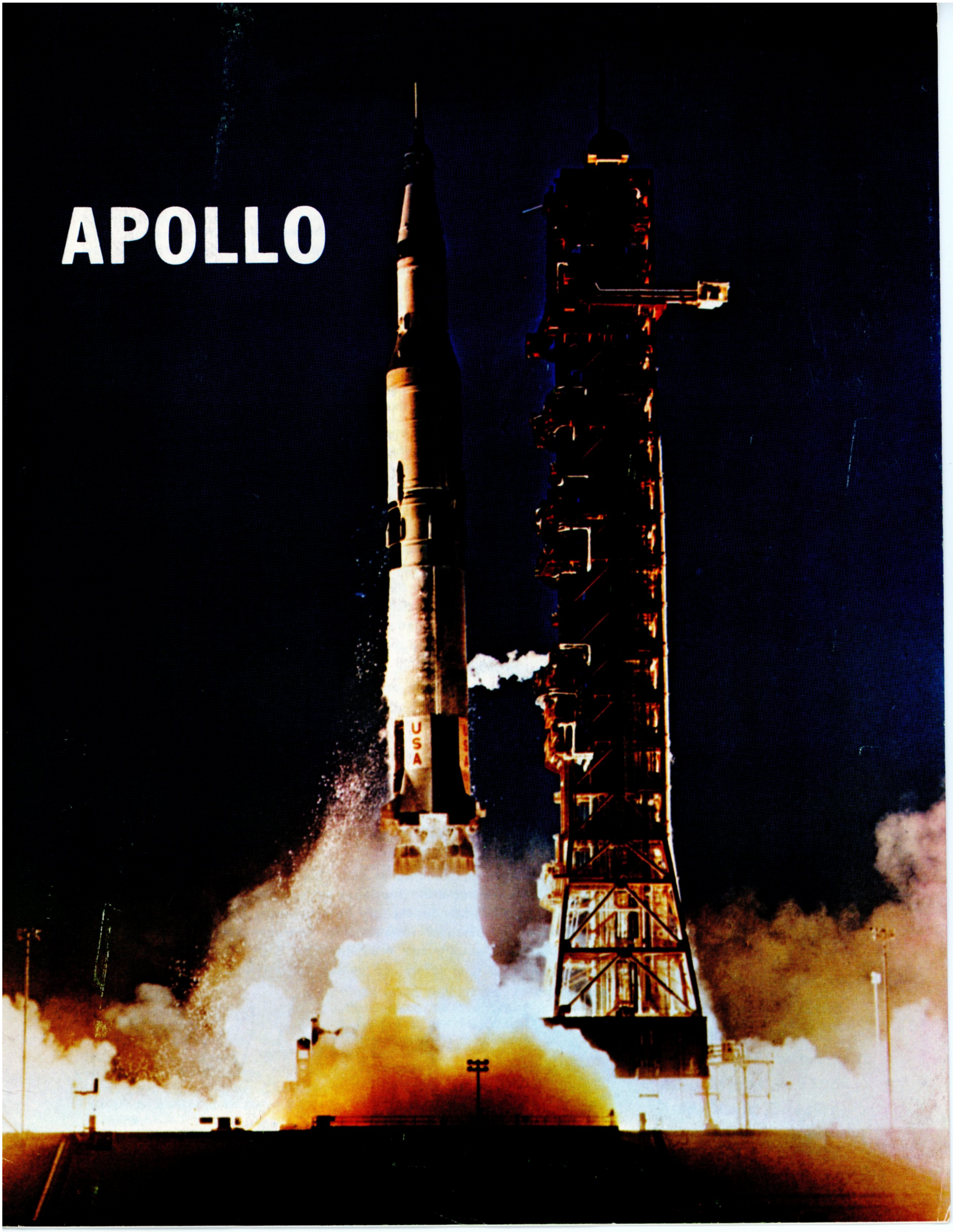

APOLLO
USA

Our Challenge In Space

Man is poised for the assault on the last great frontier—space—and we at Grumman are proud to play a major role in that spectacular adventure. Challenges of this magnitude historically evoke the utmost of man's ingenuity and reward him with achievement beyond his expectations.

Columbus sought a trade route to the Indies and found a New World.

A steam engine that was developed to pump water from a mine helped to propel the world through an Industrial Revolution that produced new technical and social accomplishments.

At Kitty Hawk, just 65 years ago, the Wright Brothers flew the first heavier-than-air flying machine. That first flight covered only 100 feet but it transported man into a new era of unlimited potential.

Today, men fly routinely near the speed of sound in jetliners. Other men fly three times that fast in military planes, and others have circled the earth in 90 minutes in Mercury, Gemini, and Vostok spacecraft.

Next comes a trip to the moon, a necessary step toward exploring the solar system.

No one can forecast the full benefits of the Apollo program. Nor can we foresee the explosion of knowledge resulting from it here on earth. Some benefits have been paid in advance: the demands of Apollo have set new standards in performance, reliability, and efficiency—standards forcing new technologies in such fields as medicine, aircraft, transportation and communications.

But our immediate goal here at Grumman is clear. We must build a Lunar Module that will take astronauts to the lunar surface and return them safely to a Command Module for the trip back to earth. This places the highest premium on personal responsibility. Everyone involved must build for unrivaled quality and reliability—this is in the Grumman tradition of concern for pilot safety and vehicle performance.

Joseph G. Gavin Jr.

Joseph G. Gavin Jr.
Vice President - Space Programs

THE APOLLO MISSION

Man's centuries-old dream of exploring the moon is nearing reality. For the first time he will unshackle himself from his native planet and walk upon another heavenly body. It will be a new dimension of thought and achievement.

Preparations for this half-million-mile round trip are complex. They involve agencies from virtually all 50 states and the diverse talents of people in government, industry, and the educational community; and yet, only one in a thousand companies in the U.S. can claim kinship to this ambitious space effort.

Specialists from Grumman, North American Rockwell, McDonnell-Douglas, Boeing, and a host of other companies have been chosen to support the National Aeronautics and Space Administration in fulfilling the Apollo mission. All of them are well aware of their pioneering responsibility. And no matter where the scene may shift—to NASA installations in Washington, at Huntsville, or Houston, to Grumman facilities at White Sands or Cape Kennedy—all share the same objective. The goal is never out of sight. On clear nights it beckons overhead . . . **THE MOON.**

The Saturn V weighs six million pounds when fully fueled, and with the Apollo spacecraft perched atop, it towers 364 feet high. The space vehicle is assembled in NASA's Vehicle Assembly Building at Cape Kennedy, the most voluminous man-made structure in the world. The building is 525 feet high and encloses nearly 200 million cubic feet. Only its air-conditioning system prevents clouding or raining inside the building. The Apollo/Saturn, supported by its launch umbilical tower, is moved to the launch complex by the world's largest tracked vehicle, the transporter-crawler.

(The following sections are titled to allow the reader to follow progress of the Apollo mission displayed on the center spread.)

Lift-off

Vehicle development and crew training takes years, preparation of the spacecraft takes months, mission countdown takes days, but lift-off is measured in just seconds. Five huge F-1 rocket engines that consume tons of kerosene and liquid oxygen each second build to more than seven-and-a-half million pounds of thrust at ignition at lift-off! Thirty three stories above this powerful inferno, three astronauts recline in their Command Module as the first stage of the Saturn lifts them rapidly toward the vacuum of space. The white-suited explorers are pressed heavily against their couches as acceleration forces increase and velocity builds.

Staging

Propellants in the first stage are consumed in less than three minutes and the depleted stage is jettisoned to lighten the load. The five engines of the second stage (S-II) then take over, boosting the payload further with a combined thrust of a million pounds. Velocity increases rapidly as the liquid propellants are used up. In less than nine minutes from lift-off the astronauts are more than 100 miles above the Atlantic and far east of their Florida launch pad. (Had there been any serious problem up to this time, the launch escape system would have pulled the Command Module to a safe altitude for a parachute landing.)

At second stage burnout, staging again takes place. The single restartable third-stage (called the S-IVB) engine ignites and burns briefly so as to put the space vehicle into earth orbit at nearly 18,000 miles an hour. Ground stations determine its exact position in space and the astronauts run checks of onboard systems while computers in Houston generate the guidance information essential for setting an accurate course to the moon.

Translunar injection

The S-IVB engine is ignited again, this time to accelerate the spacecraft to 25,000 mph into a translunar trajectory that will intercept the moon's flight path in about three days. Like the other two stages, the engine is controlled by the Saturn guidance system in the Instrument Unit, located atop the third stage.

Transposition and docking

The astronauts then use hand controllers to fire the Service Module's reaction control system in order to separate the Command and Service Modules from the Saturn third stage, instrument unit, and spacecraft LM adapter (SLA). It is the SLA that houses the Lunar Module. As the crew "drives" forward, the SLA's upper section opens, looking like four flower "petals," revealing Grumman's two-man LM.

Jettison S-IVB

The Commander then turns his Command/Service Module around and maneuvers back toward the Saturn and the Lunar Module. He docks the Command Module's upper hatch with the Lunar Module's upper hatch, and then uses the Service Module's small maneuvering rockets to pull the combined Apollo modules free of the now expendable Saturn section.

Midcourse correction

Shortly after separating from the Saturn, the astronauts make their first midcourse correction, using the Service Module's restartable engine, which, like those of the Lunar Module, uses hypergolic propellants—fuel and oxidizer that ignite spontaneously when combined. The astronauts may make as many as three midcourse corrections during the translunar journey to keep their Apollo spacecraft on a precise path to the moon.

Lunar Module Mission

The Lunar Module's mission is to land two astronauts on the moon and return them to the Command and Service Modules in lunar orbit. It begins shortly after the Apollo Spacecraft intercepts the moon and decelerates into orbit around it.

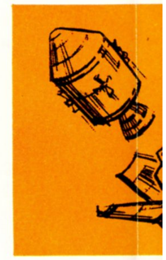
As the three-module Apollo spacecraft coasts toward the moon, earth's gravity gradually slows it to about 2,500 mph. But then the moon's gravitational influence is felt as the astronauts, navigating by the stars, near the mission objective. (If the astro-

Grumman Plane News
Special Edition
Manned Flight Awareness
Public Affairs — Space
R. M. Voris, Director

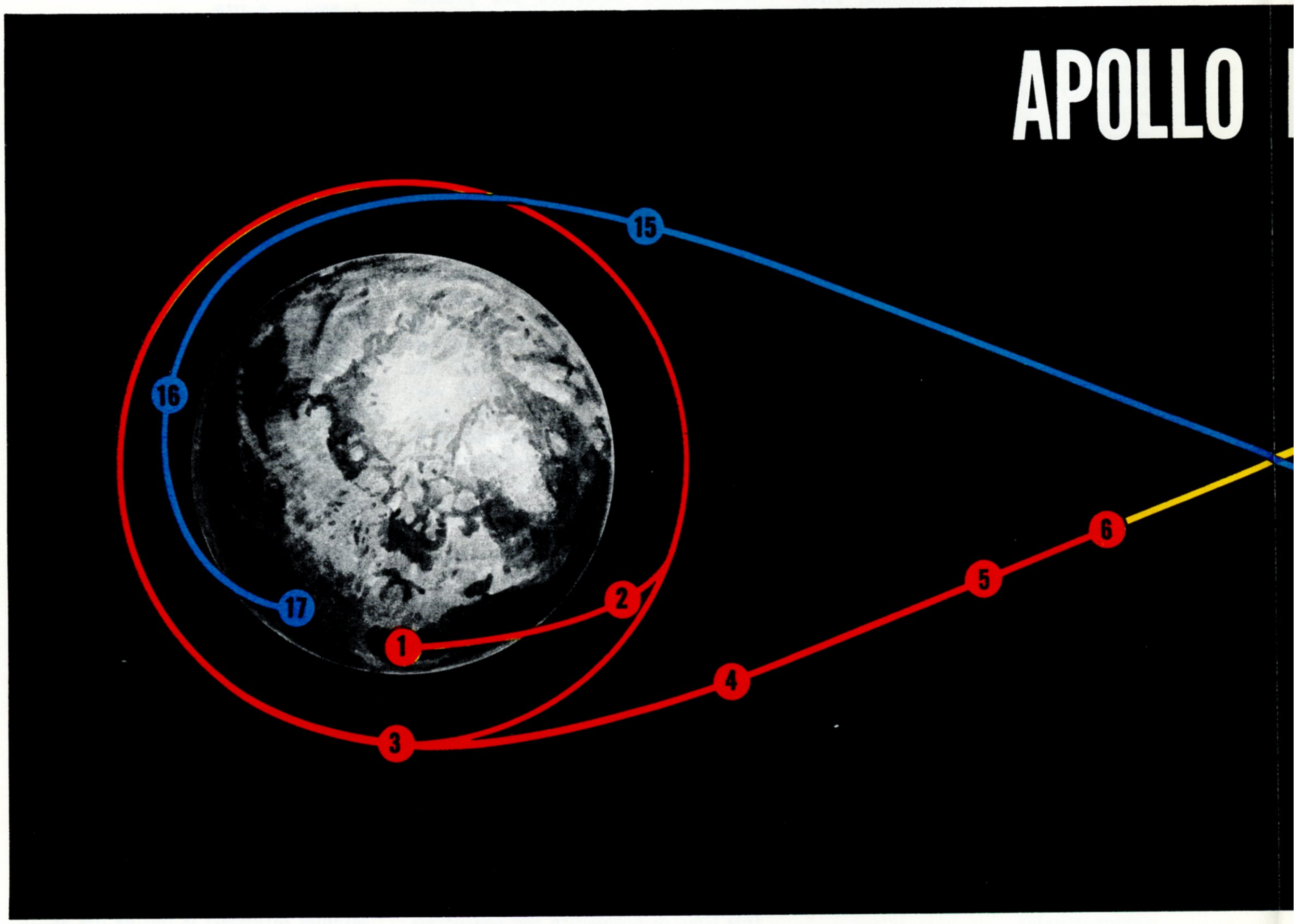
1 LIFTOFF

2 STAGING

3 TRANSLUNAR INJECTION

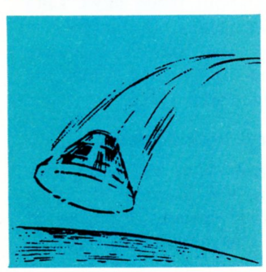


4 TRANSPOSI AND DOCK

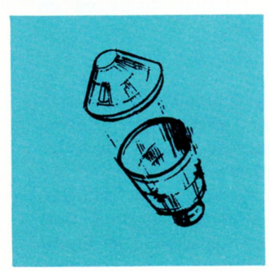


17 LANDING AND RECOVERY

16 ENTER EARTH'S ATMOSPHERE



15 JETTISON SM



14 MIDCOURS CORRECTI

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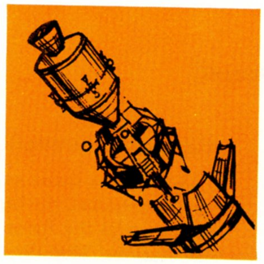
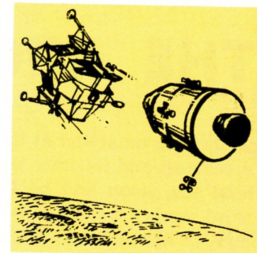


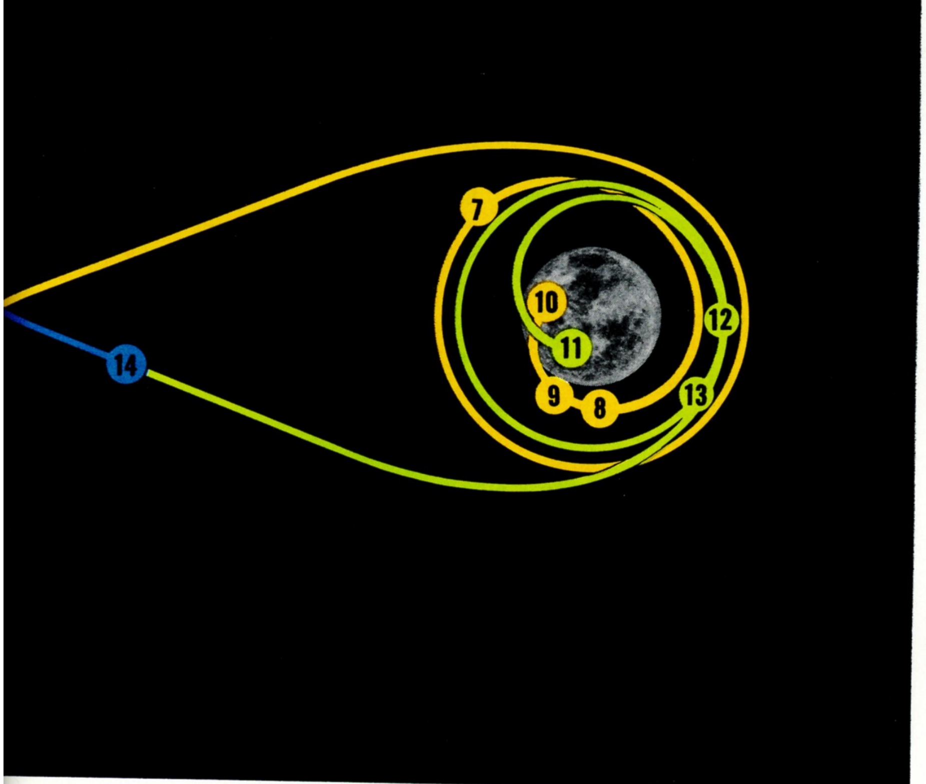
5 JETTISON S-IVB

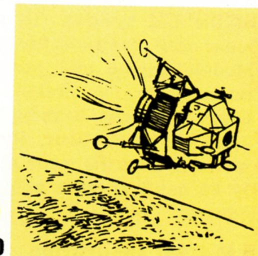
6 MIDCOURSE CORRECTIONS



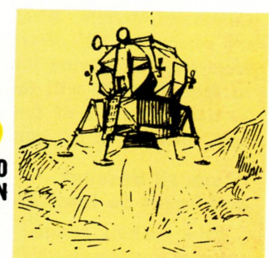
7 LM-CSM SEPARATION

MISSION PROFILE

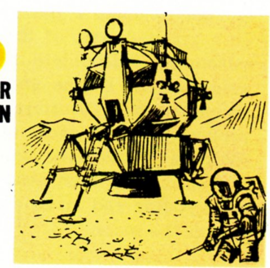




8 POWERED DESCENT



9 HOVER TO TOUCHDOWN



10 LUNAR EXPLORATION

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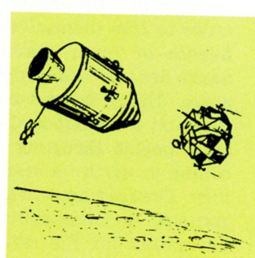
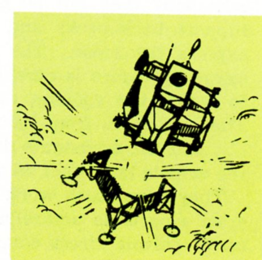
13 JETTISON LM AND BEGIN TRANS-EARTH INJECTION

12 RENDEZVOUS AND DOCKING



11 POWERED ASCENT



THE APOLLO MISSION (continued)

nauts take no action at this point, the spacecraft and its crew will circle behind the moon and be thrust earthward again on a "free return trajectory.") The internal pressures of the LM and CSM are equalized and two of the three astronauts transfer through the docking hatch bay into the LM. They apply power and check out all of the LM systems. To ease into a lunar orbit, the pilots fire their Service Module engine and perform a retrograde burn or braking maneuver. Once the speed is reduced to about 3,500 miles an hour, the combined modules orbit the moon approximately 60 nautical miles above the lunar equator.

LM-CSM separation

The Commander and LM pilot separate the LM from the orbiting CSM. One astronaut stays in the Command Module. When all systems are ready, the LM crew fires the descent engine, slowing their spacecraft so that its orbit will drop to within 10 nautical miles of the moon's surface, uprange of the landing site.

Powered descent and hover to touchdown

After making another check of LM systems and scanning the lunar surface, the crew uses its variable thrust descent engine to slow the vehicle so that it "hovers," helicopter-like, long enough to make a pin-point landing on a selected part of the moon. The astronauts manipulate the throttleable descent engine and the 16 reaction control thrusters until small probes beneath each of the LM's footpads contact the lunar surface. The astronauts then shut off the descent engine and make a gentle landing on the moon.

Lunar exploration

After readying the spacecraft for the trip back into lunar orbit the astronauts then put on portable life support back-packs and prepare to explore the moon. The LM's cabin oxygen pressure is carefully reduced to match the vacuum of the moon. Then the main front hatch is opened . . . and the astronauts descend from the vehicle to set foot on the moon.

They have much work to do. They erect a portable umbrella-like antenna to permit direct communications, including television, with earth stations; they take photographs, collect specimens, deploy and activate scientific packages that will remain on the moon, and make frequent oral reports to Mission Control Center, some 240,000 miles away in Houston, Texas; and they move in and out of the LM to rest and replenish their portable life support systems. In all, the lunar stay and exploration takes about 25 hours.

Powered ascent

Another systems check, some guidance calculations from onboard systems, receipt of earth-based information and communications from the orbiting Command Module pilot—and then the LM crew is ready to leave the moon, whose surface temperature may vary by as much as 500 degrees F. between the light of day and black of night. When guidance information has been programmed into their computer, the crew ignites the ascent engine, using the four-legged descent stage for a launch pad, and lifts off to rejoin the orbiting CSM.

Rendezvous and docking

Radar feeds information to the astronauts' LM guidance computer, steering them along a path to intercept the orbiting CSM. The two explorers maneuver close to the CSM, then dock the LM's upper hatch with the Command Module's upper hatch. Once joined, cabin pressures are equalized and LM systems are shut down. Films, tapes, and specimens collected on the moon are transferred into the Command Module and then the moon-walkers rejoin their companion.

Jettison LM and Transearth Injection

The astronauts jettison the now silent LM. Its mission completed, LM remains in orbit around the moon. In order to free themselves from the influence of lunar gravity, the astronauts fire the SM propulsion system again. Using ground-based information and their onboard computer, the crew begins thrusting onto a return course to earth—a transearth trajectory. Even without help from ground stations, the astronauts can perform navigation for the return voyage.

Midcourse correction

As many as three small corrections may be required during the three-day trip between the moon and the earth. The Service Module engine is used for this function. The duration and direction of each firing depends upon the magnitude of the correction needed to place the spacecraft on a precise course.

Jettison Service Module

As the astronauts steer toward the earth, they make final adjustments with the Service Module engine, then jettison the Service Module and prepare for re-entry. They enter a narrow re-entry corridor which is chosen to minimize the effects of heating and the forces of deceleration on themselves and their vehicle.

Earth entry

The first molecules of air in the thin upper atmosphere act to slow the Command Module's entry velocity of nearly 25,000 miles an hour, since they strike the CM's main heat shield, causing aerodynamic "drag." By increasing and decreasing drag, the crew controls the intensity of the re-entry heat. The crew enters "heads down" for maximum lift, then rolls "heads up" to cause maximum drag and a steeper entry path. Then, depending on the location of the recovery forces awaiting them in the Pacific Ocean, the astronauts control the flight path—which varies in altitude, much like the path of a roller coaster—for the final plunge through the earth's atmosphere.

Landing and recovery

Aerodynamic braking slows the spacecraft enough to allow deployment of small parachutes that stabilize the Command Module in the lower atmosphere. Finally, three main parachutes are deployed at about 10,000 feet above seaborne recovery forces. By now the astronauts are talking by radio with ships waiting below their slowly descending Command Module. Soon they will be aboard one of these ships, bound for the NASA Manned Spacecraft Center in Texas, where, during a quarantine period, they will relate the story of man's greatest adventure.

THE APOLLO SPACECRAFT

The Lunar Module—The Grumman-built Lunar Module is a two-man space vehicle, the largest of three modules comprising the Apollo spacecraft. Two of the three-man Apollo crew fly the LM on the final leg of the journey to the moon's surface and later launch themselves from the moon on the first phase of their return trip to earth.

The two-stage spacecraft is unlike any other manned spacecraft. It has no heat shield, no parachutes, no flotation devices. These are not necessary because the LM is designed to fly **only** in space. The LM does not return to earth.

LM is 23 feet high and 31 feet wide with its landing gear extended. Its upper stage houses the crew, their controls and instruments, and an engine capable of launching them from the moon. The lower stage contains the landing pads, an engine to slow the spacecraft for a gentle landing on the lunar surface, and equipment used to support the astronauts during their lunar exploration.

The two crew members stand side-by-side, facing two triangular windows that afford forward and downward lines of sight. There are no seats in the LM. A support-and-restraint harness provides the crew with the stability needed to accomplish their tasks during the landing maneuver and helps them to cushion the light impact of the lunar landing. A large center instrument panel permits the astronauts to share the displays and controls.

The Command Module — North American Rockwell's Space Division builds the cone-shaped, three-man Apollo Command Module. Three astronauts recline side-by-side in the CM during launch and re-entry, and they spend much of their time enroute to and from the moon at duty stations in the spacecraft. A crew member not on duty has to strap himself to his couch to sleep; otherwise he would float freely in the weightless space environment.

The CM and Lunar Module are connected after leaving earth orbit on course for the moon, and are not separated again until just prior to the landing by the Lunar Module. During lunar exploration, one astronaut remains in orbit around the moon in the Command Module.

The CM is 13 feet wide at its base, and 12 feet high. Most of its systems —electrical power, propulsion, oxygen supplies—are housed in a Service Module that is attached to the CM throughout the lunar journey and until just prior to earth re-entry a week after launch.

The Service Module—Also built by NR/SD, the cylindrical Service Module is 13 feet wide and 22 feet long. It carries most of the expendables like propellant, oxygen, and electrical power that supply the CM. For instance, it carries chemical fuel cells that convert hydrogen and oxygen to electrical energy for the CM systems. The CM uses batteries only after the Service Module is jettisoned before earth entry. The Service Module's main engine is used for midcourse corrections, to slow the spacecraft into lunar orbit, and to propel it homeward again. Like the LM, the SM has sixteen 100-pound thrusters for attitude control and low-energy maneuvers.

What's in a name

"Apollo" is a fitting title for the most complex and demanding technological undertaking attempted by man—a challenge to the future staked out when President John F. Kennedy set, as a national goal, the task of placing men on the moon within this decade. Charged with this awesome responsibility is the National Aeronautics and Space Administration, guiding the far-flung efforts of hundreds of contractors and thousands of people.

"Apollo—a god of manifold function who occupied the loftiest place next to Zeus in the Greek pantheon. Through prophets and oracles he communicated to man his knowledge of the future and the will of his father, Zeus. No god save his father awoke such dread and awe as he, and no god was handled with more respect by poets and mythmakers." — Encyclopedia Britannica, Vol. 2, 1966, pg. 120.

Rockets and staging

Space rockets are made up of units called stages, each of which has propellant tanks and rocket engines. Early mission studies of Apollo showed that the Saturn V booster should have three stages, just as the spacecraft has three propulsion-system stages: one in the Service Module and two in the Lunar Module.

The function of the stages is to accelerate a payload to a desired speed. A velocity of 17,000 miles per hour is necessary to achieve an earth orbit. A velocity of 25,000 miles per hour is needed to escape to the moon.

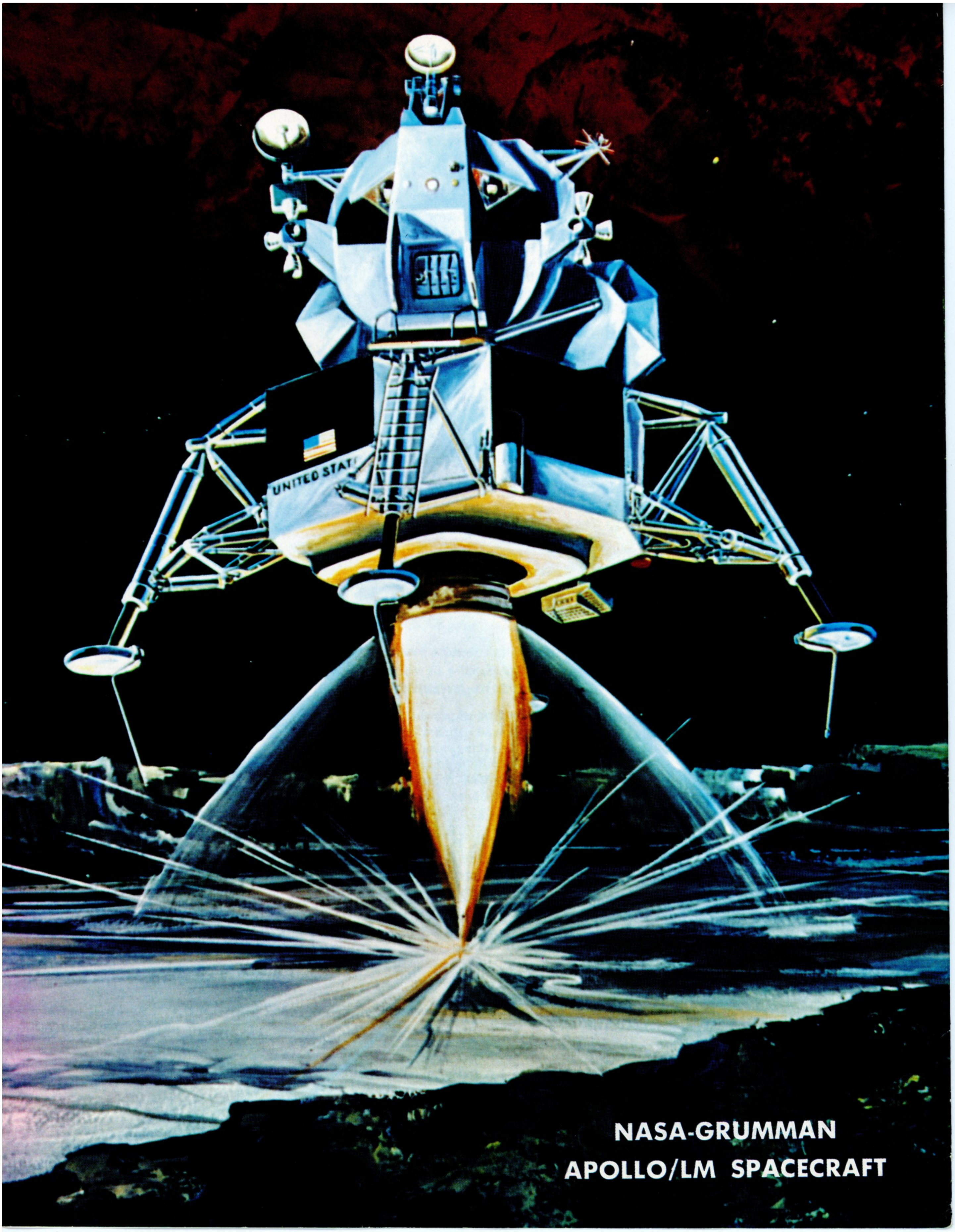
Although the booster rockets are very powerful. more than 85 per cent of the booster weight at launch is propellant. To progressively lessen the weight as the propellant tanks become empty, they are discarded—a process known as staging.

Lunar Orbit Rendezvous

A lunar-landing mission with no rendezvous, or join-up of spacecraft in space, would require a very large spacecraft, one able to fly directly to the moon and take off again with enough velocity to return to earth. Such a spacecraft would require a much larger launch vehicle than the Saturn V, much larger assembly and launch facilities, and much more fuel. Fuel is particularly critical: the more fuel that is carried, the more is needed to propel its own additional weight.

An alternative method is called "earth orbit rendezvous" (EOR). It uses a very large spacecraft capable of landing on the moon and returning directly to earth. Such a spacecraft requires assembly in earth orbit—necessitating two critically timed launches of rockets about the size of the Saturn IB.

Lunar Orbit Rendezvous (LOR) is the technique chosen by NASA which astronauts will use to land on the moon and return safely to earth. It requires a powerful Saturn V launch vehicle and a three-module Apollo spacecraft. Lunar orbit rendezvous allows two of the three Apollo spacecraft modules to remain in orbit around the moon. It requires less fuel and power, since the engines needed to land and to take off can be smaller.

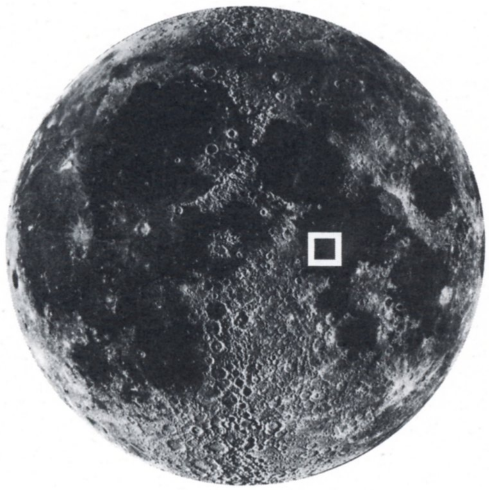

NASA-GRUMMAN
APOLLO/LM SPACECRAFT

Apollo 11

The Lunar Landing

"I believe this nation should commit itself to achieving the goal before this decade is out of landing a man on the moon and returning him safely to earth."

John F. Kennedy — May 25, 1961



Mission Objectives

Capping the chain of successes of Apollo 8, 9, and 10, Apollo 11 will land on the Moon, forging the final link to the program's original objective. The selected Lunar Module landing site is in the Sea of Tranquility. (See photo).

On this mission, the men will spend almost 22 hours on the lunar surface, collect about 50 pounds of rock samples, and erect three experiments in the EASEP, or Early Apollo Scientific Experiments Package. These are:

- Passive Seismometer — to detect meteoroid impacts and monitor seismic activity, such as volcanoes and moonquakes.
- Solar Wind Reflector — to entrap in foil sheets and return to Earth particles of gases such as argon, krypton, xenon, neon, and helium.
- Laser Ranging Retro-Reflector—to measure the exact distance between the Earth and Moon.

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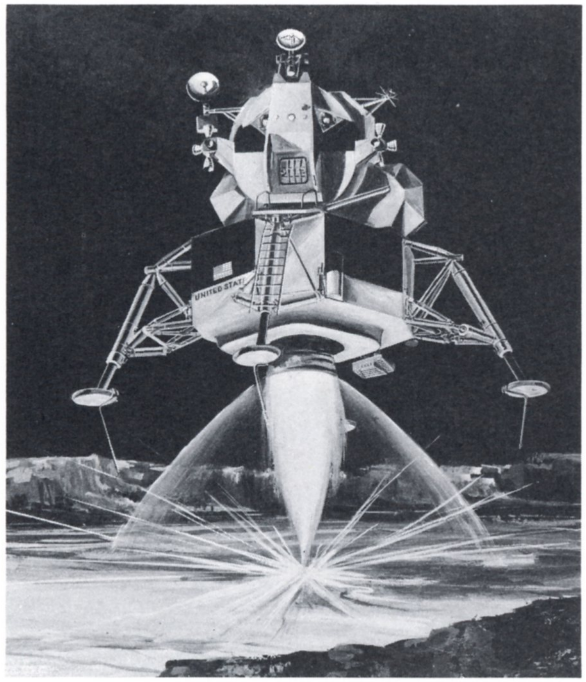


Spacecraft

On Apollo 11, LM-5 will transport Astronauts Armstrong and Aldrin from lunar orbit to the Moon's surface and back while Astronaut Collins circles above in the Command/Service Modules (CSM).

LM is a two-stage spacecraft weighing 16 tons. The upper, or ascent stage, is the habitable stage. It carries the ascent engine, the crew compartment, and all the equipment necessary to sustain the men during the time they are separated from the Command Module. The astronauts depart from the Moon in the ascent stage using the lower, or descent stage, as a launch pad. This stage has the descent engine and landing gear with which the men make a safe, controlled landing.

DAY 1 — Earth Orbit Insertion and Translunar Injection

Apollo 11 begins its 200-hour journey, lifting off from Cape Kennedy's Launch Pad 39A aboard the Saturn V launch vehicle. Just over 2½ minutes later, as the booster arches over the Atlantic Ocean, the first section, the S-1C, exhausts its fuel supply and drops off as the next stage, the S-II, ignites or "stages." The S-II burns out about 9 minutes after lift-off and falls away as the third stage, the S-IVB, fires. Two minutes later, the S-IVB inserts the Apollo spacecraft into a 100-nautical mile high Earth orbit.

If all spacecraft systems check out satisfactorily, the S-IVB is reignited for 5 minutes 21 seconds during the second revolution of the Earth. This frees the Apollo from the pull of Earth's gravity and thrusts it onto a translunar trajectory for the long three-day coast to the Moon.

About three hours into the mission, the astronauts perform a transposition and docking maneuver. First, the CSM thrusts a short distance from the S-IVB. Then, it turns about and docks to the LM which, with landing gear folded, has been exposed by removal of its protective adapter panels. Now joined to the LM, the CSM pulls back to a safe distance while the spent S-IVB is reignited and commanded into a solar orbit. Later this day, the astronauts will correct their trajectory, if necessary.

DAYS 2 AND 3 — Translunar Coast

More midcourse corrections take place, if needed, as Apollo 11 approaches the Moon. On Day 3, Armstrong and Aldrin crawl through the tunnel from the CM to the LM to check out the landing craft, review operating procedures, and perform routine housekeeping chores. The men return to the CM until the next day.

DAY 4 — Lunar Orbit Insertion

Lunar gravity has now captured the spacecraft. As Apollo 11 swings behind the Moon and reaches an altitude of 90 nm, the astronauts command the Service Propulsion System (SPS) engine to burn for just over six minutes. This slows the spacecraft and drops it into an elliptical orbit 60 x 170 nm high. About four hours later, another 15-second SPS burn cuts the speed further and changes the orbit to one circling the Moon 60 nm up. Aldrin re-enters the LM an hour later and spends two hours turning on power and checking communications.

DAY 5 — Lunar Landing

SEPARATION

Armstrong and Aldrin transfer to the LM, turn on its systems, and deploy the landing gear. They undock from the CSM and back off a short distance to permit Collins to inspect their craft.

DESCENT ORBIT INSERTION (DOI)

Having passed inspection, the LM crew ignites the descent engine for 28 seconds to slow the spacecraft and drop it into a 50,000-foot x 60 nm orbit.

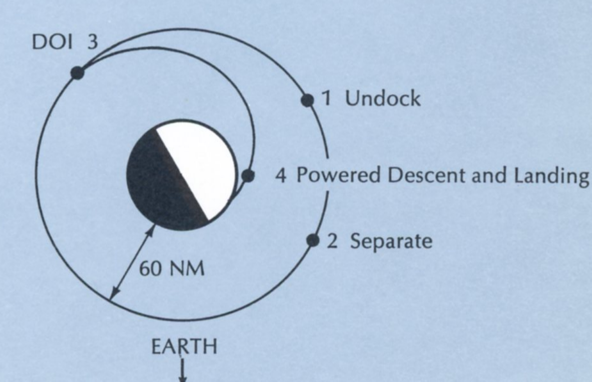
POWERED DESCENT AND LANDING

Again, the descent engine is fired, and the LM begins its final approach to touchdown. At 500 feet altitude, the crew takes manual control, monitoring altitude and descent rate. Passing 100 feet altitude, the spacecraft is descending at three feet per second. At about five feet above the surface, the sensing probes which extend below the landing gear touch the ground, signalling "LUNAR CONTACT". Both men remain aboard for the next eight hours to eat and rest.

DAY 6 — Lunar Surface Activity and Transearth Injection

EXTRAVEHICULAR ACTIVITIES (EVA)

Astronaut Armstrong opens the forward hatch and begins descending the nine-rung ladder to the surface. Half-way down, he grasps a ring with his left hand and pulls a lanyard, opening a hatch in the descent stage



and deploying a TV camera. Millions of viewers on Earth now watch as Armstrong descends the final steps and sets foot on the Moon.

About 27 minutes later, after Armstrong has gathered and stowed some soil specimens, Aldrin joins him to televise and photograph the scene, collect more samples, and set up the EASEP. Aldrin re-enters the LM followed by Armstrong 10 minutes later, completing the 2-hour 40-minute EVA. The men eat, rest, and prepare the ascent stage for liftoff.

ASCENT AND INSERTION

On command, the ascent engine ignites, lifts the ascent stage from the descent stage, and propels the craft into a 9 x 45 nm orbit.

CONCENTRIC SEQUENCE INITIATION (CSI)

A 46-second burn of the reaction control system (RCS) thrusters changes the LM's orbit to nearly a circle 44 nm high and places it slightly behind and 15 nm below the CSM.

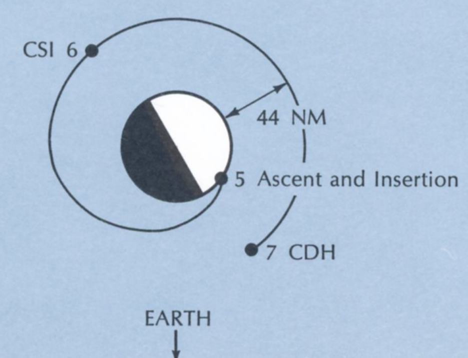
CONSTANT DELTA HEIGHT (CDH)

Another three-second RCS burn circularizes the LM orbit at 45 nm and fixes the difference in altitude between the LM and CSM at 15 nm. The two craft now are circling the Moon in separate concentric orbits, with the LM on the inside track catching up to the CSM.

TERMINAL PHASE INITIATION (TPI)

When the elevation angle between the two reaches 26 degrees, the LM crew fires its RCS thrusters for 23 seconds, permitting the spacecraft to "change lanes" and rendezvous with the CSM in the 60 nm high orbit. The two ships dock. Armstrong and Aldrin transfer the lunar soil sample packages to Collins and then

LM—Separation through Rendezvous



rejoin him in the CSM. They undock, withdraw a safe distance from the LM, and fire the LM RCS engines remotely to propel the now unmanned spacecraft into a trajectory that will avoid interfering with future flights.

TRANSEARTH INJECTION (TEI)

On the far side of the Moon, Collins fires the SPS engine for 2 minutes 50 seconds to increase speed, break the spacecraft free of lunar gravity, and place it into a transearth trajectory.

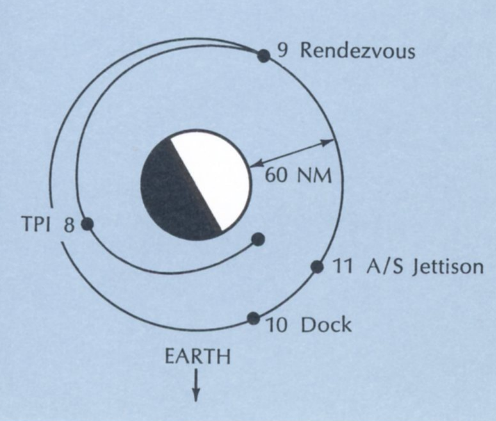
DAYS 7 AND 8 — Transearth Coast

The three-day coast to Earth is punctuated by routine activities and midcourse trajectory corrections, if necessary.

DAY 9 — Entry and Recovery

As the CSM approaches Earth at 24,000 miles per hour, the crew jettisons the Service Module. The CM enters the atmosphere at 400,000 feet altitude and lands in the Pacific Ocean about 2,000 miles southwest of Hawaii.

After splashdown, biological isolation garments are tossed into the spacecraft by frogmen. Once these have been donned, the astronauts and the container of lunar rock samples are airlifted to the recovery aircraft carrier by helicopter. There they enter an isolation van in which they will remain while the carrier proceeds to Hawaii. At Pearl Harbor the van is loaded aboard a cargo aircraft and flown to the Lunar Receiving Laboratory in Houston, Texas, where the crew will be confined for 3 weeks.



Apollo 11 Crew

NEIL A. ARMSTRONG
(Civilian),
Commander;
Born 5 August 1930;
Married, 2 children;
B.S., Aeronautical
Engineering, Purdue
University;
Graduate School,
University of
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MICHAEL COLLINS
(Lieutenant Colonel, USAF)
Command Module Pilot;
Born 31 October 1930;
Married, 3 children;
B.S., U.S. Military
Academy at West Point

EDWIN E. ALDRIN, JR.
(Colonel, USAF)
Lunar Module Pilot;
Born 20 January 1930;
Married, 3 children;
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Academy at West Point;
Doctor of Science,
Astronautics, Massa-
chusetts Institute
of Technology

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK

9235

LM SYSTEM DESCRIPTION

The following sections describe the major systems of the Lunar Module.

COMMUNICATIONS SECTION

The Communication Subsystem is made up of redundant 3-band transceivers and power amplifiers, redundant VHF transceivers, and signal processing equipment with associated antenna systems. These equipments provide the following capabilities: (1) S-band for transmission of PCM telemetry, TV, voice, emergency key and range data between LM and earth; (2) VHF for linking LM and Command Module, and the LM and astronaut of the lunar surface; (3) VHF telemetry capability from LM to Command Module on the far side of the moon; (4) EVA (Extravehicular Astronaut) link to earth via VHF/S-band relay.

PROPULSION SYSTEM

The LM spacecraft uses separate descent and ascent propulsion systems, each of which is complete and independent of the other. Each consists of a liquid-propellent rocket engine with its propellant, storage, pressurization and feed components. The descent propulsion system is contained within the descent stage and uses a throttleable, gimballed engine that is first fired to inject the LM

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spacecraft into the descent transfer orbit. It is then used in the final descent trajectory as a retrorocket to control the rate of descent and to enable the LM to hover and move horizontally. The ascent propulsion system is contained within the ascent stage and uses a fixed, constant-thrust engine to launch the ascent stage from the lunar surface and place it into lunar orbit. The ascent engine can also provide any gross orbit adjustments that may be necessary for rendezvous with the Command Service Module (CSM).

Both propulsion systems use hypergolic propellants consisting of a 50-50 fuel mixture of hydrazine (N_2H_4) and unsymmetrical dimethylhydrazine (UDMH) with nitrogen tetroxide (N_2O_4) as the oxidizer. The mixture ratio of oxidizer to fuel is 1.6 to 1 by weight, at injection. In both stages, the propellants are fed from tanks, with helium as the tank pressurant.

The descent propulsion system consists of two fuel and two oxidizer tanks with the associated propellant pressurization and feed components, and a throttleable rocket engine that develops a maximum thrust of 9710 pounds and can be operated at any power setting down to a minimum thrust of 1050 pounds. The engine can also be shut down and restarted as required.

The engine is mounted in the center compartment of the descent stage cruciform, suspended at the throat of the combustion chamber on a gimbal ring which is an integral portion of the engine assembly. The gimbal ring is pivoted in the descent stage structure along an

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axis normal to that of the engine pivots so that the engine can be gimballed 6° in any direction by means of gimbal drive actuators to provide trim control in the pitch and roll axes during powered descent.

The ascent propulsion system uses a fixed, constant-thrust rocket engine installed along the center line of the ascent stage midsection and includes the associated propellant supply components. The engine developes 3500 pounds of thrust, in a vacuum, sufficient to launch the ascent stage from the lunar surafce and place it into orbit. Two main propellant tanks are used, one for fuel and the other for oxidizer. The tanks are installed on either side of the ascent stage structure. The propellant supply sections in this system include provisions for fuel and oxidizer crossfed to the reaction control system as a backup propellant supply for the latter.

GUIDANCE, NAVIGATION AND CONTROL SYSTEM

The Guidance, Navigation and Control (GN&C) system provides the measuring and data processing capabilities and control functions necessary to accomplish lunar landing and ascent, and rendezvous and docking with the Command/Service Module (CSM). The GN&C system comprises two functional loops, each of which is a completely independent guidance and control path. The primary guidance path performs all functions necessary to complete the LM mission. If a major failure in the primary guidance path necessitates mission abort, the abort guidance path performs all functions necessary to

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effect a safe rendezvous with the orbiting CSM.

The primary guidance path comprises a Primary Guidance and Navigation Section (PGNS) and a Control Electronics Section (CES). The PGNS is an aided inertial guidance section whose principal aids are the Landing Radar (LR), the Rendezvous Radar/Transponder (RR/T), and the Alignment Optical Telescope (AOT). The CES processes the guidance and navigation data from the PGNS and applies them to the descent engine, the ascent engine, and selected RCS jets.

REACTION CONTROL SYSTEM

The Reaction Control System (RCS) provides small rocket thrust impulses to stabilize the LM during descent and ascent, and to control the LM attitude and translation about or along all axes during hover, rendezvous, and docking maneuvers. The RCS consists basically of 16 thrust chamber assemblies supplied by two separate propellant pressurization and supply sections made up of parallel, independent systems (A and B). The 16 thrust chamber assemblies are mounted in cluster of four, the clusters being equally spaced around the LM ascent stage. Each of the clusters is fitted with a plume deflecting shield under the downward firing thrusters to prevent flame impingement on the descent stage surface.

The arrangement is such that two of the thrust chamber assemblies in each cluster are mounted parallel to the vehicle's X axis, facing in opposite directions (up and down); the other two are spaced 90° apart (one facing to the side, the other facing

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forward or aft) in a plane normal to the X axis. Two thrust chamber assemblies in each cluster are supplied by System A; the other by System B.

ELECTRICAL POWER SYSTEM

The Electrical Power System (EPS) interfaces with all major LM systems. Primary d-c power is provided by two storage batteries in the ascent stage, and by four storage batteries in the descent stage. Primary a-c power is supplied by two redundant solid-state inverters.

The Guidance, Navigation and Control System (GN&CS) uses d-c power from the EPS for operation of the Primary Guidance, Navigation and Control Section; the Abort Guidance Section; and the Computing and Radar Sections.

The Reaction Control System (RCS) uses 28-volt d-c power for activation of fuel and oxidizer valves that feed each of the thrust chamber assemblies (TCA's). Shutoff and crossfeed valves are used to interconnect lines between the ascent stage propulsion system and RCS.

The Main Propulsion System (MPS) uses 28-volt d-c power for operation of solenoid operated and electroexplosive valves that govern the flow and combustion of fuel and oxidizer required for ascent and descent engine operation. Primary a-c power is used for operation of the descent engine control assembly and the gimbal drive actuator.

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The Environmental Control System (ECS) uses 28-volt d-c power for activation of LM cabin pressurization and emergency oxygen valves and operation of the primary and secondary glycol coolant pumps that provide thermal stabilization and control of LM equipment and environment.

The Communication System (CS) uses EPS d-c power for operation of all CS voice, television and telemetry transmitting and receiving devices, which include the VHF section, the S-Band section transform input EPS power necessary for the operation of the S-Band radiofrequency power amplifiers and modulation equipment.

The Instrumentation System (IS) uses 28-volt d-c power for operation of IS timing equipment and the Caution and Warning Electronics Assembly (CWEA), which processes and routes LM systems status information to various audio and visual indicating devices.

ENVIRONMENTAL CONTROL SYSTEM

The Environmental Control System (ECS) interfaces with the Electrical Power System (EPS) and Instrumentation System (IS). It controls the atmosphere entering the cabin and Pressure Garment Assemblies (PGS's). It also provides coolant for the batteries, Electronic Replaceable Assemblies (ERA's) and instrumentation. The ECS interfaces with the EPS through the circuit breakers for activation of ECS components and controls and displays. The ECS interfaces with the IS through the controls and displays panels and the Explosive Devices System (EDS) through the explosive separations of umbilicals and hardlines of LM descent staging.

EXPLOSIVE DEVICES SYSTEM

The Explosive Devices System (EDS) interfaces with most of the LM systems. The EDS aids in landing gear deployment; pressurization of the RCS, descent engine and ascent engine; interrupts the electrical circuits during staging and provides the means of separating the descent and ascent stage, explosively, for a normal staging operation or for an abort.

Helium is used to pressurize the descent engine propellant tanks, ascent engine propellant tanks and reaction control propellant tanks. Helium isolation valves, after explosive initiation of these valves, provide the helium for the pressurization.

There are three circuit interrupters in the ascent stage, with two Apollo standard initiators, which when explosively initiated, remove all electrical power from the interstage umbilical and provide positive de-energization before the electrical umbilical is cut.

INSTRUMENTATION SYSTEM

Most all inputs to the instrumentation system (IS) are routed from surrounding system sensors. These sensors continuously check system status by sensing temperature, valve action, pressure, switch position, voltage, current, water quantity and state separation distance. These sensed data are changed into electrical signals and routed to the signal conditioning electronics assembly (SCEA),

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the pulse code modulation and timing equipment assembly (PCMTEA), and to the controls and displays. The SCEA converts all unconditioned system and transducer signals and events to proper voltage levels required by the PCMTEA, CWEA and controls and displays. The preconditioned parallel digital and high level analog data that is routed directly to PCMTEA for sampling is converted to one serial digital output signal for transmission to Manned Space Flight Network (MSFN) or CSM. Controls and displays also receive preconditioned data from system sensors and monitor system status with flag indicators or lights.

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STRUCTURE OF THE NASA/GRUMMAN LUNAR MODULE

The LM consists of a descent stage (with landing gear) and an ascent stage. Provision is made for separating the stages and the interconnecting umbilicals at lunar launch. The weight of the LM at earth launch is approximately 32,000 pounds.

ASCENT STAGE

The ascent stage is the manned portion of the LM spacecraft and will carry two astronauts. Power and coasting descent, lunar landing, lunar launch, power ascent, and rendezvous and docking with the Command/Service Modules (CSM) are controlled from the crew compartment. The crew compartment, a pressurized shell, is also the operations center for the astronauts during the lunar stay. The entire pressurized compartment of the ascent stage is called the cabin. In addition to the crew compartment, the ascent stage consists of the mid section, the aft equipment bay, tank sections, engine supports, windows, tunnels, and hatches. Pressure and temperature within the crew compartment are controlled by the Environmental Control System (ECS).

Crew Compartment (Cabin)

The ascent stage is constructed of aluminum alloy. A structural skin surrounded by a composite layer of insulation and a thin aluminum skin provides thermal and micrometeoroid protection for the astronauts. The outer skin is approximately three inches from

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the structural skin. The cabin (crew compartment) is a 92-inch diameter cylinder stiffened by two-inch deep circumferential frames. The frames are spaced approximately 10 inches apart and are located between the structural skin and the thermal shield. The compartment has two triangular cabin windows in the front-face bulkhead, an overhead docking window on the left side, a forward ingress/egress hatch, an upper docking hatch, controls and displays, and items necessary for astronaut comfort and support.

Midsection

The midsection is a smaller compartment directly behind the cabin. The ascent engine is aligned with the center of gravity in the midsection. The ascent engine plumbing and valving is accessible when the removable cover that extends above the deck in the midsection is removed. In addition, the midsection contains the overhead docking hatch, Environmental Control System (ECS), and stowage for equipment that must be accessible to the astronauts.

Tunnels

The upper docking tunnel, at the top centerline of the ascent stage, is used for docking when transposition is performed, for transfer of two astronauts to the LM spacecraft after injection into lunar orbit, for docking after rendezvous in lunar orbit, and for transfer of the LM crew and scientific payload to the Command Module. The ingress/egress hatch, at the lower portion of the forward cabin section, is used on the lunar surface. Pressure-tight, plug-type

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hatches in each tunnel are manually controlled, and are sealed with preloaded silicone elastomeric seals. The ingress/egress hatch leads to an external platform upon which the astronauts step after leaving and before entering the LM.

Aft Equipment Bay

The aft equipment bay is unpressurized and is aft of the mid-section pressure-tight bulkhead. It contains an equipment rack with integral cold plates on which electronic replaceable assemblies (ERA's) are mounted. It includes two gaseous oxygen (GOX) tanks for ascent stage main propellant pressurization, inverters, and batteries for the Electrical Power System (EPS).

Tank Sections

The propellant tank sections are on either side of the mid-section, outside the pressurized area. The tank sections contain ascent engine fuel and oxidizer tanks, and fuel, oxidizer, and helium tanks for the Reaction Control System (RCS). Because the ratio of oxidizer to fuel is 1.6 to 1 by weight, the ascent engine propellant tanks are offset to one side to maintain the lateral center of gravity on the X-axis. Two ECS water tanks are in the overhead of the ascent stage, and two gaseous oxygen storage tanks are in the aft equipment bay.

Windows

Two triangular cabin windows in the front-face bulkhead of the forward cabin section (crew compartment) provide visibility during

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descent, lunar landing, and rendezvous phases of the LM mission. The windows have approximately two square feet of viewing area and are canted down to the side to permit adequate peripheral and downward visibility. Each window consists of two panes separated from each other and vented to space environment. The outer pane is thermal and radiation-protective (Vycor) glass and the inner pane is strong, flexible (Chemcor) glass. A clamp-type seal consisting of a teflon jacket surrounding a metallic spring seals the inner pane.

An overhead window, similar in construction to the forward windows, is on the left side of the forward cabin section directly over the commander's head, and provides the commander with visibility during docking. The window contains a sighting reticle as an aid in lining up the CSM with the LM spacecraft. The field-of-view is at least plus or minus 10° each side of the window centerline, and minus 5° and plus 40° from the vertical centerline. Visibility is obtained by the commander leaning backward and looking up from his normal duty station. The approximate visible opening of the window is 5 inches wide and 12 inches long.

Hatches

Two hatches in the ascent stage permit ingress and egress to and from the LM. The upper or docking hatch, used mainly for docking, is in the midsection directly above the ascent engine cover. Three recesses in the hatch permit use of a ladder for observation while on the lunar surface. The forward hatch is beneath the center instrument

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console (controls and displays) and is used for ingress and egress on the lunar surface. Each hatch contains a dump valve and manually-operated single detent mechanism which preloads the hatch against its seal.

Each hatch has a preloaded elastomeric silicone compound seal mounted in the structure of the spacecraft. When the hatch is closed, a lip near the outer circumference of the hatch enters the seal, ensuring a pressure-tight contact. Both hatches open inward, and normal cabin pressurization forces the hatch into the seal. To open either hatch, it is necessary to depressurize the cabin through the dump valve, and unfasten the latch.

DESCENT ENGINE

The descent stage is the unmanned portion of the LM spacecraft. It consists of that equipment necessary for landing on the lunar surface (e.g., landing gear) and serves as a platform for launching the ascent stage after completion of the lunar stay. In addition to the descent engine and its related components, the descent stage houses scientific equipment to be used on the lunar surface, tanks for water and oxygen used by the ECS, four batteries located in the battery storage bay for the EPS, and six spare PLSS batteries.

The descent stage is constructed of aluminum alloy. Chem-milling is used extensively to reduce weight. The inner structural skin is surrounded by a composite layer of insulation and a thin aluminum-alloy skin that forms a modified octagonal shape around the descent

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stage and thermally protects and isolates the structure. The beams are of conventional skin and stringer construction. All joints are fastened with standard mechanical fasteners. The space between the intersections of the beams forms the center compartment, which contains the descent engine.

Outriggers that extend from the end of each of the two pairs of beams provide support and attachment for the landing gear legs. Four main propellant tanks surround the engine; two oxidizer tanks and two fuel tanks are mounted within the cruciform structure. Scientific equipment, helium oxygen, and water tanks, the lunar surface antennas, EPS batteries, and PLSS batteries are in the bays adjacent to the propellant tanks.

Landing Gear

The landing gear is of the cantelever type. It consists of four sets of legs connected to outriggers that extend from the ends of the descent stage structural beams. The legs extend from the front, rear, and sides of the LM. Each landing gear leg consists of a primary strut and footpad, a drive-out mechanism, two secondary struts, two downlock mechanism, and a truss. In addition, all footpads, but the one on the forward landing gear leg, have lunar surface sensing probes extending below each footpad. All struts have crushable shock absorbing honeycomb inserts. The primary struts absorb compresion loads. The secondary struts absorb compression and tension loads. The forward landing gear has a boarding ladder

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on the primary strut, which is used to climb to and from the ascent stage forward hatch.

The landing gear is in a retracted position until shortly after the astronauts enter the LM during lunar orbit. The landing gear uplocks are then explosively released and springs in each driveout mechanism extend the landing gear and lunar surface sensing probes. Once extended, each landing gear is locked in place by the two down-lock mechanisms.

Interstage Attachments, Umbilicals, and Separations

At earth launch, the LM spacecraft is within the Spacecraft LM Adapter (SLA) between the Service Module and the S-IV booster. The outriggers to which the landing gear is attached provide for attachment of the LM to the lower section of the SLA at their apex. Before transposition, the upper section of the SLA is explosively separated into four segments. These segments are hinged to the lower section and jettisoned. After transposition, the lower section is released, separating the SLA and the booster from the LM spacecraft.

Four explosive nuts and bolts connect the ascent and descent stages. At lunar launch, or for an abort, the two stages are separated by firing these explosive devices. Interstage wiring umbilicals are explosively disconnected and hardlines are mechanically severed at stage separation.

Electroexplosive Devices (EED)

Explosive devices are used to release the landing gear for deployment; to enable helium pressurization of the Ascent Propulsion, Descent, or Reaction Control systems; and for stage separation. The electroexplosive devices are exploded by a standard Apollo initiator controlled by switches on the Explosive Devices Panel.

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MANUFACTURING HISTORY - LM-5

The Lunar Module (LM-5), scheduled to land the first men on the moon, began its manufacturing life at Grumman Aerospace Corporation, Bethpage, New York, on June 16, 1966 when welding began on the ascent stage structure.

Other milestones in the construction of the ascent stage include:

ASSEMBLY - The ascent stage moved into assembly (Plant 2) in mid-February, 1967 where these installations were made: helium pressurization module, helium tanks, propellant tanks and feed lines, RCS tanks, manifold lines, water tanks (ECS), oxygen tank, cabin pressure relief and dump valve, suit circuit assembly and water control module, avionics, electrical harnesses and cable assemblies, relay junction box, power failure relay and ECS relay box, and tracking light. One of the last installations at Plant 2 was the RCS engines, installed in late December 1967.

COLD FLOW TESTING - LM-5 ascent stage underwent tests at Grumman's High Pressure Test Facility where substitute gases and liquids were used to test propulsion systems, environment control systems and the cabin proof pressure and leak rate. The checkouts began in January 1968 and were conducted periodically during final assembly and check-out.

FINAL ASSEMBLY AND TEST - The ascent stage was moved into the final assembly area "clean room", located in Plant 5 at Grumman's main Bethpage facility on January 29, 1968. The ascent stage was fitted onto the Rotate and Clean fixture where it was prepared for final assembly. Installations performed here include: controls and displays, rendezvous radar, attitude and translation control assembly, stowage compartments, thermal blankets and skins. Electronic and communications tests were conducted during this phase of buildup.

The Ascent Propulsion System was completed with the installation of the engine on October 29, 1968, followed by engine leak tests on November 1, and engine functional tests on November 4.

CLEAN AND INSPECT - The ascent stage was again rotated and cleaned on December 30, 1968 and began pre-ship inspections on January 3, 1969.

DELIVERY - The ascent stage, crated in a pressurized container, was flown to the NASA Kennedy Space Center aboard a Super Guppy aircraft on January 8, 1969 from our Grumman airfield.

DESCENT STAGE

The descent stage for LM-5 began taking shape on December 3, 1966, when welding began in the main fixture at Grumman's Plant 2. During descent stage manufacture, the separate spacecraft stages came together, or were "mated" several times. These times were: June 13 to August 21, 1968; September 28 to October 25, 1968; November 11 to December 12, 1968.

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Milestones in buildup of the descent stage for LM-5 are:

ASSEMBLY - The ascnet stage moved into Plant 2 Assembly on February 23, 1967 where the following installations were made: helium pressurization module, helium tanks, propellant tanks, fluid lines, heat exchanger, electrical harness and cable assembly, explosive devices relay box and electrical control assembly.

COLD FLOW TESTING - LM-5 descent stage was moved to the High Pressure Test facility on January 18, 1968 and underwent a series of tests including interconnecting water main valve assembly verification, harness and propellant pressure test, tank and flow-proof pressure and descent stage propellant feed section dry and sample tests.

On April 19, 1968 another series of cold flow tests including water management proof leak and proof press.

The final descent stage cold flow testing started on September 13, 1968 for propulsion system verification.

FINAL ASSEMBLY AND TEST - On February 19, 1968 the descent stage left cold flow and went to Plant 2 in preparation for installation of ALSEP AND MESA stowage bays. The descent stage then arrived in Plant 5 final assembly and test area on March 18, 1968. The installations performed in Plant 5 include gimbal drive actuator, descent engine control assembly, landing radar antenna assembly and base thermal shield and blanket and skin assembly.

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Tests performed included electrical circuit interpreter operation, landing radar interface check, ECI pin depth check, and descent stage HTS Structure integrity.

The descent engine was installed on March 12, 1968 and a descent stage engine interface leak check performed on March 14, 1968

The landing gear was installed on December 3, 1968 through January 3, 1969 and removed for shipping on January 9, 1969.

CLEAN AND INSPECT - The descent stage was then rotated and cleaned on December 13, 1968 and pre-ship inspection occurred on January 8, 1968.

DELIVERY - The descent stage, crated in a pressurized container, was flown to NASA KSC aboard a Super Guppy aircraft on January 12, 1969.

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DEVELOPMENT OF THE NASA/GRUMMAN LUNAR MODULE

Grumman Aircraft Engineering Corporation, Bethpage, New York, primarily known as a maker of fighter planes for the Navy, began research back in 1960 with a LM team which now comprises approximately 6000 scientists, engineers and technicians.

Two years of pioneer work on Apollo paid off in 1962 when the National Aeronautics and Space Administration (NASA) called for bids on developing a LM. A major criterion, NASA said, would be knowledge the companies had already acquired in the field. Grumman was able to present NASA with a mountain of data, evidence that it understood the two paramount problems -- weight and dependability.

In late 1962, Grumman won the contract that plunged it deep into the Apollo Moon-Landing Program -- the NASA/Grumman Lunar Module. The cost-incentive contract totals approximately $1.61 billion for development, manufacture, test and delivery of two mission simulators, 10 ground test articles (LTA's) and 15 flight articles (LM's).

M-1, an engineering mockup, was first displayed in Spring 1964. LTA-1 is being used at Grumman for testing LM electrical and electronics systems.

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The thermal-vacuum test article, LTA-8, was delivered to the NASA Manned Spacecraft Center September 17, 1967. It has completed a series of tests in the Space Simulation Laboratory under temperature and vacuum extremes simulating a typical moon mission.

Before the LM was committed to the lunar mission, its ability to meet the operational requirements of the mission was demonstrated to assure astronaut safety and mission success. The Flight Development Test Program (FDTP) provided this assurance by a series of developmental missions.

LTA-10R was aboard the November 9, 1967 flight of Apollo 4. It was instrumented to measure vibration, acoustics and structural integrity during launch. Data was telemetered to ground stations during the first 12 minutes of flight of the first Saturn V.

The first flight vehicle, LM-1, was shipped from Grumman's Bethpage facility to NASA Kennedy Space Center June 23, 1967. LM-1 was launched January 22, 1968 on Apollo 5 for its first unmanned test flight. During this mission the Lunar Module's ascent and descent propulsion systems, along with the reaction control system, were successfully test fired for the first time in space. As a result of the LM-1 flight, the second scheduled unmanned flight, LM-2, was deleted from the NASA flight program. LM-2 is undergoing ground tests at MSC.

Another LM Test Article, LTA-2R aboard Apollo 6, provided flight test data on the Saturn V launch load and environment criteria.

LTA-B, designed to simulate the weight and mass of a Lunar Module was launched aboard Apollo 8. LTA-B consisted of two concentric rings arranged to form a cylinder with four internal water ballast tanks.

LM-3, the first manned LM, was launched on Apollo 9 for an earth orbital flight on March 3, 1969. USAF Col. James McDivitt was Commander; USAF Col. David Scott, Command Module Pilot; Civilian Russell Schweickart, LM Pilot.

LM-4, the second manned flight of the spacecraft, was launched aboard Apollo 10 on May 18, 1969 for a flight to within 10 miles of the moon's surface. Its' crew, commanded by USAF Col. Thomas Stafford, included USN Cdr. John Young, Command Module Pilot; and USN Cdr. Eugene Cernan, LM Pilot.

LM-5 (Apollo 11) will make the first lunar landing. Mission plans include the deployment of scientific instruments, photography, and the retrieval of lunar surface materials for return to Earth. The descent stage of LM-5 was shipped to Kennedy Space Center on January 12, 1968 and the ascent stage on January 8, 1969. The crew of Apollo 11 is Civilian Neil Armstrong, Commander; USAF Lt. Col. Michael Collins, Command Module Pilot; and USAF Col. Edwin Aldrin, Jr., LM Pilot.

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THE NASA/GRUMMAN APOLLO LUNAR MODULE

GENERAL DESCRIPTION

A two-stage vehicle, with an earth weight of about 32,000 lbs., the Apollo Lunar Module (LM) will function as a ferry, transporting two astronauts from lunar-orbiting Apollo Command and Service Modules (CSM) to the Lunar surface and back.

Basically, the ascent (upper) stage consists of a pressurized crew compartment, equipment areas, and an ascent rocket engine. The descent (lower) stage, to which the landing gear is attached, contains a gimbaled, throttleable descent rocket engine, and the Scientific Experiment Package. The LM is a completely self-sufficient spacecraft; it is equipped with the systems necessary for life support, guidance and navigation, attitude control, communications, and instrumentation in a manned vehicle. The two crewmen stand side-by-side, facing two triangular windows that afford forward and downward lines of sight. A support and restraint harness provides the crew with the stability they require to accomplish their tasks throughout varying gravity environments, and helps them withstand the lunar landing impact. A large center panel permits them to share the displays and controls.

LM will be coupled to the CSM in a turnaround docking maneuver during the earth-to-moon passage. Shortly after the combined CSM-LM has entered a lunar orbit, two of the three astronauts in the

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Command Module (CM) will enter LM through a connecting tunnel. After vehicle checkout, LM will be separated from the CSM and, under the control of its crew, descend and land at a preselected site.

During their planned stay on the lunar surface, the astronauts will perform such scientific tasks as gathering soil samples; measuring temperature, gravity, and magnetic-field strength; and conducting communications experiments. Local explorations in the vicinity of the LM landing site are also planned.

To start their return journey, the astronauts will sever communications between the ascent and descent stage, ignite the ascent engine and liftoff in LM's ascent stage. The descent stage, serving as a launch platform for the ascent stage, will remain on the moon. The launch profile will bring LM to an orbit providing a rendezvous point with the CSM. After docking, the LM crewmen will rejoin the third astronaut in the CM. The ascent stage will then be left in lunar orbit as the CSM starts back to earth. (Simply stated, this is the role which LM will play in the Apollo mission.)

Before earth launch, the LM spacecraft will be subjected to rigorous tests to achieve maximum mission reliability. System acceptance and functional tests, integrated equipment tests, assembly tests, launch pad tests, and countdown operational tests permit constant system monitoring. A general-purpose spacecraft-checkout system, the Acceptance Checkout Equipment-Spacecraft (ACE-S/C) is used for computer-controlled or manually-controlled acceptance tests and pre-launch tests of the LM systems.