Part 2:
Apollo 8: Lunar Orbit

INST 154

Apollo at 50

Apollo Mission Sequence

<u>As Planned</u>

- A Uncrewed Saturn V
- B Uncrewed LM
- C CSM Earth Orbit
- D CSM/LM Earth Orbit
- E CSM/LM higher Earth Orbit
- F CSM/LM Lunar Orbit
- G Lunar Landing

<u>As Flown</u>

- A Apollo 4, 6
- B Apollo 5
- C Apollo 7
- C’ Apollo 8
- D Apollo 9
- F Apollo 10
- G Apollo 11

Astronaut Math in mid-1967

- 30 astronauts in first 3 groups
  - The Original 7, The New 9, The 14
- 10 were no longer available
  - 2 grounded, 2 retired, 6 dead (3 in the Apollo 1 fire, 3 in airplane crashes)
- 18 were needed to fill 6 crews
  - Cooper and Bean were not assigned
- 13 had flight experience
  - 6 (of 9) Gemini commanders were assigned as Apollo CDR
  - 5 were assigned as Apollo CMP
  - 2 were assigned as Apollo LMP
- 5 rookies were needed
  - 1 as CMP (Eisele), 4 as LMP (Cunningham, Anders, Schweickart, Williams)

Apollo Crew Planning

Apollo 7 (C)
- CDR: Schirra
- CMP: Eisele
- LMP: Cunningham

Apollo 8 (D) ⇔ Apollo 9 (E)

Apollo 8 (D)
- CDR: McDivitt
- CMP: Scott
- LMP: Schweickart

Apollo 9 (E)
- CDR: Borman
- CMP: Collins
- LMP: Anders

Apollo 10 (F)
- CDR: Stafford
- CMP: Young
- LMP: Cernan

Apollo 11 (G) ⇔ Apollo 12 (H)

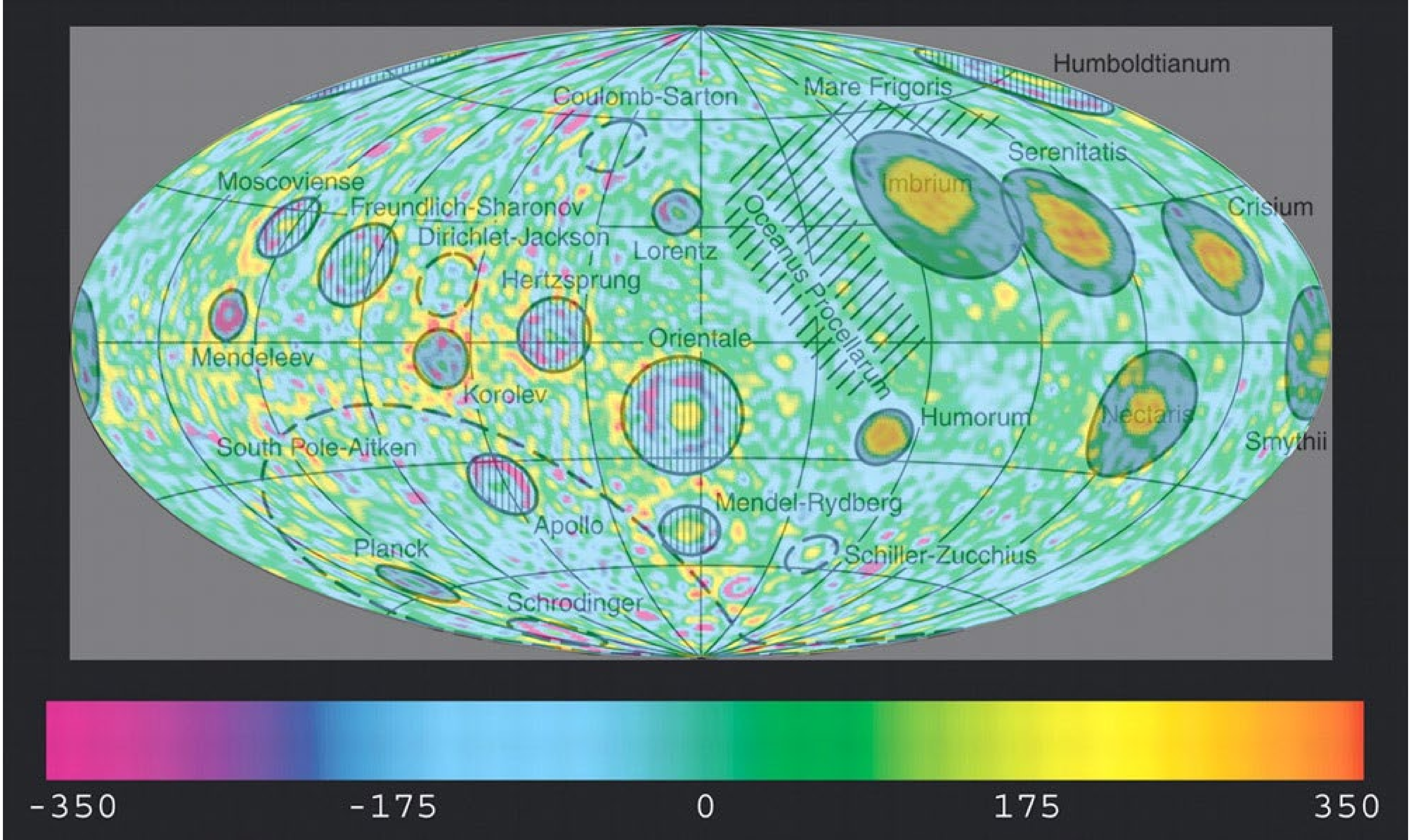
Apollo 11 (G)
- CDR: Conrad
- CMP: Gordon
- LMP: Williams ⇧ Bean

Apollo 12 (H)
- CDR: Armstrong
- CMP: Lovell
- LMP: Aldrin ⇧ Haise

Arguments in Favor of a Lunar Orbit Mission

- Provide valuable operational experience … This will enhance the probability of success of subsequent more complex lunar missions
- Provide an opportunity to evaluate … MSFN and onboard navigation …
- Permit validation of communications … at lunar distance
- … improve consumables requirements prediction …
- … verification of ground support elements and the onboard computer program
- Increase the depth of understanding of thermal conditions …
- Confirm astronauts' ability to see, use and photograph lunar landmarks …
- … an opportunity for additional photographs … for training crewmen …

Memorandum from Sam Phillips to George Mueller, November 11, 1968


Humboldtianum
Mare Frigoris
Coulomb-Sarton
Serenitatis
Imbrium
Crisium
Moscoviense
Freundlich-Sharonov
Dirichlet-Jackson
Lorentz
Oceanus Procellarum
Hertzsprung
Orientale
Mendeleev
Korolev
Humorum
Nectaris
Smythii
South Pole-Aitken
Mendel-Rydberg
Apollo
Planck
Schiller-Zucchius
Schrodinger
-350
-175
0
175
350

Arguments Against a Lunar Orbit Mission

- Marginal design conditions in the Block II CSM may not have been uncovered with only one manned flight
- The life of the crew depends on the successful operation of the Service Propulsion System during the Transearth Injection maneuver
- The three days endurance level required of backup systems in the event of an abort is greater than from an Earth orbit mission
- Only landmark sightings and lunar navigation require a lunar mission …

Memorandum from Sam Phillips to George Mueller, November 11, 1968

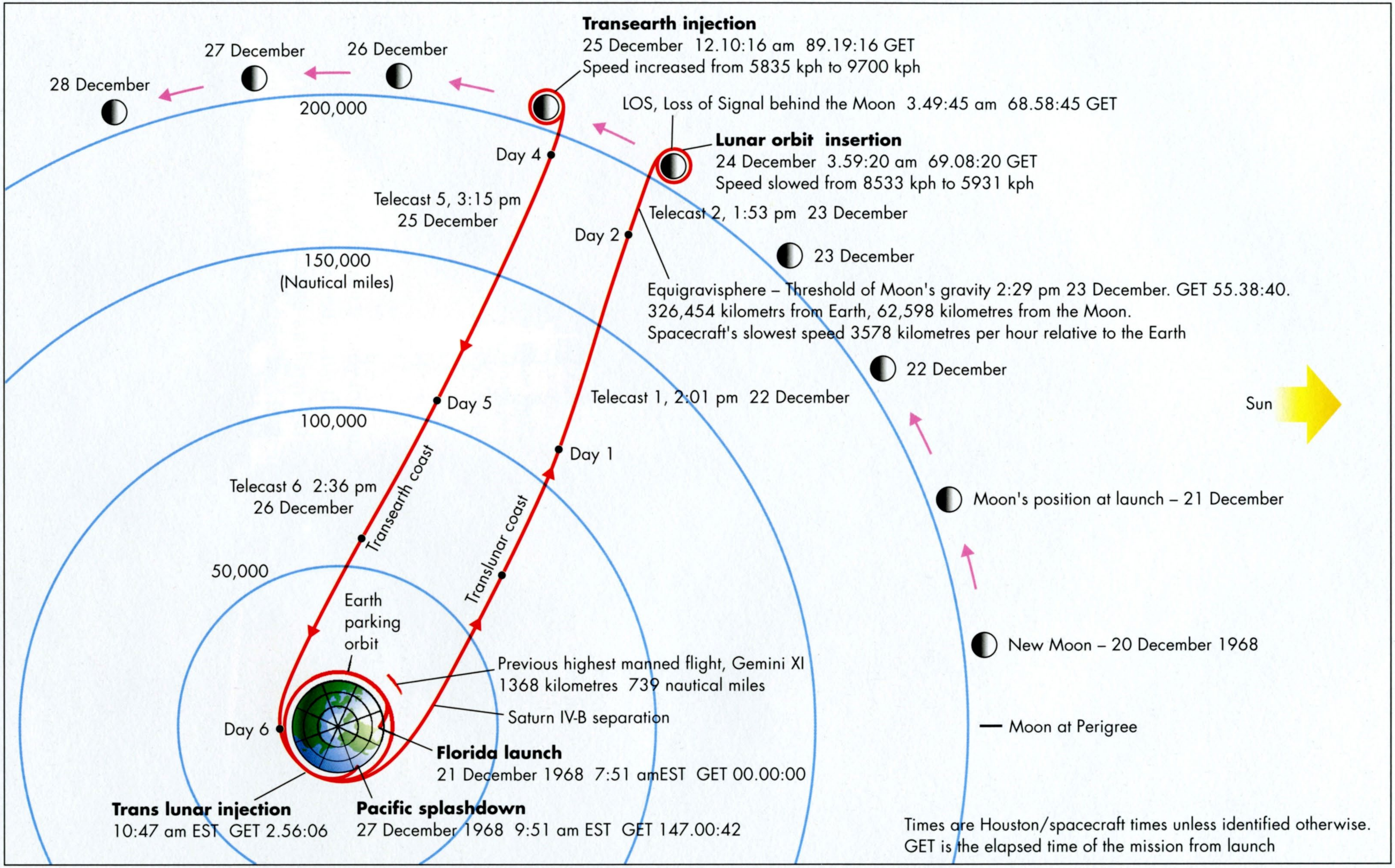
Missing Redundancy

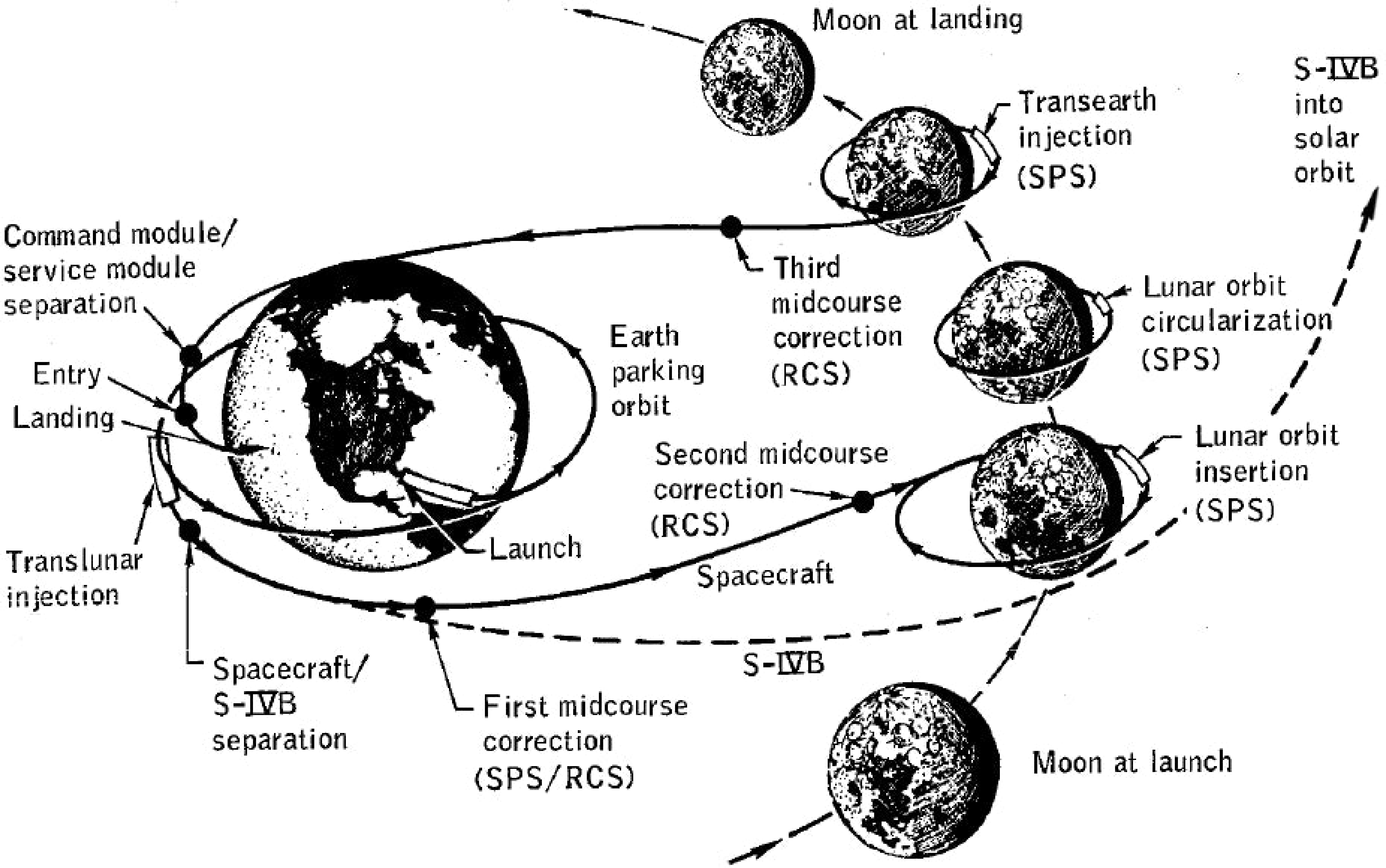
- No “LM Lifeboat” between TLI and TEI
  - Apollo 13 scenario would have been fatal on Apollo 8
- No option for LM DPS TEI in the event of an SPS failure during LOI
  - All lunar landing missions lost this redundancy after PDI

Primary Mission Objectives

- Demonstrate crew/space vehicle/mission support facilities performance during a manned Saturn V mission with CSM

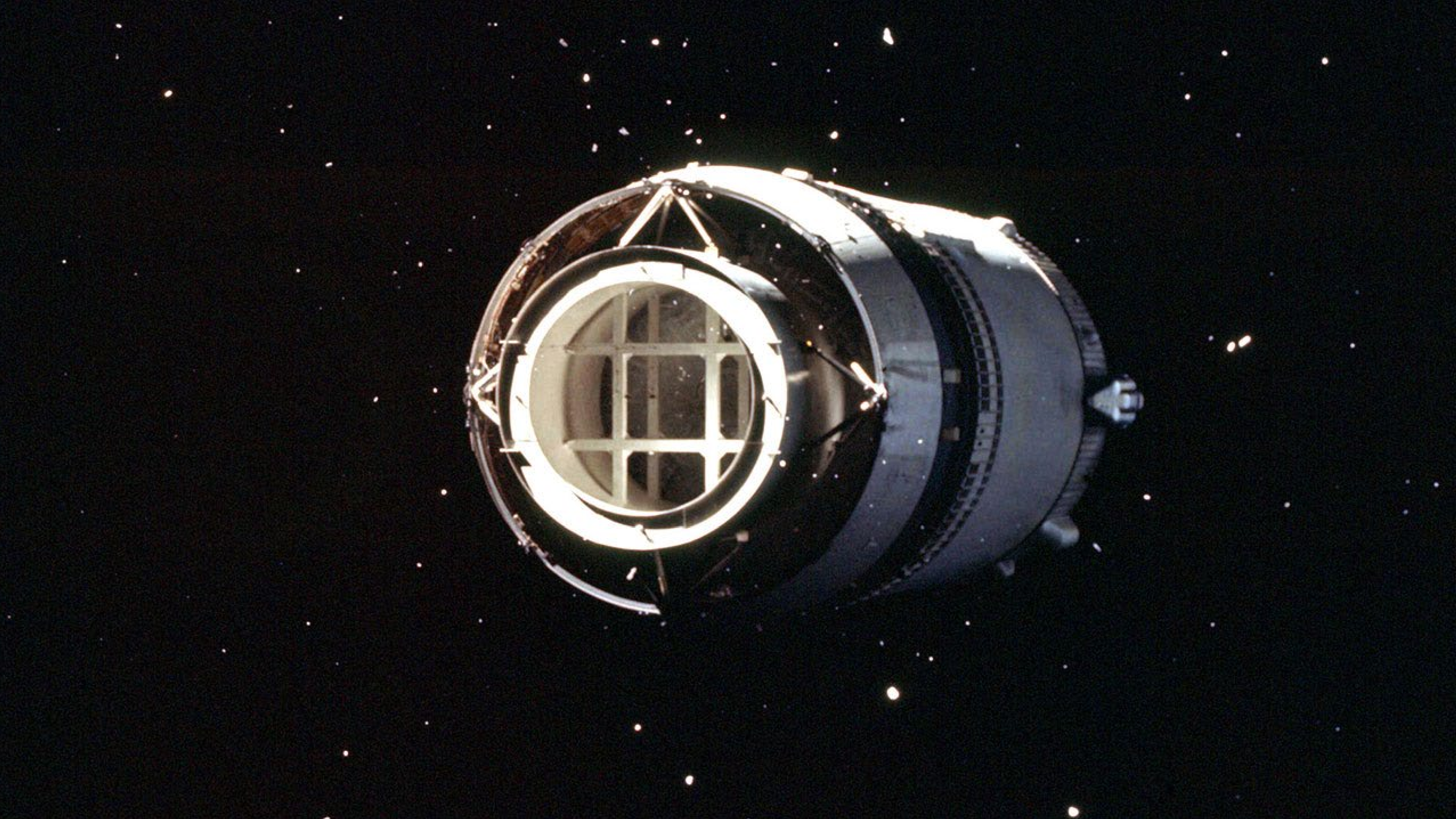
- Demonstrate performance of nominal and selected backup Lunar Orbit Rendezvous (LOR) mission activities, including: Trans-Lunar Injection; CSM navigation, communications, and midcourse corrections; CSM consumables assessment, and passive thermal control

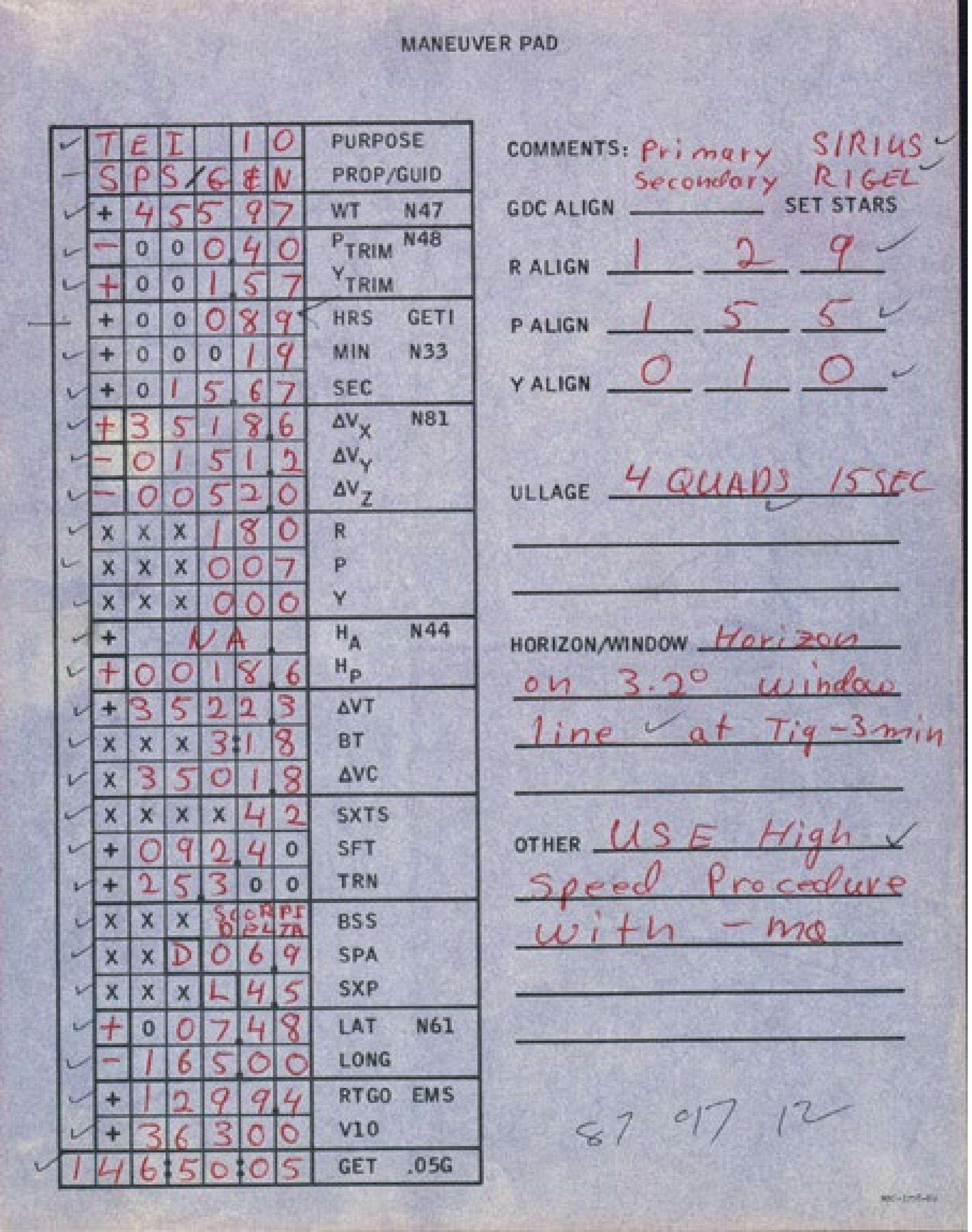

Transearth injection
25 December 12.10:16 am 89.19:16 GET
Speed increased from 5835 kph to 9700 kph
28 December
27 December
26 December
200,000
LOS, Loss of Signal behind the Moon 3.49:45 am 68.58:45 GET
Lunar orbit insertion
24 December 3.59:20 am 69.08:20 GET
Speed slowed from 8533 kph to 5931 kph
Day 4
Telecast 5, 3:15 pm
25 December
Telecast 2, 1:53 pm 23 December
Day 2
23 December
150,000
(Nautical miles)
Equigravisphere – Threshold of Moon's gravity 2:29 pm 23 December. GET 55.38:40.
326,454 kilometrs from Earth, 62,598 kilometres from the Moon.
Spacecraft's slowest speed 3578 kilometres per hour relative to the Earth
22 December
Telecast 1, 2:01 pm 22 December
Sun
Day 5
100,000
Day 1
Transearth coast
Telecast 6 2:36 pm
26 December
Moon's position at launch – 21 December
Translunar coast
50,000
Earth
parking
orbit
New Moon – 20 December 1968
Previous highest manned flight, Gemini XI
1368 kilometres 739 nautical miles
Saturn IV-B separation
Day 6
Moon at Perigree
Florida launch
21 December 1968 7:51 amEST GET 00.00:00
Trans lunar injection
10:47 am EST GET 2.56:06
Pacific splashdown
27 December 1968 9:51 am EST GET 147.00:42
Times are Houston/spacecraft times unless identified otherwise.
GET is the elapsed time of the mission from launch



Moon at landing
S-IVB
into
solar
orbit
Transearth
injection
(SPS)
Command module/
service module
separation
Third
midcourse
correction
(RCS)
Lunar orbit
circularization
(SPS)
Earth
parking
orbit
Entry
Landing
Second midcourse
correction
(RCS)
Lunar orbit
insertion
(SPS)
Launch
Spacecraft
Translunar
injection
S-IVB
Spacecraft/
S-IVB
separation
First midcourse
correction
(SPS/RCS)
Moon at launch


NASA
LOVELL





MANEUVER PAD

TEI 10	PURPOSE
SPS/G&N	PROP/GUID
+ 4 5 5 9 7	WT N47
− 0 0 0 4 0	P_{TRIM} N48
+ 0 0 1 5 7	Y_{TRIM}
+ 0 0 0 8 9	HRS GETI
+ 0 0 0 1 9	MIN N33
+ 0 1 5 6 7	SEC
+ 3 5 1 8 6	ΔV_X N81
− 0 1 5 1 2	ΔV_Y
− 0 0 5 2 0	ΔV_Z
X X X 1 8 0	R
X X X 0 0 7	P
X X X 0 0 0	Y
+ NA	H_A N44
+ 0 0 1 8 6	H_P
+ 3 5 2 2 3	ΔVT
X X X 3:1 8	BT
X 3 5 0 1 8	ΔVC
X X X X 4 2	SXTS
+ 0 9 2 4 0	SFT
+ 2 5 3 0 0	TRN
X X X SCORPII DELTA	BSS
X X D 0 6 9	SPA
X X X L 4 5	SXP
+ 0 0 7 4 8	LAT N61
− 1 6 5 0 0	LONG
+ 1 2 9 9 4	RTGO EMS
+ 3 6 3 0 0	V10
1 4 6 : 5 0 : 0 5	GET .05G

COMMENTS: Primary SIRIUS, Secondary RIGEL

GDC ALIGN ______ SET STARS

R ALIGN 1 2 9

P ALIGN 1 5 5

Y ALIGN 0 1 0

ULLAGE 4 QUADS 15 SEC

HORIZON/WINDOW Horizon on 3.2° window line at Tig−3 min

OTHER USE High Speed Procedure with −MQ

87 47 12

Purpose: *The PAD is intended for the burn that will return the Apollo 8 crew to Earth at the end of Rev 10.*

Systems: *The burn will be made using the SPS engine, under the control of the Guidance and Navigation system.*

CSM Weight (Noun 47): *45,597 pounds.*

Pitch and yaw trim (Noun 48): *-0.40° and +1.57°.*

Time of ignition (Noun 33): *89 hours, 19 minutes, 15.67 seconds.*

Change in velocity (Noun 81), fps: *x, +3,518.6; y, -151.2; z, -52.0.*

Spacecraft attitude: *Roll, 180°; Pitch, 7°; Yaw, 0°.* **Expected apogee of resulting orbit (Noun 44):** *Not applicable.*

Expected perigee of resulting orbit (Noun 44): *18.6 nautical miles (34.4 km).*

Delta-V_T: *3,522.3 fps (1,073.6 m/s).*

Burn duration or burn time: *3 minutes, 18 seconds.*

Delta-V_C: *3,501.8 fps.*

Sextant star: *Star 42 (Peacock, or Alpha Pavonis)*

Boresight star: *Dschubba, or Delta Scorpii.*

COAS Pitch Angle: *Down 6.9°.*

COAS X Position Angle: *Left 4.5°.*

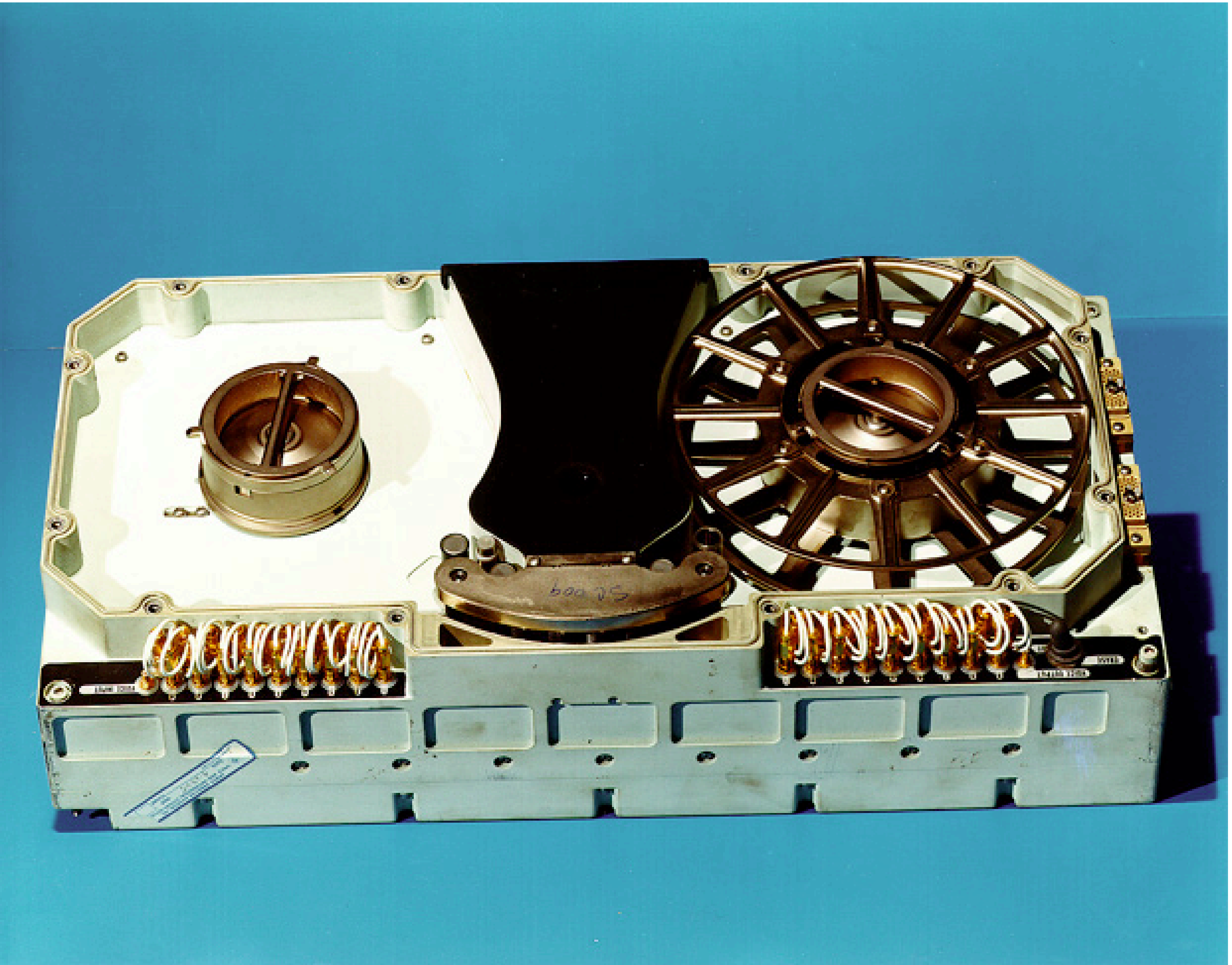
Expected splashdown point (Noun 61): *7.48° north, 165° west*

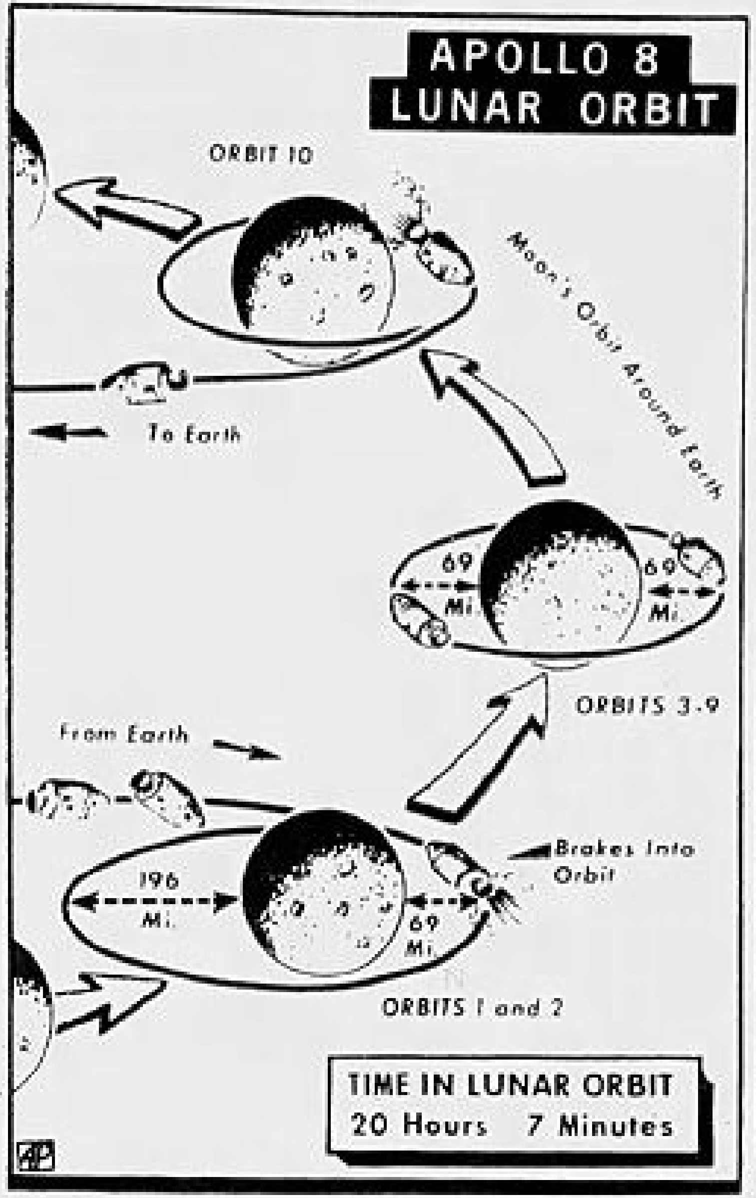
Range to go at the 0.05 g event: *1,299.4 nautical miles.*

Expected velocity at the 0.05 g event: *36,300 fps.*

Predicted GET of 0.05 g event: *146 hours, 50 minutes and 5 seconds GET.*

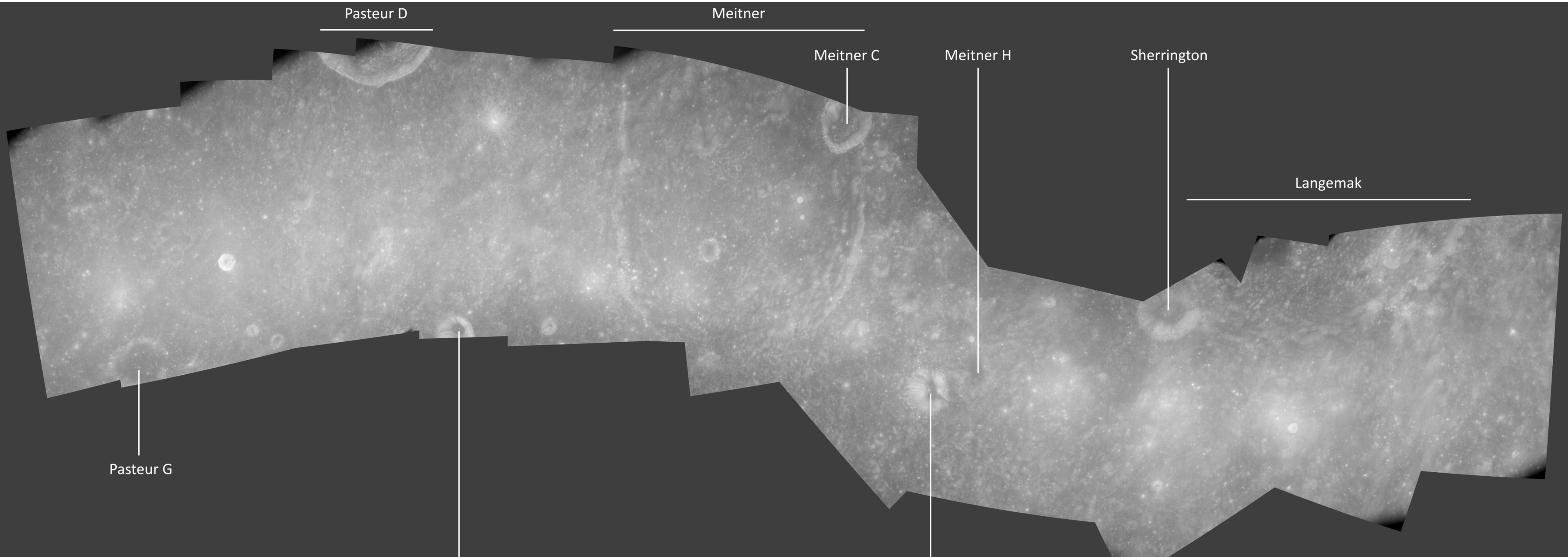
Lunar Orbit Insertion





Spacecraft's Orbit

This artist's conception diagrams the lunar orbital phase of the Apollo 8 mission. Drawings show the capsule entering orbit, bottom, circling the moon, and breaking from lunar orbit and heading back to earth. (AP Wirephoto)



Apollo 8 - Rev 4, Magazine D, Vertical Stereo Sequence, Pan 5
AS08-12-2136 to 2149

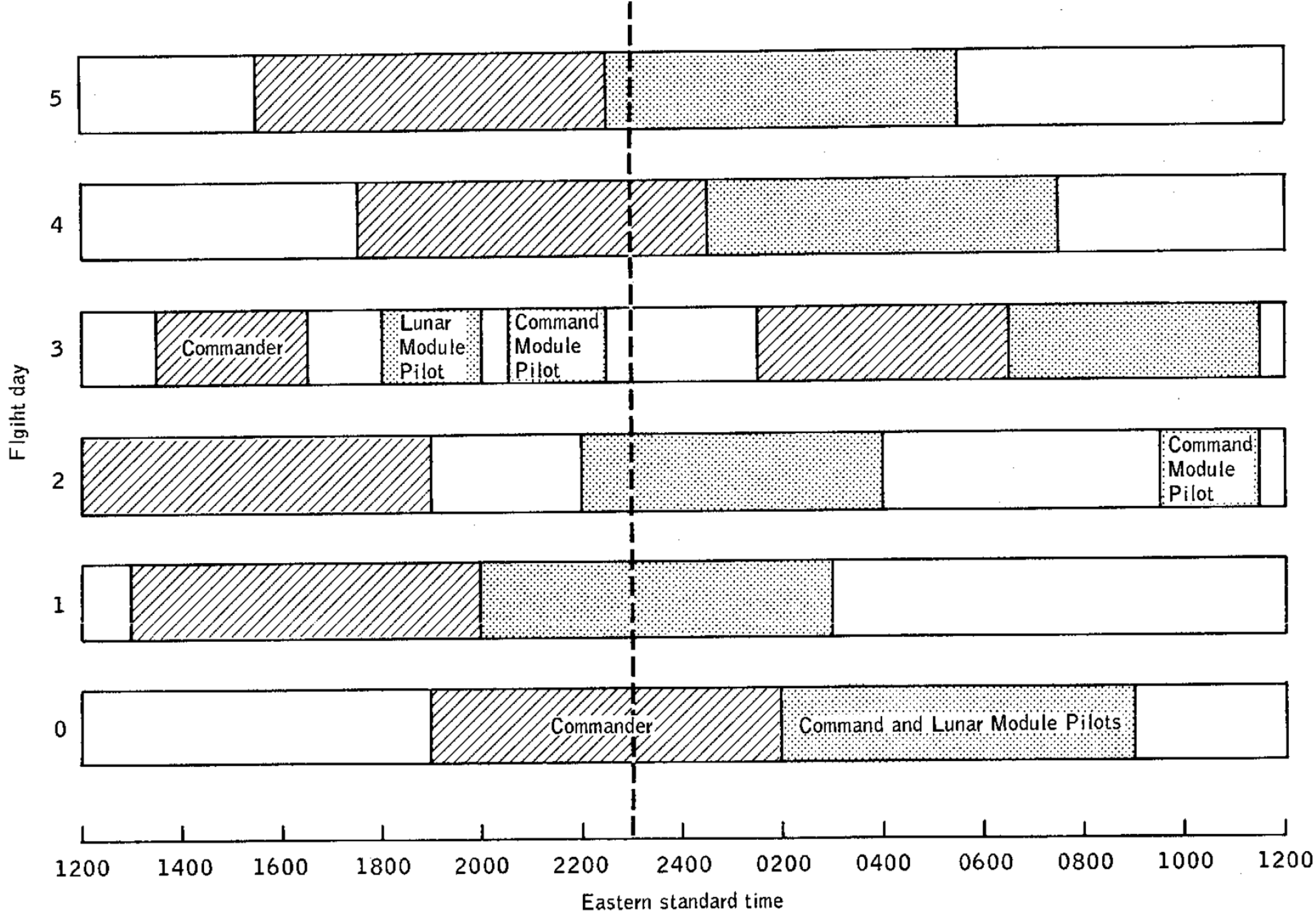
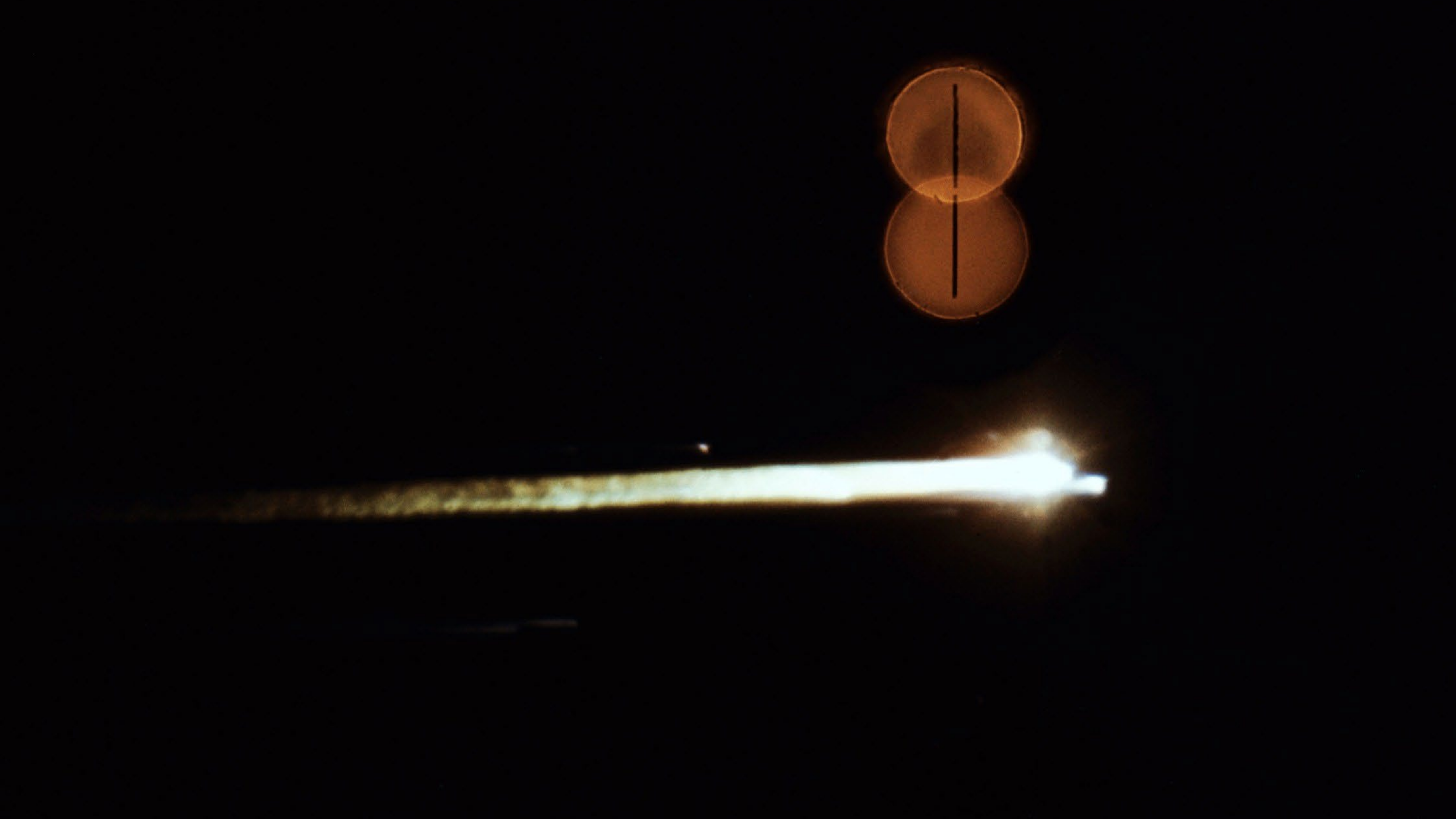


Figure 8-2.- Crew rest cycles.



Apollo 8 Primary Detailed Test Objectives

1. To perform a guidance and navigation control system controlled entry from a lunar return.
2. To perform star-lunar horizon sightings during the translunar and transearth phases.
3. To perform star-earth horizon sightings during translunar and transearth phases.
4. To perform manual and automatic acquisition, tracking, and communication with the Manned Space Flight Network using the high-gain command and service module S-band antenna during a lunar mission.
5. To obtain data on the passive thermal control system during a lunar orbit mission.
6. To obtain data on the spacecraft dynamic response.
7. To demonstrate spacecraft lunar module adapter panel jettison in a zero-g environment.
8. To perform lunar orbit insertion service propulsion system guidance and navigation control system controlled burns with a fully loaded command and service module. Achieved.
9. To perform a transearth insertion guidance and navigation control system controlled service propulsion system burn.
10. To obtain data on the command module crew procedures and timeline for lunar orbit mission activities.
11. To demonstrate command service module passive thermal control modes and related communication procedures during a lunar orbit mission.
12. To demonstrate ground operational support for a command and service module lunar orbit mission.
13. To perform lunar landmark tracking in lunar orbit from the command and service module.
14. To prepare for translunar injection and monitor the guidance and navigation control system and launch vehicle tank pressure displays during the translunar injection burn.
15. To perform translunar and transearth midcourse corrections.
16. To verify that modifications incorporated in the S-IC stage since the Apollo 6 flight suppress low frequency longitudinal oscillations (POGO).
17. To confirm the launch vehicle longitudinal oscillation environment during the S-IC stage burn.
18. To verify the modifications made to the J-2 engine since the Apollo 6 flight.
19. To confirm the J-2 engine environment in the S-II and S-IVB stages.
20. To demonstrate the capability of the S-IVB to restart in Earth orbit.
21. To demonstrate the operation of the S-IVB helium heater repressurization system.
22. To demonstrate the capability to safe the S-IVB stage in orbit.
23. To verify the capability to inject the S-IVB/instrument unit/lunar module test article "B" into a lunar "slingshot" trajectory.
24. To verify the capability of the launch vehicle to perform a free-return translunar injection.

Anomalies

1.	Preflight:	Contamination of spacecraft LOX
2.	Launch:	S1C camera malfunction
3.	Launch:	Intermittent operation of S-II power supplies
4.	Launch:	SII engine oscillations
5.	Translunar:	Drop in chamber pressure during first SPS burn
6.	Throughout:	Hatch and side windows obscured
7.	Throughout:	Obscuration of telescope field of view
8.	Throughout:	Abnormal shifts in computer readout of optics trunnion angle
9.	Throughout:	Noisy cabin fans
10.	Throughout:	Inoperative personal radiation dosimeter
11.	Transearth:	Erratic potable water quantity measurement
12.	Reentry:	Entry monitor system malfunctions
13.	Landing:	Seawater inflow through cabin pressure relief valve
14.	Recovery:	Inoperative swimmer's interphone
15.	Recovery:	Failure of CM recovery loop

Function/System	Changes
Changes Implemented for Apollo 9 and Apollo 10 Missions (LM-3 and LM-4)	
Structures	Doublers added to upper deck of descent stage. Apollo lunar surface experiment package and modular equipment stowage assembly mass simulated. Descent battery support structure modified to mount two batteries in quadrant I and two batteries in quadrant IV. Emergency detection relay box support structure modified to mount one box on ascent stage and one box on descent stage. Crushable honeycomb inserts added to landing gear leg assemblies.
Thermal control, passive	Insulation lightened by reducing number of layers of insulation in blankets. Window shade material thermal capability increased from 200° to 300° F.
Pyrotechnics	Electro-explosive devices batteries and relay boxes relocated, one mounted on ascent stage and one mounted on descent stage. Number of circuit interrupters reduced from three to two (LM-4).
Electrical power	Four descent stage batteries relocated. Descent electrical control assembly modified to allow command module to power ascent stage alone.
Instrumention	Development flight instrumentation deleted (Apollo 10 only).
Communications	Digital uplink assembly added to replace digital command assembly. Ranging tone transfer assembly added for command and service module/lunar module VHF ranging.
Radar systems	Landing radar modified for earth orbital mission and lunar orbital mission, per respective flights.
Changes Implemented for Apollo 9 and Apollo 10 Missions - Concluded (LM-3 and LM-4)	
Guidance and control	Ascent engine arm assembly modified to allow unmanned abort guidance system firing. Alignment optical telescope weight reduced. Reaction control system thruster-on time was increased for a given input signal.
Descent propulsion	Helium explosive valve reinforced by adding an external braze.
Ascent propulsion	Rough combustion cutoff assembly deleted. Propellant tank support cone installation changed from rivets to bolts. Relief valves modified to gold braze with notched poppet step.
Environmental control	Suit circuit assembly changed from titanium to aluminum for better fan operation. Primary sublimator feedline solenoid valve deleted in water management system.

Discussion Groups

- From the Earth to the Moon video episode 4 (“1968”)
  - An interleaved telling of the story of 1968’s social unrest and Apollo 8
- Chaikin Chapter 3 (“First Around the Moon”)
  - Apollo 8 from the Astronaut’s perspective
- Woods Chapter 6 (“Navigating to the Moon”)
  - The procedures used on every lunar mission