# Apollo 10: Lunar Orbit Rendezvous

INST 154

Apollo at 50

Sea of Tranquility

# 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.

| 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.<br>Apollo lunar surface experiment package and modular equipment stowage assembly mass simulated.<br>Descent battery support structure modified to mount two batteries in quadrant I and two batteries in quadrant IV.<br>Emergency detection relay box support structure modified to mount one box on ascent stage and one box on descent stage.<br>Crushable honeycomb inserts added to landing gear leg assemblies. |
| Thermal control, passive | Insulation lightened by reducing number of layers of insulation in blankets.<br>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.<br>Number of circuit interrupters reduced from three to two (LM-4). |
| Electrical power | Four descent stage batteries relocated.<br>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.<br>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. |

| Function/System | Changes |
|---|---|
| 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.<br>Alignment optical telescope weight reduced.<br>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.<br>Propellant tank support cone installation changed from rivets to bolts.<br>Relief valves modified to gold braze with notched poppet step. |
| Environmental control | Suit circuit assembly changed from titanium to aluminum for better fan operation.<br>Primary sublimator feedline solenoid valve deleted in water management system. |

# Apollo 9 <u>**Mandatory**</u> Detailed Test Objectives

1. To perform a medium duration descent propulsion system firing to include manual throttling with command and service module and lunar module docked, and a short duration descent propulsion system firing with an undocked lunar module and approximately half full descent propulsion system propellant tanks.
2. To perform a long duration ascent propulsion system burn.
3. To perform a long duration descent propulsion system burn and obtain data to determine that no adverse interactions existed between propellant slosh, vehicle engine vibration, and descent propulsion system performance during a burn.
4. To demonstrate the performance of the environmental control system during lunar module activity periods.
5. To determine the performance of the lunar module electrical power subsystem in the primary and backup modes.
6. To operate the landing radar during the descent propulsion system burns.
7. To deploy the lunar module landing gear and obtain data on landing gear temperatures resulting from descent propulsion system operation.
8. To verify the performance of the passive thermal subsystems (thermal blanket, plume protection, ascent and descent stage base heat shields, and thermal control coatings) to provide adequate thermal control when the spacecraft is exposed to the natural and propulsion induced thermal environments.
9. To demonstrate the structural integrity of the lunar module during Saturn V launch and during descent propulsion system and ascent propulsion system burn in an orbital environment.

# Apollo 9 **Primary** Detailed Test Objectives

1. To demonstrate block II command and service module attitude control during service propulsion system thrusting with the command and service module and lunar module docked.
2. To perform inertial measurement unit alignments using the sextant while docked.
3. To perform an inertial measurement unit and a star pattern visibility check in daylight while docked.
4. To perform manual thrust vector control takeover of a guidance navigation control system initiated service propulsion docked burn.
5. To obtain data on the effects of the tower jettison motor, S-II retrorockets, and service module reaction control system exhaust on the command and service module.
6. To perform lunar module inertial measurement unit alignments using the alignment optical telescope and calibrate the coarse optical alignment sight.
7. To demonstrate reaction control system translation and attitude control of the staged lunar module using automatic and manual primary guidance and navigation control system controls.
8. To obtain data to verify inertial measurement unit performance in the flight environment.
9. To perform a primary guidance and navigation control system/digital autopilot controlled long duration ascent propulsion burn.
10. To demonstrate an abort guidance system calibration and obtain abort guidance system performance data in the flight environment.
11. To demonstrate reaction control system translation and attitude control of unstaged lunar module using automatic and manual abort guidance system/control electric section control modes.
12. To perform an abort guidance system/control electric section controlled descent propulsion system burn with a heavy descent stage. Achieved.
13. To demonstrate tracking of command and service module rendezvous radar transponder at various ranges between the command and service module and the lunar module.
14. To perform a landing radar self-test.
15. To obtain data on rendezvous radar corona susceptibility during lunar module -X translation reaction control system engine firings while undocked and during -X reaction control system engine firings while docked.
16. To demonstrate the lunar module/Manned Space Flight Network operational S-band communication subsystem capability.
17. To demonstrate lunar module/command and service module/Manned Space Flight Network/extravehicular activity operational S-band and VHF communication compatibility.
18. To demonstrate command and service module docking with the S-IVB/spacecraft/lunar module adapter/lunar module.
19. To demonstrate lunar module separation and ejection of the command and service module/lunar module from the spacecraft/lunar module adapter.
20. To demonstrate the technique to be employed for the undocking of the lunar module from the command and service module prior to lunar descent.
21. To perform a lunar module active rendezvous with a passive command and service module.
22. To demonstrate lunar module active docking capability with the passive command and service module.
23. To perform a pyrotechnic separation of the lunar module and command and service module in flight.
24. To demonstrate mission support facilities performance during an Earth orbital mission.
25. To perform procedures required to prepare for a command and service module active rendezvous with the lunar module.
26. To demonstrate crew capability to transfer themselves and equipment from the command and service module to the lunar module and return.
27. To demonstrate extravehicular transfer and obtain extravehicular activity data.
28. To demonstrate S-IVB/instrument unit control capability during transposition, docking and lunar module ejection maneuver.


UNITED
STATES

# Deciding to fly Apollo 10 Without Landing (Video from 7:20)

- LM-4 (Apollo 10) flew 197 pounds heavier (dry) than LM-5 (Apollo 11)
  - And that LM-5 weight included all the lunar surface equipment
    - TV camera, PLSS backpacks, rock boxes, erectable antenna, 3 experiments, …
- Apollo 10 could be launched in May
  - But LM-5 would not be available before June
  - Flying Apollo 11 in July would allow two more tries (in September and November)
- Stafford had not flown the Lunar Landing Training Vehicle
  - It was grounded after a December 1968 accident (until June 14, 1969)
- 4 primary detailed test objectives required a LM in lunar orbit
- Additional tracking would improve models of the lunar gravity field
- The first test of the Soviet N-1 lunar booster in February 1969 had failed
  - That put the Soviet lunar landing program more than a year behind NASA's

# Apollo 10 **Primary** Detailed Test Objectives

1. To perform primary guidance and navigation control system/descent propulsion system undocked descent orbit insertion and a high thrust maneuver.
2. To perform manual and automatic acquisition, tracking, and communications with the Manned Space Flight Network using the steerable S-band antenna at lunar distance.
3. To operate the landing radar at the closest approach to the Moon and during descent propulsion system burns.
4. To obtain data on the command module and lunar module crew procedures and timeline for the lunar orbit phase of a lunar landing mission.
5. To perform a lunar module active simulated lunar landing mission rendezvous.
6. To perform lunar landmark tracking in lunar orbit from the command and service module with the lunar module attached.
7. To perform lunar landmark tracking from the command and service module while in lunar orbit (not fully accomplished on Apollo 8)

# Apollo 10 Prime and Backup Crews


APOLLO 10 CREW TRAINING SUMMARY
As of May 17, 1969

| ASTRONAUTS | | PLANNED HOURS | STAFFORD | YOUNG | CERNAN | COOPER | EISELE | MITCHELL |
|---|---|---|---|---|---|---|---|---|
| CSM SYS BRIEF | | | | | | | | |
| Docking | 12 | 2 | 2 + 15 | 2 + 15 | 2 + 15 | 2 + 15 | 0 + 15 | 2 + 15 |
| ECS | 23 | 2 | 1 + 30 | 2 + 30 | 2 + 30 | 7 + 30 | 0 + 30 | 8 + 30 |
| EPS | 17 | 2 | 1 + 30 | 2 + 30 | 2 + 30 | 4 + 35 | 0 + 30 | 5 + 35 |
| G&C | 64 | 12 | 5 + 30 | 5 + 30 | 5 + 30 | 23 + 30 | 0 + 30 | 23 + 30 |
| PROP & RCS | 34 | 3 | 2 + 45 | 2 + 45 | 2 + 45 | 11 + 45 | 0 + 45 | 11 + 45 |
| SECS | 18 | 2 | 2 + 00 | 2 + 00 | 2 + 00 | 8 + 00 | | 8 + 00 |
| COMM | 28 | 6 | 2 + 30 | 5 + 30 | 6 + 30 | 5 + 30 | 0 + 30 | 7 + 30 |
| CREW SYS | 10 | 2 | 2 + 00 | 2 + 00 | 2 + 00 | 2 + 00 | | 2 + 00 |
| CM SIMULATORS | | | | | | | | 69 |
| CMS | 904 | 100 | 87 + 15 | 377 + 45 | 74 + 20 | 75 + 45 | 185 + 05 | 103 + 30 |
| CMPS | | 30 | | | | | | |
| DCPS | 64 | 12 | 25 + 45 | 18 + 45 | | 9 + 45 | 9 + 10 | |
| RDS | 27 | 8 | 5 + 40 | 11 + 40 | | | 5 + 00 | 5 + 00 |
| CENTRIFUGE | 4 | 4 | | 4 + 00 | | | | |
| ME 106 | 17 | | | 16 + 30 | | | | |
| SIM BRIEF | 51 | 10 | 6 + 00 | 15 + 00 | 6 + 00 | 5 + 10 | 10 + 30 | 8 + 25 |
| CSM TESTS (DOWNEY) | | | | | | | | |
| Integrated | 68 | - | | | | 34 + 00 | | 34 + 00 |
| CSM TESTS (KSC) | | | | | | | | |
| Alt Chbr | 96 | 16 | 16 + 00 | 16 + 00 | 16 + 00 | 16 + 00 | 16 + 00 | 16 + 00 |
| Docking | 30 | 4 | 4 + 00 | 4 + 00 | 4 + 00 | 6 + 00 | 6 + 00 | 6 + 00 |
| Flt Readiness | 26 | 8 | 6 + 00 | 6 + 00 | | | 14 + 00 | |
| Countdown Demo | 24 | 8 | 8 + 00 | 8 + 00 | 8 + 00 | | | |
| CCFF | 33 | 4 | 7 + 00 | 7 + 00 | 7 + 00 | 4 + 00 | 4 + 00 | 4 + 00 |
| LM SYS BRIEF | | | | | | | | |
| COMM | 34 | 6 | 3 + 15 | | 10 + 15 | 10 + 15 | | 10 + 15 |
| CES | 26 | 15 | 12 + 30 | | 12 + 30 | 10 + 30 | | 10 + 30 |
| ECS | 25 | 8 | 4 + 45 | | 7 + 45 | 7 + 45 | | 4 + 45 |
| EPS | 22 | 6 | 5 + 30 | | 7 + 35 | 4 + 30 | | 4 + 00 |
| Instrumentation | 10 | 4 | 2 + 30 | | 2 + 30 | 2 + 30 | | 2 + 30 |
| Radar | 38 | 10 | 9 + 30 | | 11 + 30 | 9 + 30 | | 7 + 30 |
| PROP & RCS | 31 | 10 | 8 + 30 | | 8 + 30 | 8 + 30 | | 5 + 30 |
| AGS | 56 | 15 | 13 + 30 | | 13 + 30 | 14 + 30 | | 14 + 30 |
| LM SIMULATORS | | | | | 71 | | | |
| LMS | 881 | 200 | 243 + 35 | | 250 + 10 | 167 + 55 | | 219 + 25 |
| LMPS | 27 | 30 | | | 11 + 00 | 4 + 00 | | 12 + 00 |
| MIT HYBRID | | | | | | | | |
| TDS | 9 | 10 | 4 + 15 | | | | | 5 + 00 |
| SIM BRIEF | 54 | 20 | 15 + 45 | | 14 + 15 | 11 + 35 | | 12 + 35 |
| LM TESTS (BETHPAGE) | | | | | | | | |
| FEAT | 34 | - | | | | 17 + 00 | | 17 + 00 |
| LM TESTS (KSC) | | | | | | | | |
| Alt Chbr | 110 | 16 | 22 + 00 | | 22 + 00 | 33 + 00 | | 33 + 00 |
| Flt. Readiness | 15 | 8 | 5 + 00 | | | | | 10 + 00 |
| CCFF | 20 | 4 | 6 + 00 | | 6 + 00 | 4 + 00 | | 4 + 00 |

APOLLO 10 CREW TRAINING SUMMARY
As of May 17, 1969

| ASTRONAUTS | | PLANNED HOURS | STAFFORD | YOUNG | CERNAN | COOPER | EISELE | MITCHELL |
|---|---|---|---|---|---|---|---|---|
| LV BRIEF | 24 | 6 | 6 + 00 | 6 + 00 | | 6 + 00 | | 6 + 00 |
| G&N PROGRAMS | 190 | 40 | 31 + 00 | 34 + 30 | 31 + 00 | 29 + 30 | 33 + 00 | 31 + 00 |
| PHOTOGRAPHY | 48 | 8 | 9 + 00 | 9 + 00 | 9 + 00 | 7 + 15 | 4 + 30 | 8 + 45 |
| LUNAR TOPOGRAPHY REVIEWS | 107 | 25 | 24 + 00 | 28 + 00 | 23 + 00 | 8 + 00 | 12 + 00 | 12 + 00 |
| PROCEDURES | | | | | | | | |
| Design/Acceptance | 203 | 20 | 11 + 00 | 8 + 00 | 2 + 00 | 91 + 00 | 1 + 00 | 90 + 00 |
| Checklist | 217 | 25 | 28 + 00 | 50 + 00 | 58 + 00 | 20 + 00 | 29 + 00 | 32 + 00 |
| Mission Tech. | 475 | 40 | 99 + 30 | 93 + 30 | 82 + 15 | 58 + 30 | 67 + 30 | 74 + 00 |
| Mission Rules | 77 | 10 | 10 + 00 | 8 + 00 | 10 + 00 | 5 + 00 | 5 + 00 | 39 + 00 |
| Flight Plan | 151 | 25 | 23 + 00 | 24 + 00 | 23 + 00 | 43 + 00 | 19 + 00 | 19 + 00 |
| Stowage | | 20 | | | | | | |
| Walkthrus | 105 | 16 | 17 + 30 | 23 + 30 | 21 + 30 | 15 + 30 | 12 + 00 | 15 + 00 |
| WIF/Zero G ACFT | | 20 | | | | | | |
| EMU C/O | 82 | 6 | 13 + 00 | | 27 + 30 | 13 + 00 | | 28 + 00 |
| Egress TNG | 65 | 8 | 6 + 30 | 2 + 30 | 6 + 30 | 17 + 30 | 12 + 30 | 19 + 30 |
| S/C Fire | 2 | 6 | | | | 1 + 05 | | 1 + 05 |
| Bench Checks | 97 | 15 | 17 + 00 | 9 + 00 | 17 + 00 | 21 + 00 | 9 + 00 | 24 + 00 |
| Planetarium | 34 | - | | | | 13 + 00 | | 21 + 00 |
| LLTV C/O | | - | | | | | | |
| Medical | 42 | - | 9 + 30 | 9 + 30 | 9 + 30 | 4 + 30 | 4 + 30 | 4 + 30 |

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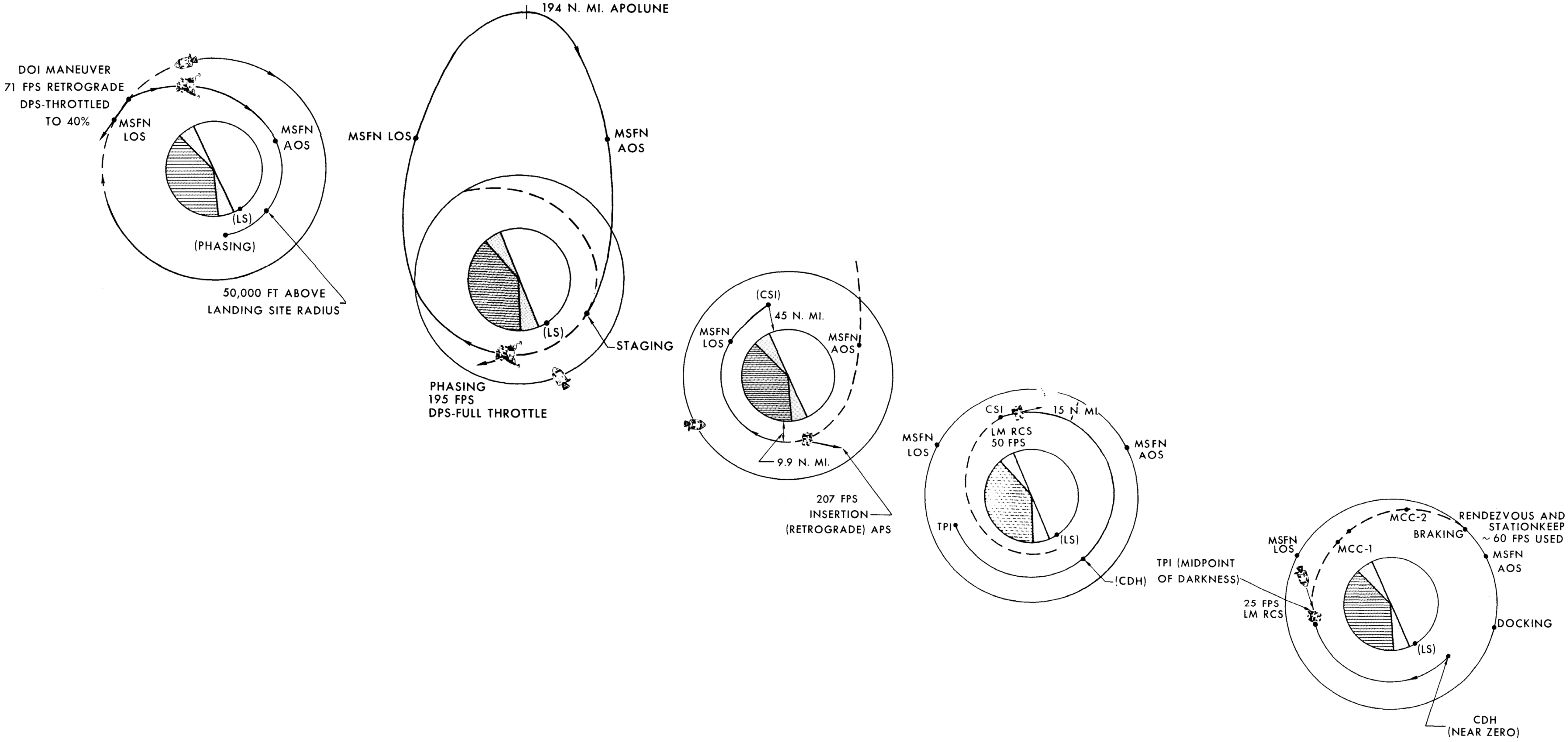
# Launch Pad 39B

# Apollo 10 LM Descent Orbit & Rendezvous Sequence



# PHASING

A. TEST OBJECTIVES

P11.15-1 Capability of the PGNCS to Execute a DPS High Thrust Level Undocked Maneuver
S11.17-3 Overall PGNCS Errors During Thrusting Maneuvers

S12.6-1 AGS Overall Inertial Sensor Performance During an Undocked DPS Burn at Fixed Throttle
S13.14-1 Supercritical Helium Pressure Profile
S16.14-2 No Velocity/Altimeter Frequency Tracker Lock On to Spurious Doppler Signals
S20.82-1 Ground Monitoring of LM PGNCS/AGS
S20.82-2 Crew Monitoring of LM PGNCS/AGS

B. TEST REQUIREMENTS

1. At least 15 seconds of phasing DPS burn to be performed at a thrust level of 40 percent or higher, [11.15] with fixed throttle. [12.6].

2. AGS to be aligned to PGNCS prior to DPS burn. [12.6]

3. AGS sensor performance data and LM IMU performance data to be acquired during the DPS burn at fixed throttle point. [11.17, 12.6]

4. LR to be operated in position 2 during the DPS burn. [16.14]

5. MCC data, displays, procedures and computations shall be utilized in support monitoring of LM PGNCS/AGS performance to permit recommending guidance transfer if necessary in real time. [20.82]

6. LM crew displays, procedures and computational aids shall be used in monitoring LM PGNCS/AGS performance to determine if guidance should be transferred at any point during the burn. [20.82]

7. MSFN coverage. [11.17, 11.15]

C. TEST PROCEDURES/CHECKLISTS

1. LM AOH paragraph 4.10.1, "DPS Thrust Program (P40) With AGS Follow-Up/In Control"

2. LM AOH paragraph 4.9.2.1, "PGNCS/AGS Align"

3. LM AOH paragraph 4.6.3.2, "Landing Radar Power Up"

D. DATA REQUIREMENTS

1. Flight Crew Reports/Logs

   a. Comments on adequacy of procedures necessary to accomplish the high thrust maneuver. [11.15] (M)

   b. Comments on PGNCS performance during the high thrust maneuver and on control response during start and throttle up periods. [11.15] (HD)

   c. Confirm that false LR lock did not occur. [16.14] (HD)

   d. Record LR antenna temperature at end of DPS burn and two minutes later. [16.14] (HD)

   e. Comments on adequacy of LM displays, onboard procedures and on-board charts used to perform guidance monitor functions during lunar orbit operations. [20.82] (M)

   f. Comments on adequacy and clarity of MSFN data concerning PGNCS/AGS residuals during lunar orbit operations as furnished by voice link to the LM. [20.82] (M)

   g. Comments on adequacy and clarity of GNCS and VHF derived range rate data as furnished by voice link from the CM to the LM. [20.82] (M)

2. Ground Support

   a. MSFN tracking 60 seconds prior to, during and 60 seconds after the high thrust maneuver. [11.15] (M)

   b. BET LM [11.15] (M); BET CSM/LM [20.82] (HD)

   c. LM TM HBR [11.17, 11.15, 12.6, 16.14, 20.82] (M)

   d. LM TM LBR [13.14-1, 16.14, 20.82] (M)

   e. Flight Director reports of timeline/procedural difficulties. (M)

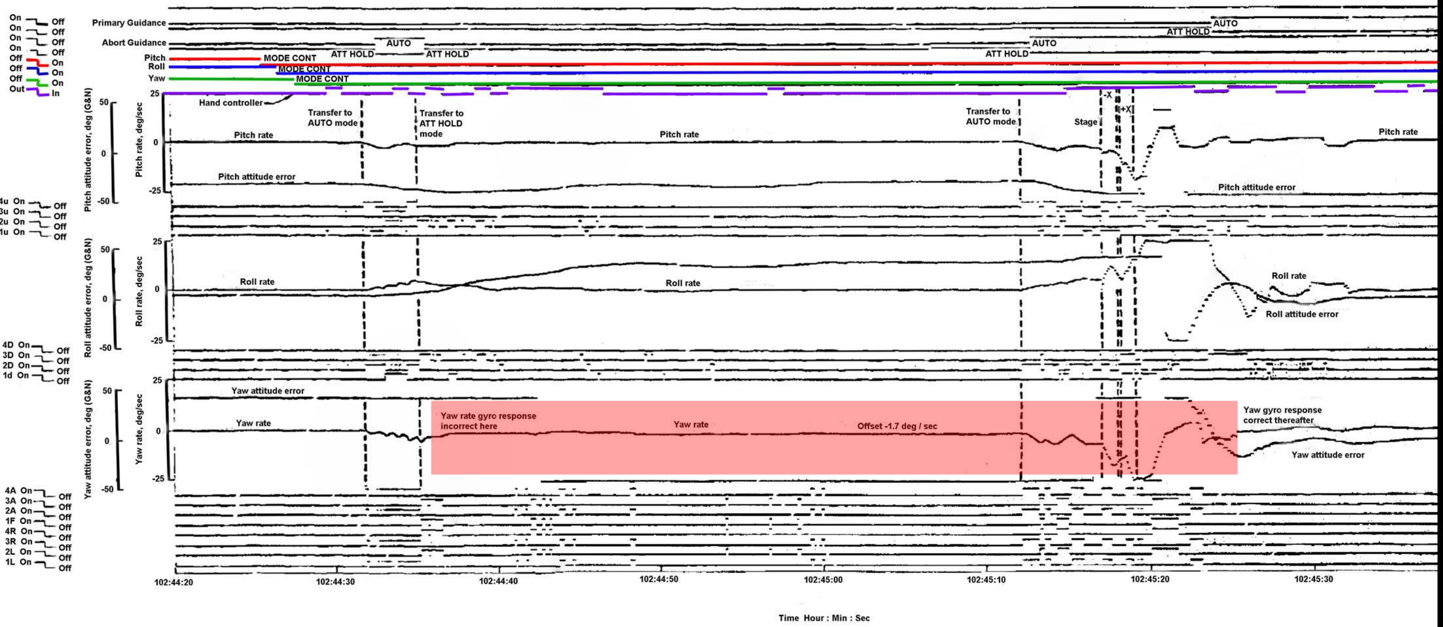
   f. Real time S-band ranging data from LM. [20.82] (M)

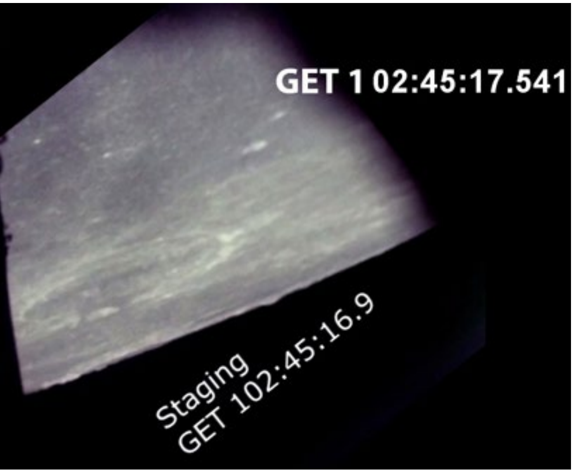
   g. Real time S-band ranging data from CSM. [20.82] (HD)

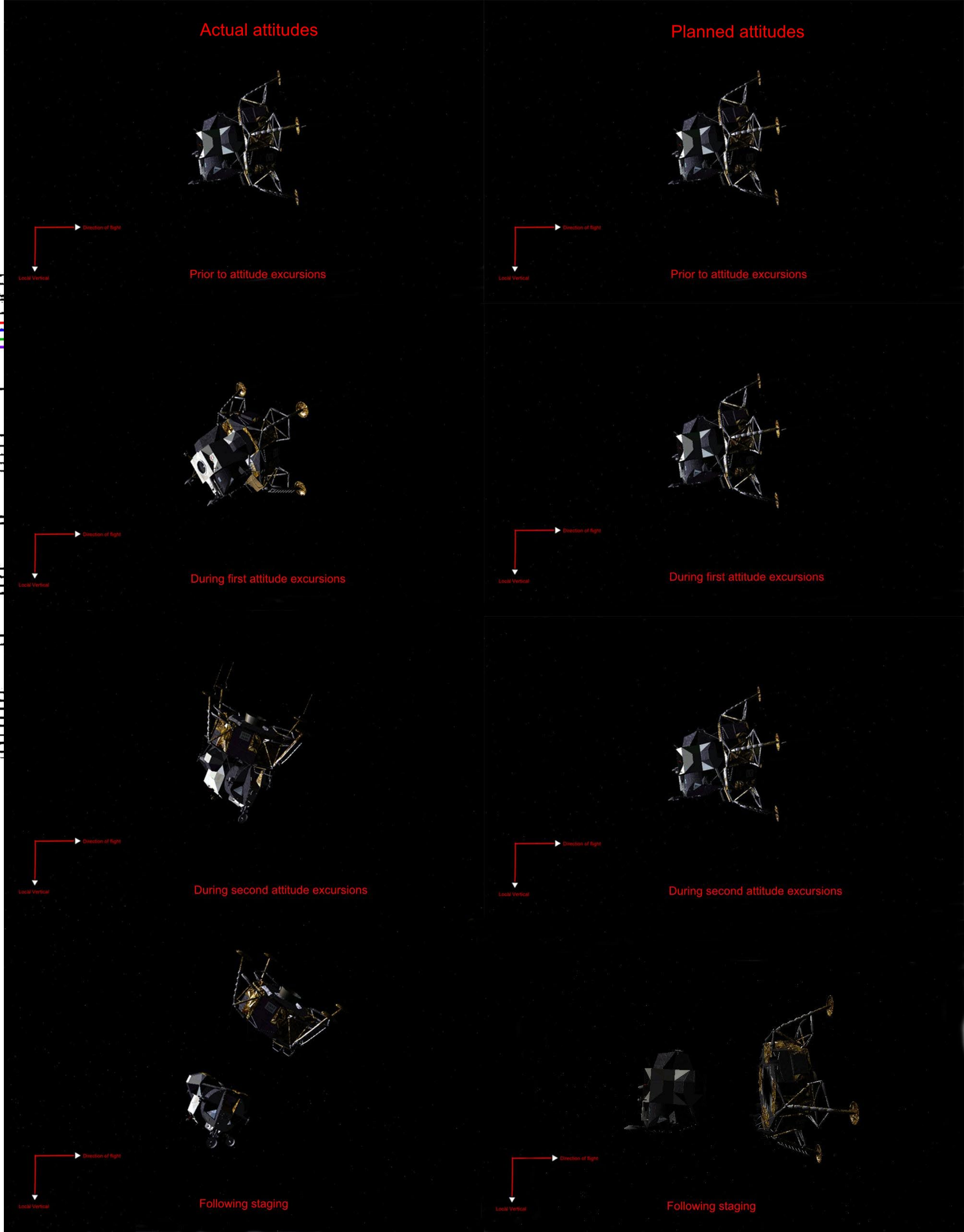
   h. MSFN doppler data during powered phases. [20.82] (M)

   i. AGS/PGNCS downlink data on uninterrupted TM for at least 5 minutes during drifting flight prior to phasing with astronaut motions minimal. [12.6] (M)

# Attitude Excursions at Staging



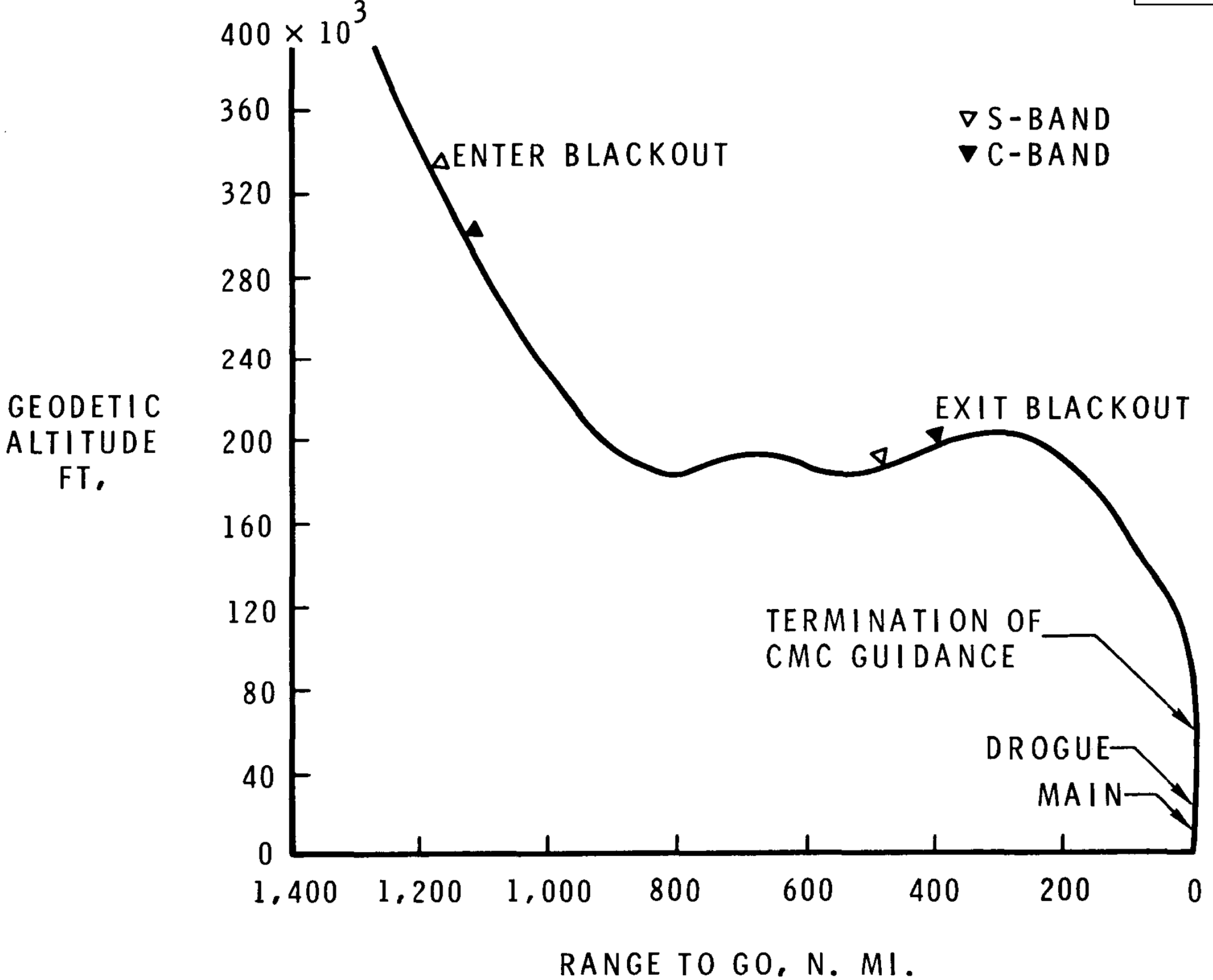




# Sequence Camera

# World Speed Record for Human Flight

24,816 (statute) Miles Per Hour



# Discussion Groups

- Chaikin Chapter 4: “Before This Decade is Out”
  - The astronaut’s view of Apollo 9 and Apollo 10
- **Cox Chapter 23: “It Was Darn Scary”**
  - **The engineer’s view of Apollo 10**
- Merritt: “Review of Apollo Test Objectives Remaining After Mission D”
  - Why fly Apollo 10?
- “The Charming Genius of the Apollo Guidance Computer” video
  - How the onboard navigation was done

# Apollo 11 Readings

- Harland Chapter 2 (“Magnificent Desolation”)
  - The first moonwalk
- Glenn lecture video (“40th Anniversary of Apollo 11”)
  - The three Apollo 11 astronauts tell their story 40 years later
- Cox Chapter 24 (“We … We’re Go on That Flight!”)
  - Mission control’s view of Apollo 11
- **Chaikin Chapter 5 (“The First Lunar Landing”)**
  - **The astronauts’ view of Apollo 11**