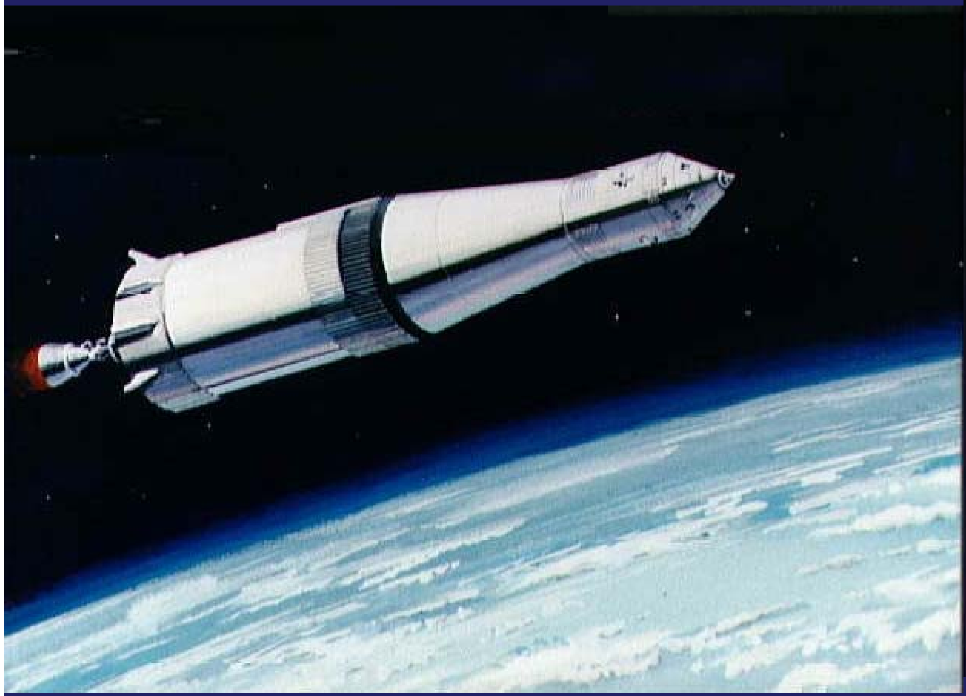
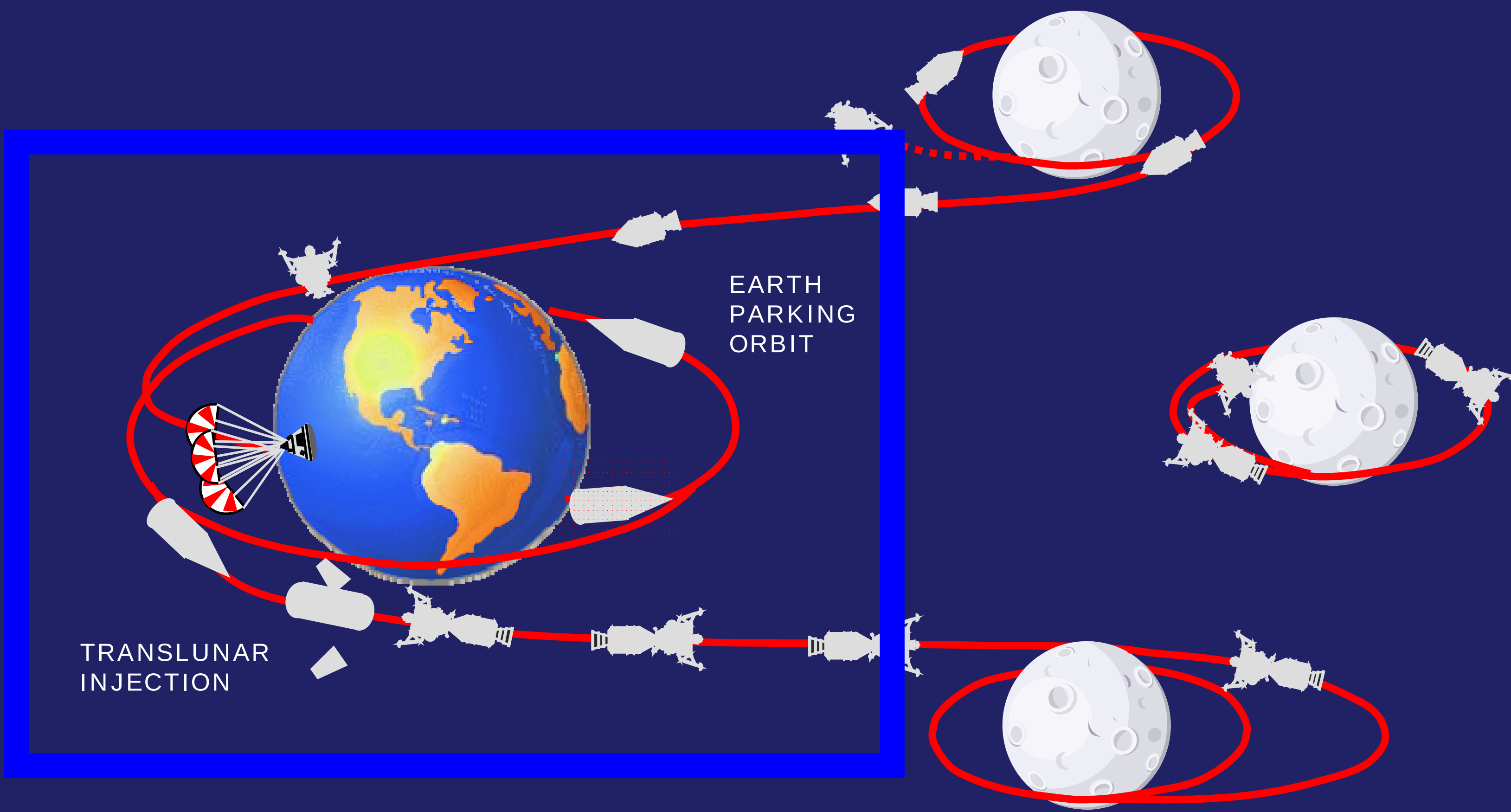


Earth Parking Orbit and Translunar Injection

Apollo Mission Profile



Overview

- Earth Parking Orbit (EPO)
  - General Characteristics
  - General Activities
  - TLI Go / No-Go Decision

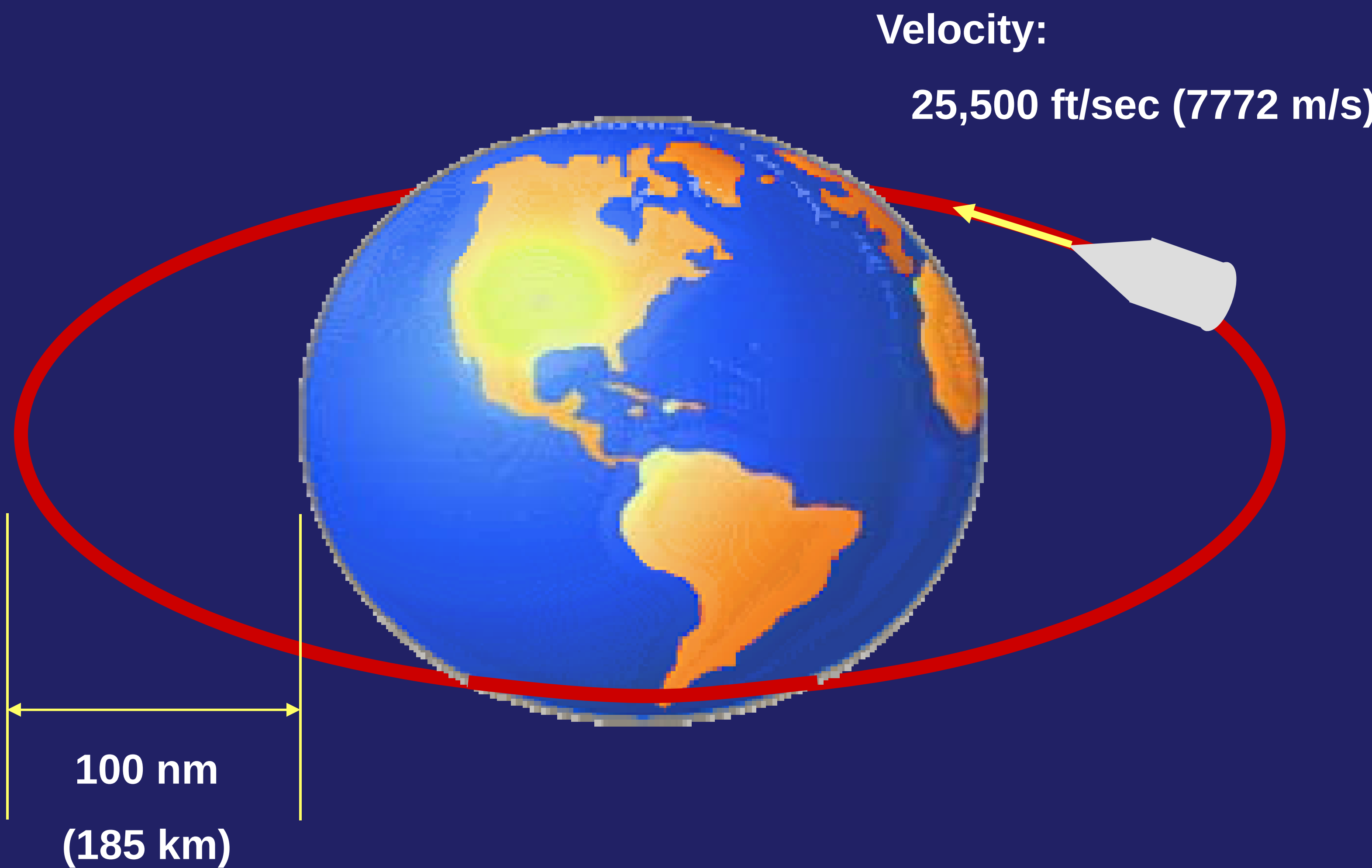
- Translunar Injection (TLI)
  - General Characteristics
  - Free-Return vs. Hybrid Non-Free-Return
  - Crew Monitoring
  - Abort Modes

Objectives

- Describe the general characteristics of the EPO & TLI
- List the general activities that occurred during EPO
- State what went into verifying a working S-IVB IU and a CSM GNC
- Differentiate between a Free-Return Trajectory vs. a Hybrid Non-Free-Return Trajectory
- Identify the crew monitoring task during the TLI Burn
- Identify the abort modes in the event of severe systems problems during the TLI timeframe


Earth Parking Orbit (EPO)

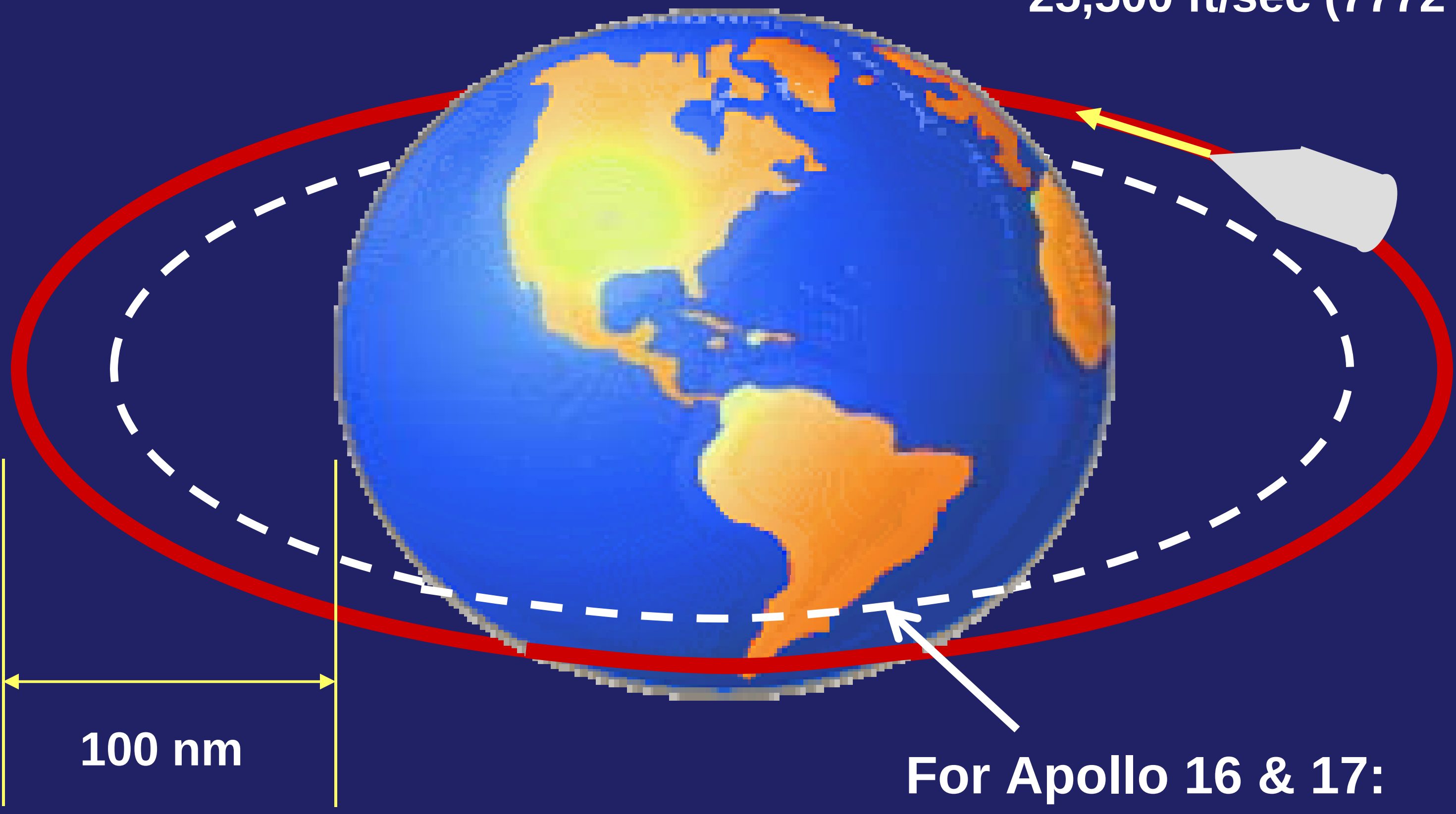
EPO: General Characteristics



EPO: General Characteristics

Velocity:

25,500 ft/sec (7772 m/s)



For Apollo 16 & 17:

- 90 nm (166 km)
- Gained 700 lbs (317 kg) payload capacity

EPO: General Characteristics

Preparing for Translunar Injection (TLI)

- 1st TLI Opportunity
  ⇒ After 1½ revolutions
- 2nd TLI Opportunity
  ⇒ After 3 revolutions

EPO: General Activities

- ❑ Get the state vector from Manned Space Flight Network (MSFN) uplinked to the Command Module Computer

- ❑ Perform checks of the following systems:
  - Biomedical & safety equipment
  - Environmental control system
  - Comm & instrumentation system
  - SM propulsion system (SPS)
  - SM reaction control system (RCS)
  - Electrical power system (EPS)
  - Stabilization and control system (SCS)
  - Crew equipment system
  - Command Module Computer optics
  - Entry monitoring system (EMS)

- ❑ Align the CSM inertial measurement unit (IMU), when able

EPO: TLI Go / No Go Decision

Two important ground rules:

- A properly working S-IVB instrument unit (IU)

- A properly operating CSM GNC system

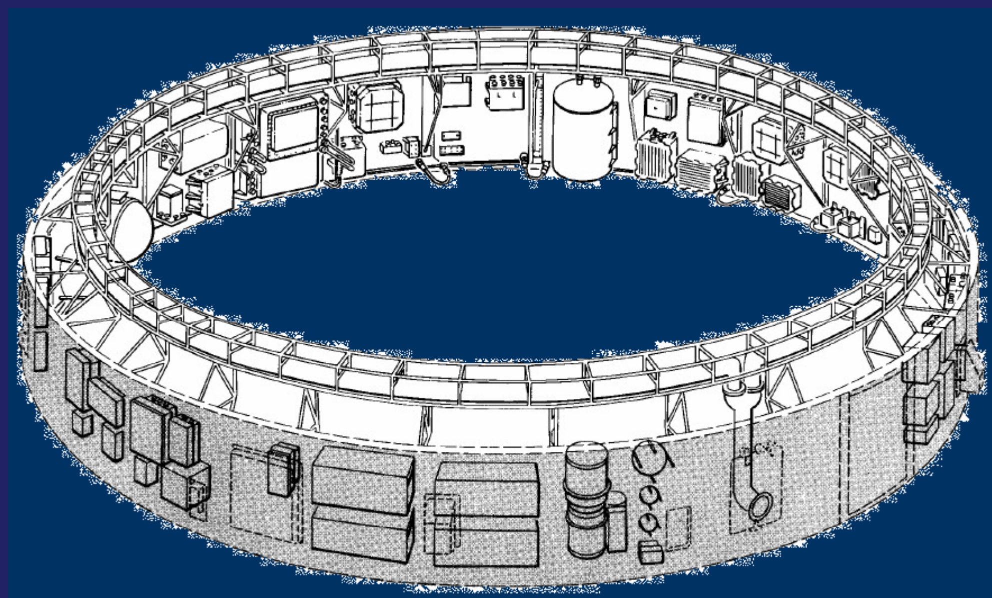
EPO: TLI Go / No Go Decision

Two important ground rules:

- A properly working S-IVB instrument unit (IU)
- A properly operating CSM GNC system

EPO: TLI Go / No Go Decision

- A properly working S-IVB instrument unit (IU)



- Marshall Space Flight Center verified both the guidance and fuel reserves of the S-IVB motor
- IU failure did not necessarily rule out TLI
  - Crew could take manual control (e.g. inertial platform failure)
  - Crew could manually shut down burn (i.e. accelerometer failure)

EPO: TLI Go / No Go Decision

Two important ground rules:
- A properly working S-IVB instrument unit (IU)

- A properly working S-IVB instrument unit (IU)
- A properly operating CSM GNC system

EPO: TLI Go / No Go Decision

Two important ground rules:

- A properly working S-IVB instrument unit (IU)
- A properly operating CSM GNC system

EPO: TLI Go / No Go Decision

- ❑ A properly operating CSM GNC system

Mission Control Center (MCC) compared the ground state vector from the Manned Space Flight Network (MSFN) to the following conditions:

1. Orbital decision parameters in EPO
2. Launch phase velocity component differences
3. Gimbal angle differences in IMU & IU

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

1. Orbital decision parameters in EPO

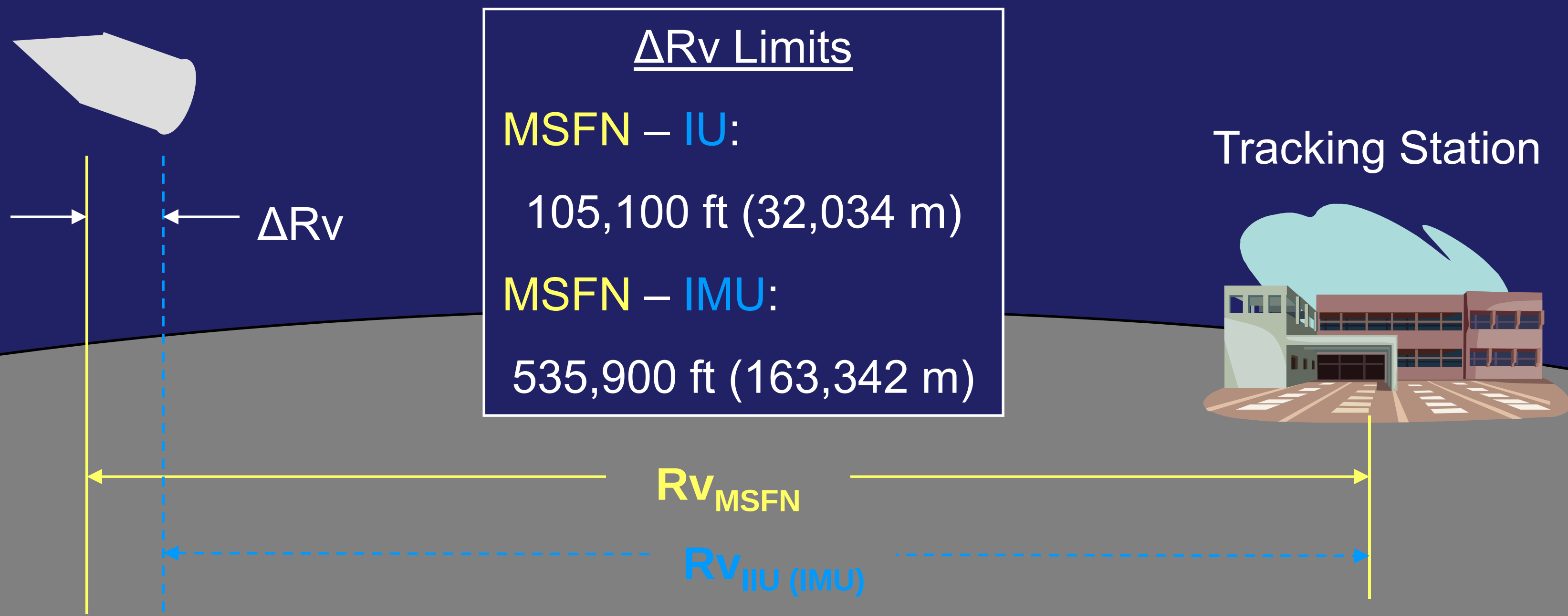
- ΔR_V – Downrange position difference
- Δa – Semi-major axis difference
- $\Delta \hat{W}_{MAX}$ – Max crossrange velocity difference

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

1. Orbital decision parameters in EPO

   - ΔR_V – Downrange position difference

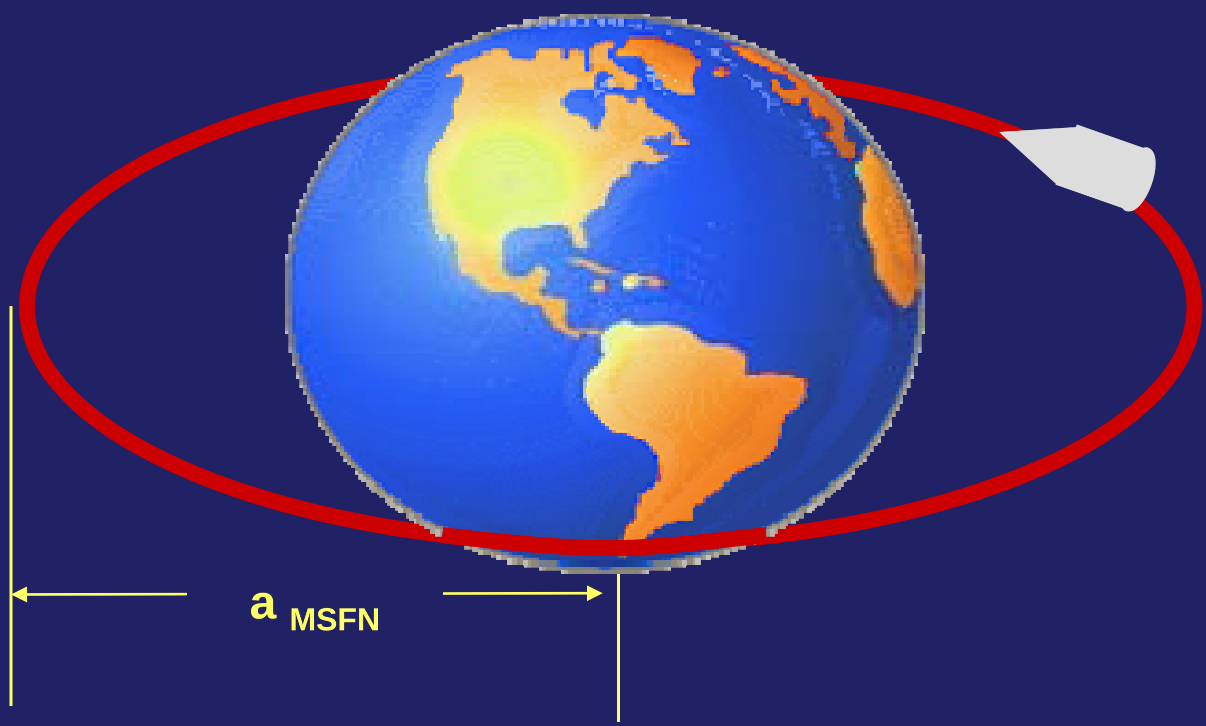


EPO: TLI Go / No Go Decision

- ❑ A properly operating CSM GNC system

1. Orbital decision parameters in EPO

    - ❑ Δa – Semi-major axis difference

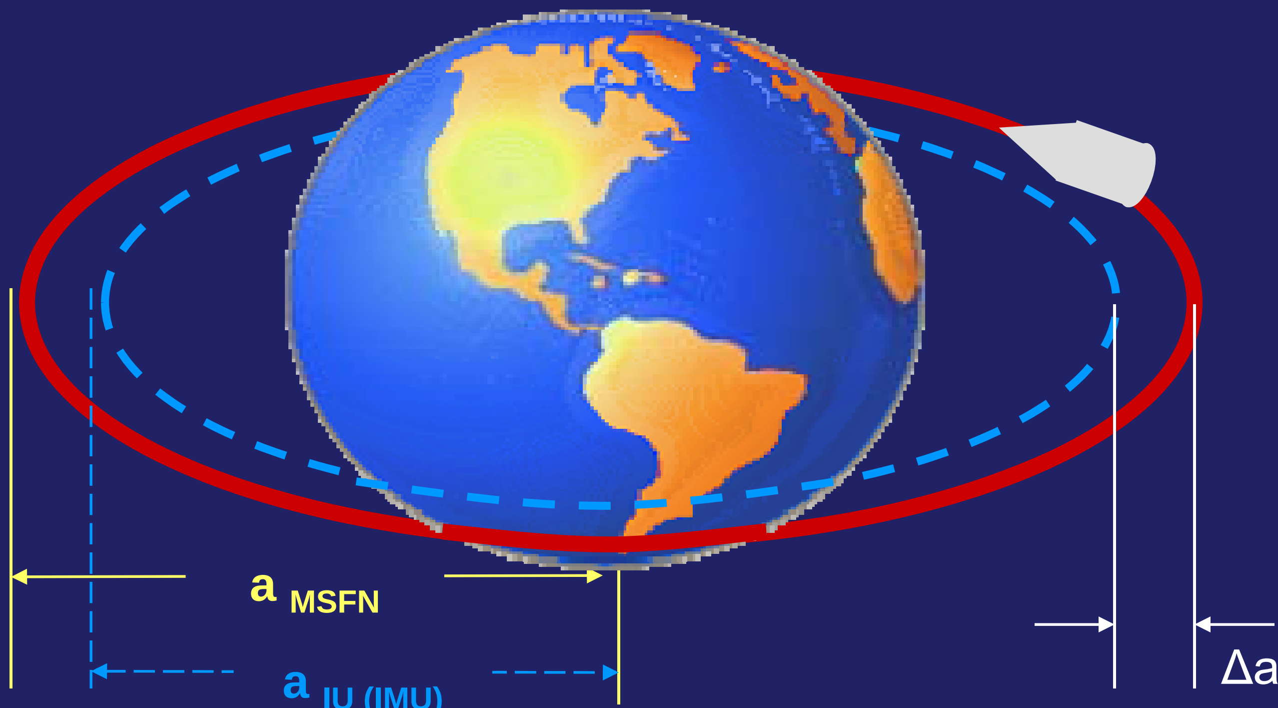


Earth Parking Orbit

- A properly operating CSM GNC system

1. Orbital decision parameters in EPO

   - Δa – Semi-major axis difference



Δa Limits

MSFN – IU:

19900 ft (6065 m)

MSFN – IMU:

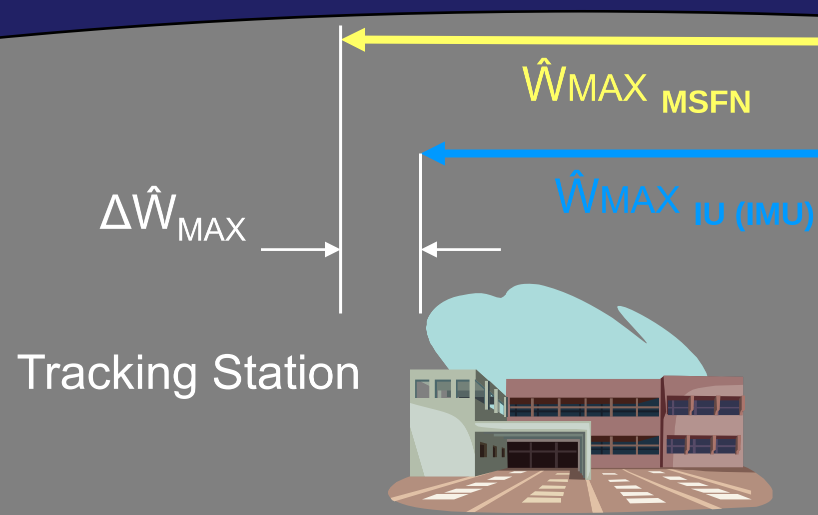
70655 ft (21535 m)

Earth Parking Orbit

- A properly operating CSM GNC system

1. Orbital decision parameters in EPO

   - $\Delta\hat{W}_{MAX}$ – Max crossrange velocity difference



$\Delta\hat{W}_{MAX}$ Limits

MSFN – IU:

32.2 ft/sec (9.7 m/s)

MSFN – IMU:

78.7 ft/sec (23.9 m/s)

Earth Parking Orbit

- A properly operating CSM GNC system

1. Orbital decision parameters in EPO

   - ΔR_V – Downrange position difference
   - Δa – Semi-major axis difference
   - $\Delta \hat{W}_{MAX}$ – Max crossrange velocity difference

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

Mission Control Center (MCC) compared the ground state vector from the Manned Space Flight Network (MSFN) to the following conditions:

1. Orbital decision parameters in EPO
2. Launch phase velocity component differences
3. Gimbal angle differences in IMU & IU

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

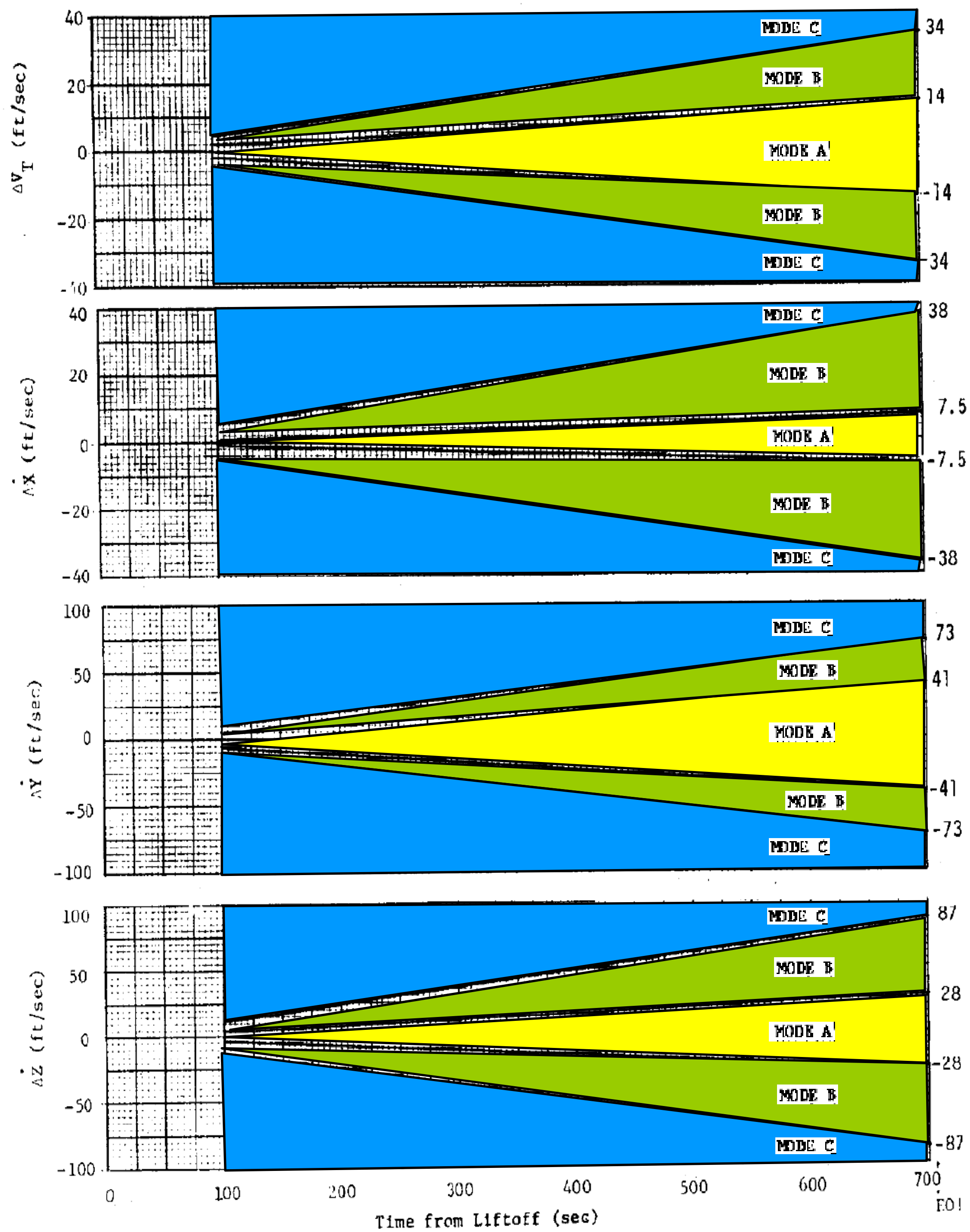
2. Launch phase velocity component differences

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

2. Launch phase velocity component differences

   The launch phase differences between the IU and IMU velocity vector were plotted against the four strip charts



3 Decision Modes

- Mode A – TLI was GO, unless ΔR_V bad
- Mode B – TLI was NO GO until orbital decision parameters were examined
- Mode C – TLI was NO GO

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

Mission Control Center (MCC) compared the ground state vector from the Manned Space Flight Network (MSFN) to the following conditions:

1. Orbital decision parameters in EPO
2. Launch phase velocity component differences
3. Gimbal angle differences in IMU & IU

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

3. Gimbal angle differences in IMU & IU

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

3. Gimbal angle differences in IMU & IU

   - The total actual IMU & IU gimbal angle differences over time were used to detect gyro drifts
   - A drift greater than ±0.6 deg/hr required an IMU realignment during EPO
   - The required torquing angles were used to determine how much each platform was drifting

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

3. Gimbal angle differences in IMU & IU

  - If the IMU drifted by more than ±1.5 deg/hr:
    $\Rightarrow$ TLI was NO GO

  - If the IU drifted by more than ±0.6 deg/hr:
    LV Guide Light ON $\Rightarrow$ TLI was GO
    LV Guide Light OFF $\Rightarrow$ TLI was NO GO

EPO: TLI Go / No Go Decision

- A properly operating CSM GNC system

Mission Control Center (MCC) compared the ground state vector from the Manned Space Flight Network (MSFN) to the following conditions:

1. Orbital decision parameters in EPO
2. Launch phase velocity component differences
3. Gimbal angle differences in IMU & IU

EPO: TLI Go / No Go Decision

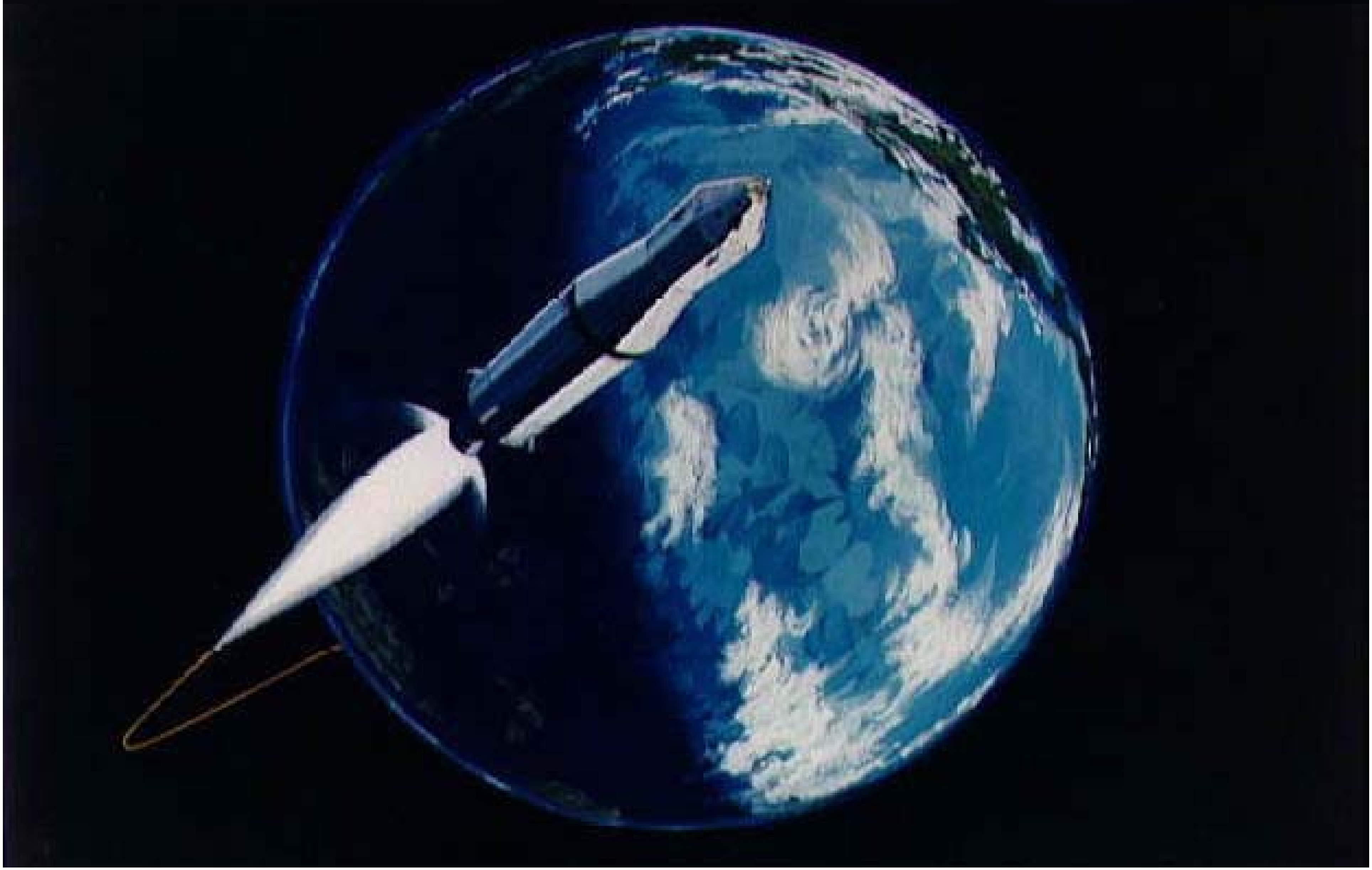
Two important ground rules:

- ❑ A properly operating CSM GNC system

- ❑ A properly working S-IVB instrument unit (IU)

GO FOR TLI !

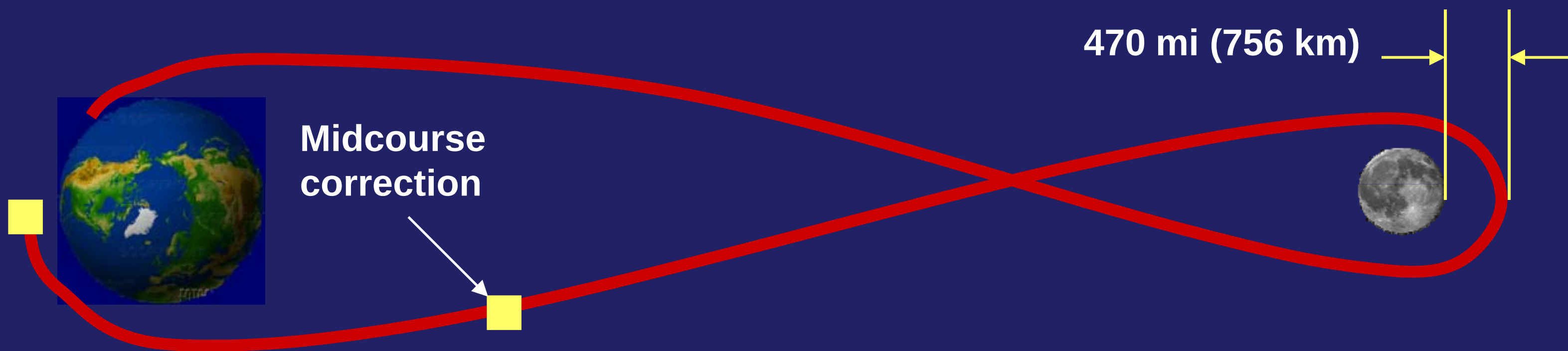
Translunar Injection (TLI)



TLI: General Characteristics

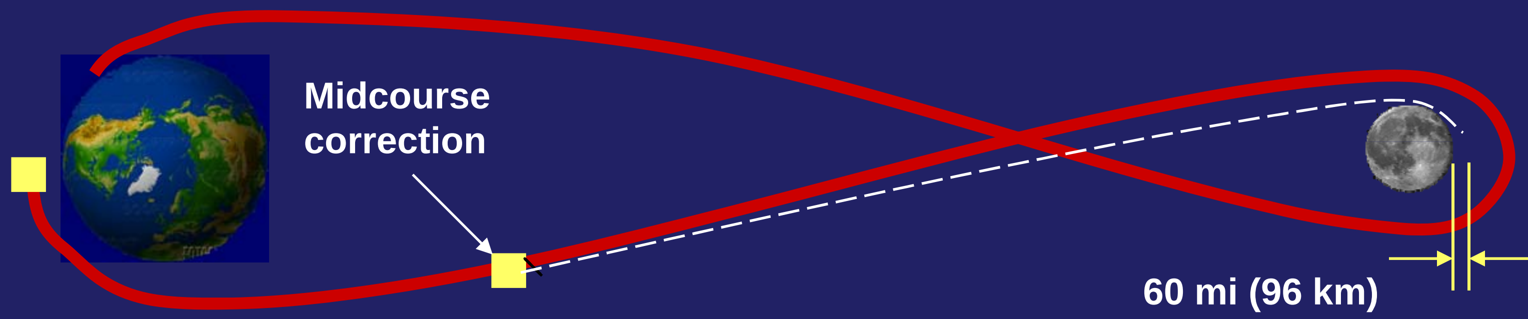
When:	**Around Liftoff + 3 hrs**
Length of burn:	**Approx 5 min**
Velocity change:	**35,500 ft/sec (10,820 m/s)**
Trajectory:	**Free-return**
	Hybrid non-free-return

TLI: Free-Return Trajectory



- Employed by Apollo 8, 10, and 11
- If SPS failed to establish a lunar orbit, already on a trajectory that coasted around the Moon, and then continued on back to Earth
- Spacecraft limited to only within 5 deg of latitude of the Moon’s equator

TLI: Hybrid Non-Free-Return



- Employed by subsequent Apollo missions
- Also looped the spacecraft around the Moon, but did not send it directly back towards Earth
- Re-establishing the Earthbound trajectory required an additional burn (the so-called “flyby maneuver”)

TLI: Crew Monitoring

During TLI Burn, crew monitored the following:

- Attitude –
  Remain within 45 deg of norm
- Attitude rates –
  Pitch and yaw rates not to exceed 10 deg/sec
  Roll rates not to exceed 20 deg/sec
- Velocity –
  Ensure S-IVB cutoff on time

Crew could either take manual control or stop burn

TLI: Abort Modes

For severe systems problems during TLI timeframe:

TLI + 90 min

- Initiated by the crew at TLI + 25 min
- CSM would immediately separate from the S-IVB
- SPS ignited at TLI + 90 min (fixed inertial attitude retro burn)
- Returned crew to a contingency landing area

Liftoff + 8 hrs

- Initiated by the crew following normal CSM / S-IVB separation (~ 4 hrs into the mission)
- Returned crew to a contingency landing area

NOTE: TLI + 10 min abort also designed; deleted after Apollo 10

Summary

- Described the general characteristics of the EPO & TLI
- Listed the general activities that occurred during EPO
- Stated what went into verifying a working S-IVB IU and a CSM GNC
- Differentiated between a Free-Return Trajectory vs. a Hybrid Non-Free-Return Trajectory
- Identified the crew monitoring task during the TLI Burn
- Identified the abort modes in the event of severe systems problems during the TLI timeframe

References

Apollo 11 Press Kit (Release No. 69-83K)
Apollo 17 Press Kit (Release No. 72-220K)

Apollo 11 Flight Plan (Final), Jul. 1, 1969
Apollo 15 Flight Plan (Final), Jun. 21, 1971
Apollo 17 Flight Plan (Final), Oct. 28, 1972

Apollo Mission Techniques: Earth Parking Orbit and Translunar Injection
Mission H-2 and Subsequent (MSC-01518), Feb. 27, 1970
Mission J-2 and Mission J-3 Update (MSC-05847), Jan. 24, 1972

Apollo Mission Techniques: Contingency Procedures
Mission H-2 and Subsequent (MSC-01524), Feb. 27, 1970
"Apollo Spacecraft Familiarization" (SID 62-435/SM2A-02)

"Apollo Experience Report – Systems & Flight Procedures Development" (NASA TN D-7436)