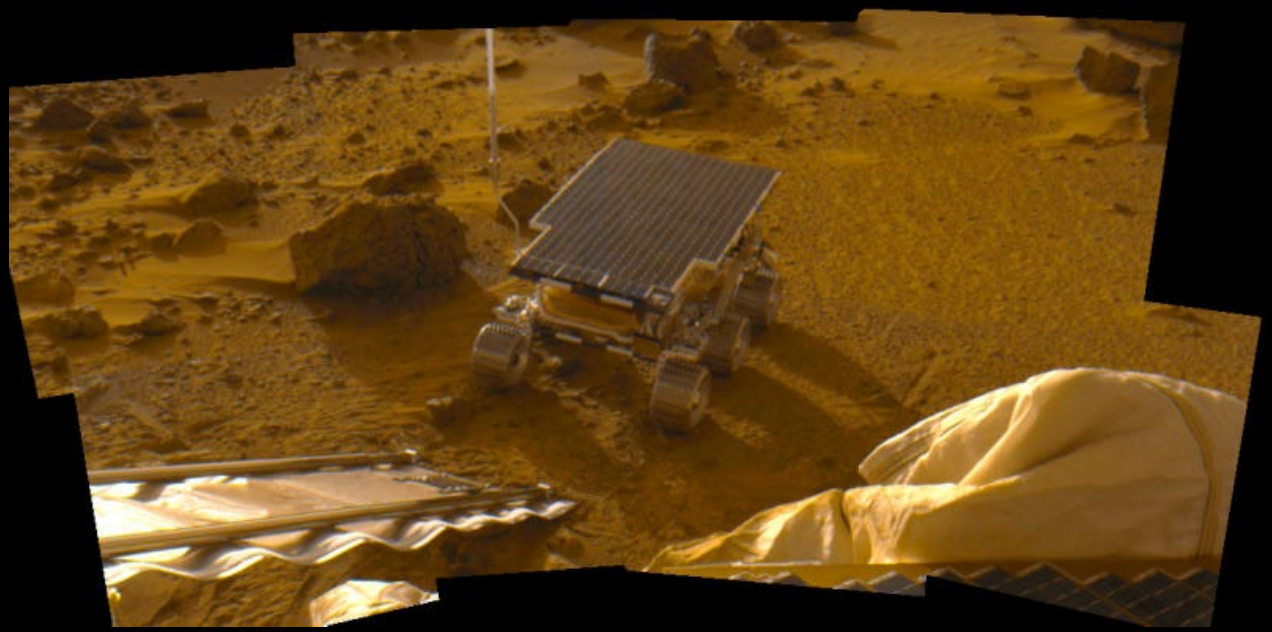
National Aeronautics and Space Administration

# 2024 NASA LaRC/ARC EDL Summer Seminar Series:

# Artemis Human Landing System Update



Alicia Dwyer Cianciolo | NASA Langley Research Center | August 1, 2024



Credit NASA/JPL

**July 4, 1997:**
**Pathfinder/Sojourner Rover Landed on Mars**

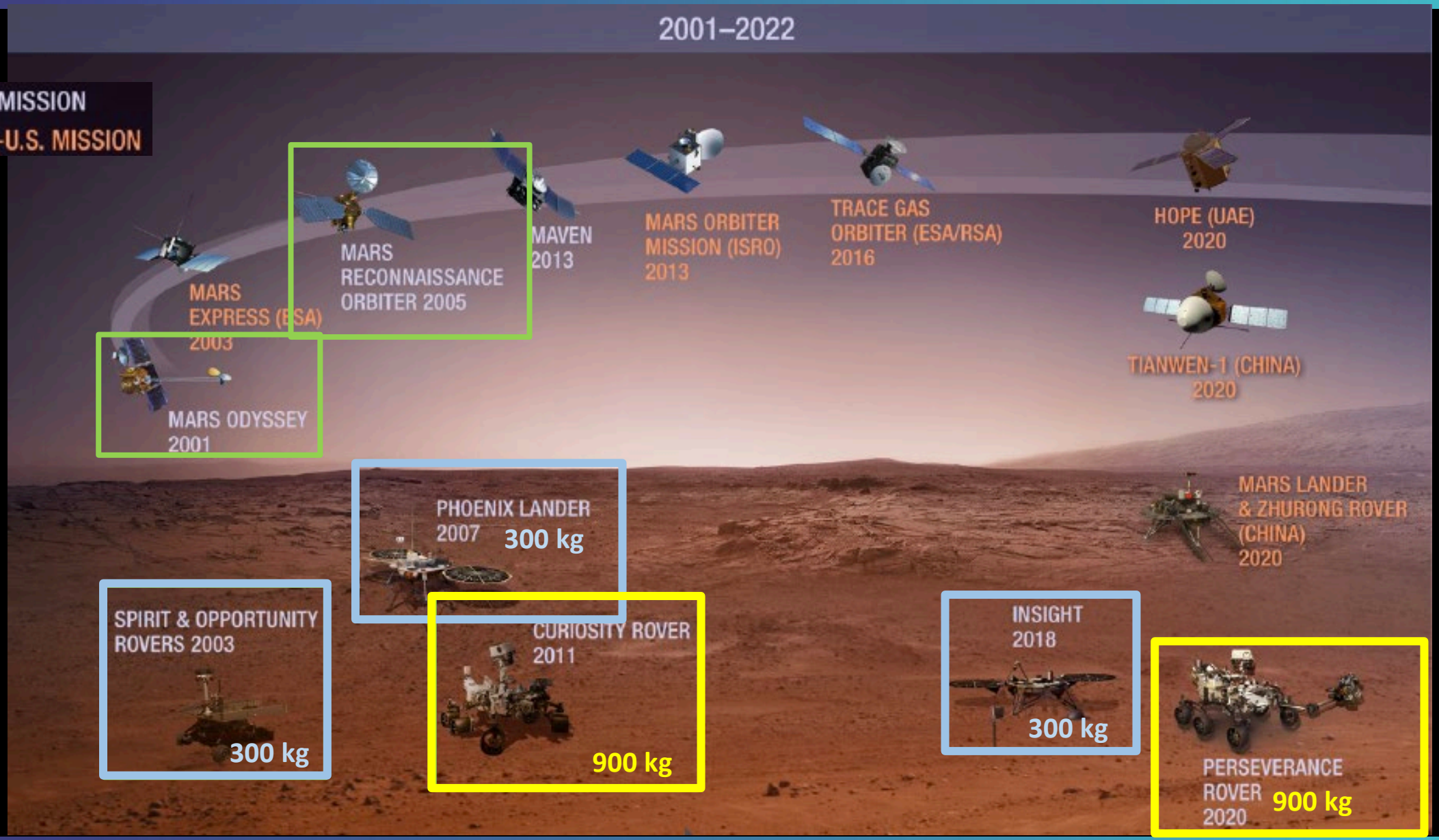
**January 22, 1998:**
**STS - 98 Launch**



Credit NASA


EXPLORE
MARS

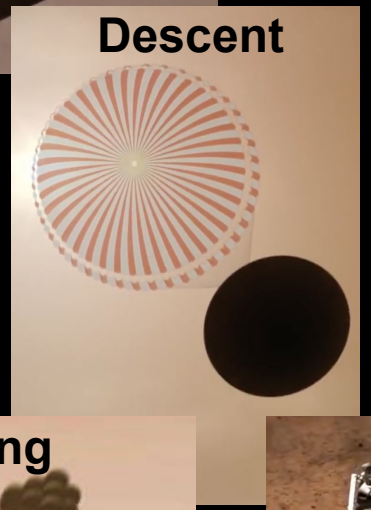
# Mars Exploration In the Past 20 Years

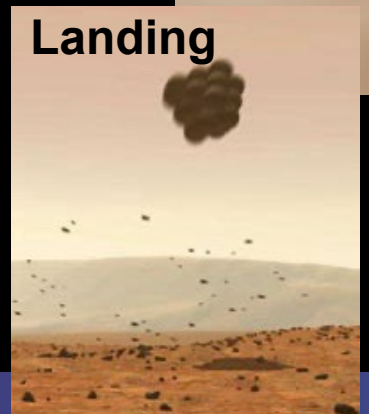


# Landing on Mars

## 300 kg Class Payload

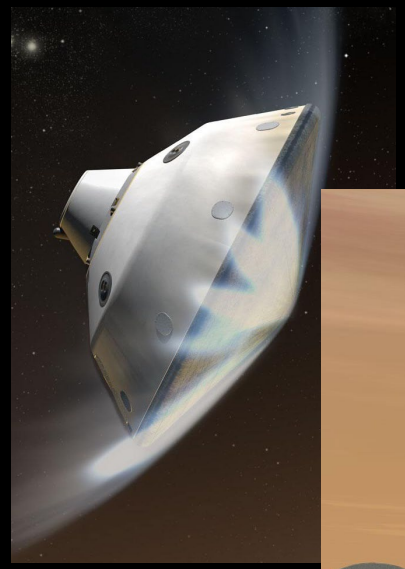


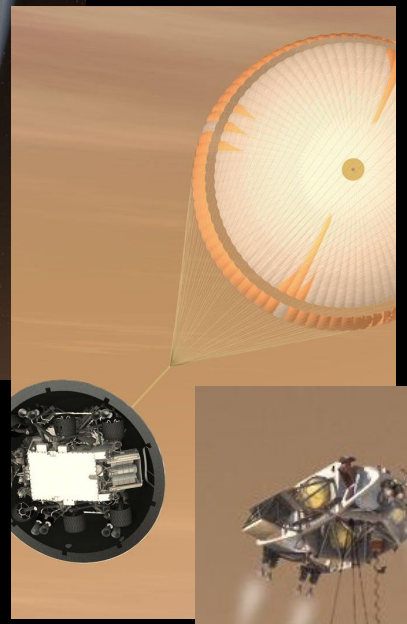



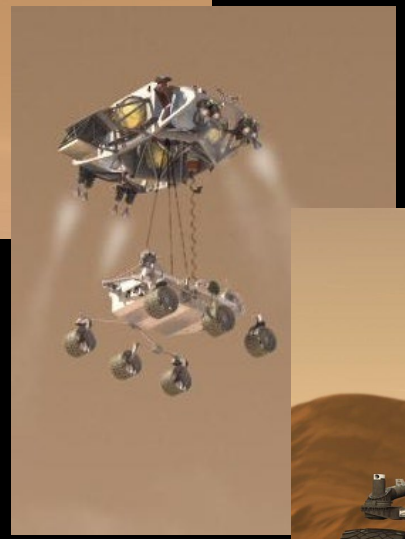

or





## 900 kg Class Payload

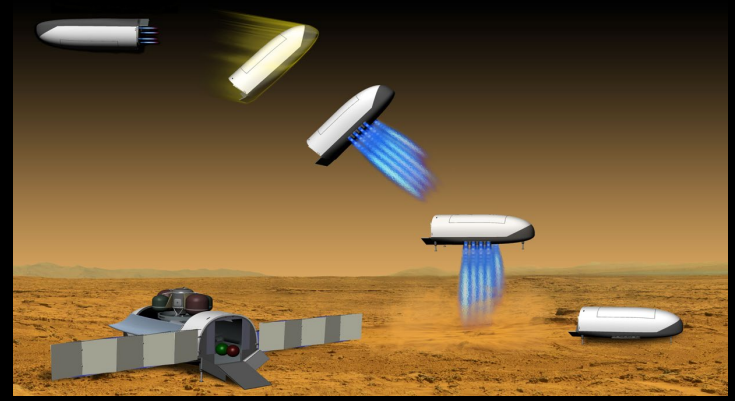






## 20,000 kg Class Payload



Images: NASA/JPL-Caltech


EXPLORE
MOON

# “The United States will Maintain its Leadership in Space Exploration and Space Science”

“Remain a global leader in science and engineering by pioneering space research and technology that propels exploration of the Moon, Mars, and beyond.”

“U.S. human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021

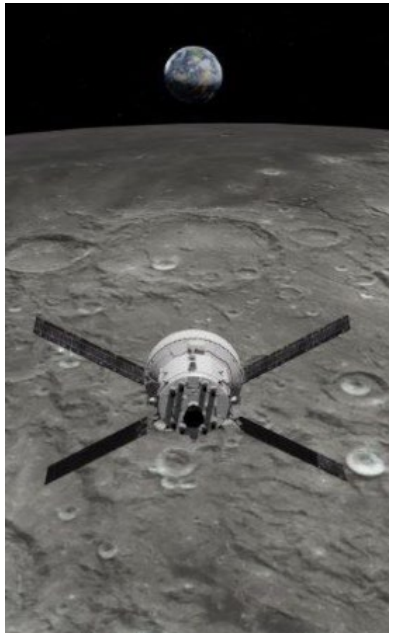
*United States Space Priorities Framework*
*NASA 2022 Strategic Plan*
*2023 NASA Budget Request*



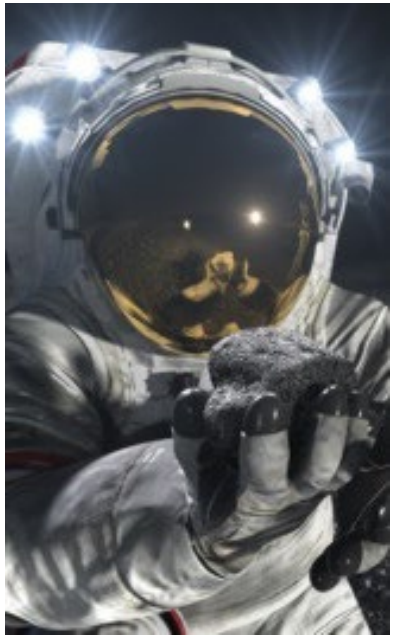
# What is Artemis?

ARTEMIS = Space Launch System + ORION + HUMAN LANDING SYSTEM PROGRAM + EHP* + GATEWAY







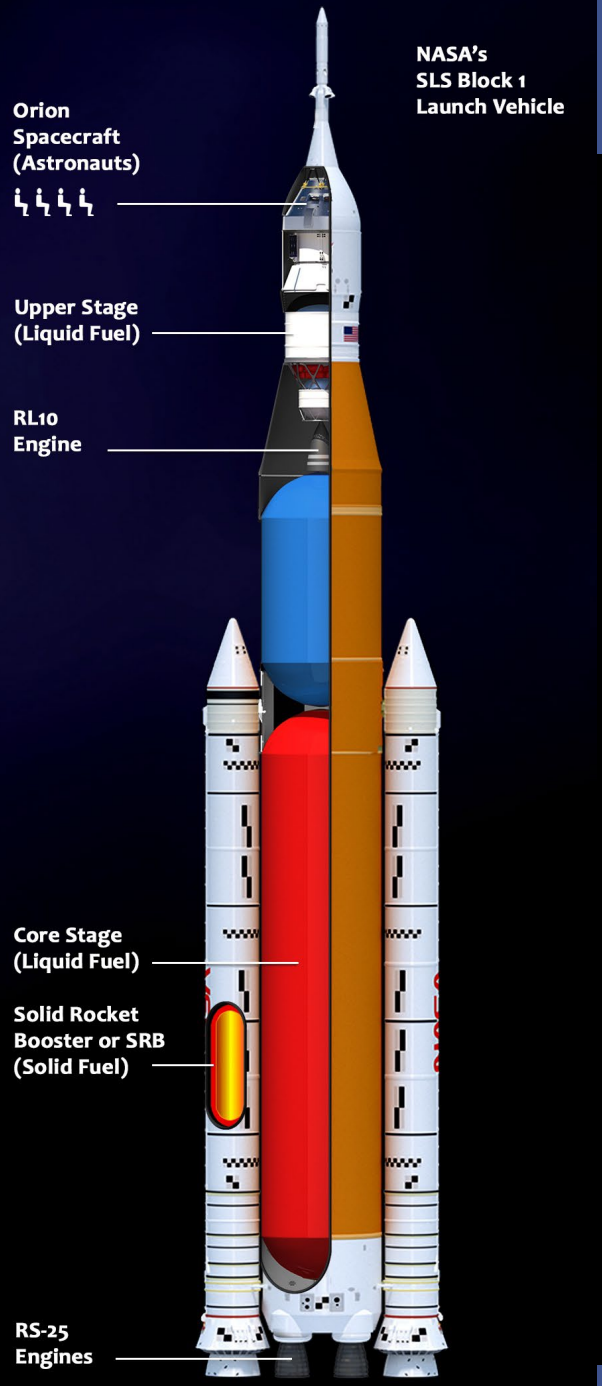




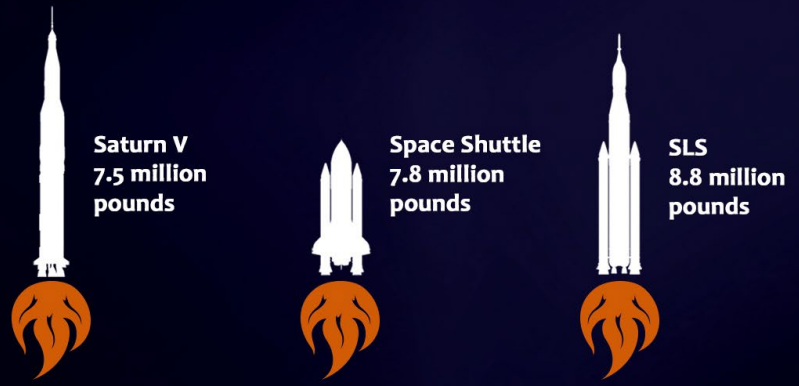
*Extravehicular Activity and Human Surface Mobility Program

***Combines programs into missions***

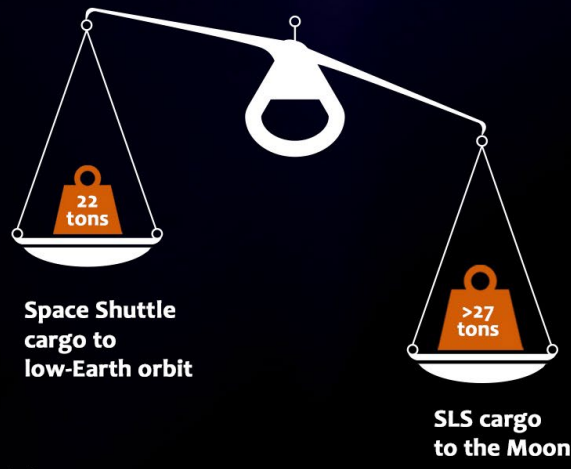
# Space Launch System




SLS will produce 13% more thrust at launch than the space shuttle and 15% more than Saturn V during liftoff and ascent.

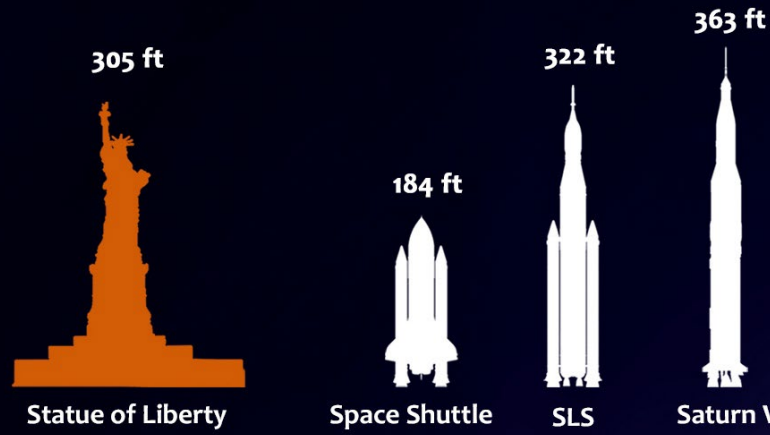


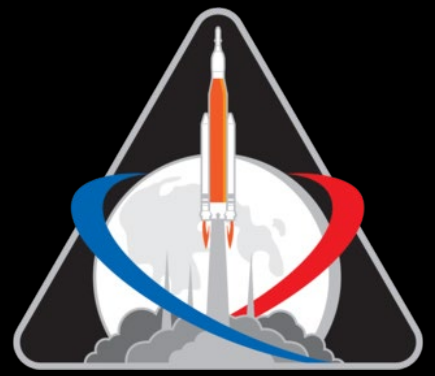

SLS will launch more cargo to the Moon than the space shuttle could send to low-Earth orbit.




www.nasa.gov/sls

If you wonder how NASA's Space Launch System, or SLS, compares to earlier generations of NASA launch vehicles:

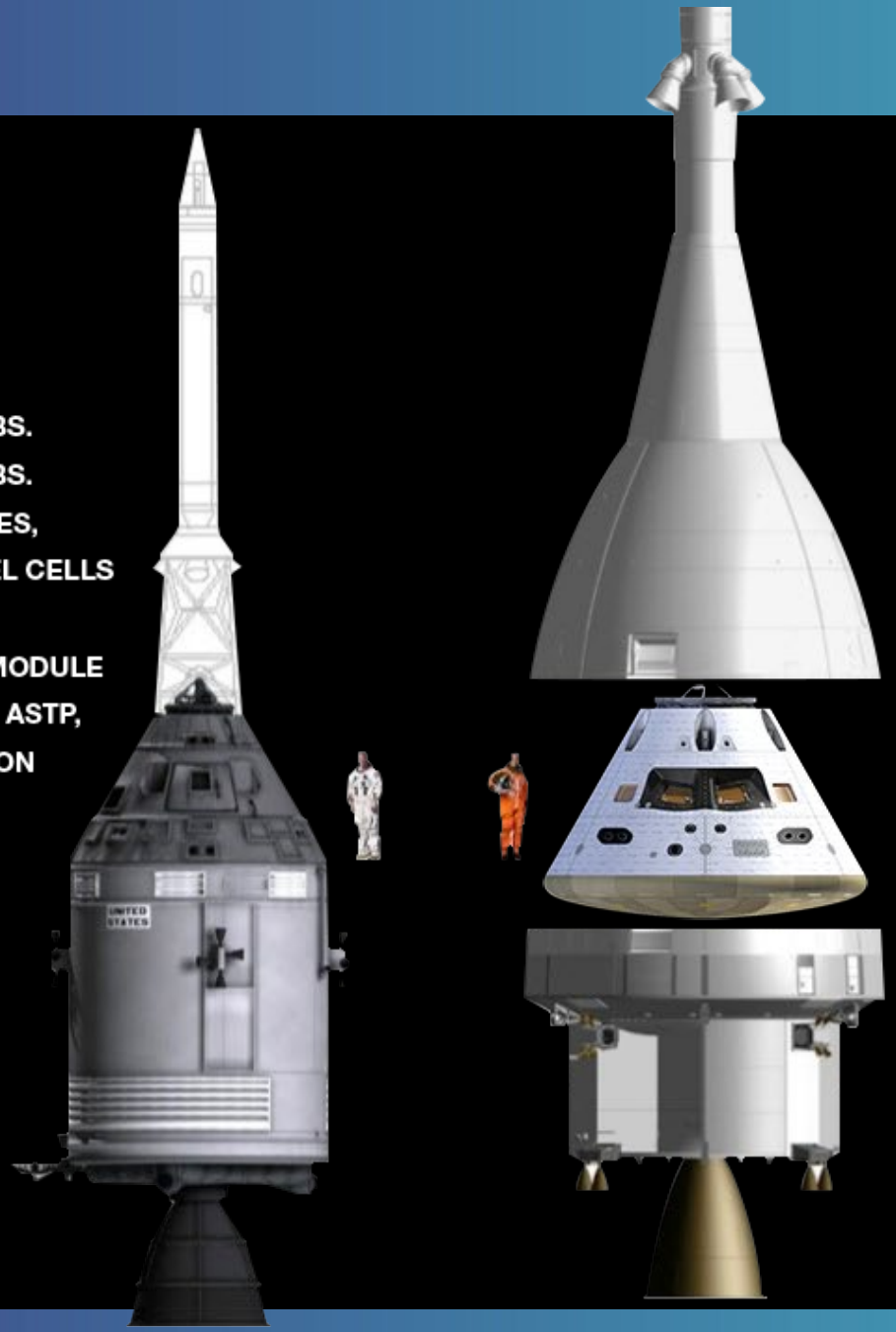


# Orion

## APOLLO

| | |
|---|---|
| CREW MODULE DIAMETER: | 12.8 FT. |
| CREW SIZE: | 3 |
| SERVICE MODULE DIAMETER: | 13 FT. |
| SERVICE MODULE LENGTH: | 24.5 FT. |
| SERVICE MODULE MASS: | 54,000 LBS. |
| SERVICE MODULE THRUST: | 20,500 LBS. |
| POWER: | BATTERIES, FUEL CELLS |
| LANDING: | WATER |
| DOCKING: | LUNAR MODULE |
| DESTINATION: | SKYLAB, ASTP, MOON |



## ORION

| | |
|---|---|
| CREW MODULE DIAMETER: | 16.5 FT. |
| CREW SIZE: | 4 (6 TO ISS) |
| SERVICE MODULE DIAMETER: | 16.5 FT. |
| SERVICE MODULE LENGTH: | 15.7 FT. |
| SERVICE MODULE MASS: | 27,500 LBS. |
| SERVICE MODULE THRUST: | 7,500 LBS. |
| POWER: | SOLAR ARRAYS, BATTERIES |
| LANDING: | WATER |
| DOCKING: | MULTI PURPOSE |
| DESTINATION: | MARS, ASTEROIDS |

# Human Landing System

## Artemis III
*SpaceX Starship*



Illustration

## Artemis IV
*SpaceX Starship*



Illustration

## Artemis V

*Blue Origin*
*Blue Moon*



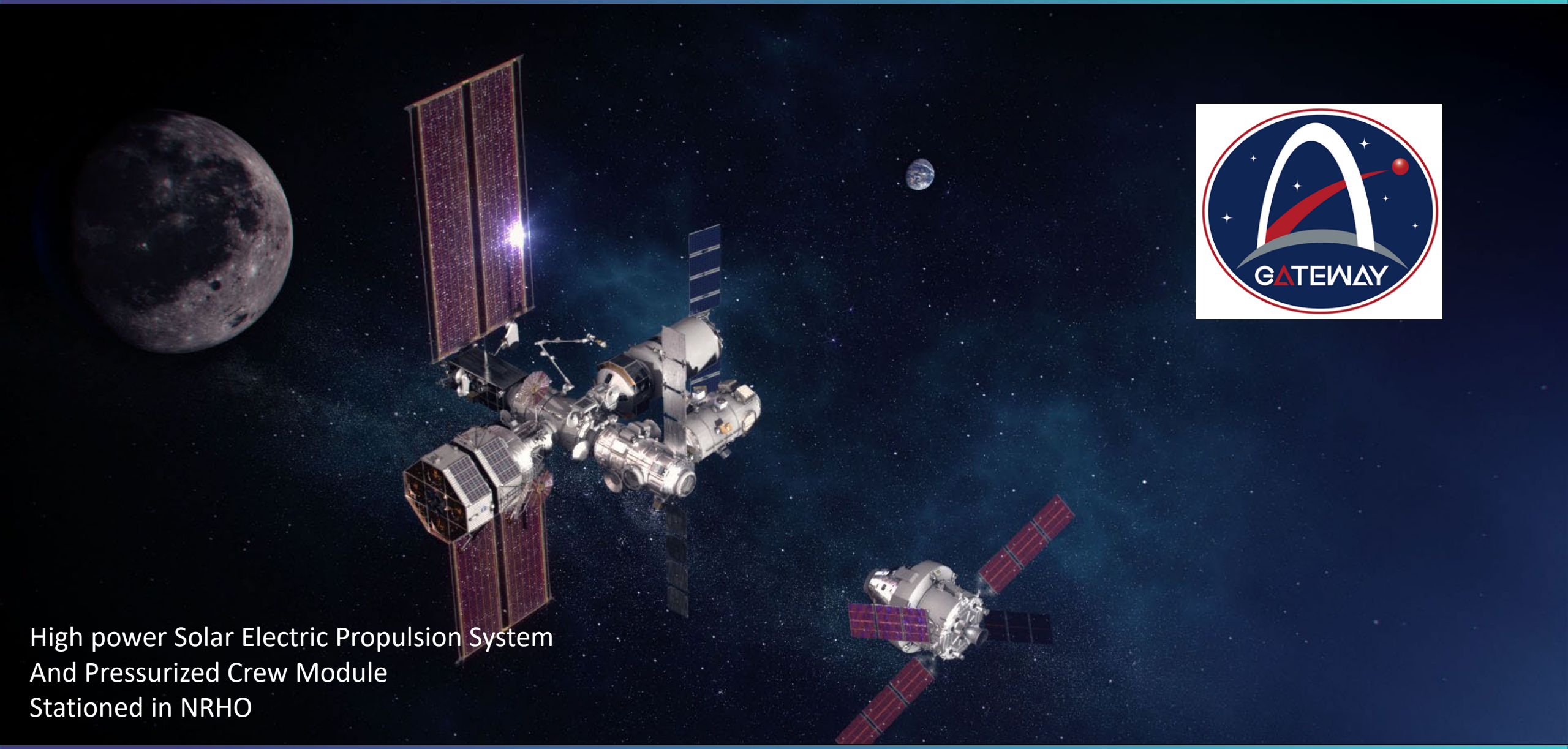
Illustration

**Single Stage Landers**

For Reference:
Apollo 11
5.5 m tall

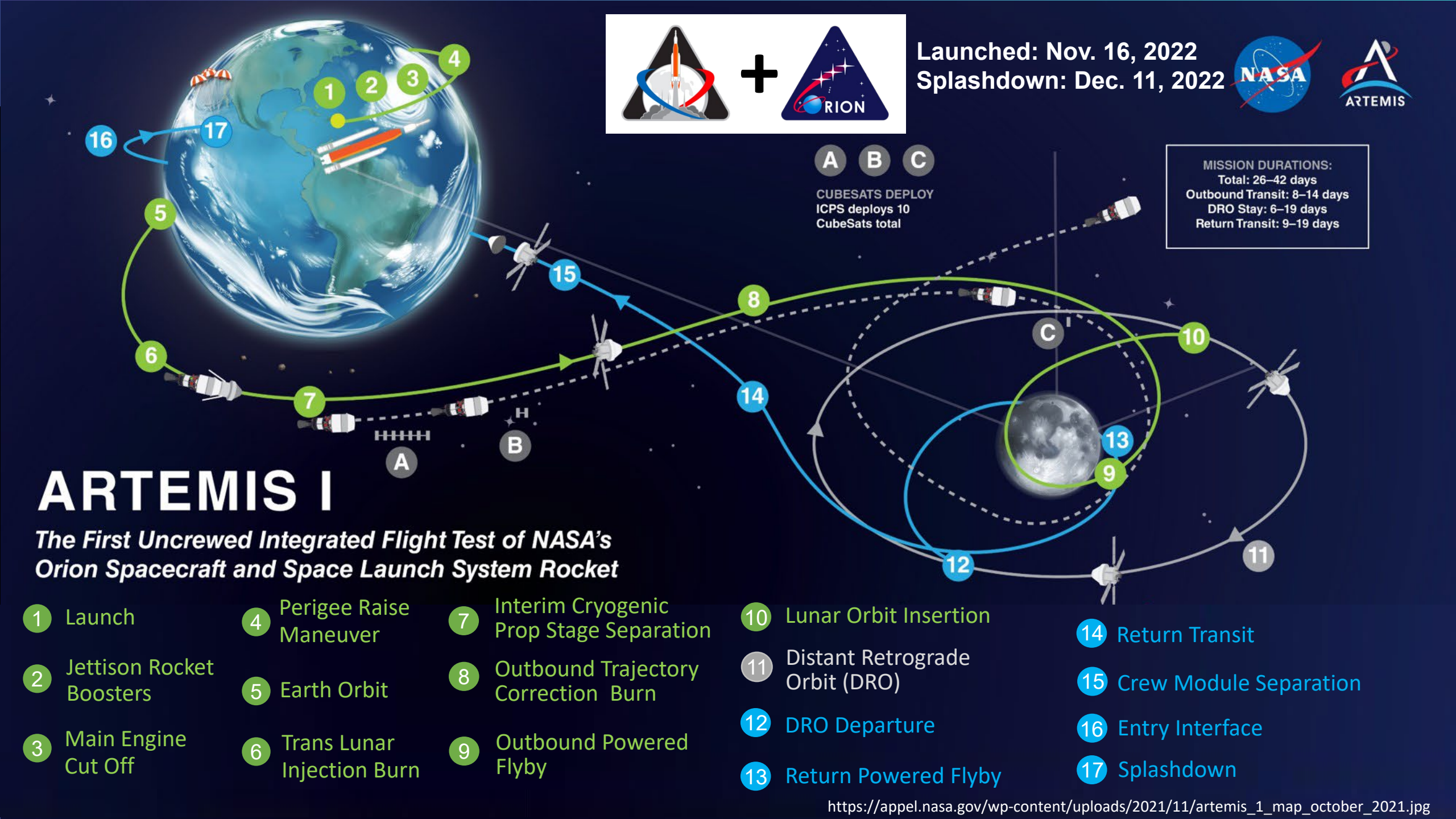

Image: NASA

# Gateway

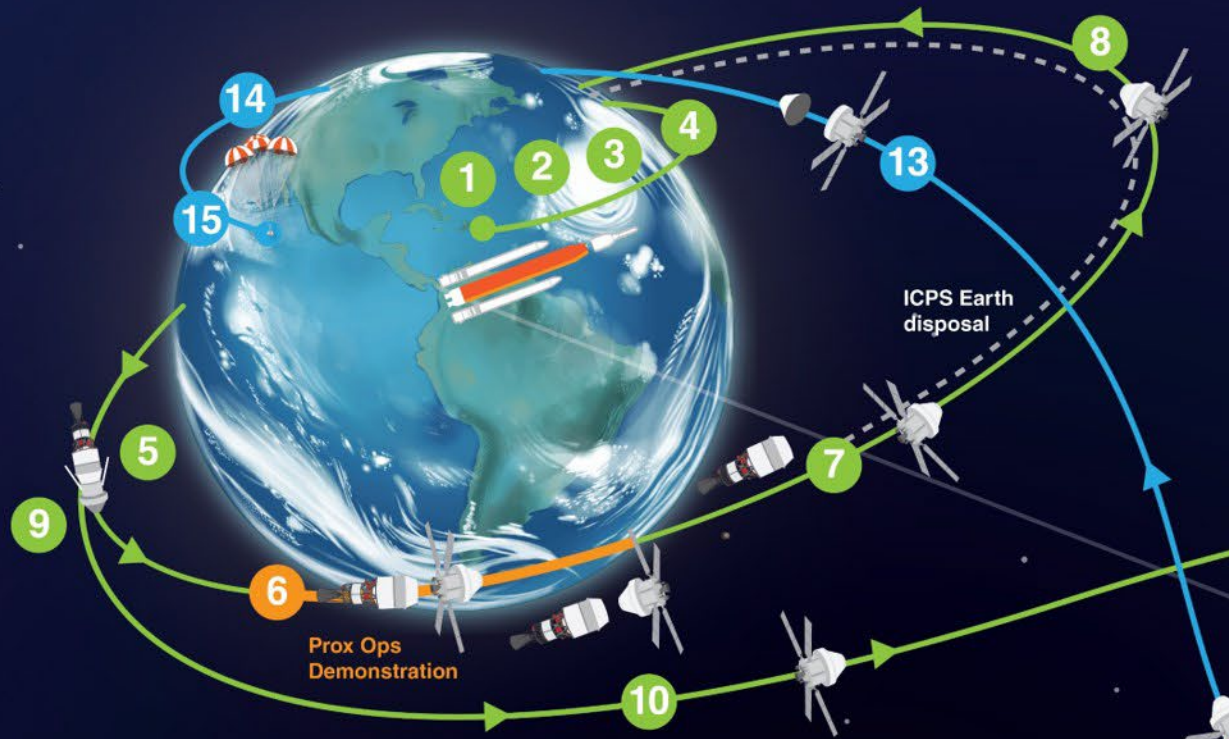


High power Solar Electric Propulsion System
And Pressurized Crew Module
Stationed in NRHO

Combine programs into missions.




https://appel.nasa.gov/wp-content/uploads/2021/11/artemis_1_map_october_2021.jpg




+ + Crew

# ARTEMIS II

***First Crewed Test Flight to the Moon Since Apollo***

1. Launch
2. Jettison Rocket Boosters
3. Main Engine Cut Off
4. Perigee Raise Maneuver
5. Apogee Raise burn to High Earth Orbit
6. Prox Ops Demonstration
7. Interim Cryogenic Prop Stage Separation
8. High Earth Orbit Checkout
9. Trans-Lunar Injection
10. Outbound Transit to the Moon
11. Lunar Flyby
12. Trans-Earth Return
13. Crew Module Separation
14. Entry Interface
15. Splashdown

Proximity Operations Demonstration Sequence



https://www.nasa.gov/missions/artemis/artemis-ii-map/

# Meet the Artemis II Crew

**Reid Wiseman**
Commander

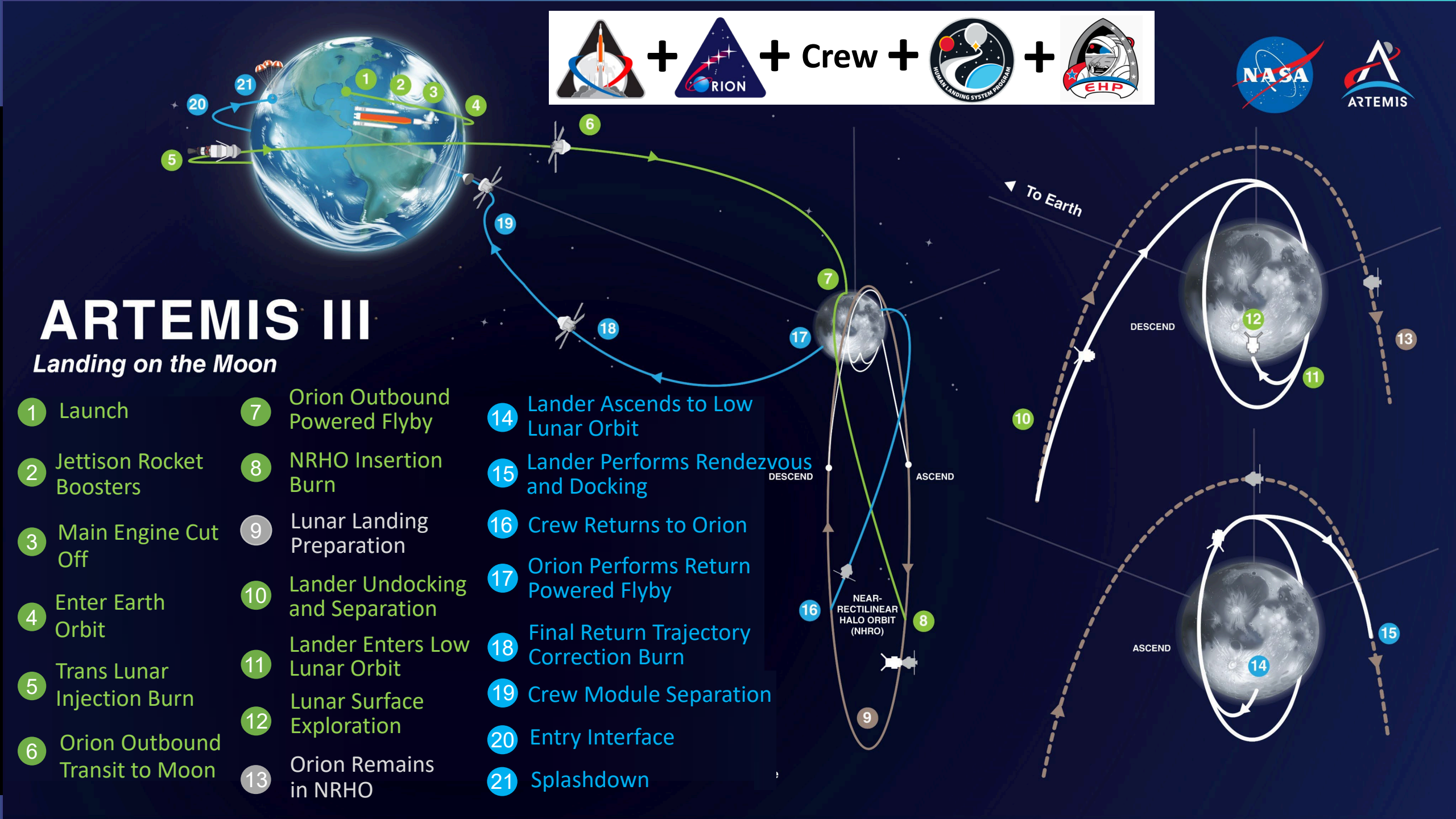
**Victor Glover**
Pilot

**Christina Hammock Koch**
Mission Specialist

**Jeremy Hansen**
Mission Specialist



Credit: NASA


+ ORION + Crew + HUMAN LANDING SYSTEM PROGRAM + EHP
NASA
ARTEMIS
ARTEMIS III
Landing on the Moon
1 Launch
2 Jettison Rocket Boosters
3 Main Engine Cut Off
4 Enter Earth Orbit
5 Trans Lunar Injection Burn
6 Orion Outbound Transit to Moon
7 Orion Outbound Powered Flyby
8 NRHO Insertion Burn
9 Lunar Landing Preparation
10 Lander Undocking and Separation
11 Lander Enters Low Lunar Orbit
12 Lunar Surface Exploration
13 Orion Remains in NRHO
14 Lander Ascends to Low Lunar Orbit
15 Lander Performs Rendezvous and Docking
16 Crew Returns to Orion
17 Orion Performs Return Powered Flyby
18 Final Return Trajectory Correction Burn
19 Crew Module Separation
20 Entry Interface
21 Splashdown
To Earth
DESCEND
ASCEND
NEAR-RECTILINEAR HALO ORBIT (NHRO)

# Human Landing System (HLS) Starship Artemis III Concept of Operations

NASA has awarded SpaceX a contract to develop its HLS Starship for use on Artemis III




Crew board Starship from Orion

Crew board Orion from Starship

Near Rectilinear Halo Orbit (NRHO)

HLS propellant fill

Fast trans-lunar injection (TLI)

Earth Orbit

Storage depot launch

Propellant aggregation

HLS Starship launch

Loiter in NRHO

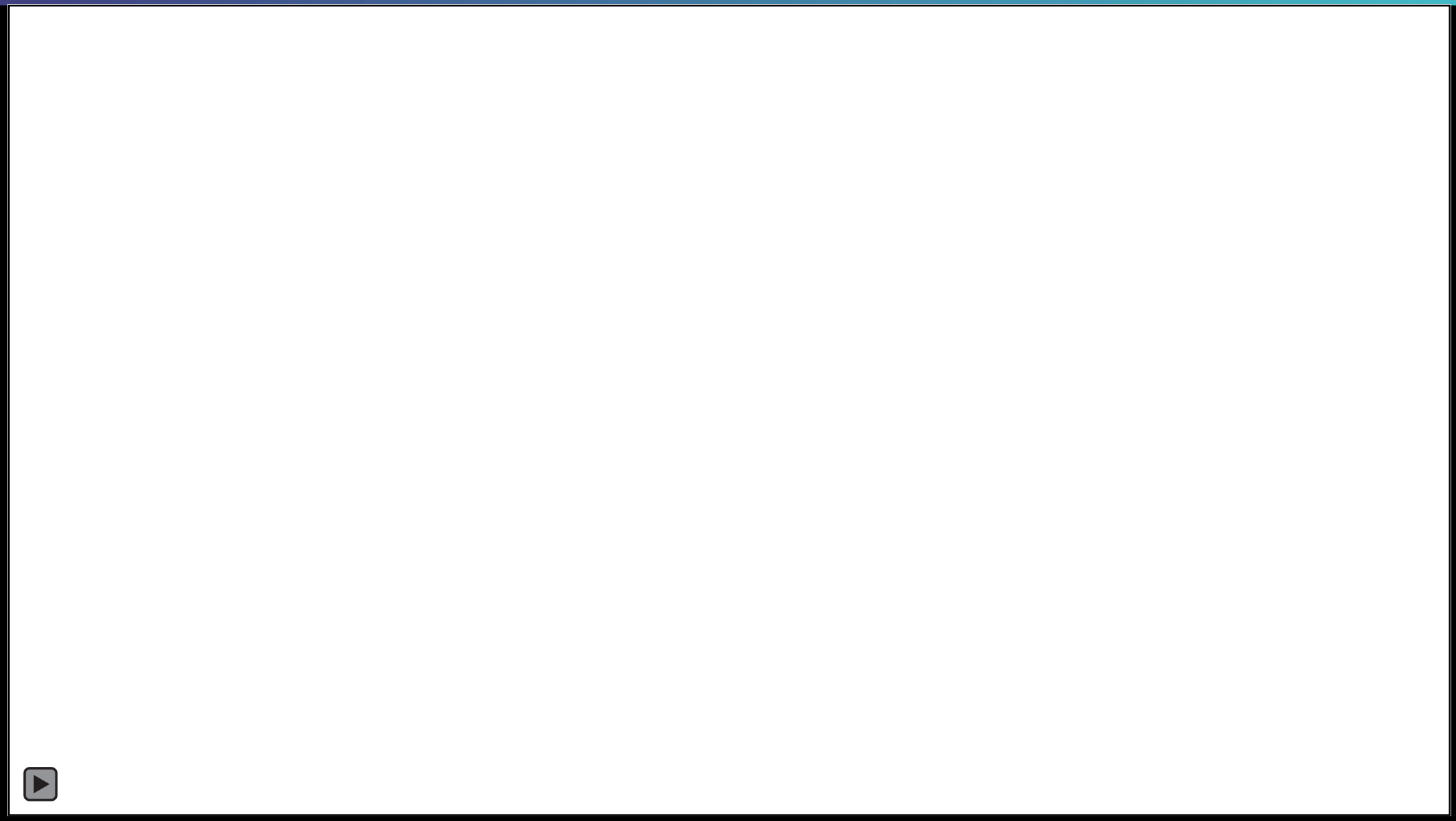
Artemis III launch

Surface expedition

Crew returns in Orion

# Challenges of Landing at the Lunar South Pole for Artemis III

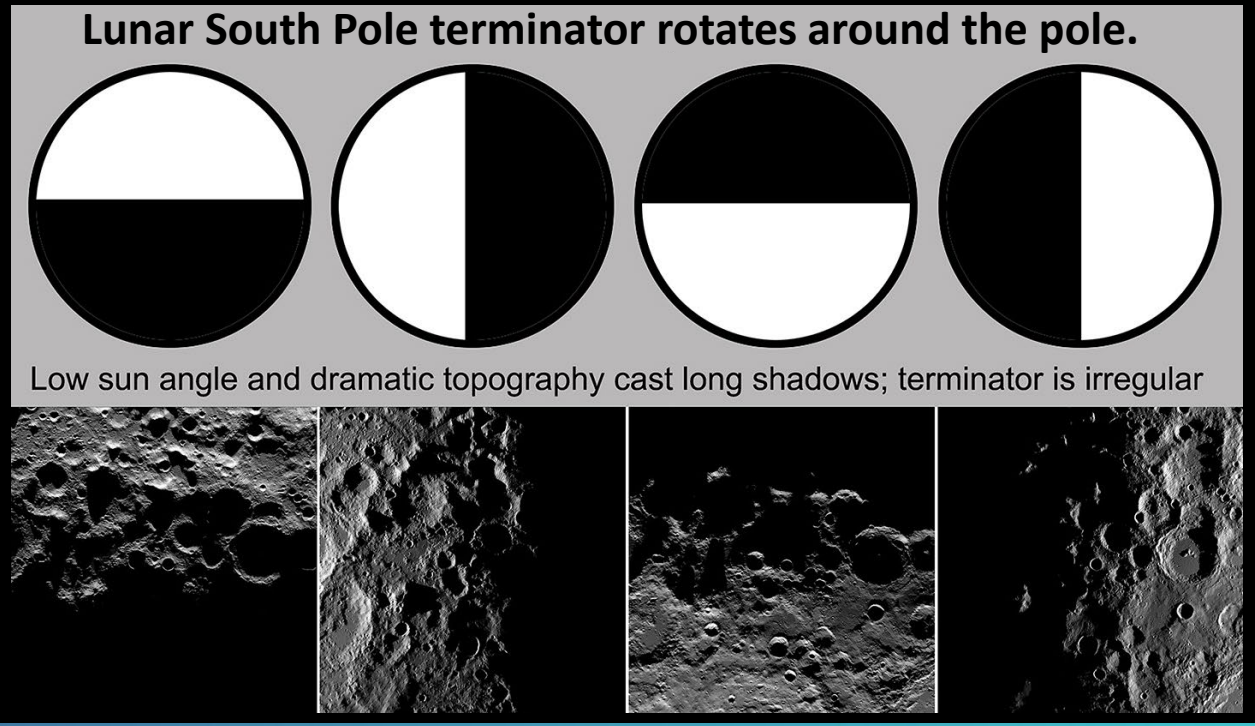
# Characteristics of the South Pole



# Characteristics of the South Pole

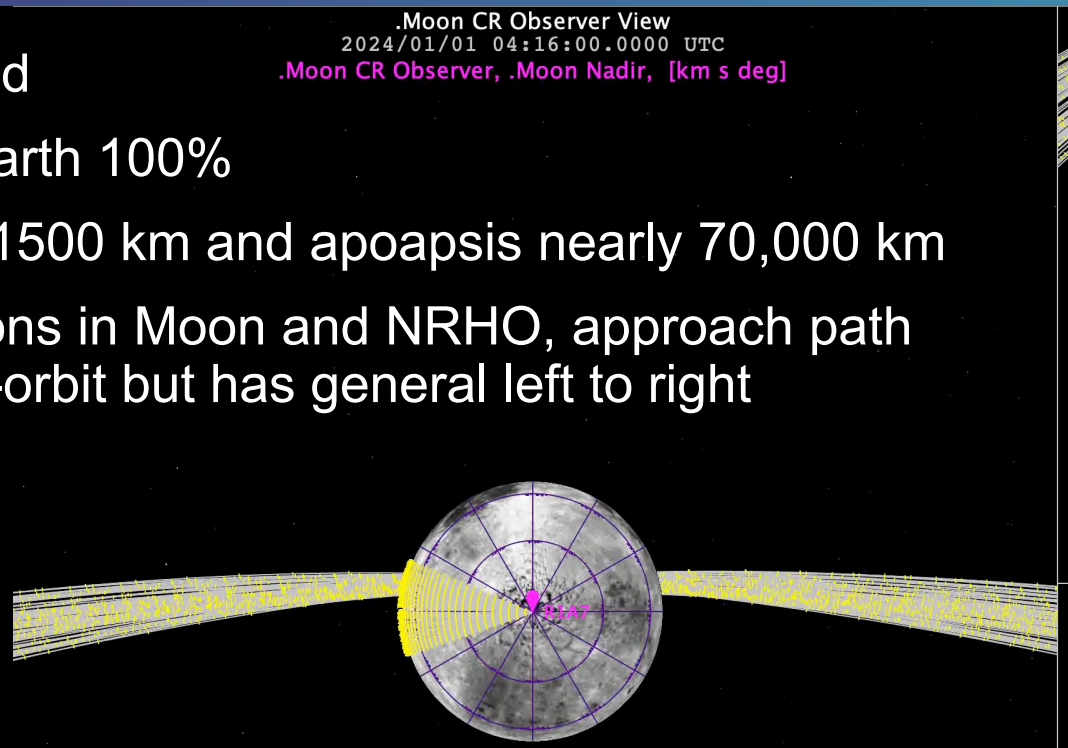
- Earth is upside down and spins backwards
- Same side of the moon always faces the Earth
- Sun and Earth only rise above the horizon ~2 to 7 deg
- Sun casts long shadows
- Earth is in a 2-week cycle: visible two weeks, not visible two weeks
- Terminator, where light meets darkness, is not smooth
- Constantly changing lighting effects at the pole



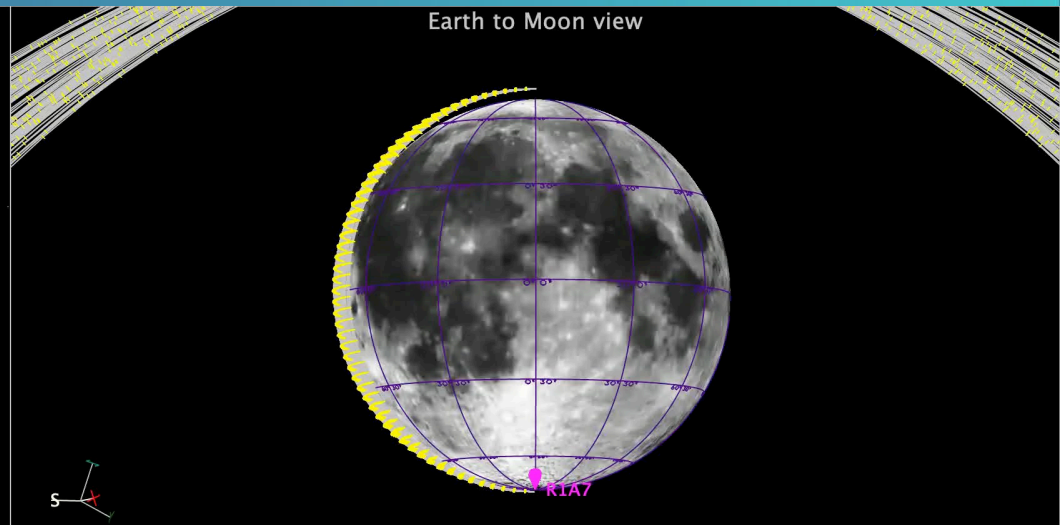



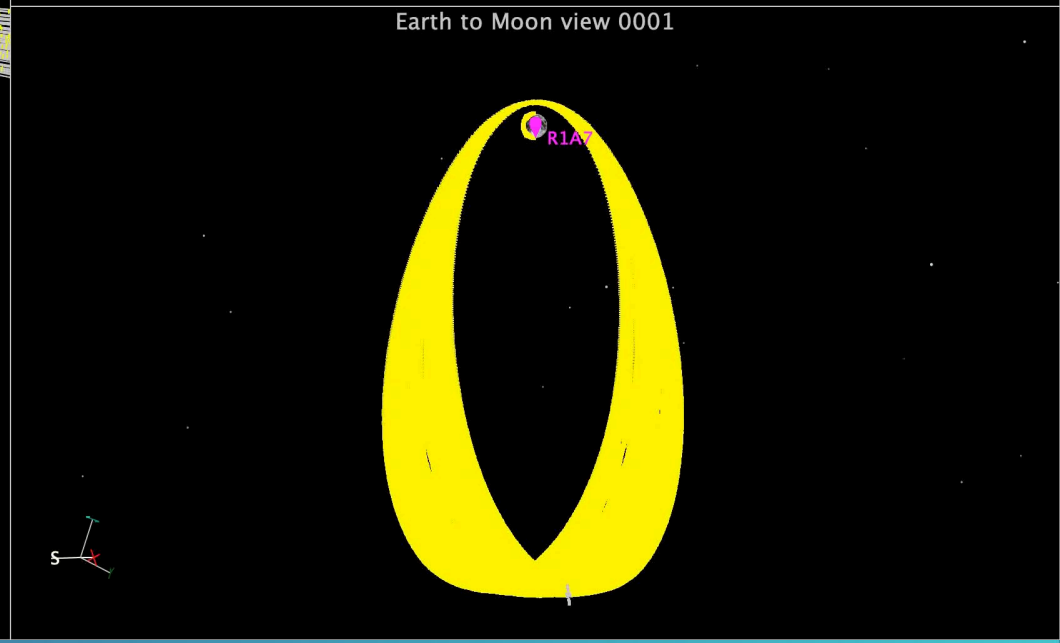
# Characteristics of Near Rectilinear Halo Orbit

- ~6.5 day period
- Visible from Earth 100%
- Periapsis of ~1500 km and apoapsis nearly 70,000 km
- Due to variations in Moon and NRHO, approach path varies orbit-to-orbit but has general left to right direction




- Other Considerations:
  - Assumes Gateway fixed NRHO, so can only descend to the surface once every 6.5 days (~55 opportunities to land per year)
  - Earth/Moon orbital mechanics and SLS/Orion limitations reduce ability to get to NRHO to ~28 NRHO departure opportunities per year



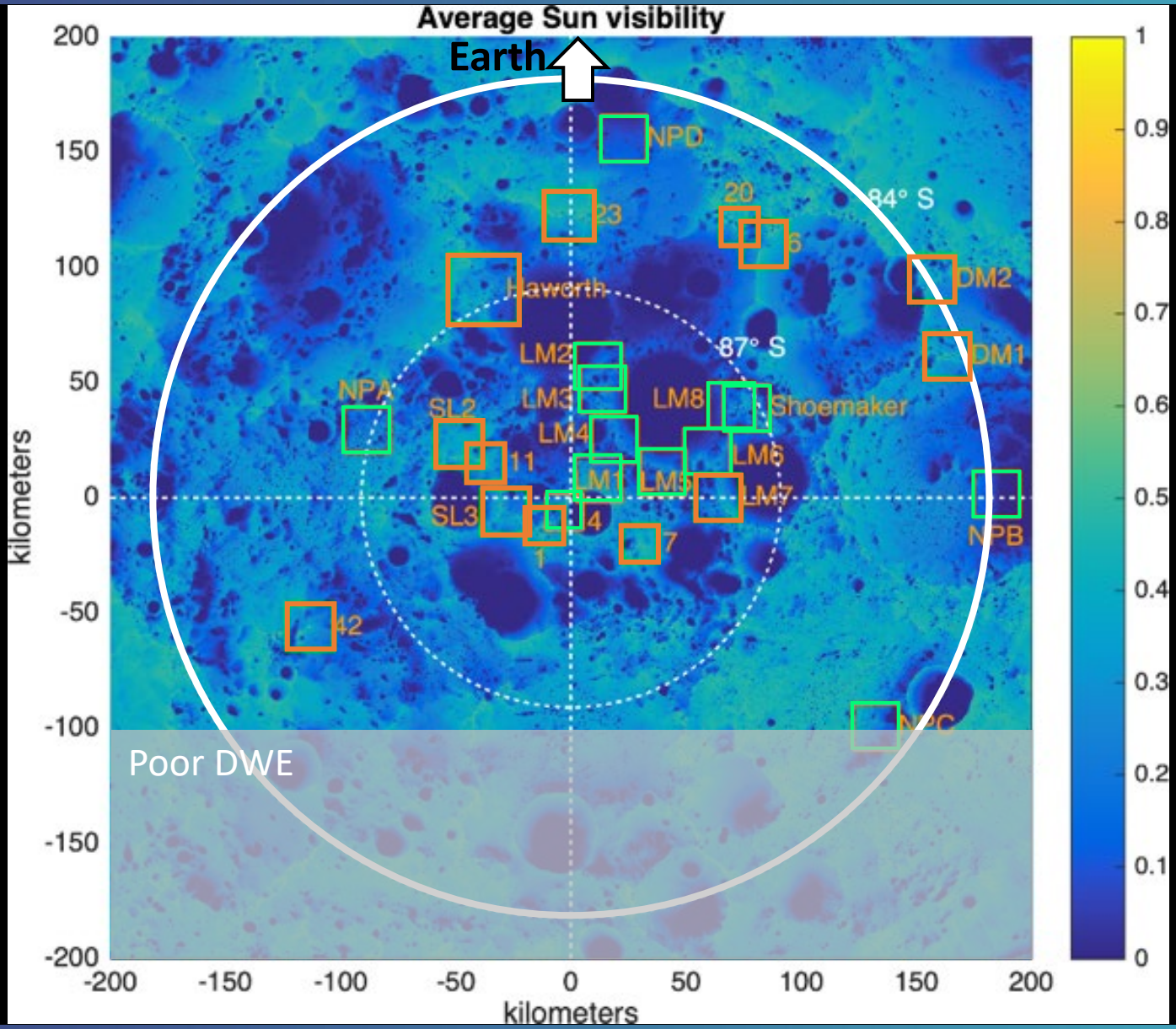



# Key Artemis III Landing Requirements

1. Land within 6 deg latitude of the South Pole
2. Surface slope for landing (100m): <10 deg
3. Surface slope limit for EVA  (2km): <20 deg
4. Direct with Earth (DWE) communication; assume no comm relay is available
5. Lighting
    a. Surface Lighting
    b. Approach lighting
6. Land within 100 m of a target

*Objective: Identify locations that are viable for landing and meet all requirements and constraints*

# 1. Land within 6 deg latitude of the pole



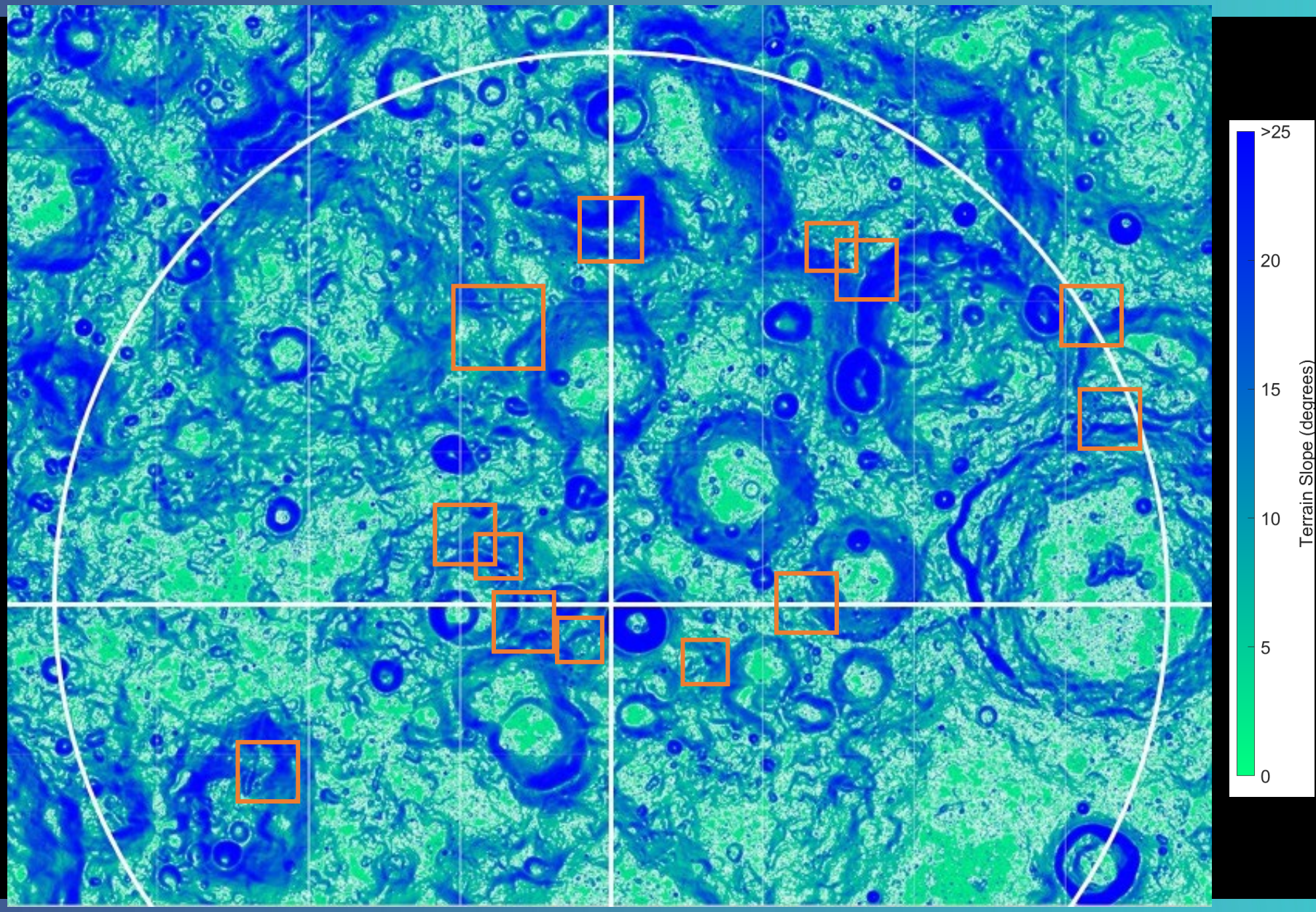

https://pgda.gsfc.nasa.gov/products/78

# 2. Surface slope for landing: <10 deg

Slopes for landing must be less than 10 deg

Green areas show slopes less than 10 deg

White contours show regions of continuous 8 deg slope

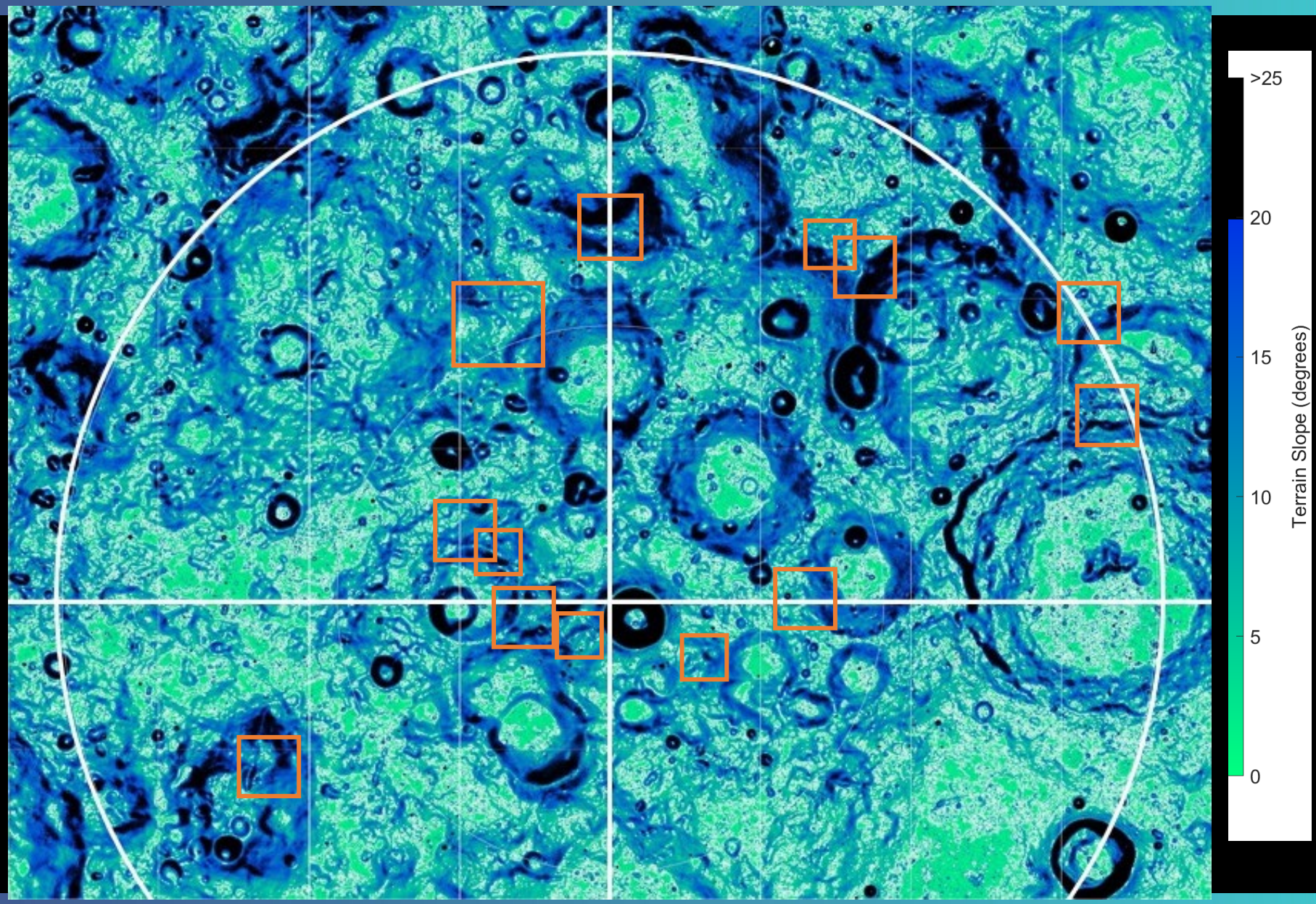


# 3. Surface slope for EVA: <20 deg

Slopes for Extravehicular Activity (EVA) must be less than 20 deg

Black designates areas of slope > 20 deg

No EVAs can occur in black areas

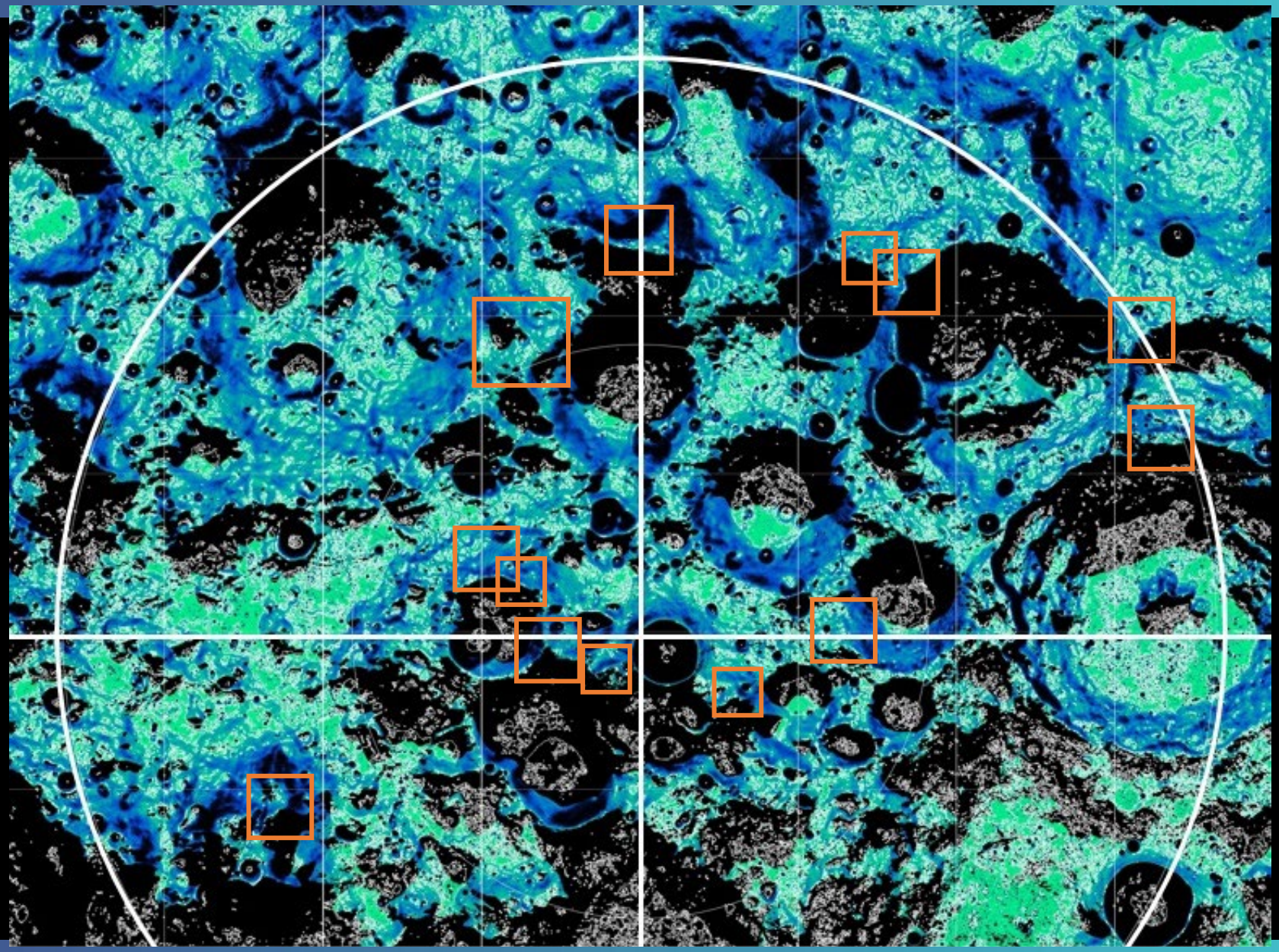


# 4. Direct with Earth Communication

Artemis III will require Earth to be visible for communications

Black designates areas of slope > 20 deg
+
Earth visibility < 25%

Reduces areas suitable for landing.

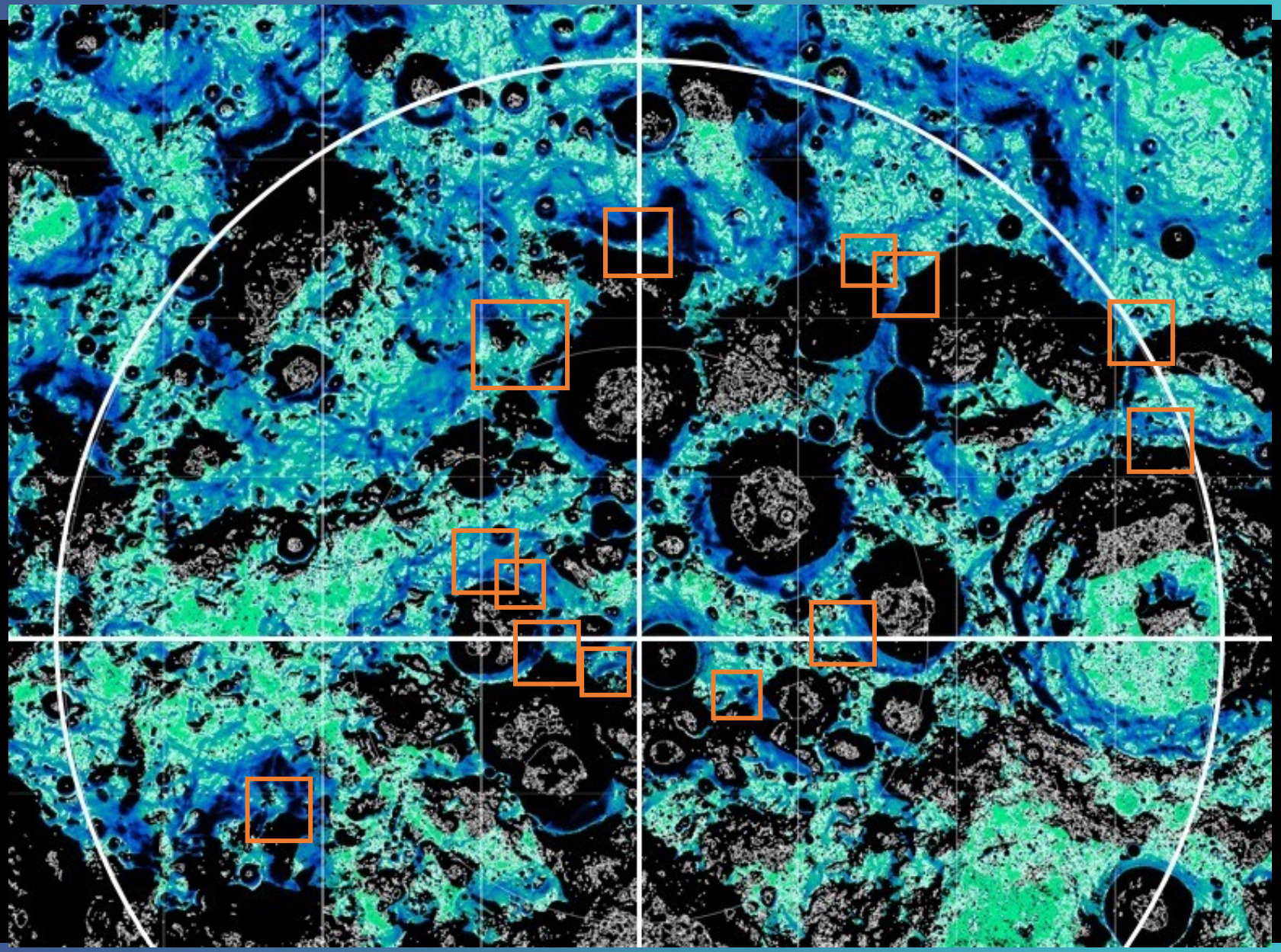


# 5a. Surface Lighting

Artemis III will require the surface to be lit for the duration of the surface stay

Black designates areas of slope > 20 deg
+
Earth visibility < 25%
+
Solar visibility less 5%

Reduces areas suitable for landing.

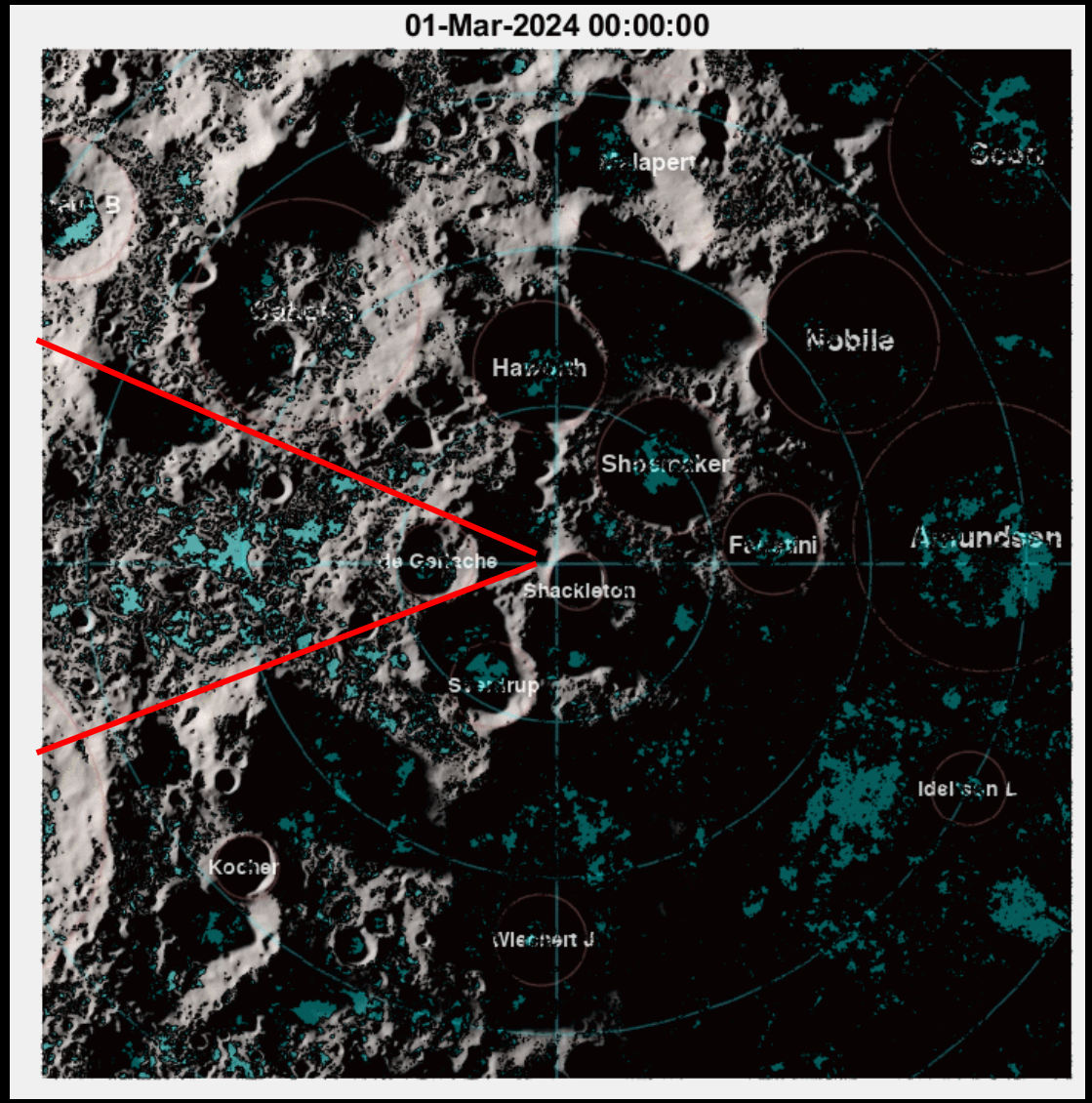


# 5b. Approach Lighting

Illumination along the approach trajectory is beneficial.

The approach trajectory is different for each landing opportunity.

Notional range designated in red



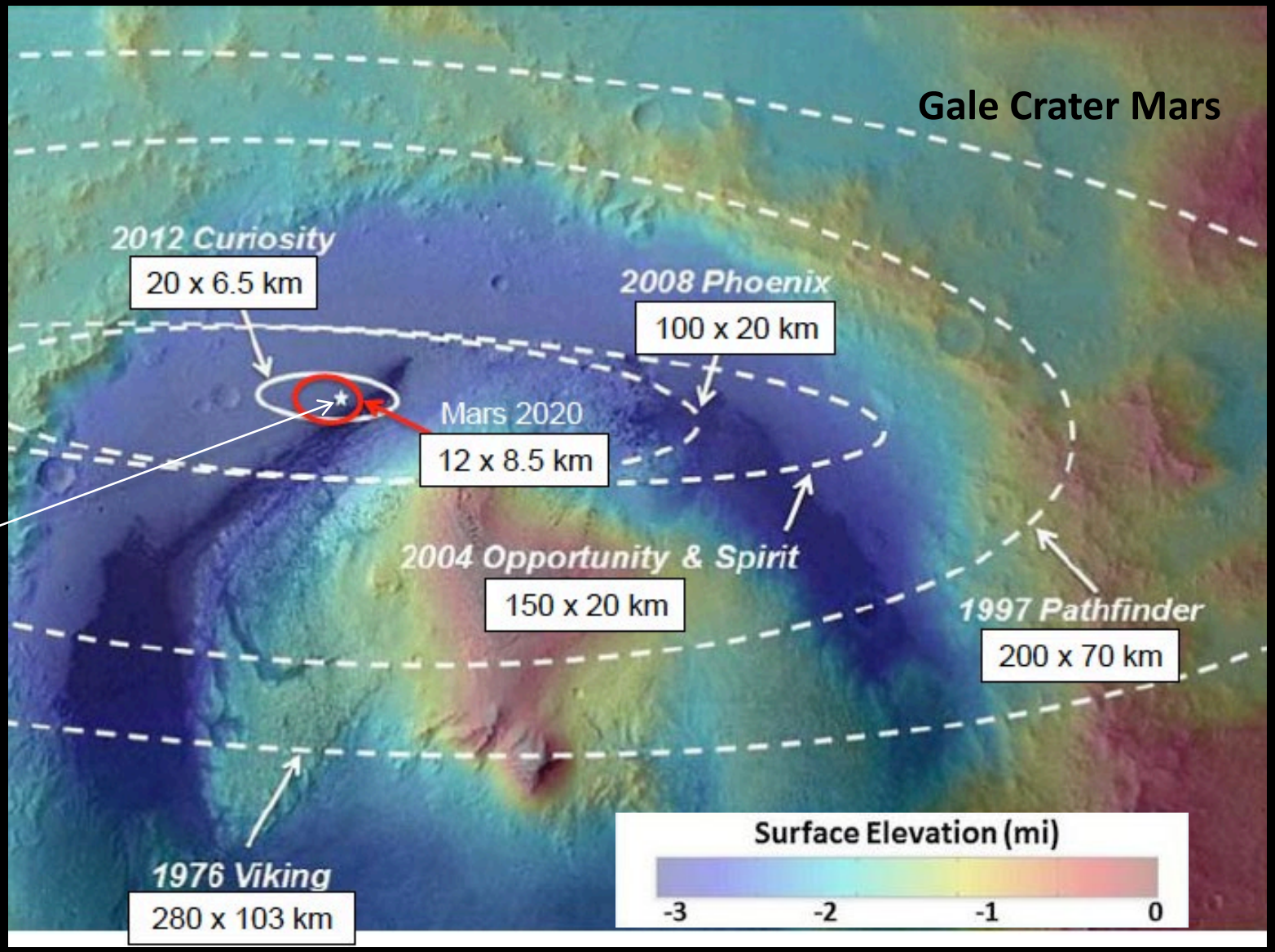

Peak lighting conditions are periodic and shift 2-3 weeks earlier each year, where by 2030, peak solar illumination occurs around the month of August

# 6. Land within 100m of a target

Past Robotic mission landing performance at Mars

Apollo 11 landing ellipse: 17 x 5 km

Human Landing Accuracy Requirements 100 m x 100 m

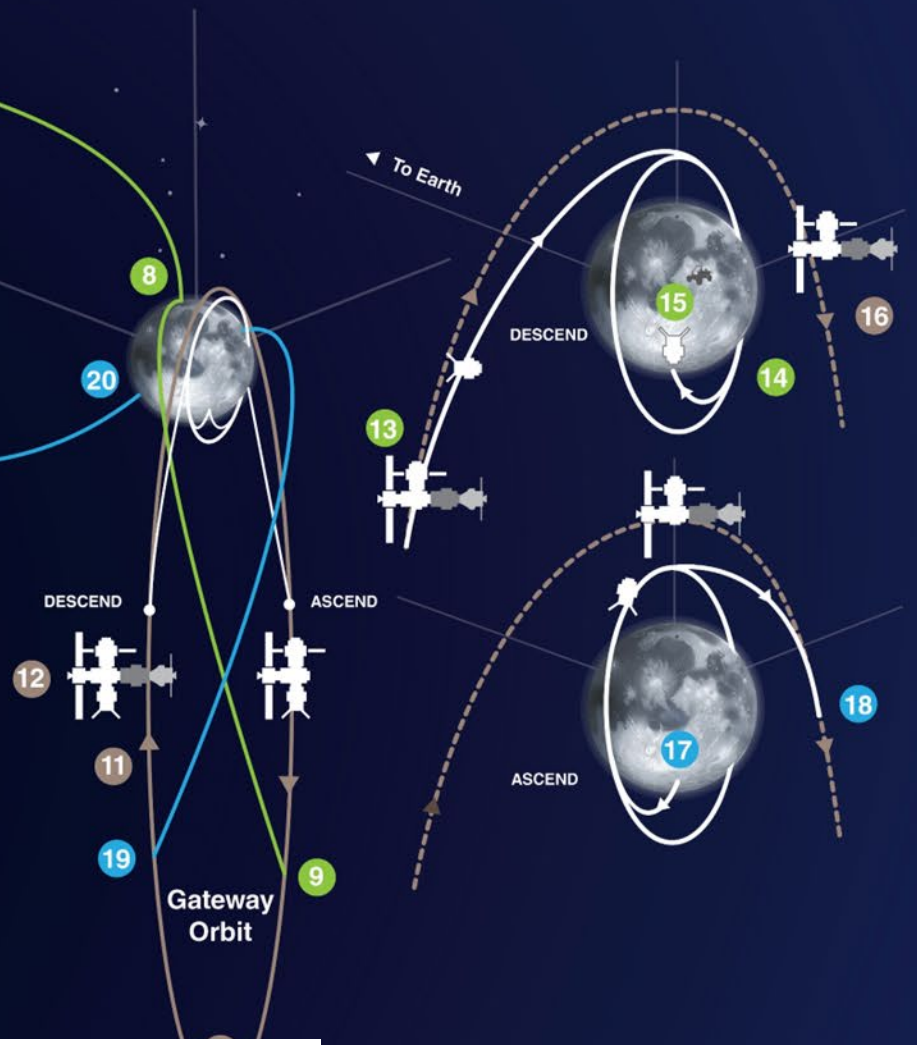


# Looking Forward

# ARTEMIS IV

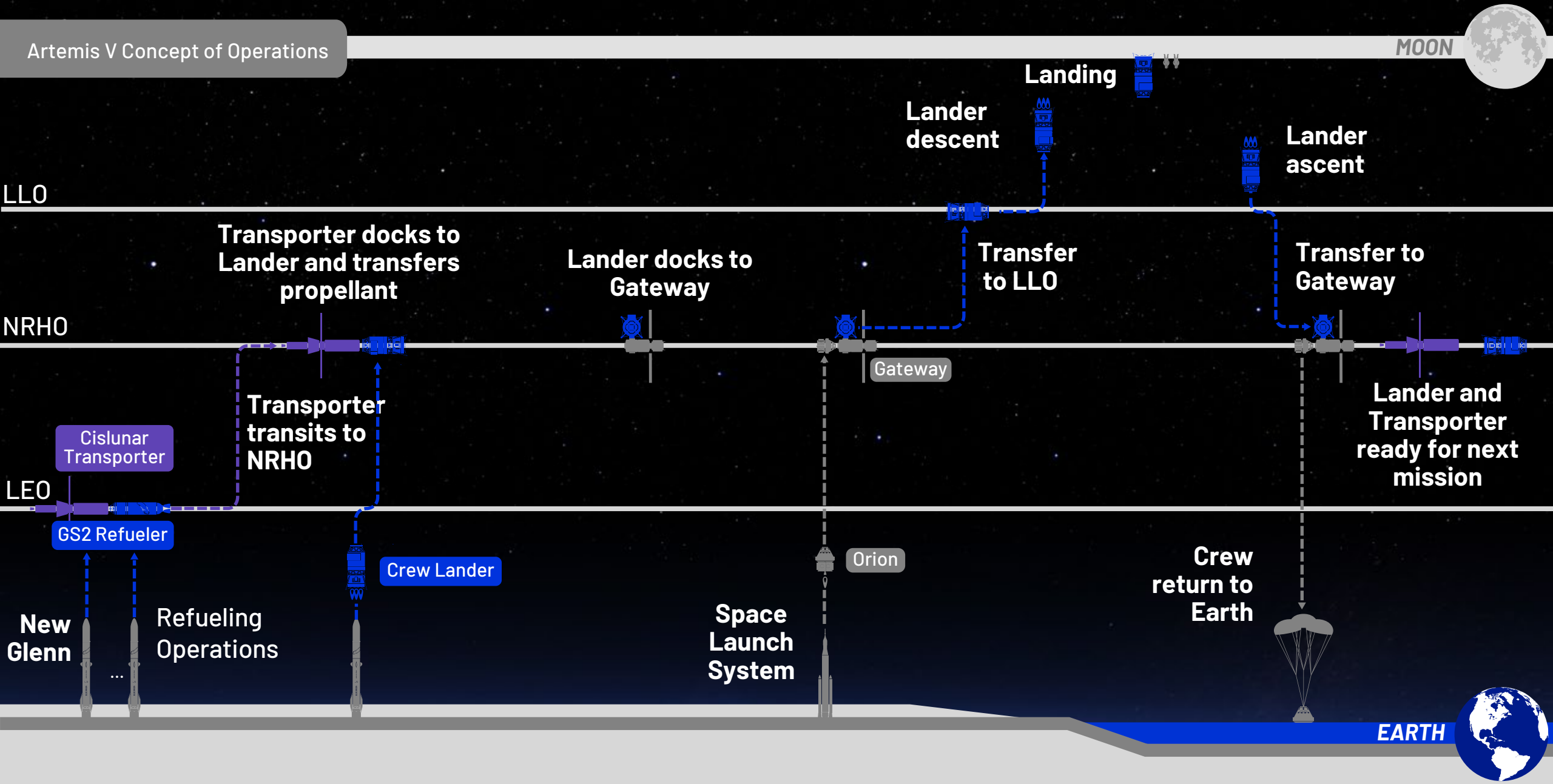
***International Habitation Module delivery to Gateway followed by Crewed Lunar Landing***



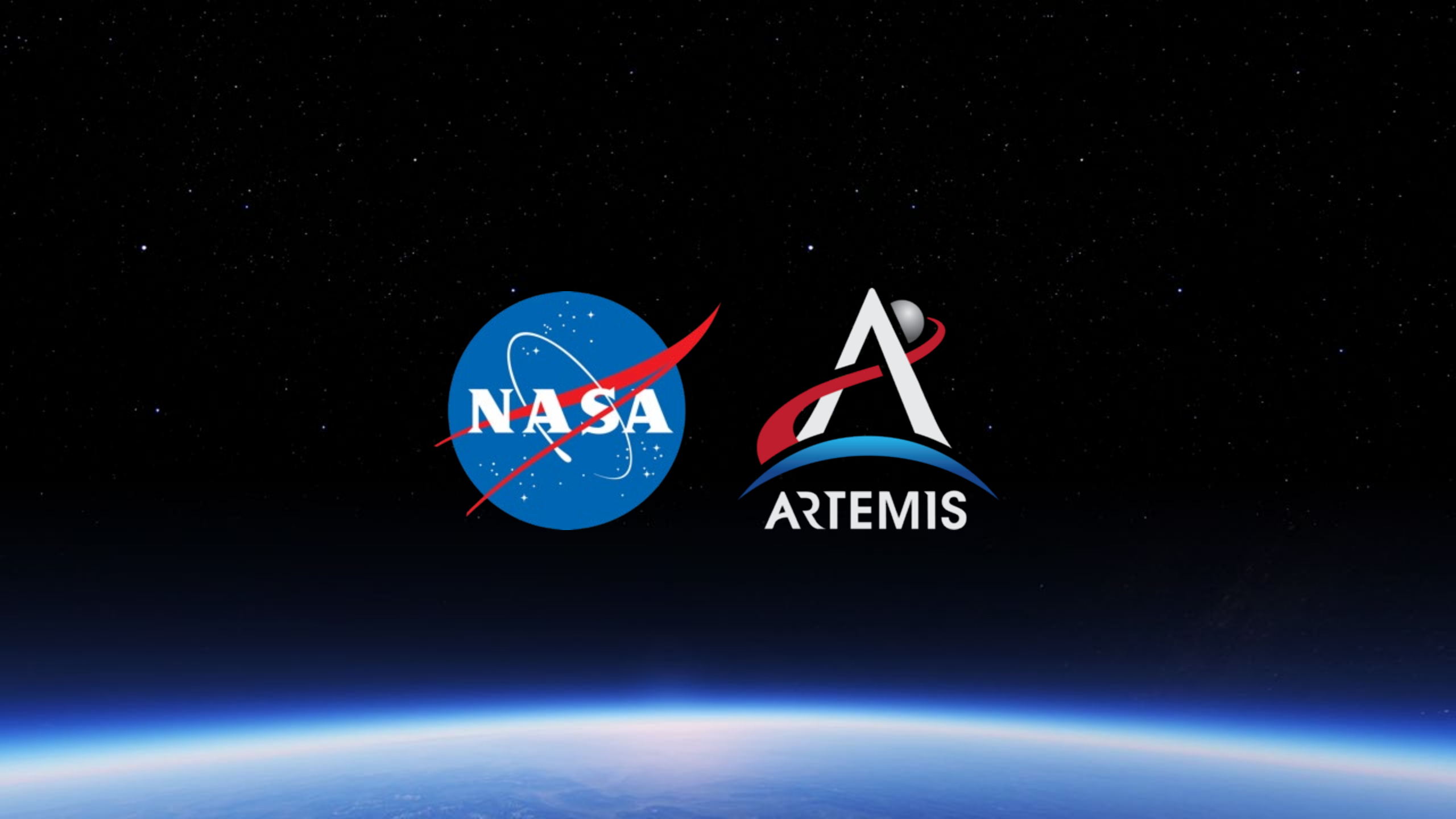




1. Launch
2. Jettison Rocket Boosters
3. Main Engine Cut Off
4. Enter Earth Orbit
5. Trans Lunar Injection Burn
6. Orion Tugs I-HAB to Moon
7. Orion Outbound Transit to Moon
8. Orion Outbound Powered Flyby
9. Gateway Orbit Insertion Burn
10. I-HAB Arrives at Gateway
11. I-HAB Activation and Crew Ingress
12. Lunar Landing Preparation
13. Lander Undock & Separation
14. Lander Enters Low Lunar Orbit
15. Lunar Surface Exploration
16. Orion Remains in Lunar GW Orbit
17. Lander Ascends to LLO
18. Lander Performs RPOD
19. Crew Returns to GW/Orion
20. Orion Performs Return Powered Flyby
21. Final Return Trajectory Correction Burn
22. Crew Module Separation
23. Entry Interface
24. Splashdown

+ + Crew + + +


Artemis V Concept of Operations
MOON
Landing
Lander descent
Lander ascent
LLO
Transporter docks to Lander and transfers propellant
Lander docks to Gateway
Transfer to LLO
Transfer to Gateway
NRHO
Gateway
Transporter transits to NRHO
Lander and Transporter ready for next mission
Cislunar Transporter
LEO
GS2 Refueler
Crew Lander
Orion
Crew return to Earth
New Glenn
Refueling Operations
Space Launch System
EARTH
PHASES
Systems Deployment and Refueling Operations
Initial Lunar Orbit Operations
Descent
Surface
Ascent
Return to Lunar Orbit Ops
Post-Mission Ops


ARTEMIS
WE GO


NASA
ARTEMIS