Return to the Moon with Artemis: Overview, Challenges, and the Future

National Aeronautics and Space Administration

Alicia Dwyer Cianciolo NASA Langley Research Center

ARTEMIS

www.nasa.gov

“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.”

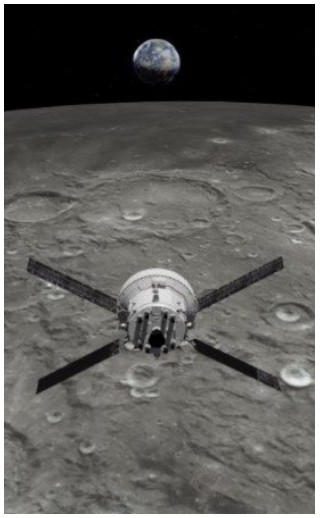
“U.S. human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

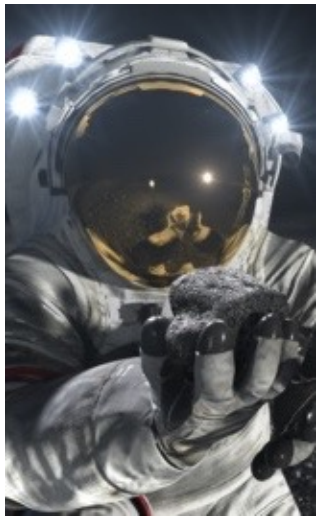
— The White House U.S Space Priorities Framework, Dec 2021

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

What is Artemis?

ARTEMIS = + ORION + HUMAN LANDING SYSTEM PROGRAM + * EHP + GATEWAY

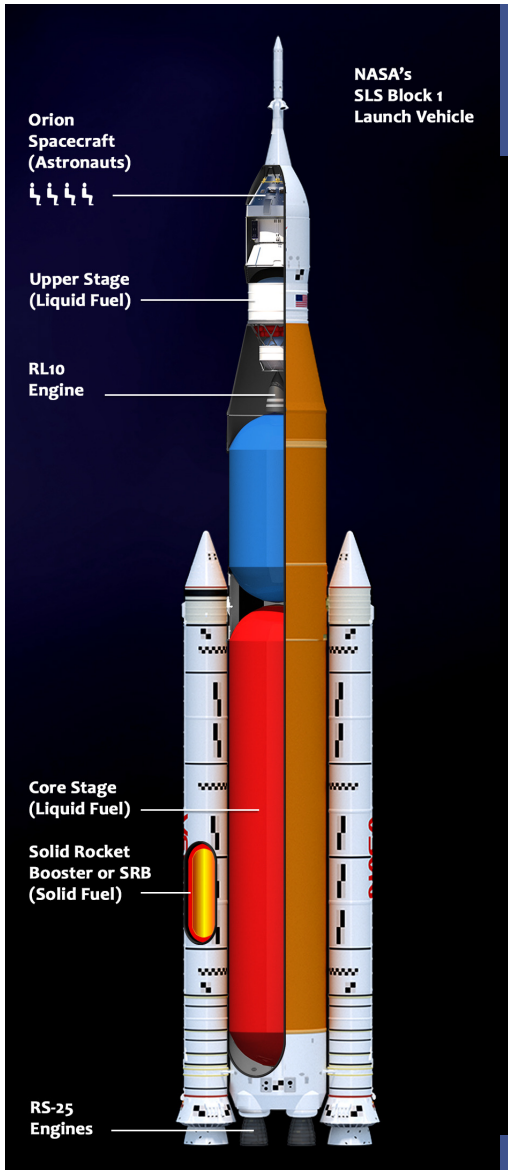





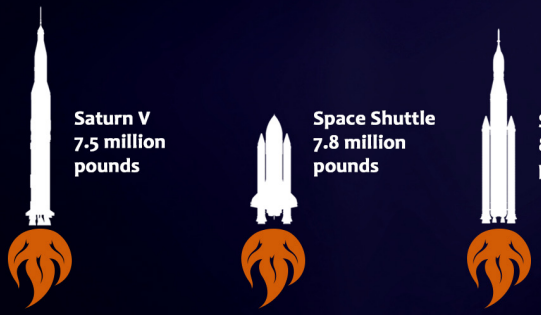

*Extravehicular Activity and Human Surface Mobility Program

Combines programs into missions

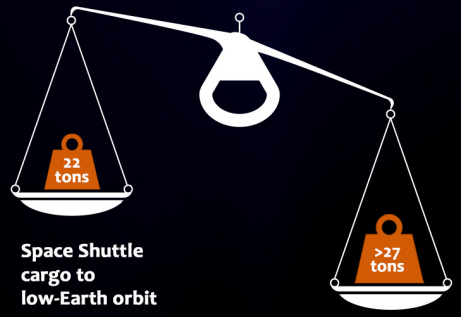
Space Launch System



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

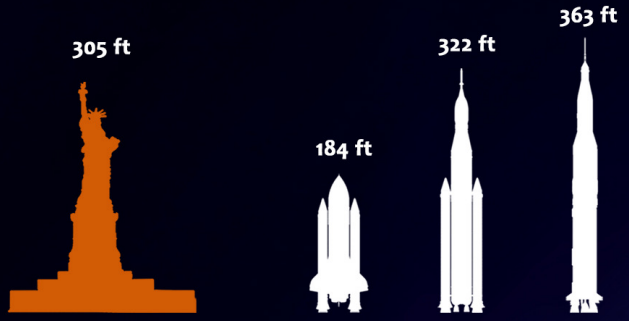


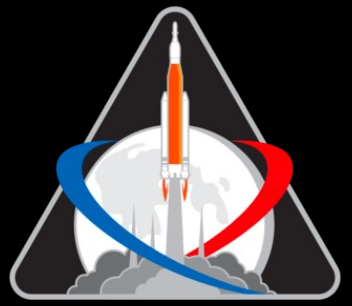
SLS will launch more cargo to the Moon than the space shuttle could send to low-Earth orbit.



www.nasa.gov/sls

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

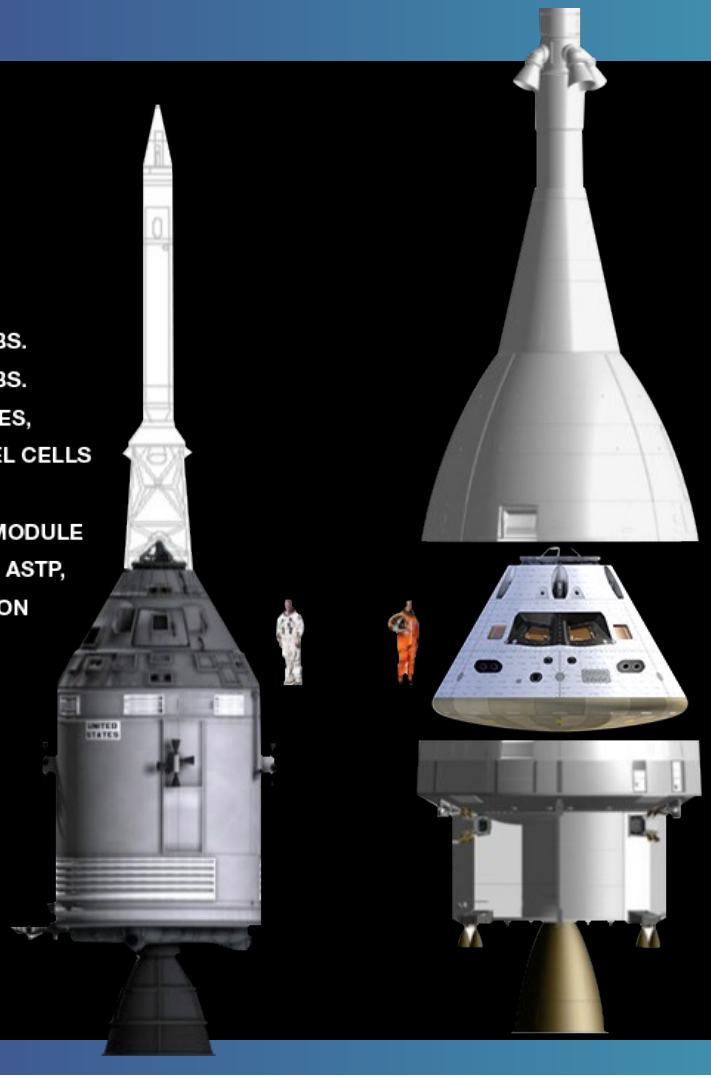




Orion

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



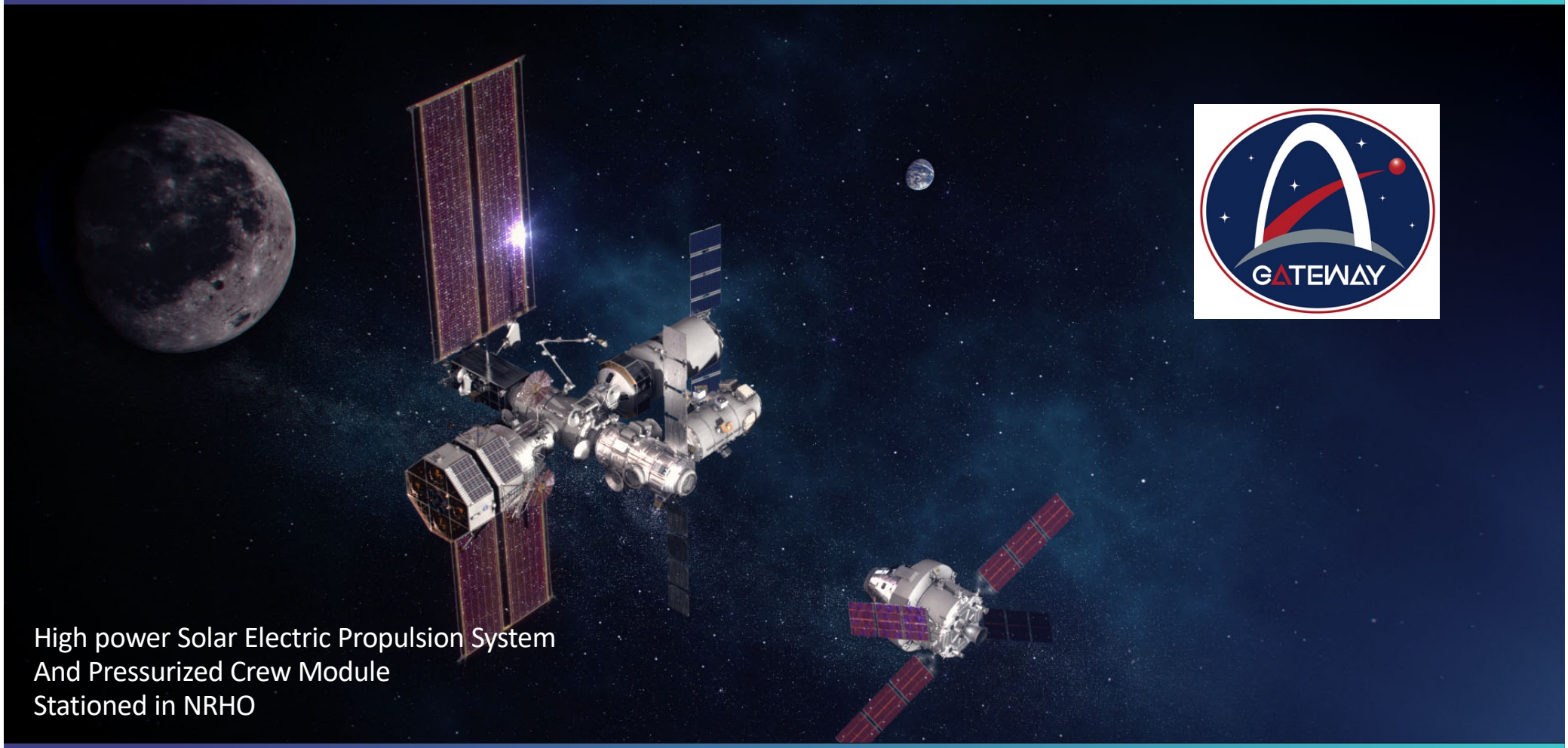
ORION

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: Option A

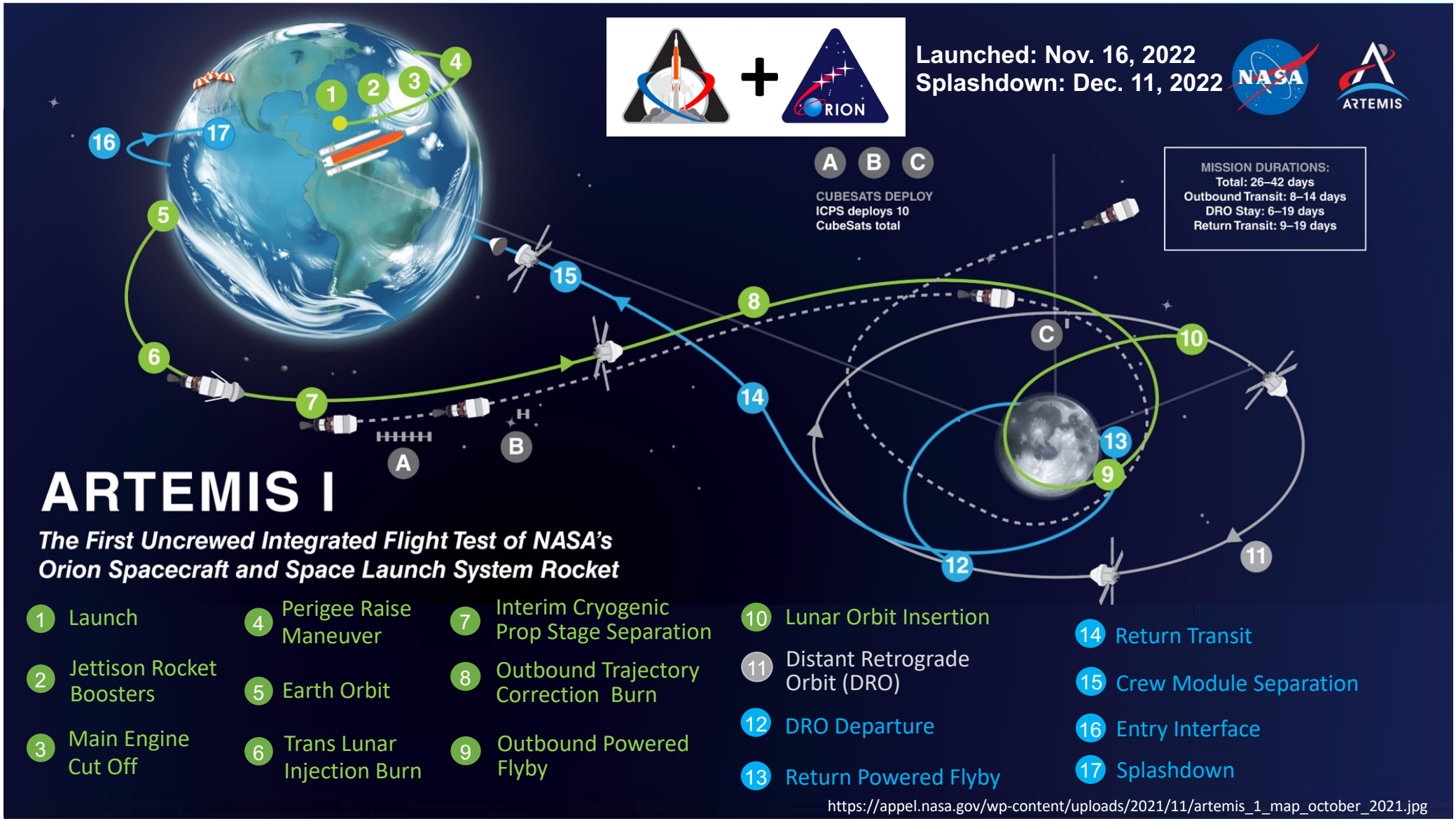
Single Stage Lander

Gateway

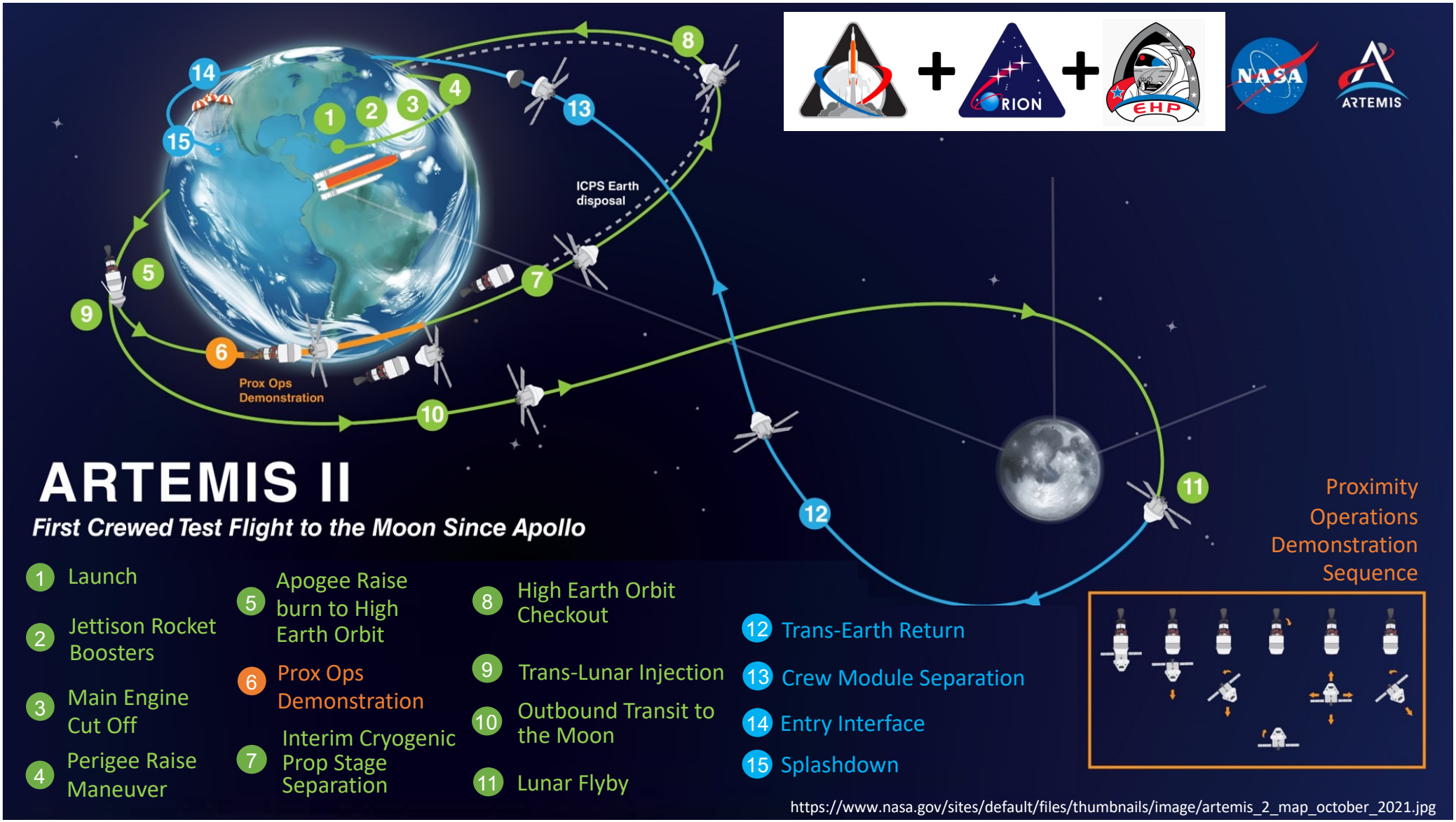


High power Solar Electric Propulsion System
And Pressurized Crew Module
Stationed in NRHO

Combine programs into missions.



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



https://www.nasa.gov/sites/default/files/thumbnails/image/artemis_2_map_october_2021.jpg

Meet the Artemis II Crew

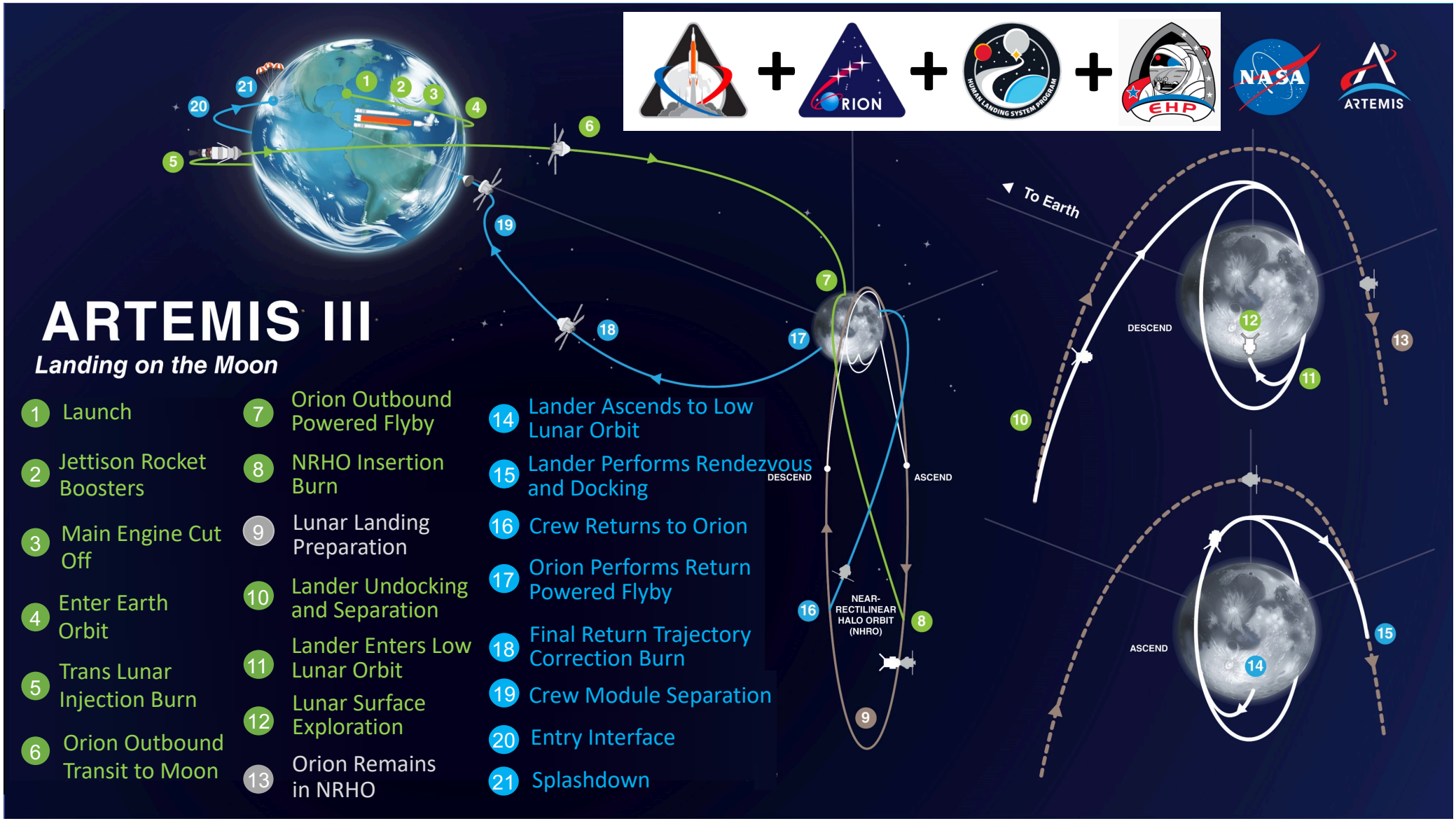
Reid Wiseman
Commander

Victor Glover
Pilot

Christina Hammock Koch
Mission Specialist

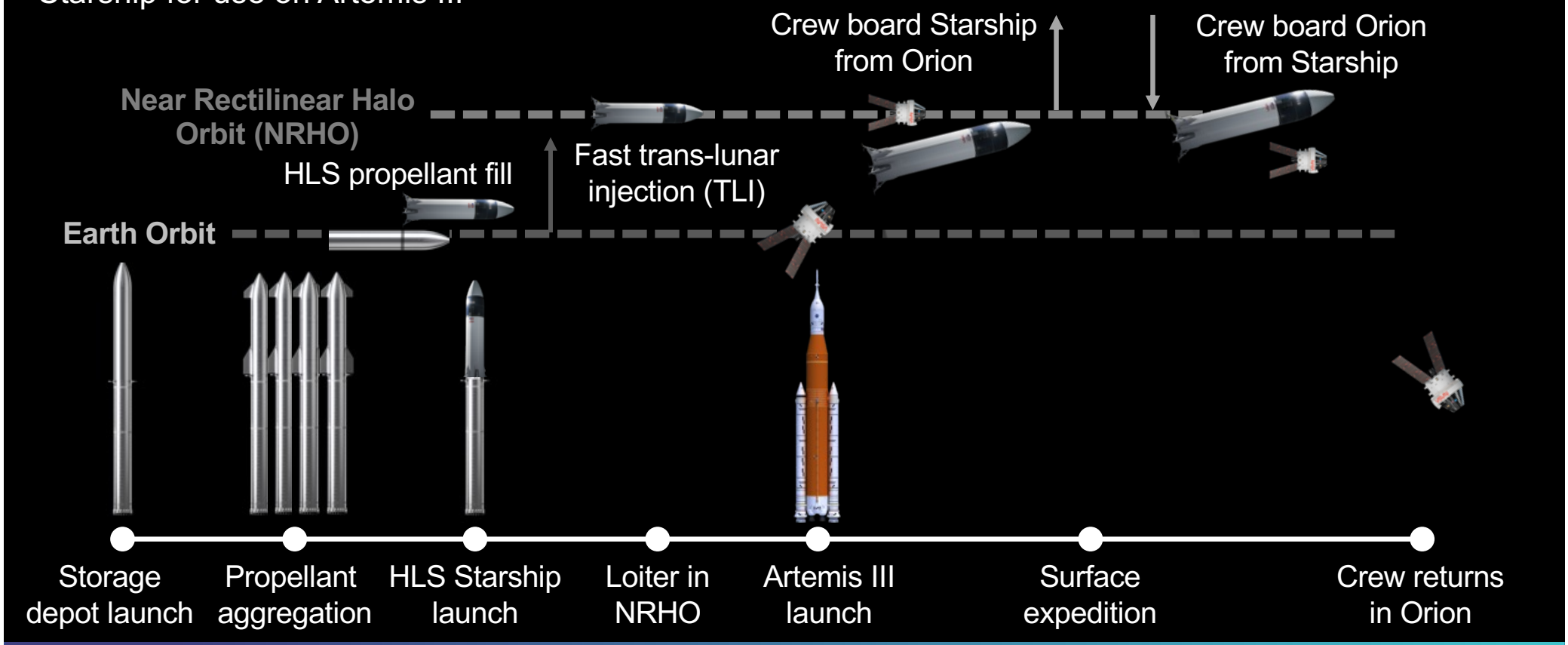
Jeremy Hansen
Mission Specialist

Credit: NASA


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
ORION
HUMAN LANDING SYSTEM PROGRAM
EHP
NASA
ARTEMIS
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



Challenges of Landing at the Lunar South Pole

Apollo Landing Sites

Apollo 11 JUL 69
Mare Tranquillitatis
0.67416°N 23.47314°E
LM: 21.6 hours EVA: 2.5 hours

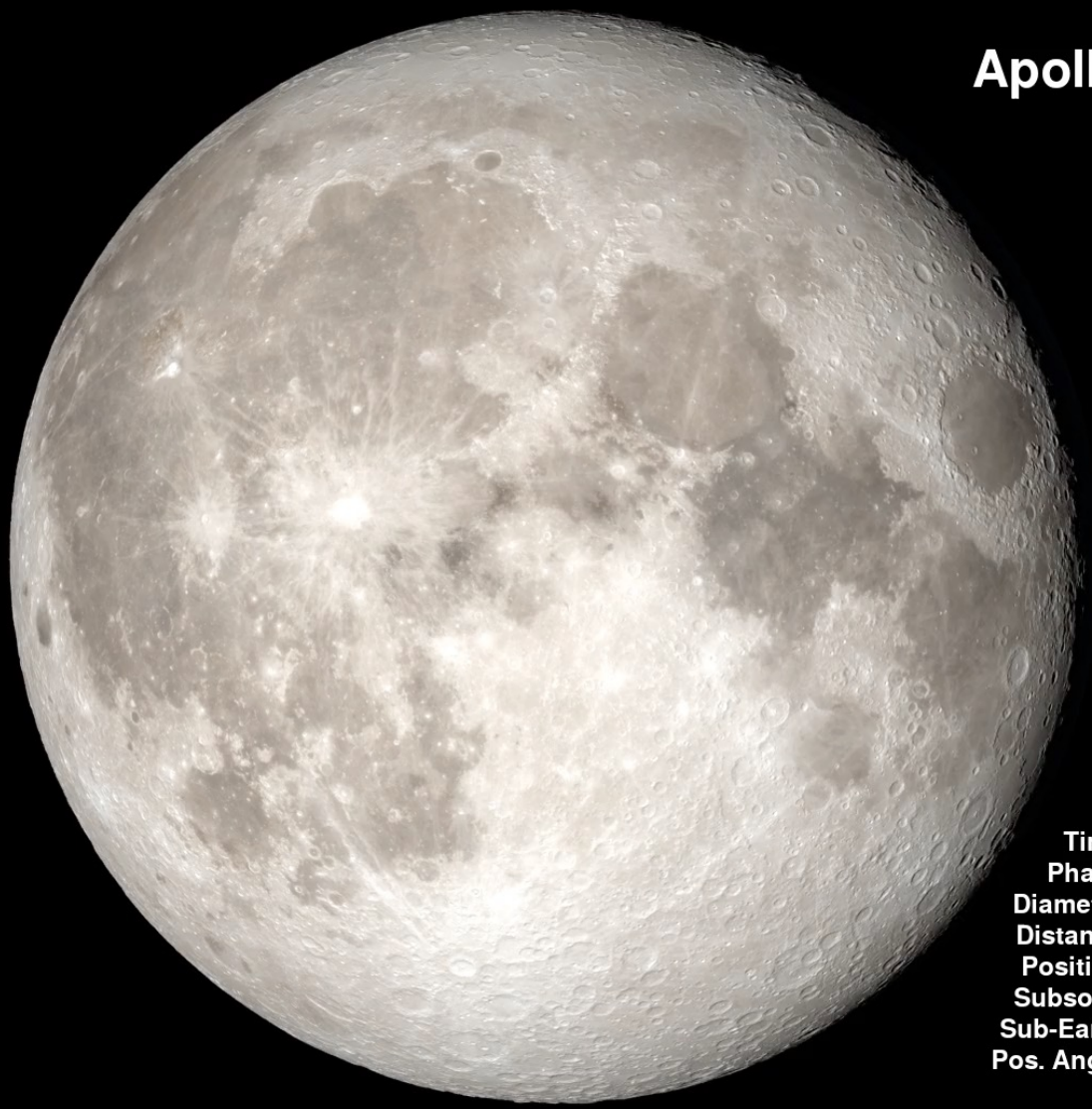
Apollo 12 NOV 69
Oceanus Procellarum
3.0128°S 23.4219°W
LM: 31.5 hours EVA: 7.8 hours

Apollo 14 FEB 71
Fra Mauro Highlands
3.64589°S 17.47194°W
LM: 33.5 hours EVA: 9.4 hours

Apollo 15 AUG 71
Hadley Rille
26.13239°N 3.63330°E
LM: 66.9 hours EVA: 19.1 hours

Apollo 16 APR 72
Descartes Highlands
8.9734°S 15.5011°E
LM: 71.0 hours EVA: 20.2 hours

Apollo 17 DEC 72
Taurus-Littrow Valley
20.1911°N 30.7655°E
LM: 75.0 hours EVA: 22.1 hours

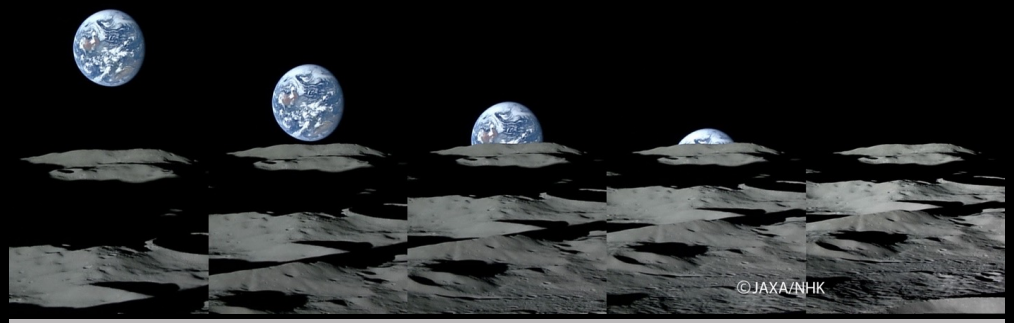


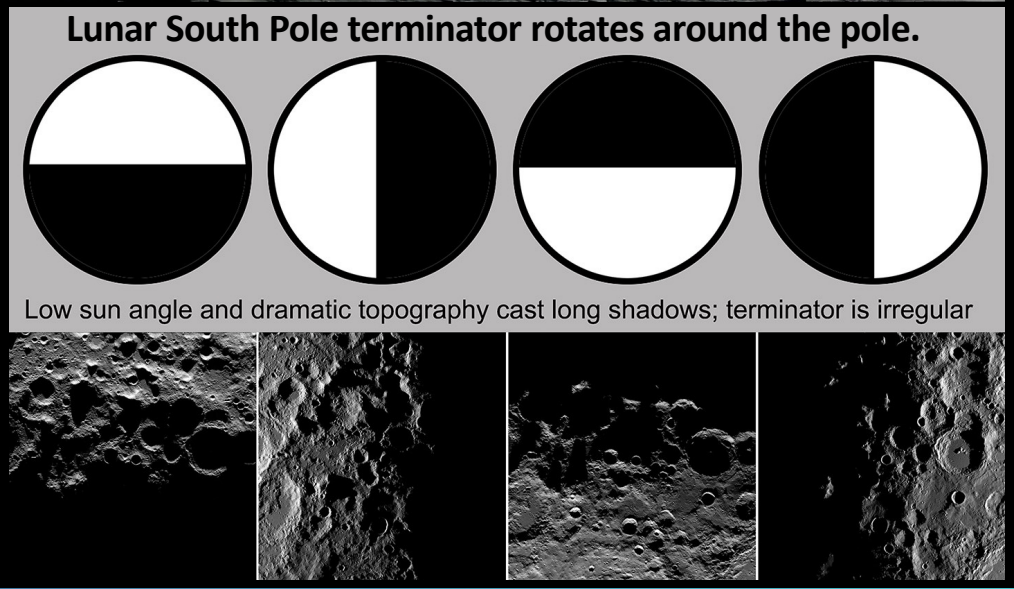
Time: 01 Jul 1969 00:00 UT
Phase: 97.8% (16d 00h 51m)
Diameter: 2002.2 arcseconds
Distance: 357960 km (28.09 Earths)
Position: 19h 56m 00s, 25° 08' 12"S
Subsolar: 1.479°N 14.482°W
Sub-Earth: 5.585°N 2.246°E
Pos. Angle: 349.630°

Characteristics of the South Pole

Characteristics of the South Pole

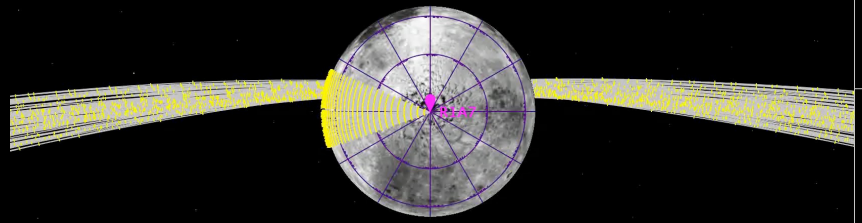
- Earth is upside down and spins backwards
- Same side of the moon always faces the Earth
- Sun and Earth only rise above the horizon ~2 to 7 deg
- Sun casts long shadows
- Earth is in a 2-week cycle: visible two weeks, not visible two weeks
- Terminator, where light meets darkness, is not smooth
- Constantly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



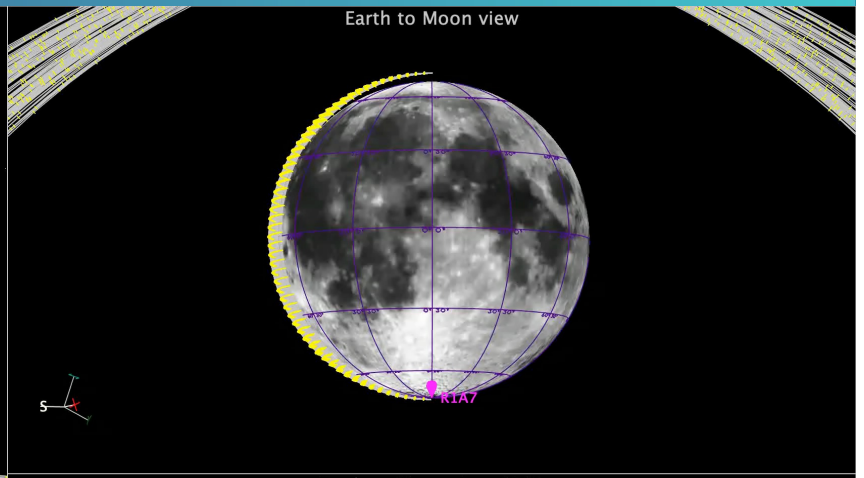


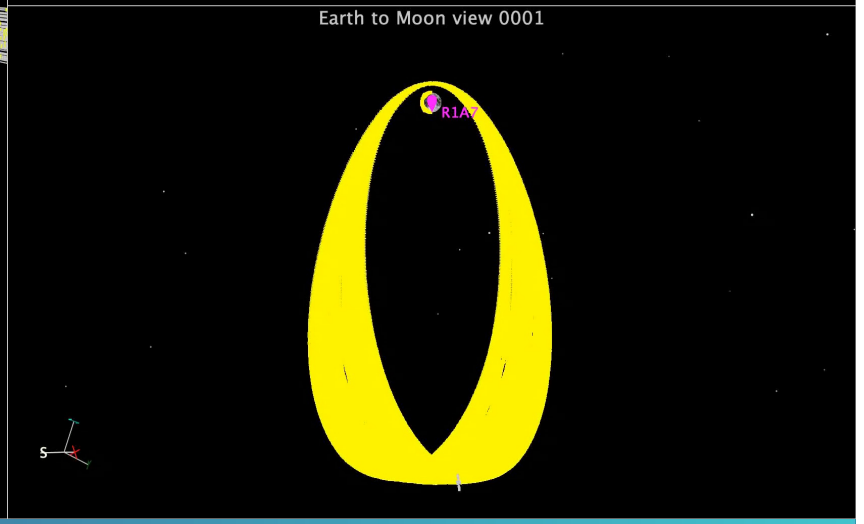
Characteristics of Near Rectilinear Halo Orbit

- ~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



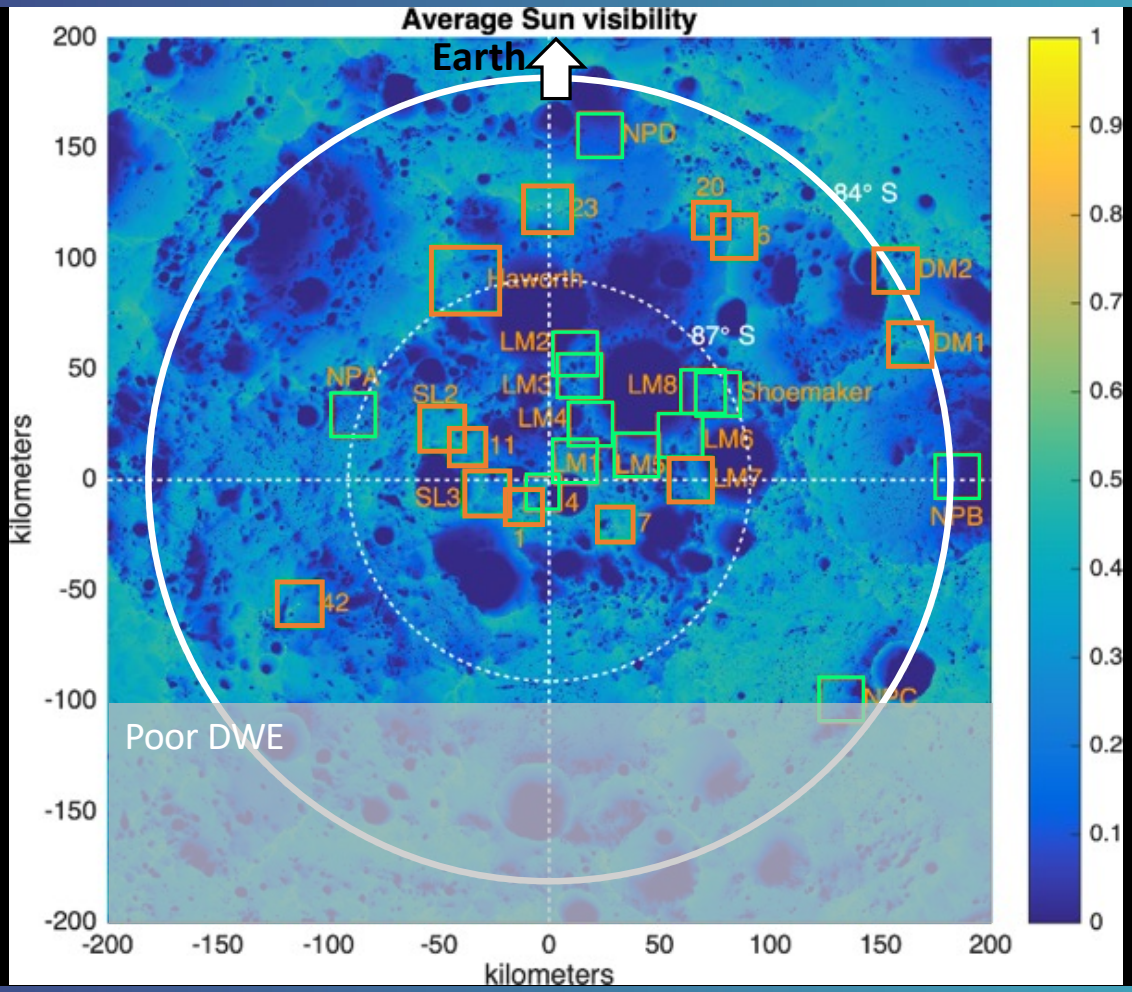


Key Artemis III Landing Requirements

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



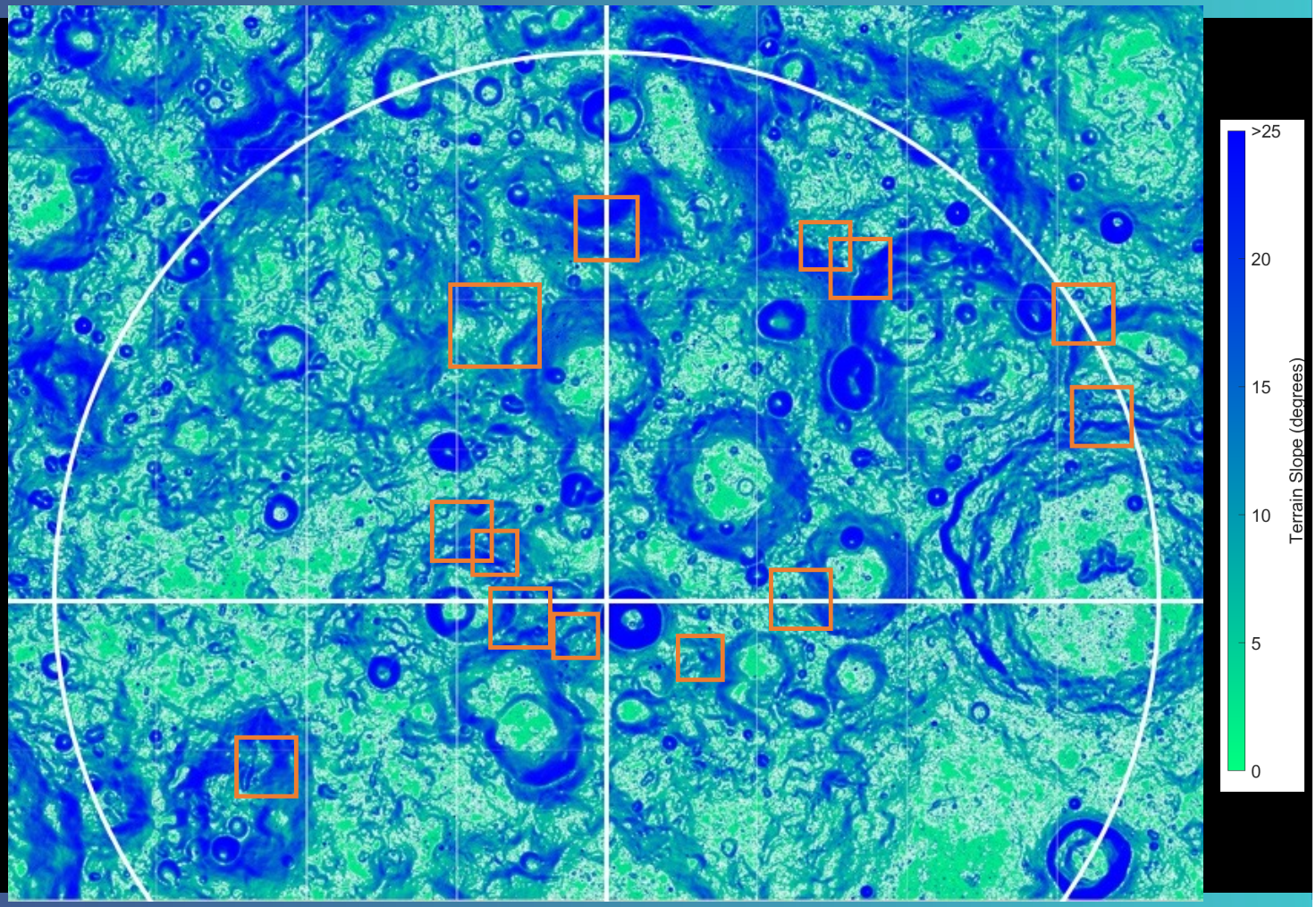
https://pgda.gsfc.nasa.gov/products/78

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

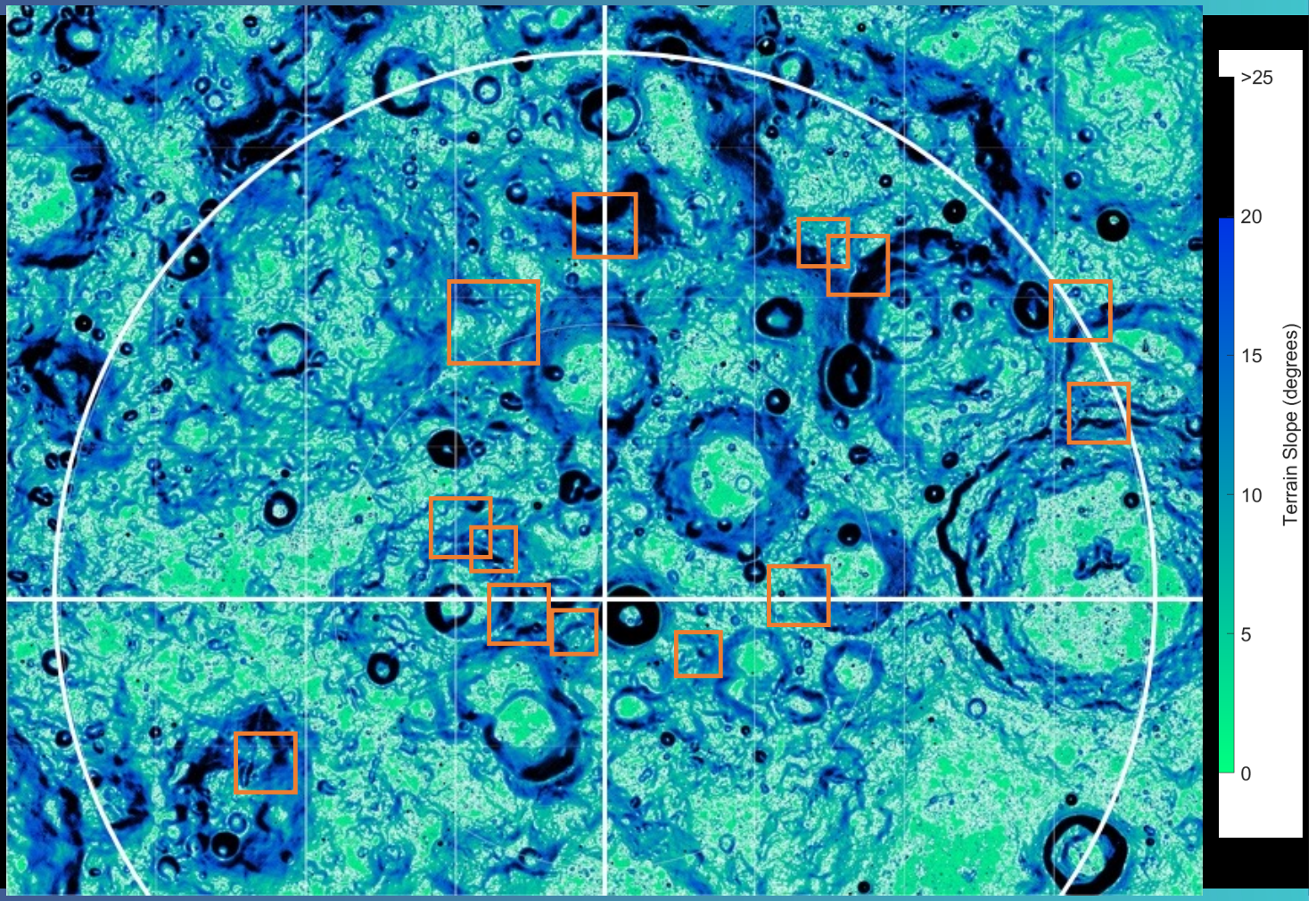


3. Surface slope for EVA: <20 deg

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

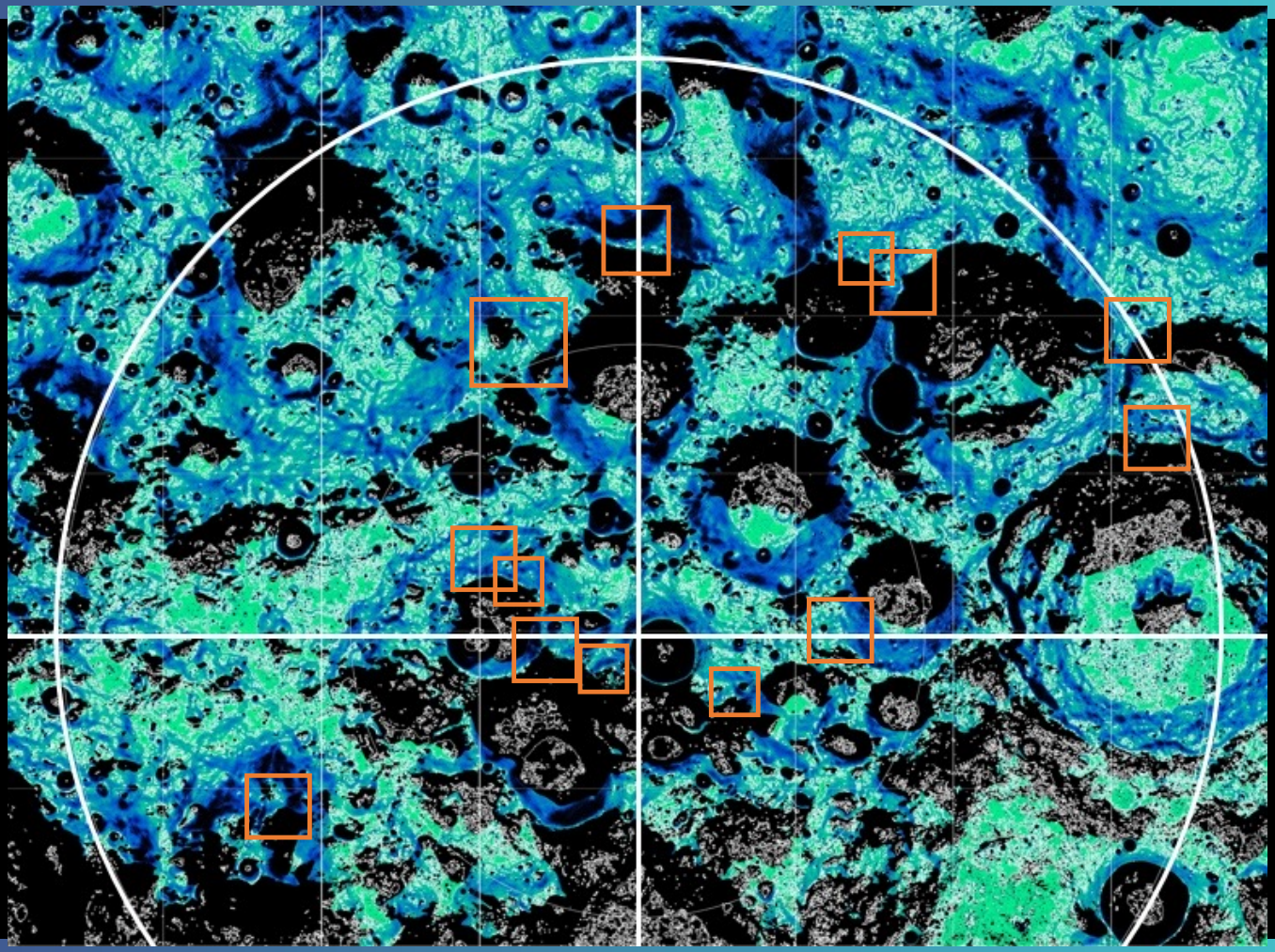


4. Direct with Earth Communication

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.

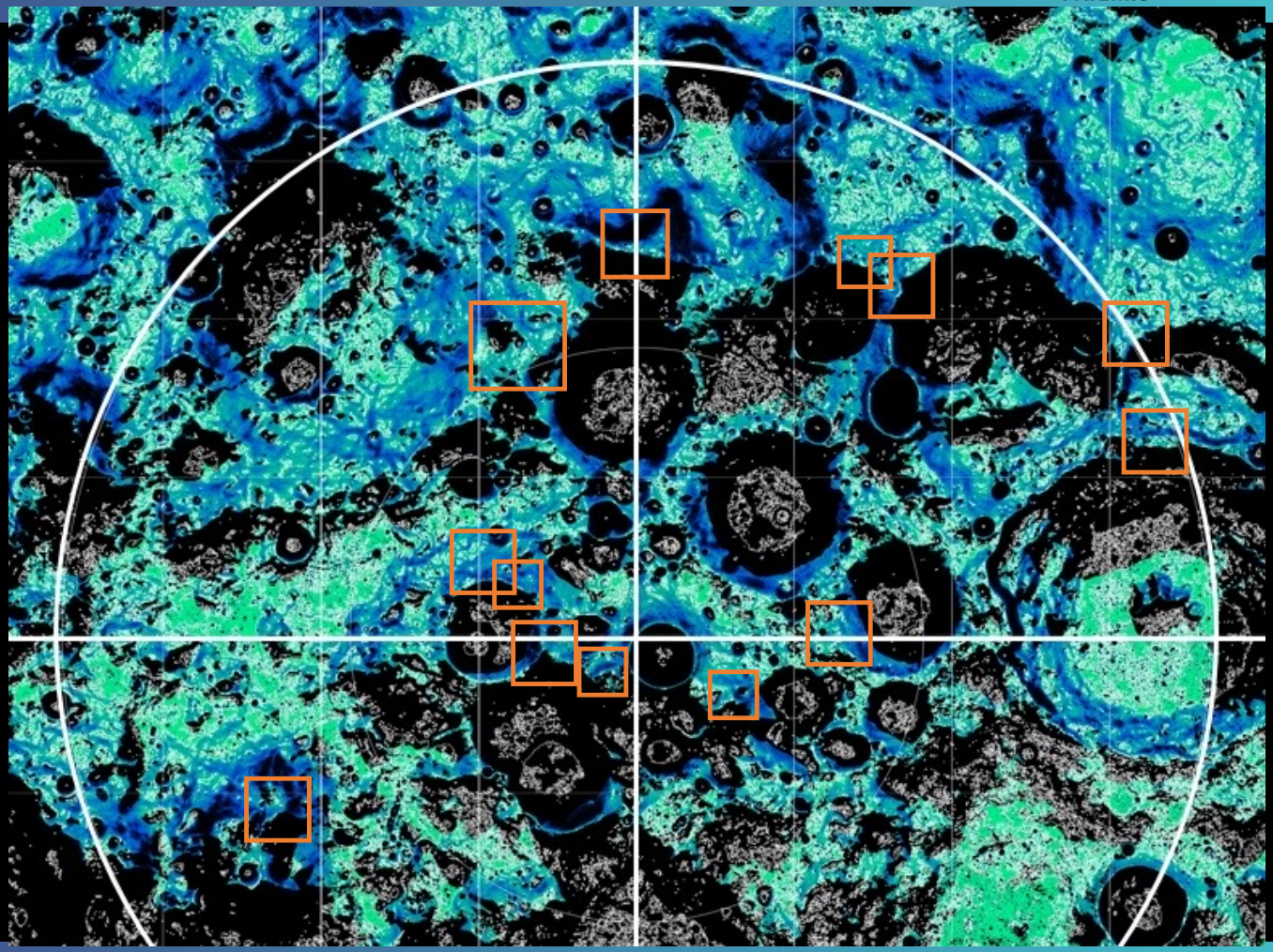


5a. Surface Lighting

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.

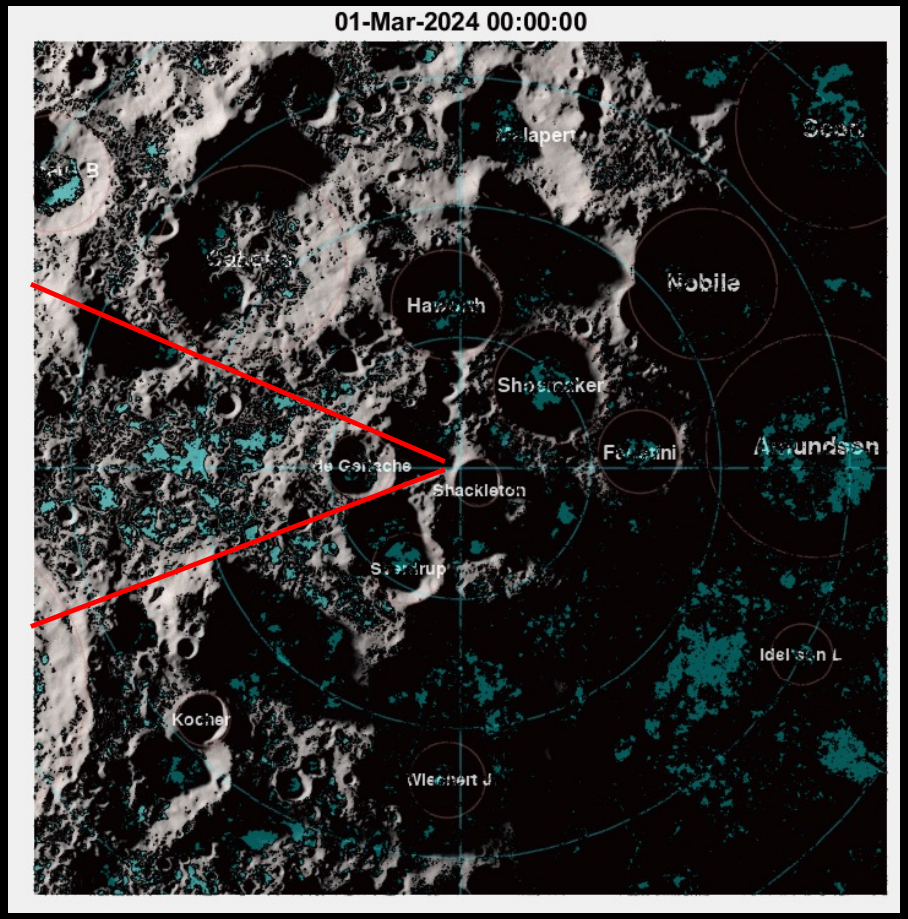


5b. Approach Lighting

Illumination along the approach trajectory is beneficial.

The approach trajectory is different for each landing opportunity.

Notional range designated in red



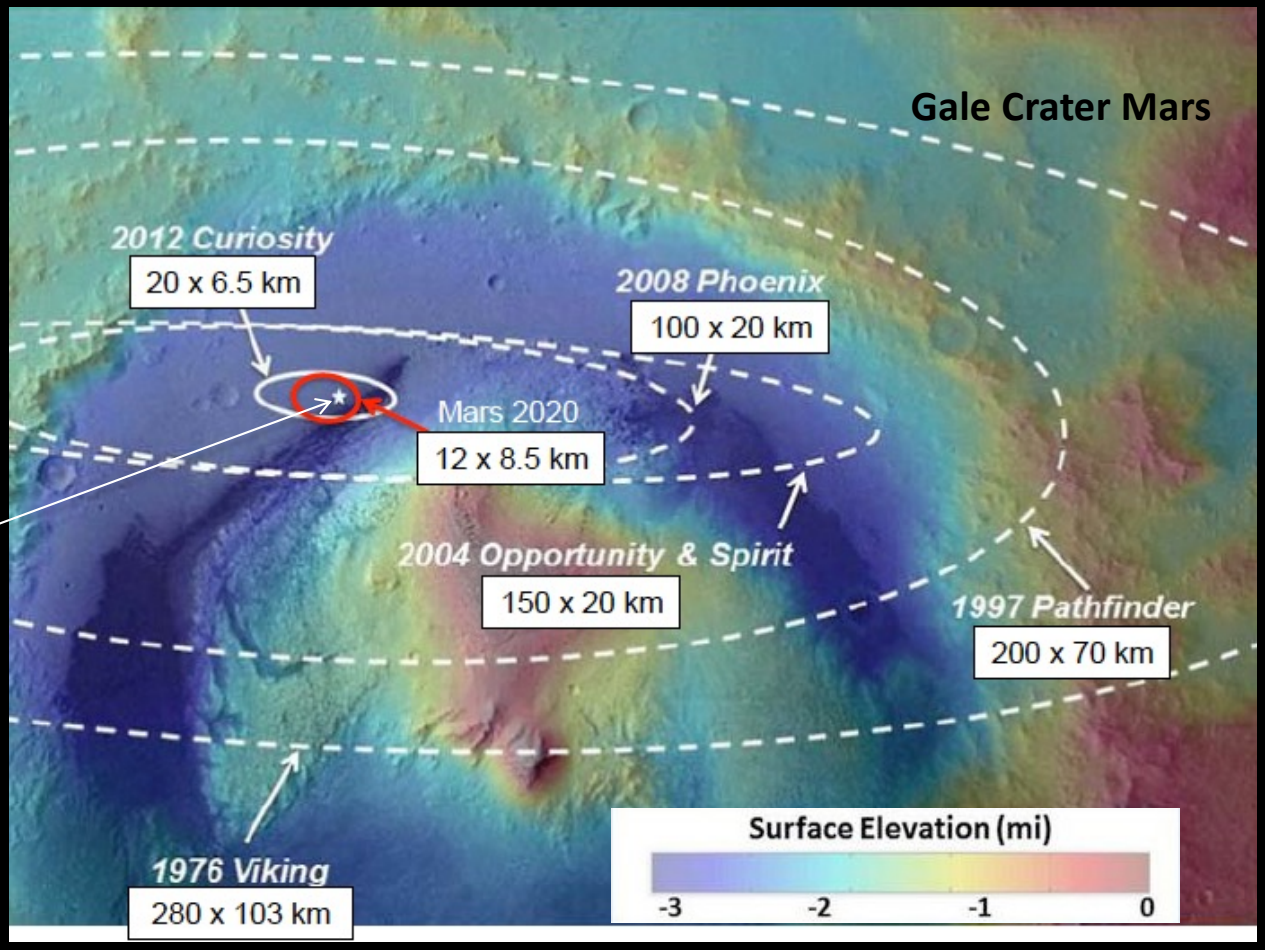
Peak lighting conditions are periodic and shift 2-3 weeks earlier each year, where by 2030, peak solar illumination occurs around the month of August

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



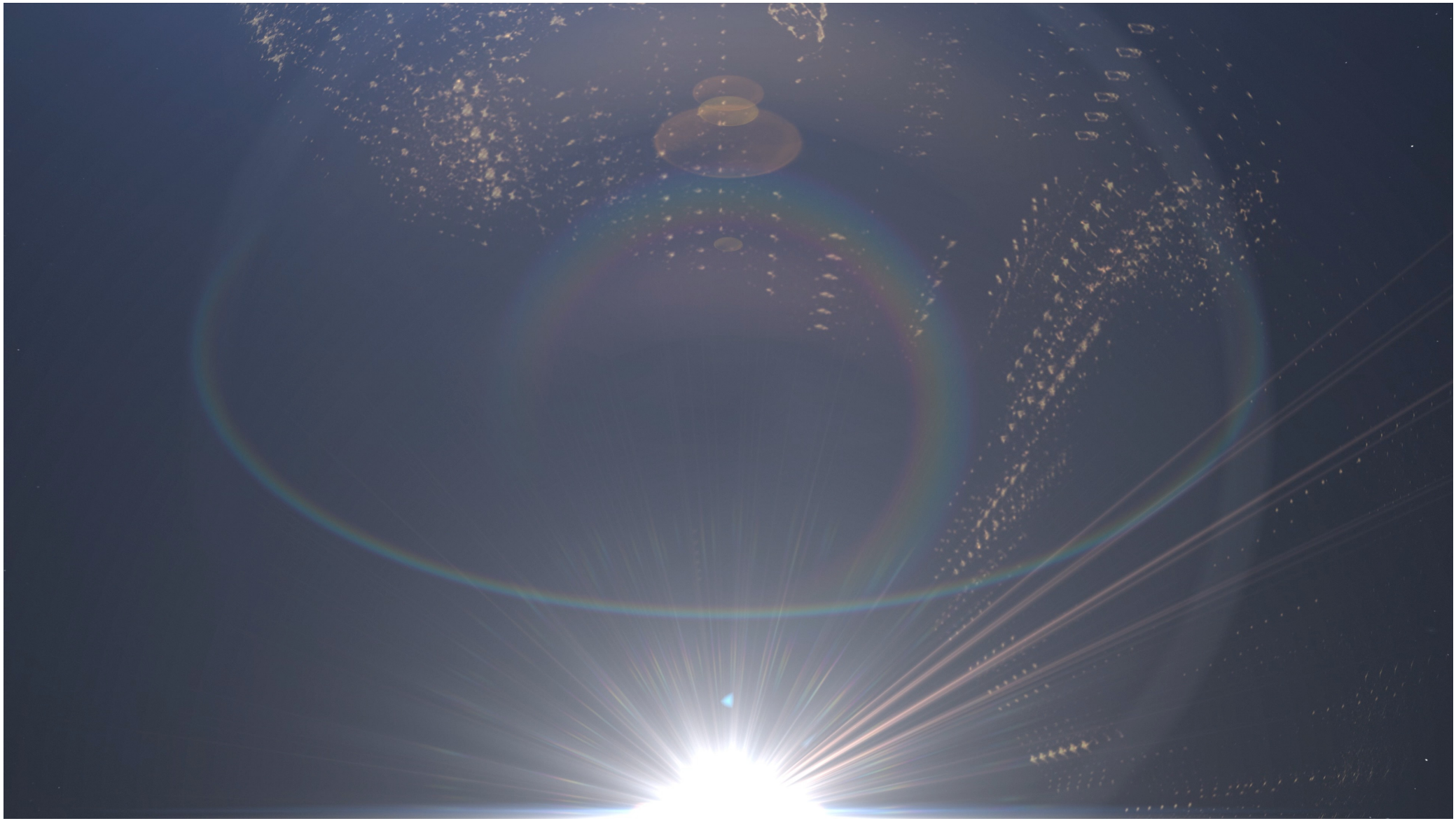
Looking Forward

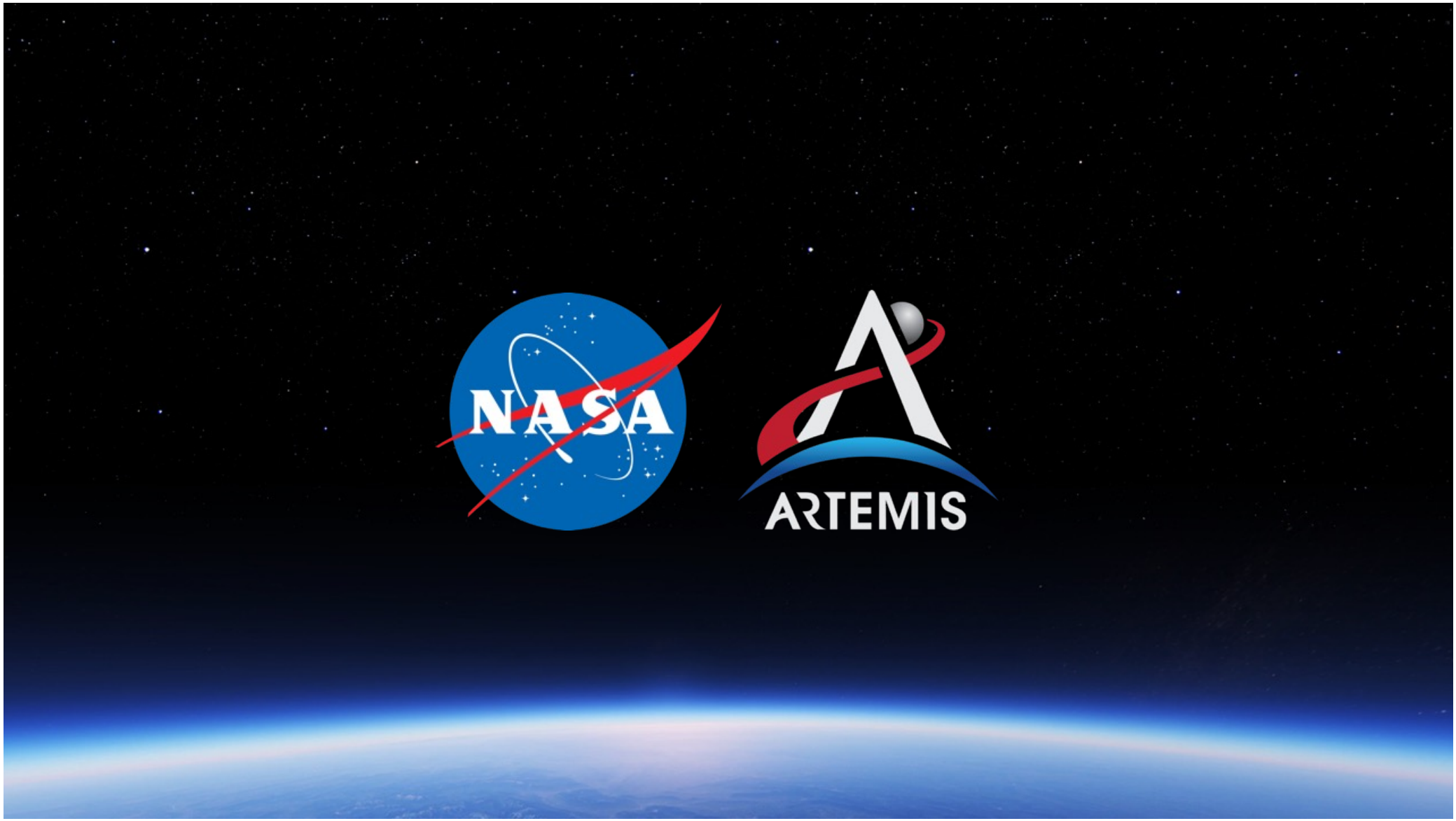
ARTEMIS IV

International Habitation Module delivery to Gateway

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. Crew Returns to Orion
13. Orion Performs Return Powered Flyby
14. Final Return Trajectory Correction Burn
15. Crew Module Separation
16. Entry Interface
17. Splashdown


ARTEMIS
WE GO




NASA
ARTEMIS