Why and How NASA is Returning to the Moon

October 2022

ARTEMIS

Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA's program to return astronauts to the lunar surface including the first female on the Moon.

When they land, Artemis astronauts will step foot where no human has ever been before: the Moon's South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.

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“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

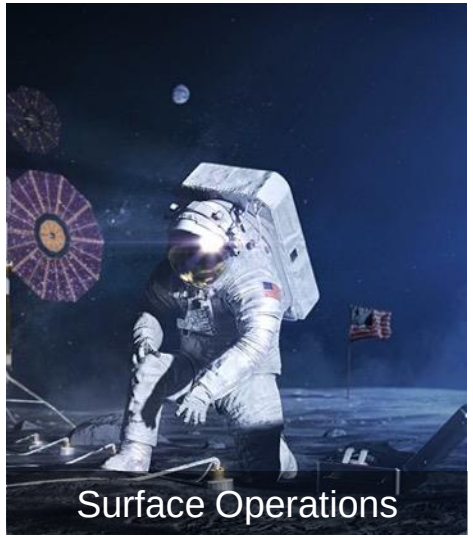
United States Space Priorities Framework
NASA 2022 Strategic Plan
2023 NASA Budget Request

Artemis: A Foundation for Deep Space Exploration


Space Launch System


Orion spacecraft


Human Landing System


Surface Operations

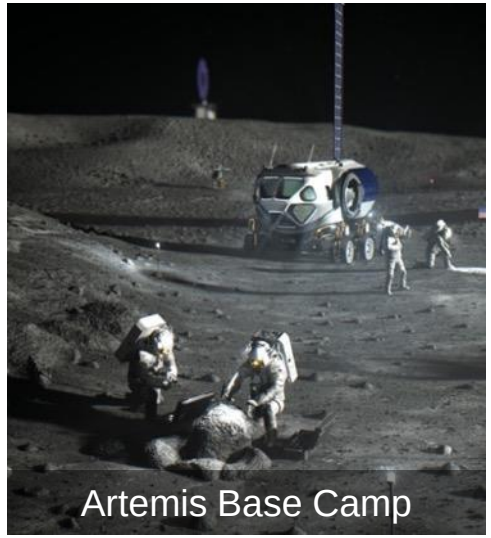

Gateway


Exploration Ground Systems


Space Communications & Navigation


Surface Mobility

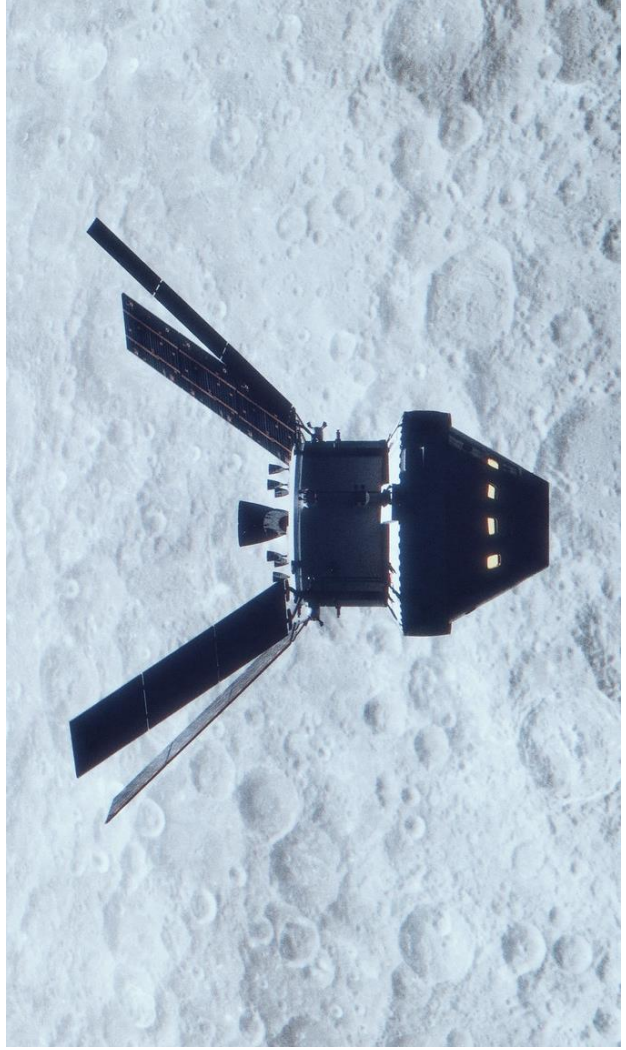

Spacesuits


Artemis Base Camp

Artemis I: 2022

Uncrewed Flight Test

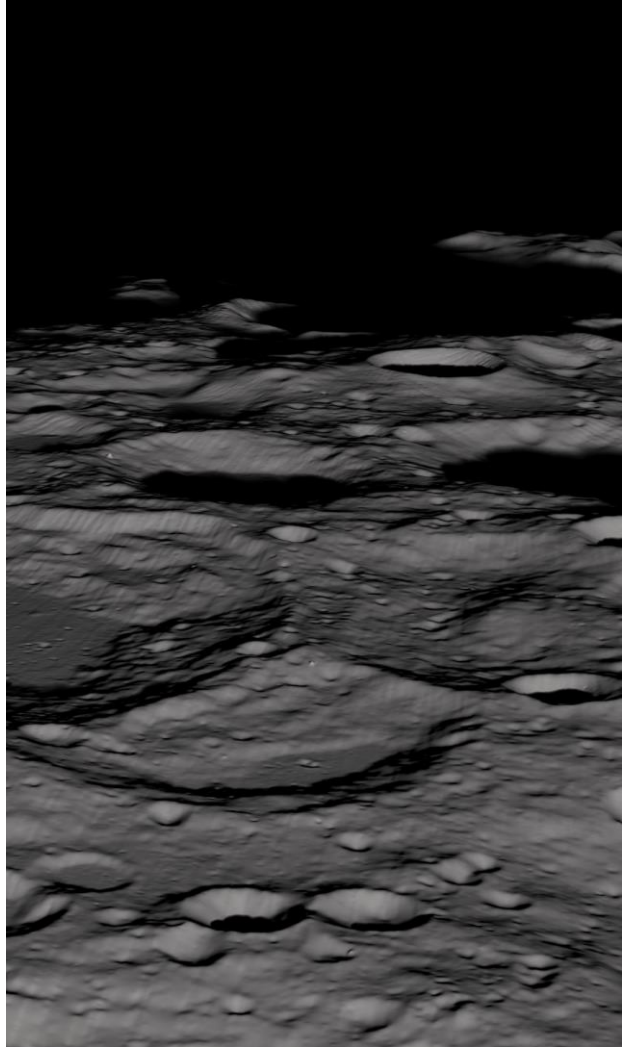
Space Launch System & Orion Spacecraft



Artemis II: 2024

Crewed Flight Test

Space Launch System & Orion Spacecraft



SpaceX Uncrewed Demo

Uncrewed Starship Demonstration to the lunar surface

Artemis III: 2025

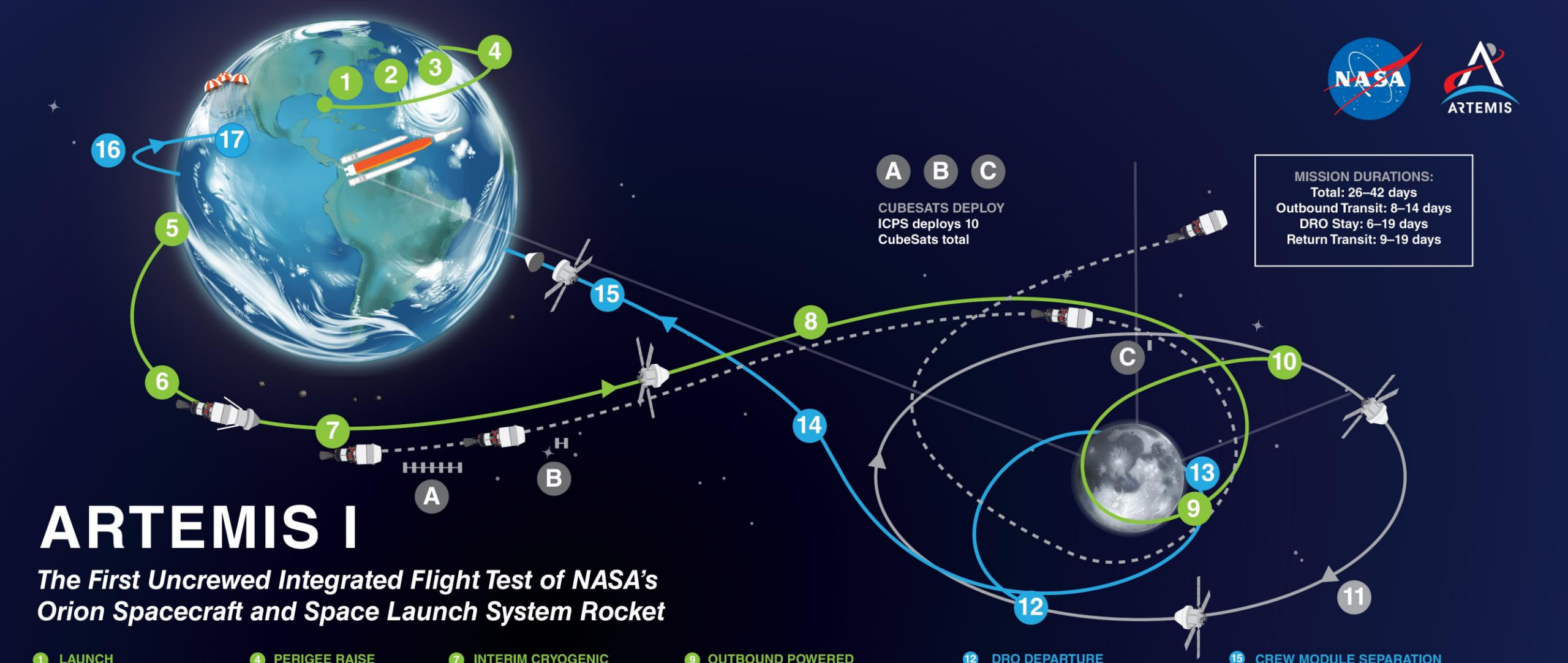
Crewed Starship Demonstration to the lunar surface

Artemis I Mission Highlights:

First flight of SLS and Orion

Uncrewed flight test of the Space Launch System (SLS) rocket, Orion spacecraft, and Exploration Ground Systems (EGS) at Kennedy Space Center

- Operate systems in flight environment
- Demonstrate Orion heatshield at lunar re-entry conditions
- Retrieve spacecraft



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

CUBESATS DEPLOY
ICPS deploys 10 CubeSats total

MISSION DURATIONS:
Total: 26–42 days
Outbound Transit: 8–14 days
DRO Stay: 6–19 days
Return Transit: 9–19 days

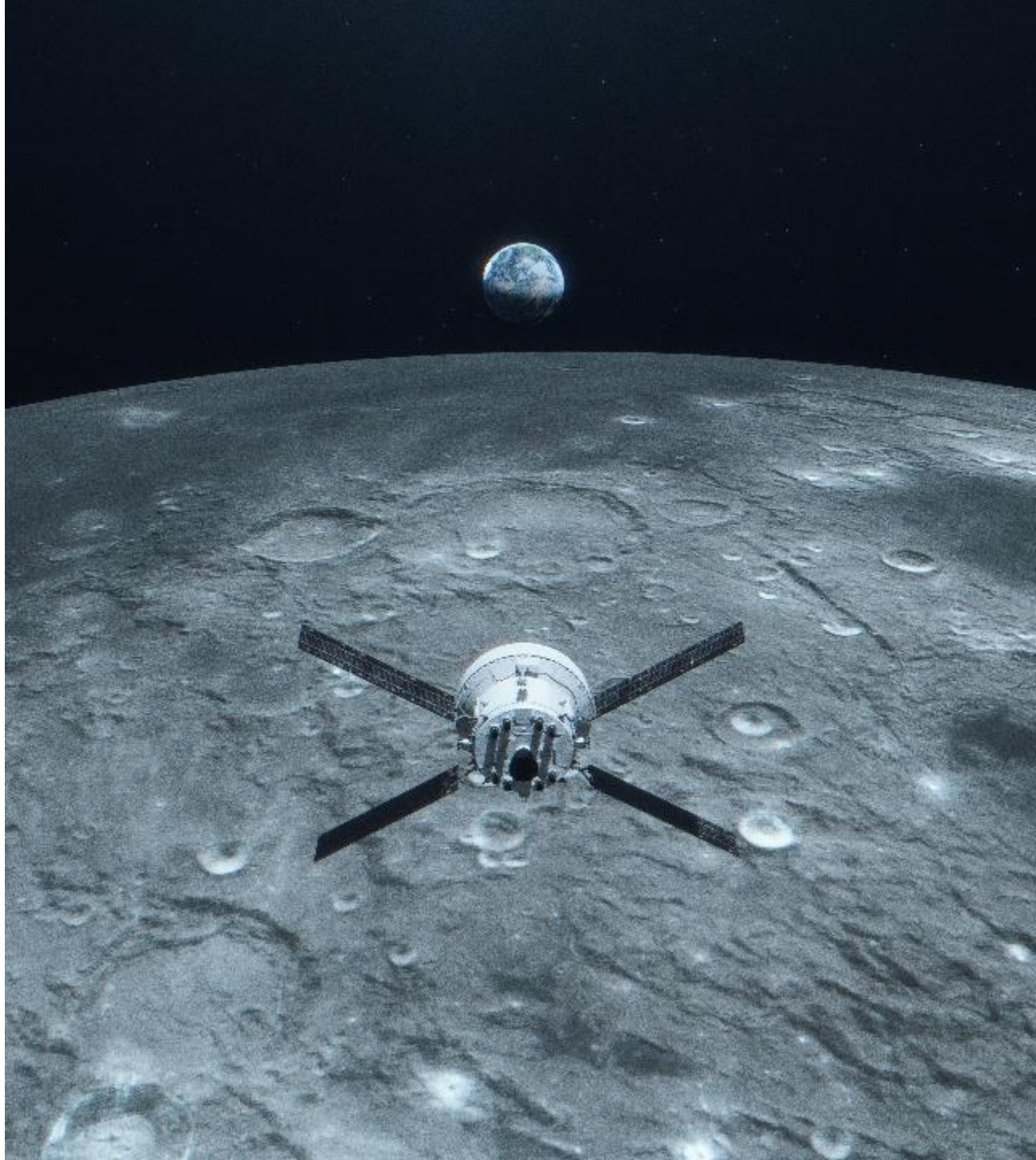
1. **LAUNCH**
   SLS and Orion lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **EARTH ORBIT**
   Systems check with solar panel adjustments.
6. **TRANS LUNAR INJECTION (TLI) BURN**
   Maneuver lasts for approximately 20 minutes.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
   ICPS commits Orion to moon at TLI.
8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
   As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
9. **OUTBOUND POWERED FLYBY (OPF)**
   60 nmi from the Moon; targets DRO insertion.
10. **LUNAR ORBIT INSERTION**
    Enter Distant Retrograde Orbit.
11. **DISTANT RETROGRADE ORBIT**
    Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.
12. **DRO DEPARTURE**
    Leave DRO and start return to Earth.
13. **RETURN POWERED FLYBY (RPF)**
    RPF burn prep and return coast to Earth initiated.
14. **RETURN TRANSIT**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**
16. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
17. **SPLASHDOWN**
    Pacific Ocean landing within view of the U.S. Navy recovery ship.

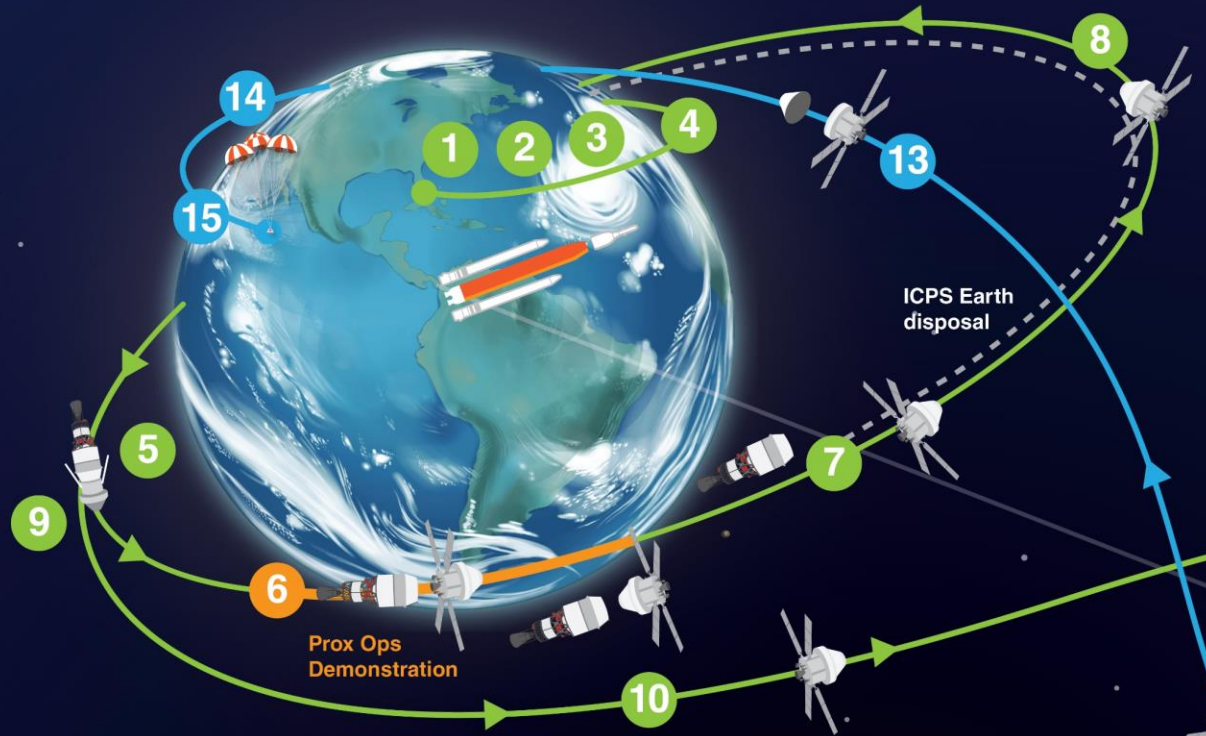
03/28/2022

Artemis II Mission Highlights:

First crewed flight of SLS and Orion

- Fly up to four astronauts to cislunar space for the first time in more than 50 years
- Return the crew safely after the mission
- Perform a lunar flyby
- Perform rendezvous and proximity operations
- Retrieve spacecraft





ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1 LAUNCH
Astronauts lift off from pad 39B at Kennedy Space Center.

2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM

3 CORE STAGE MAIN ENGINE CUT OFF
With separation.

4 PERIGEE RAISE MANEUVER

5 APOGEE RAISE BURN TO HIGH EARTH ORBIT
Begin 24 hour checkout of spacecraft.

6 PROX OPS DEMONSTRATION
Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.

7 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN

8 HIGH EARTH ORBIT CHECKOUT
Life support, exercise, and habitation equipment evaluations.

9 TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE
Lunar free return trajectory initiated with European service module.

10 OUTBOUND TRANSIT TO MOON
4 days outbound transit along free return trajectory.

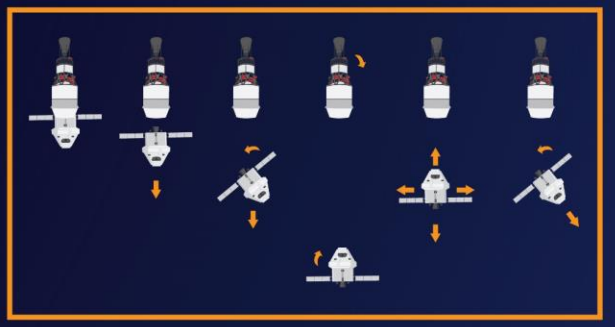
11 LUNAR FLYBY
4,000 nmi (mean) lunar farside altitude.

12 TRANS-EARTH RETURN
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.

13 CREW MODULE SEPARATION FROM SERVICE MODULE

14 ENTRY INTERFACE (EI)
Enter Earth's atmosphere.

15 SPLASHDOWN
Ship recovers astronauts and capsule.



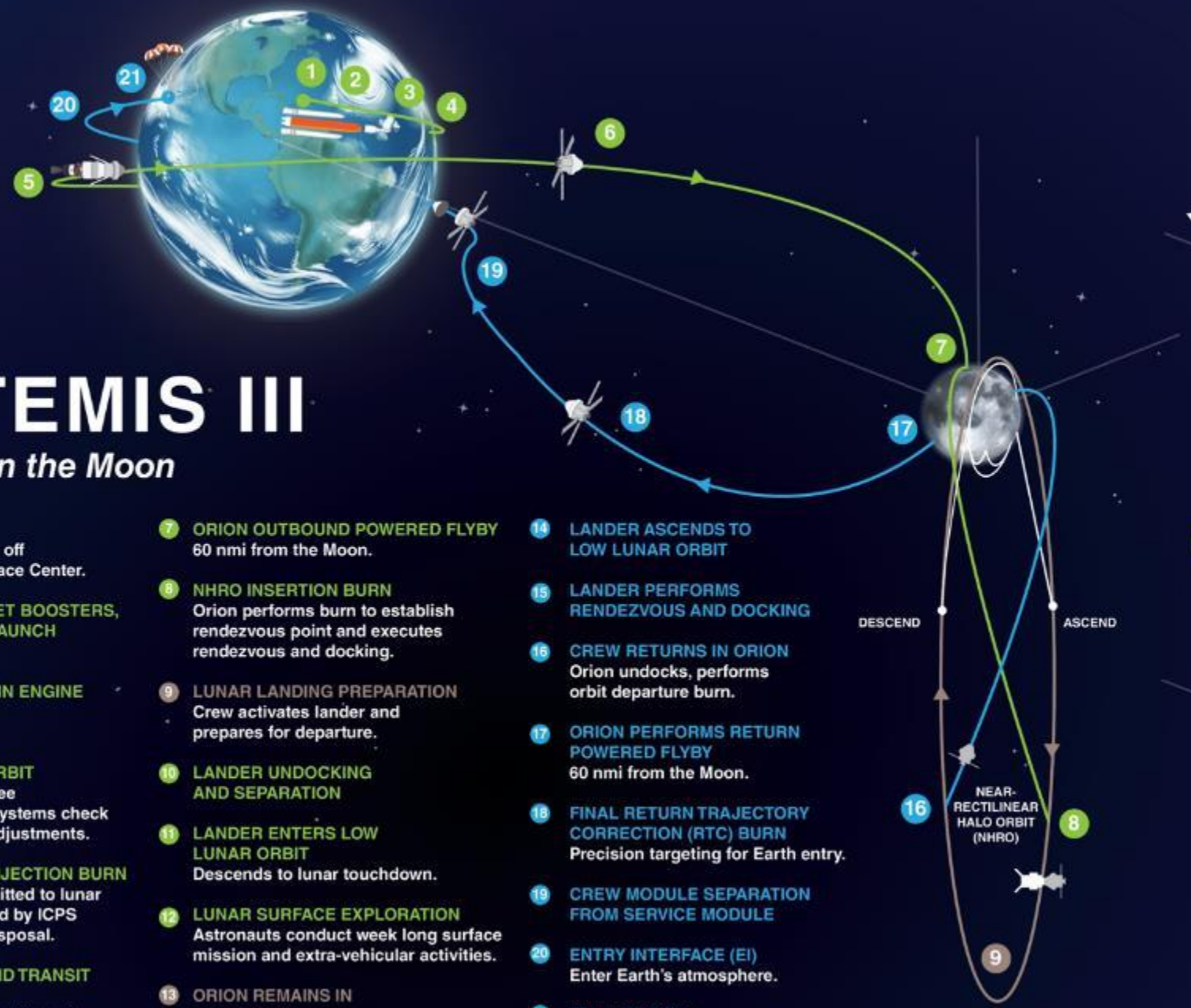
PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

03/28/2022

Artemis III Highlights:

First woman on the Moon

- First humans on the Moon’s South Pole
- Return the crew safely home after the mission
- First moonwalk in more than 50 years
  - Rock and soil samples
  - Atmosphere samples
  - Geological data
  - Photos and videos



ARTEMIS III

Landing on the Moon

1. **LAUNCH**
   SLS and Orion lift off from Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **ENTER EARTH ORBIT**
   Perform the perigee raise maneuver. Systems check and solar panel adjustments.
5. **TRANS LUNAR INJECTION BURN**
   Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
6. **ORION OUTBOUND TRANSIT TO MOON**
   Requires several outbound trajectory burns.
7. **ORION OUTBOUND POWERED FLYBY**
   60 nmi from the Moon.
8. **NHRO INSERTION BURN**
   Orion performs burn to establish rendezvous point and executes rendezvous and docking.
9. **LUNAR LANDING PREPARATION**
   Crew activates lander and prepares for departure.
10. **LANDER UNDOCKING AND SEPARATION**
11. **LANDER ENTERS LOW LUNAR ORBIT**
    Descends to lunar touchdown.
12. **LUNAR SURFACE EXPLORATION**
    Astronauts conduct week long surface mission and extra-vehicular activities.
13. **ORION REMAINS IN NHRO ORBIT**
    During lunar surface mission.
14. **LANDER ASCENDS TO LOW LUNAR ORBIT**
15. **LANDER PERFORMS RENDEZVOUS AND DOCKING**
16. **CREW RETURNS IN ORION**
    Orion undocks, performs orbit departure burn.
17. **ORION PERFORMS RETURN POWERED FLYBY**
    60 nmi from the Moon.
18. **FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
    Precision targeting for Earth entry.
19. **CREW MODULE SEPARATION FROM SERVICE MODULE**
20. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
21. **SPLASHDOWN**
    Ship recovers astronauts and capsule

10/7/2021

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, the mission that will put the next two Americans on the surface of the Moon, including the first woman.

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

20220808

ARTEMIS III

CREW SURFACE OPERATIONS

Two crew live in the landing system cabin for 6.5 days on the lunar surface

Goal of up to four moonwalks, with reserves for a fifth contingency moonwalk

Collect a variety of samples to return to Earth for later research:

- Rock samples to help date the sequence of impact events on the Moon
- Core tube samples to capture ancient solar wind trapped in regolith layers
- Paired samples of material within and outside a permanently shadowed region

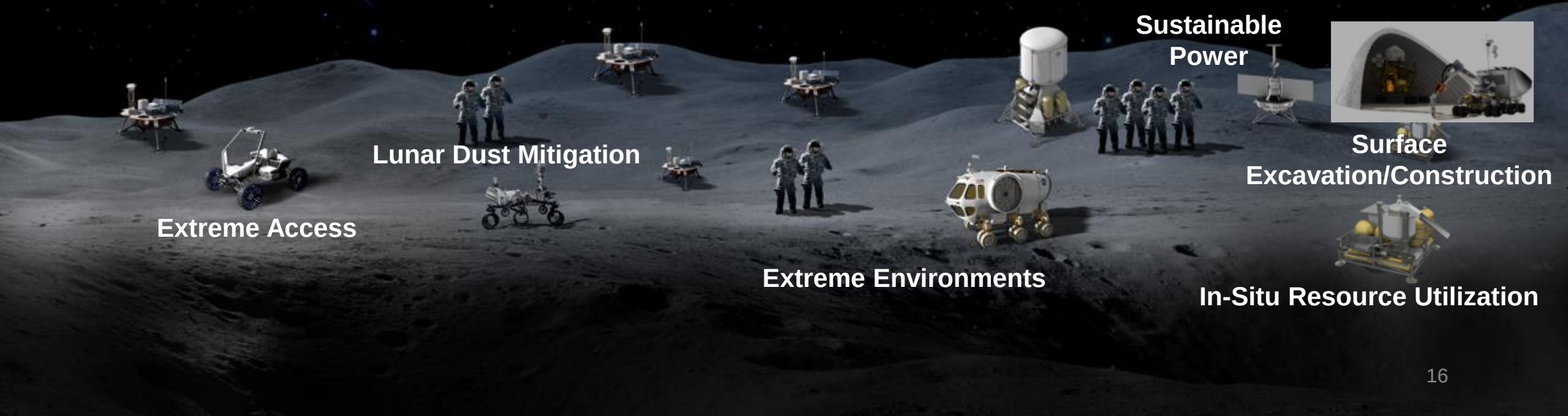
The ARTEMIS Science Objectives

- Study Planetary Processes
- Understand Volatile Cycles
- Interpret the Impact History of the Earth-Moon System
- Reveal the Record of the Ancient Sun
- Observe the Universe from a Unique Location
- Conduct Experimental Science in the Lunar Environment
- Investigate and Mitigate Exploration Risks to Humans

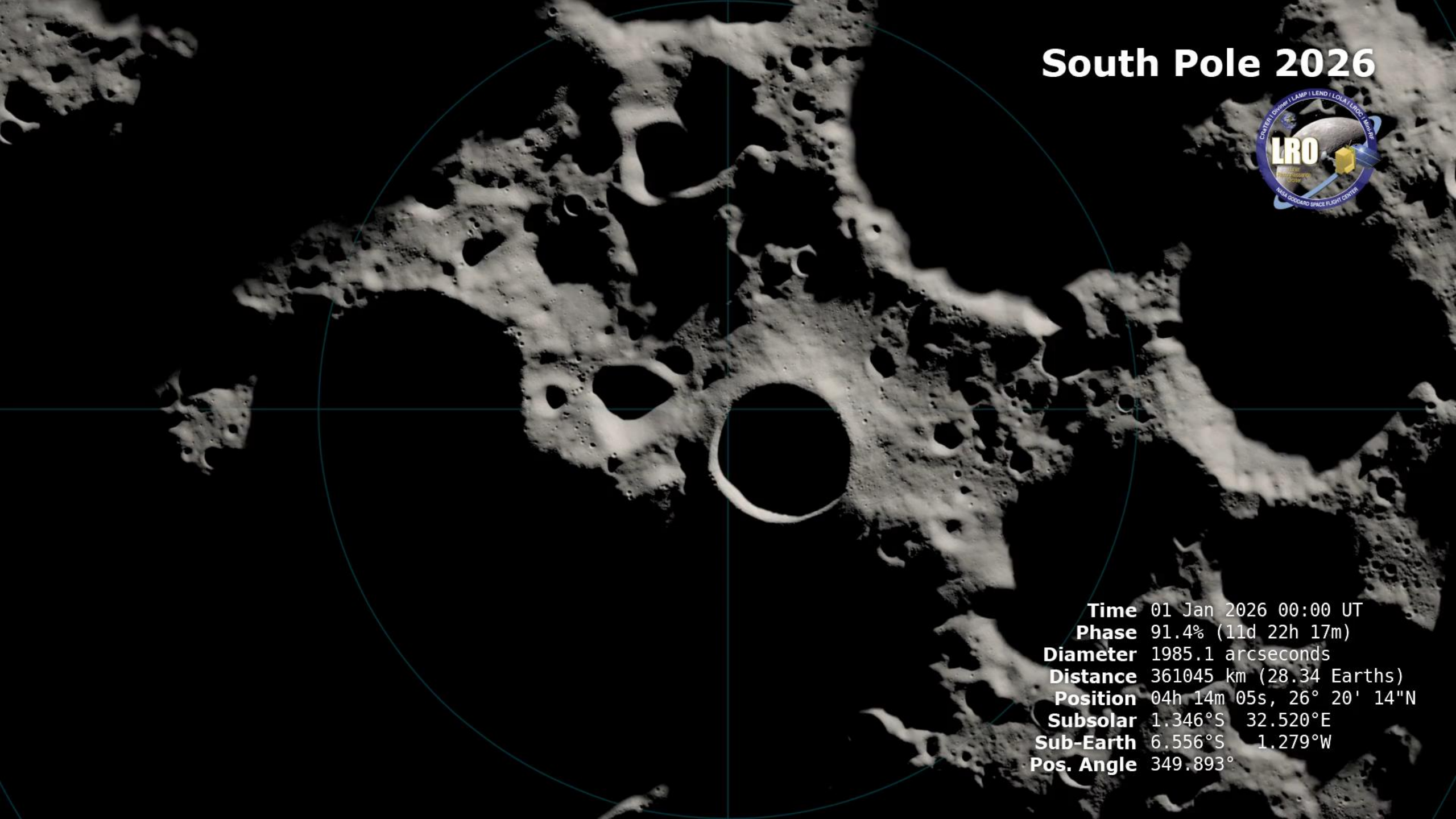
ARTEMIS Technology Objectives

The Lunar Surface Innovative Initiative works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities for lunar surface exploration.

- **In-situ resource utilization** technologies for collecting, processing, storing, and using material found or manufactured on the Moon or other planetary bodies
- **Surface power technologies** that provide the capability for sustainable, continuous power throughout the lunar day and night
- **Dust mitigation technologies** that diminish dust hazards on lunar surface systems such as cameras, solar panels, space suits, and instrumentation
- **Extreme environment technologies** that enable systems to operate throughout the range of lunar surface temperatures
- **Extreme access technologies** that enable humans or robots to efficiently access, navigate, and explore previously inaccessible lunar surface or subsurface areas
- **Excavation and construction technologies** that enable affordable, autonomous manufacturing or construction



South Pole 2026



Time	01 Jan 2026 00:00 UT
Phase	91.4% (11d 22h 17m)
Diameter	1985.1 arcseconds
Distance	361045 km (28.34 Earths)
Position	04h 14m 05s, 26° 20' 14"N
Subsolar	1.346°S 32.520°E
Sub-Earth	6.556°S 1.279°W
Pos. Angle	349.893°

Artemis III Candidate Landing Regions

KEY LANDING REGION CONSIDERATIONS

Proximity to the South Pole

Gentle slope for landing and moonwalks

Constant view to Earth for communications

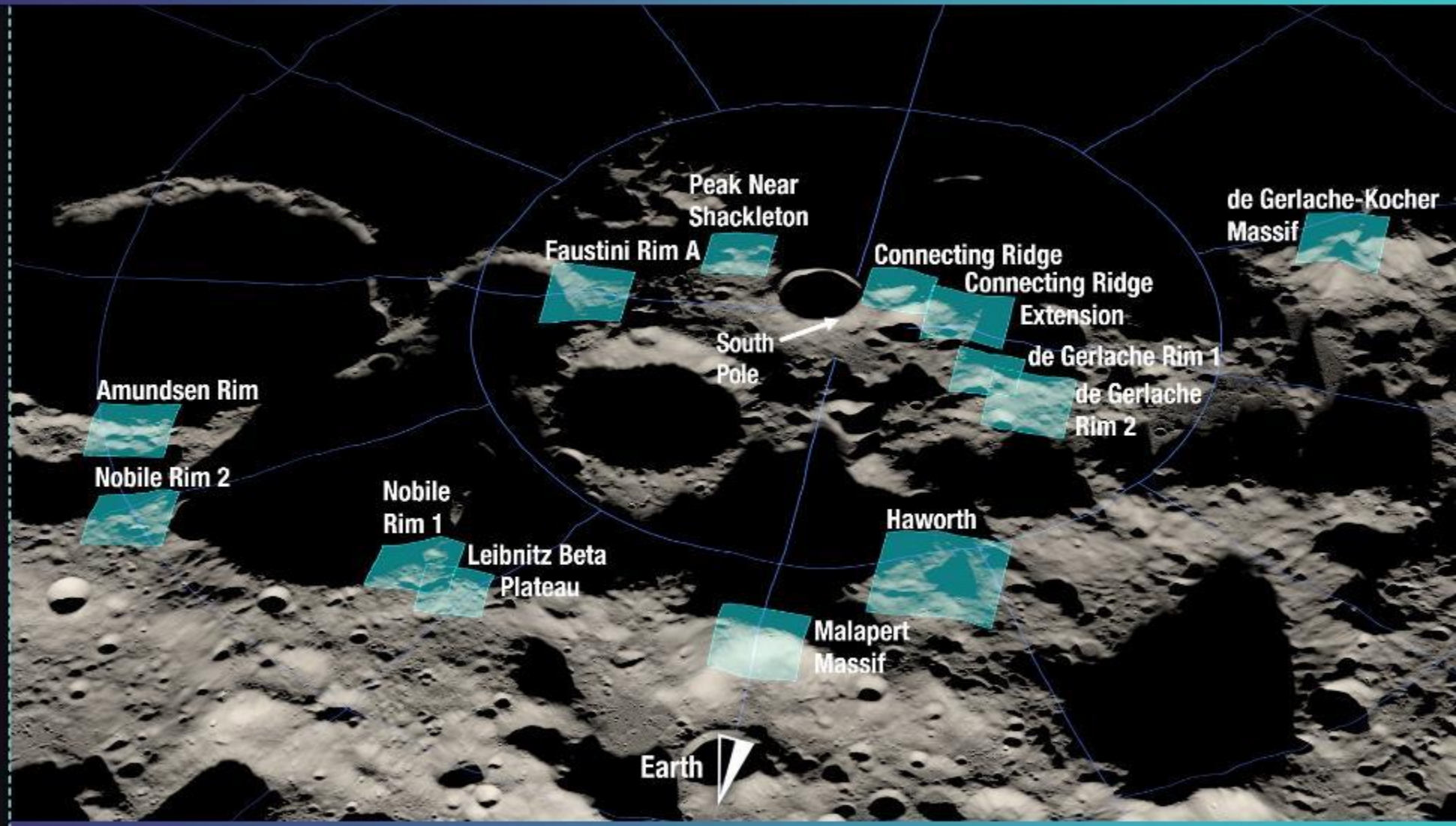
Continuous sunlight throughout the surface expedition of about 6.5 days

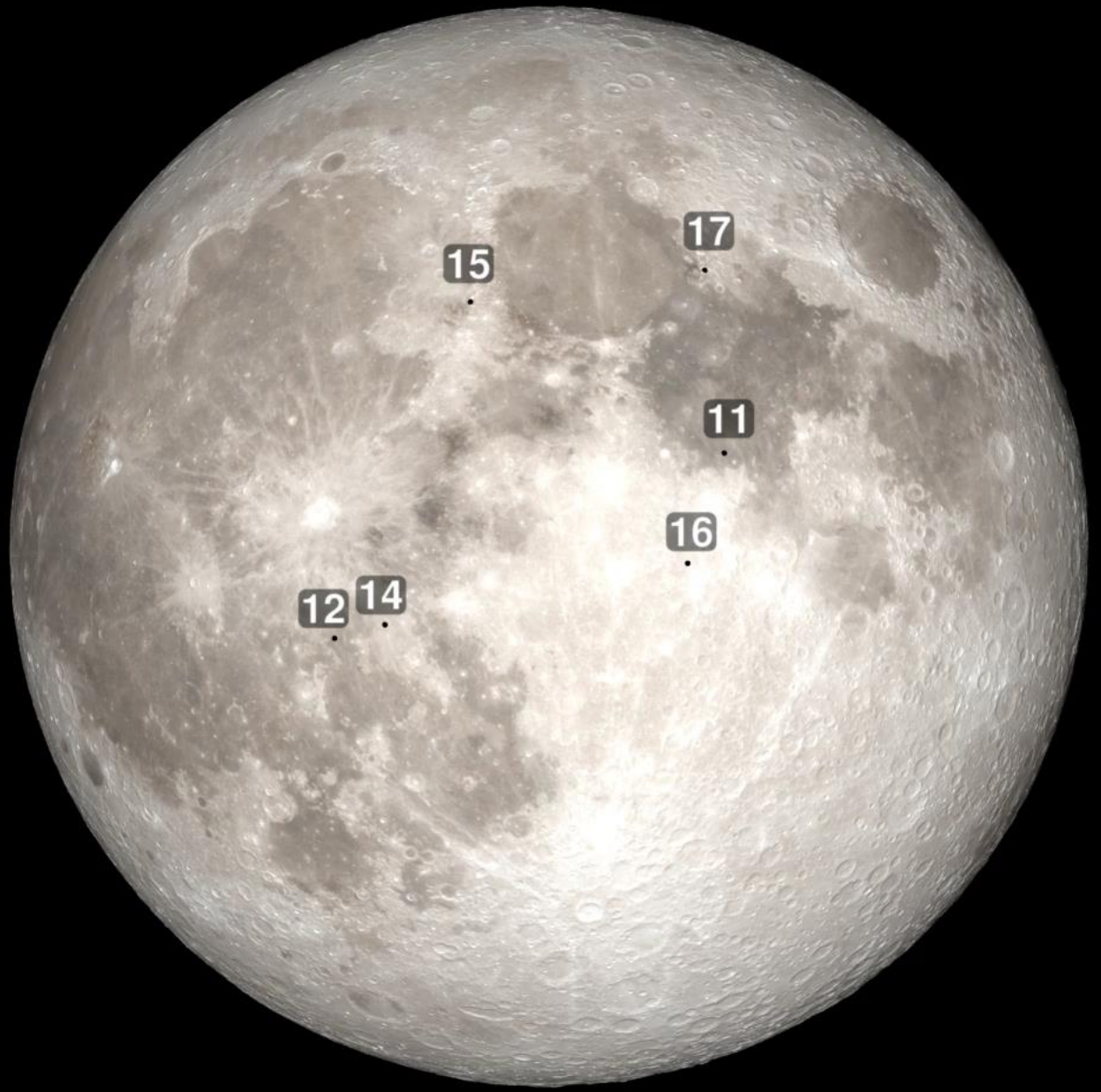
Landing Accuracy

Surface data resolution

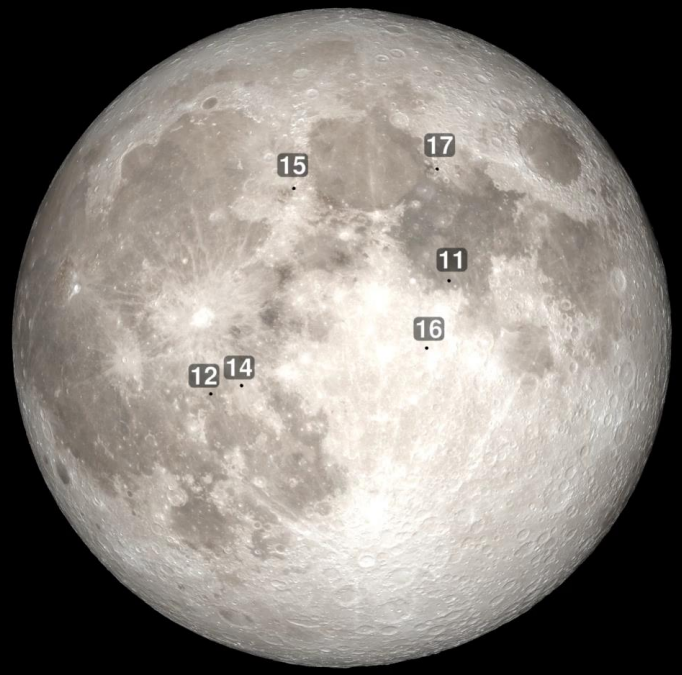
Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

A landing *region* is approximately 15 km^2. Each landing region includes multiple potential landing sites.




17
15
11
16
12
14

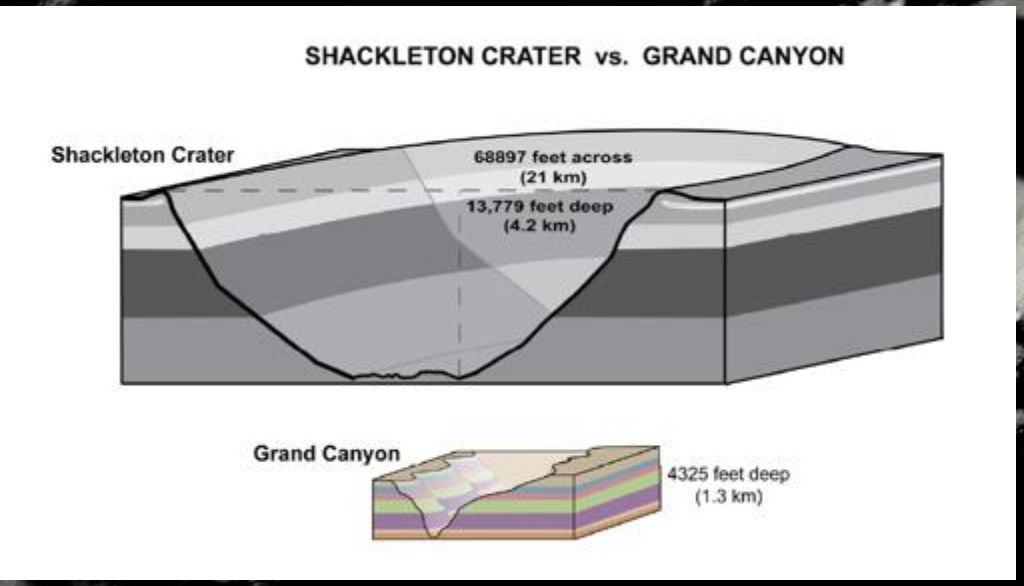
LUNAR SOUTH POLE

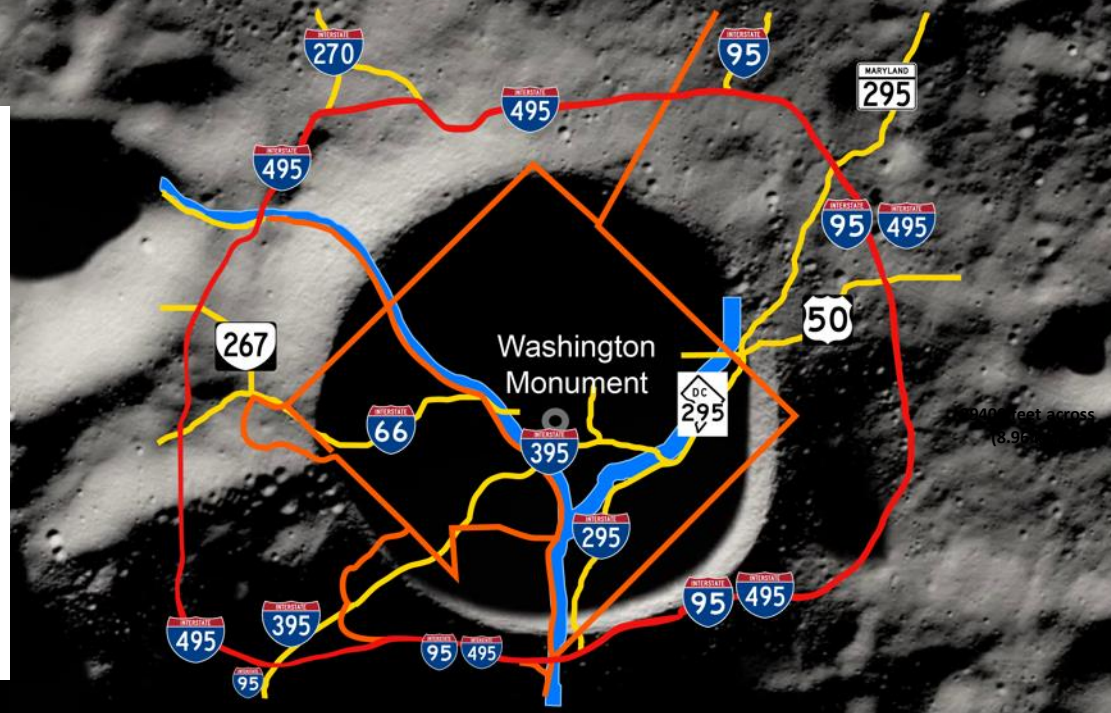


- Long duration access to sunlight
- Direct to Earth communication
- Surface roughness and slope
- Permanently Shadowed Regions and Volatiles

Viewing the Earth from the South Pole
https://svs.gsfc.nasa.gov/4944

Scale of Shackleton Crater





~20 km in diameter, ~4 km deep and ~3x deeper and wider than the Grand Canyon

(*and approximate size of the Capitol Beltway as depicted above*)

Initial Human Landing System

HLS

NASA has awarded SpaceX a contract to develop the human landing system that will put the next two Americans on the surface of the Moon.

The contract includes one uncrewed and one crewed demonstration mission, the first surface landing of Artemis.

Image Credit: SpaceX

Human Landing System

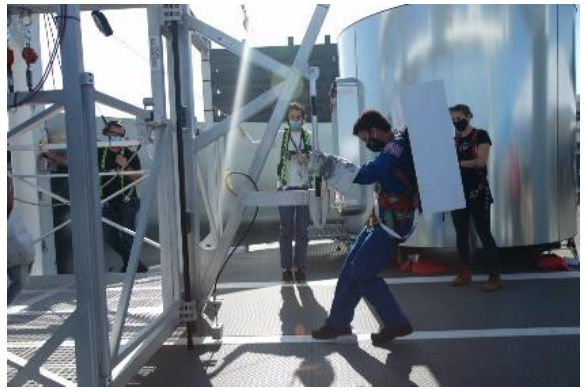
- Firm Fixed Price Broad Agency Announcement for rapid development and crewed demonstration to return humans to the lunar surface
- Leveraging commercial capabilities to the maximum extent possible; may tailor the traditional NASA program management and systems engineering processes to expedite the schedule
- NASA will not take ownership of the HLS hardware/software
- HLS will launch as commercial payload uncrewed; checkout and testing will occur on orbit prior to any crew launch and egress
- NASA provides certification and technical expertise

The HLS plan is to leverage the speed and operating models of the commercial space industry while applying NASA expertise to ensure safety and mission success

Artemis III Starship HLS Progress

Image Credit: SpaceX

Crew and cargo elevator



Crew cabin VR evaluation

Airlock


GATEWAY
NASA
CSA ASC
esa
JAXA

On the Surface of the Moon Sustaining Missions

Emergence Of Cislunar Space

Why Cislunar Space?

A Strategic High Ground

- U.S. national interests and leadership
- Geopolitical competition at cislunar/lunar
- National security considerations beyond GEO
- Expand current LEO human presence
- Economic opportunities
- Gateway for exploration of the solar system
- Possible lunar and other resources for future exploration

Moon Before Mars

On the Moon, we can take reasonable risks while astronauts are just three days away from home.

There we will prove technologies and mature systems necessary to live and work on another world before embarking on what could be a 2-3 year mission to Mars.

Mission Needs Drive Design

LOW EARTH RETURN

3 HOURS
3,000°F
17,500 MPH
250 MILES

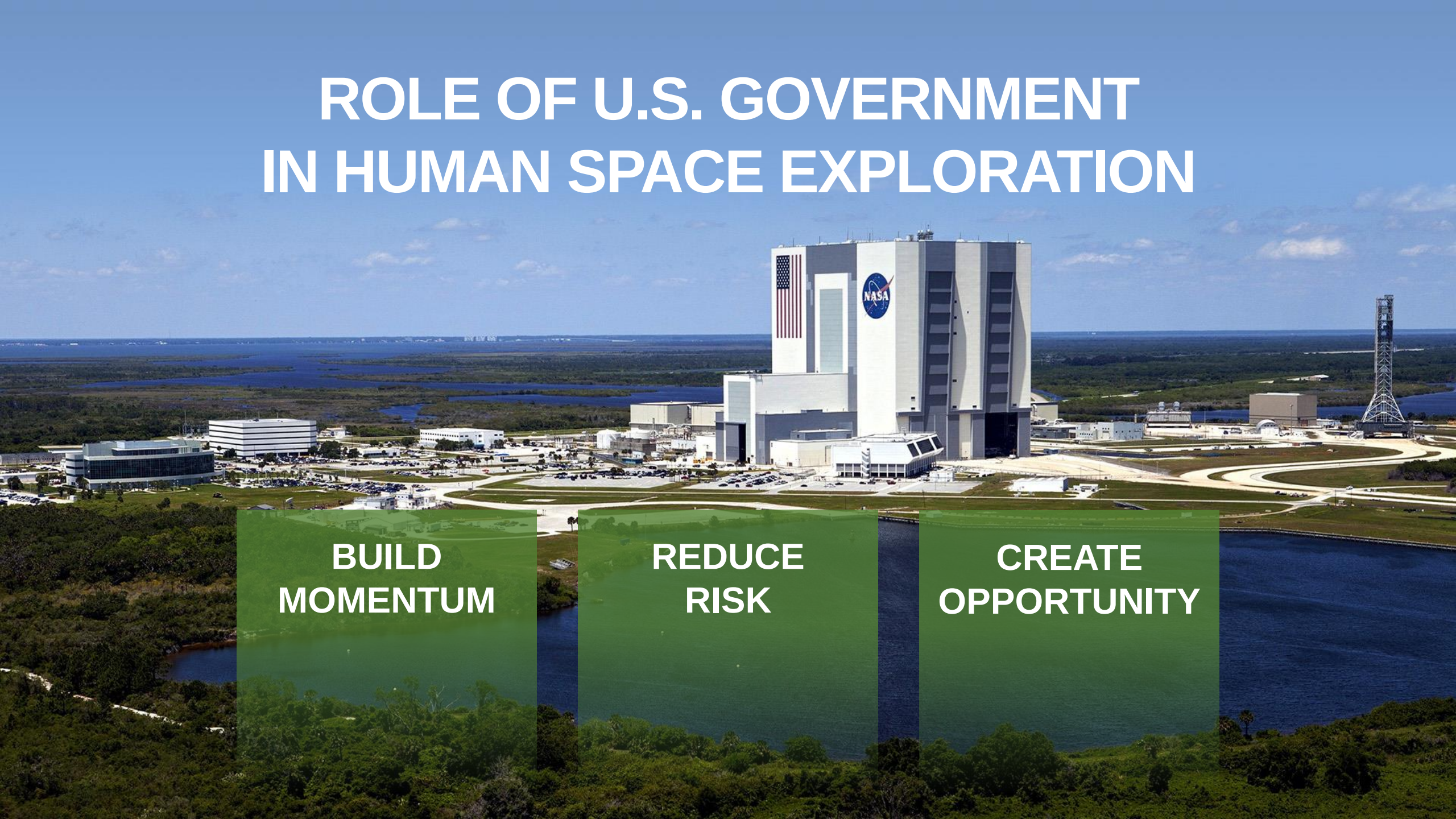
LUNAR RETURN

3 DAYS
5,200°F
24,700 MPH
240,000 MILES

MARS RETURN

9 MONTHS
6,200°F
26,800 MPH
39,000,000 MILES

ROLE OF U.S. GOVERNMENT IN HUMAN SPACE EXPLORATION



ARTEMIS

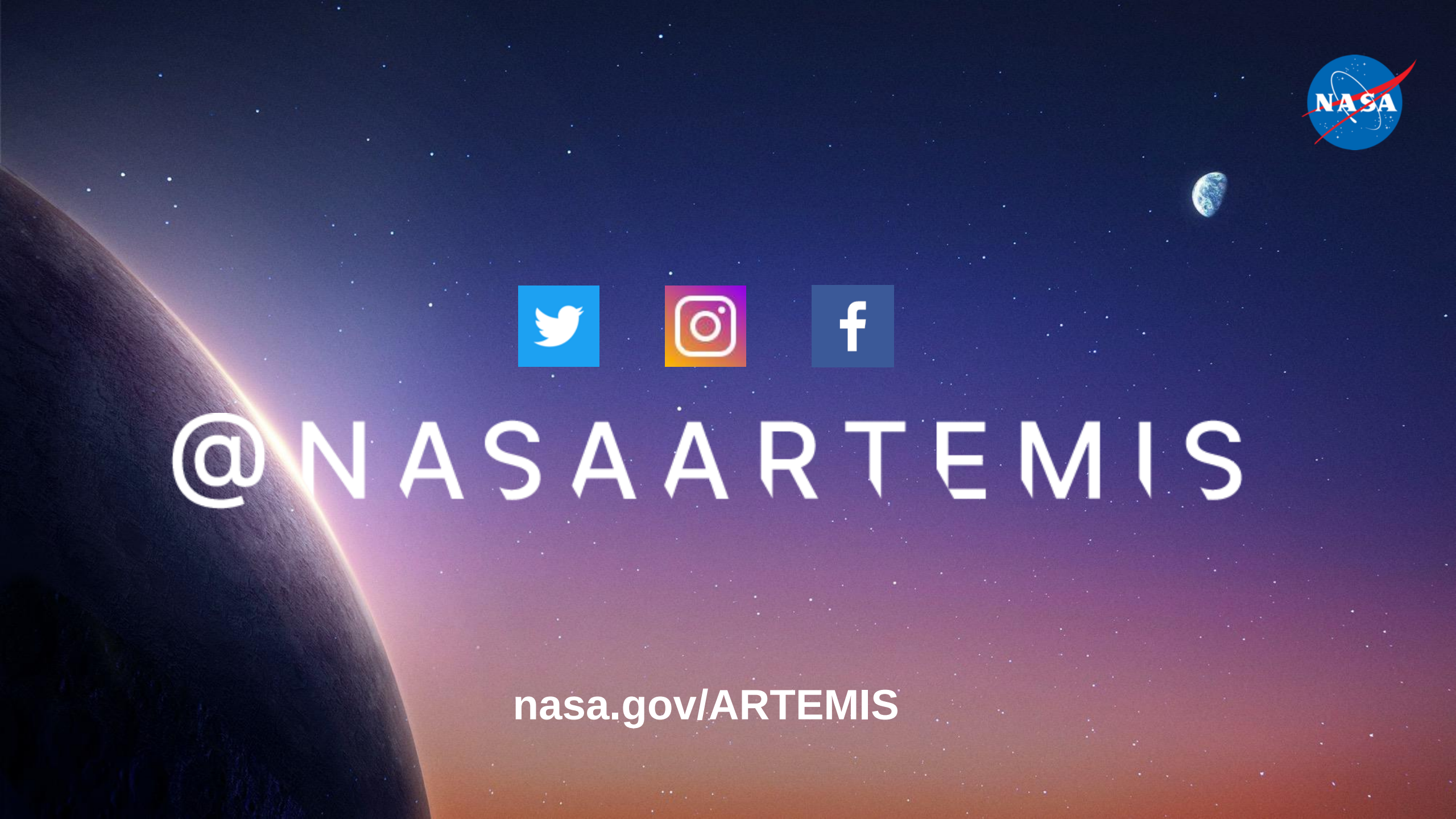
Let’s go.
The time is now.

We have the capability

We have the purpose

We have the charge

We have the responsibility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Human Landing System Program Office

Nantel Suzuki
HQ Program Executive

Heather Hall
Program & Management Analyst

Lisa Watson-Morgan
Program Manager

Lakiesha Hawkins
Deputy Program Manager

Don Krupp
Associate Manager

Lisa Hammond
Associate Manager
JSC

Melissa Walden,
Secretary

HLS Technical Authority

Rene Ortega
HLS Chief Engineer

John Crisler
HLS Chief Safety Officer

Jonathan Dory
Chief Health & Performance Officer


LP03 Program Planning & Control Office
Mgr: Davey Jones
Dep. Mgr: Joe Matus

LP10 Systems Engineering & Integration Office
Mgr: Kent Chojnaki
Dep. Mgr: Tom Percy



JSC Crew Compartment Office
Mgr: Steve Munday
Dep. Mgr: Chuck Campbell

LP20 Mission Systems Management Office
Mgr: Bill Jacobs
Tech Manager: Larry Gagliano
Management Integration Lead: Daryl Woods




JSC Lander Flight Operations Office
Mgr: Cori Kerr
Dep Mgr; Christie Bertels

LP30 Space Vehicle Systems Office
Mgr: Ryan Whitley
Dep. Mgr: Leo Barreda



KSC Lander Ground Operations Office
Mgr: Khoa Vo
Dep. Mgr: Tracy Gill

HLS Comms Team

Jena Rowe
MSFC PAO

Joe Vermette
HSL Strat Comm

Laura Means
HLS Strat Comm