National Aeronautics and Space Administration

Update on Gateway, Human Landing System, and Space Suits

Aeronautics and Space Engineering Board

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26 September 2019

Space Policy Directive 1: To The Moon, Then Mars

"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations…"

Why go to The Moon?

Proves technologies and capabilities for sending humans to Mars

Establishes American leadership and strategic presence

Inspires a new generation and encourages careers in STEM

Leads civilization changing science and technology

Expands the U.S. global economic impact

Broadens U.S. industry and international partnerships in deep space

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.

The Artemis Program

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 by 2024.

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.

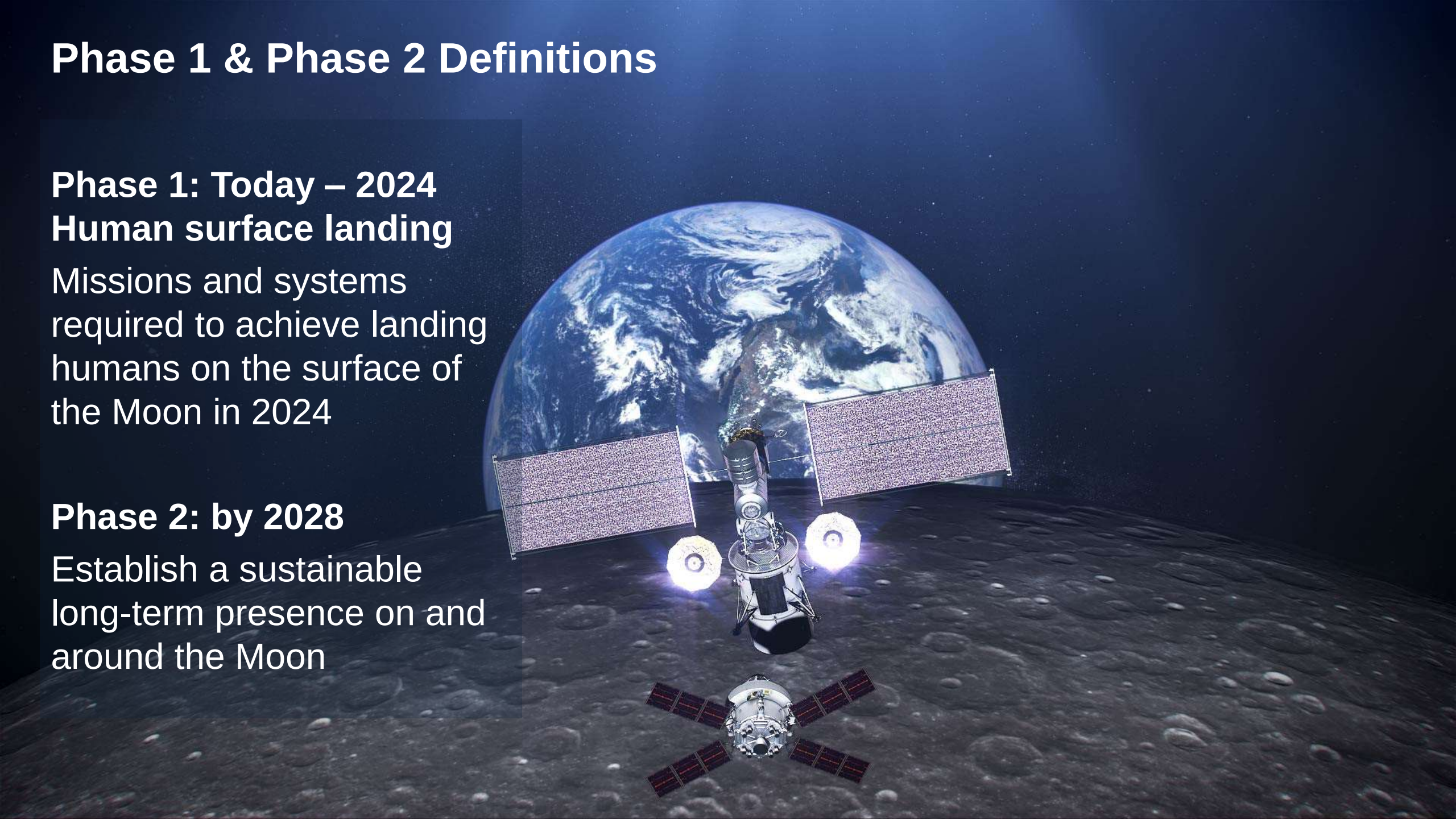
Phase 1 & Phase 2 Definitions

Phase 1: Today – 2024
Human surface landing

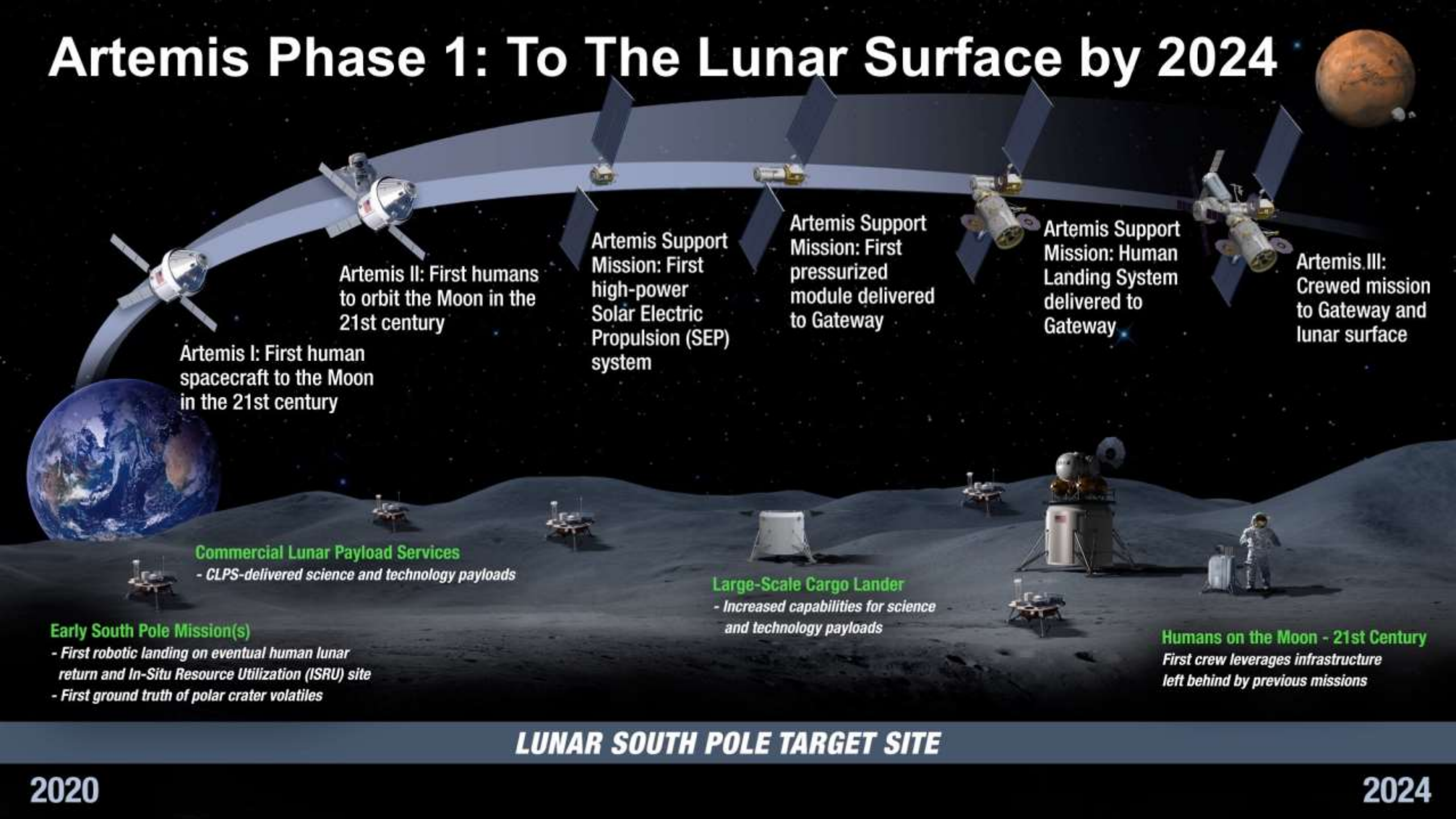
Missions and systems required to achieve landing humans on the surface of the Moon in 2024

Phase 2: by 2028

Establish a sustainable long-term presence on and around the Moon



Artemis Phase 1: To The Lunar Surface by 2024



DEVELOPMENT IS UNDERWAY

2024

Develop essential hardware and systems required for a 2024 landing

CREW

At least 2 on the South Pole

SUITS

Initial capability suit

EXPEDITION DURATION

Hours-Days
(open trade)

ROCKETS
(examples)

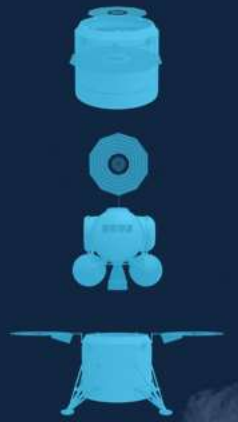
PARTNERS

Significant collaboration with U.S. industry

Potential opportunities for international partners

ACCESS

REUSABILITY
Desired, but not required



2028

Establish a sustainable human lunar presence with robust, reusable systems

CREW

Up to 4 on the Moon

SUITS

Sustained capability suit

EXPEDITION DURATION

Days-Weeks
(open trade)

ROCKETS
(examples)

PARTNERS

U.S. industry and international collaboration

ACCESS

Increased mobility from the pole; global access through robotic landings and possible human expeditions

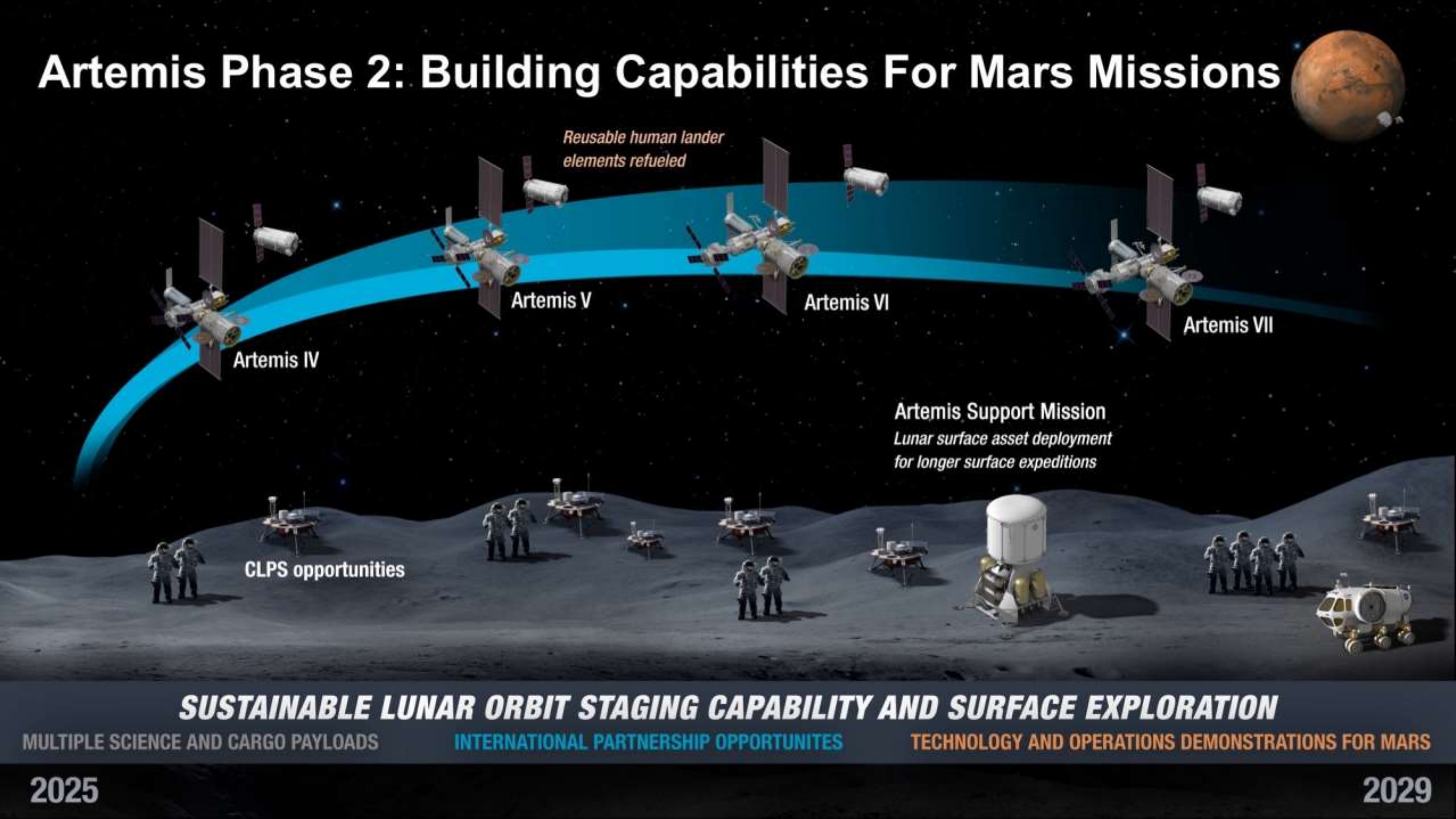
REUSABILITY
Enables sustainability

20190621

Gateway is Essential for 2024 Landing

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2
- Provides command center and aggregation point for 2024 human landing
- Establishes strategic presence around the Moon – US in the leadership role
- Creates resilience and robustness in the lunar architecture
- Open architecture and interoperability standards provides building blocks for partnerships and future expansion

Artemis Phase 2: Building Capabilities For Mars Missions



SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

MULTIPLE SCIENCE AND CARGO PAYLOADS | INTERNATIONAL PARTNERSHIP OPPORTUNITES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

2025 — 2029

GATEWAY ORBIT

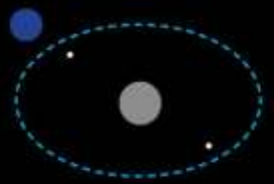
Cislunar space offers innumerable orbits for consideration, each with merit for a variety of operations. The Gateway will support missions to the lunar surface and serve as a staging area for exploration farther into the solar system, including Mars.

ORBIT TYPES

LOW LUNAR ORBITS

Circular or elliptical orbits close to the surface. Excellent for remote sensing, difficult to maintain in gravity well.

» Orbit period: 2 hours



DISTANT RETRO-GRADE ORBITS

Very large, circular, stable orbits. Easy to reach from Earth, but far from lunar surface.

» Orbit period: 2 weeks

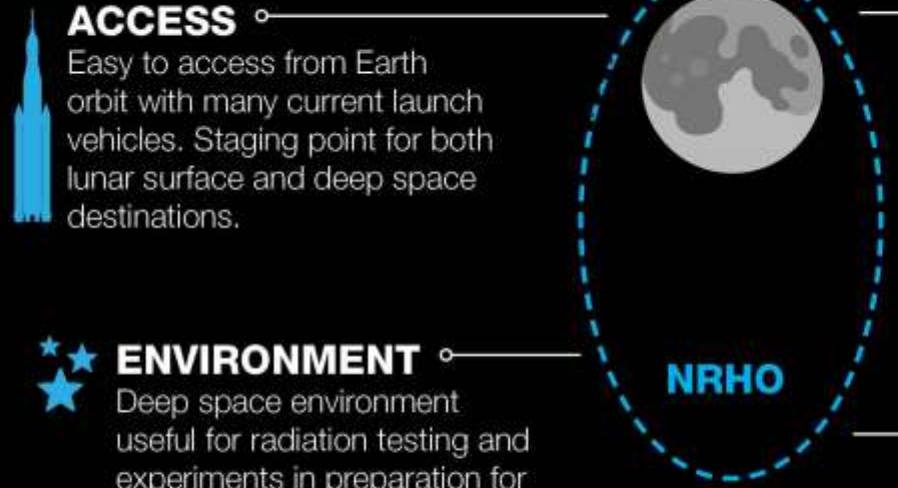
HALO ORBITS

Fuel-efficient orbits revolving around Earth-Moon neutral-gravity points.

» Orbit period: 1-2 weeks

NEAR-RECTILINEAR HALO ORBIT (NRHO)

1,500 km at its closest to the lunar surface, 70,000 km at its farthest.



ACCESS

Easy to access from Earth orbit with many current launch vehicles. Staging point for both lunar surface and deep space destinations.

ENVIRONMENT

Deep space environment useful for radiation testing and experiments in preparation for missions to the lunar surface and Mars.

SCIENCE

Favorable vantage point for Earth, sun and deep space observations.

COMMUNICATIONS

Provides continuous view of Earth and communication relay for lunar farside.

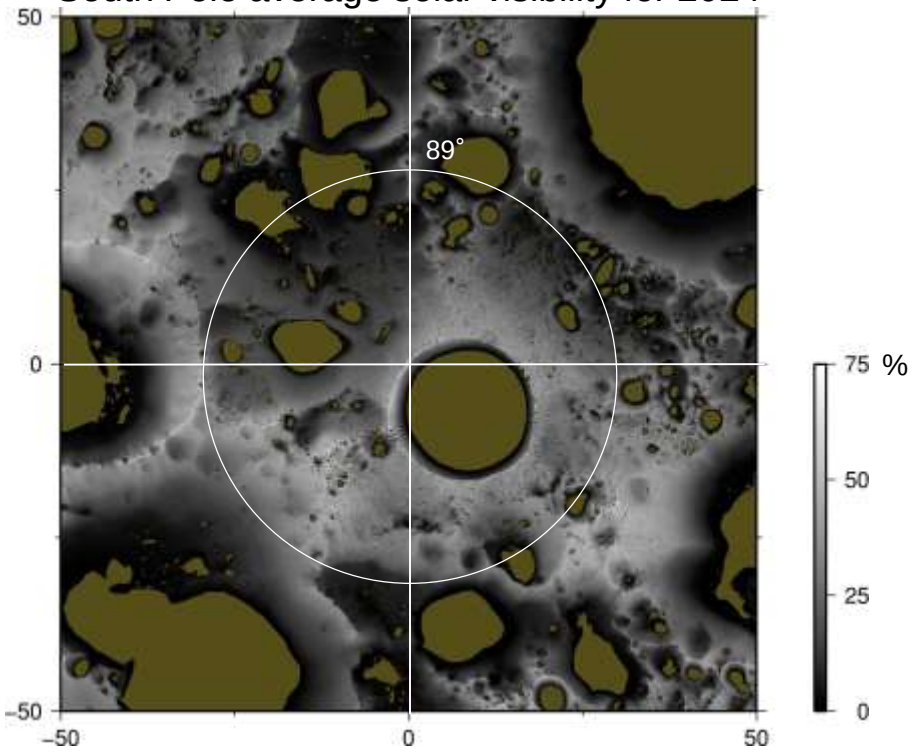
SURFACE OPERATIONS

Supports surface telerobotics, including lunar farside. Provides a staging point for planetary sample return missions.

American Strategic Presence on the Moon –

High solar illumination areas within 2 degrees (<50 km) of the lunar south pole.

South Pole average solar visibility for 2024



Gnomonic X (km)

Gold = permanently shadowed regions (PSRs)

High Priorities for Sustained Surface Activities

- **Long duration access to sunlight:** A confirmed resource providing power and minimal temperature variations
- **Direct to Earth communication:** Repeatable Earth line-of-sight communication for mission support
- **Surface roughness and slope:** Finding the safest locations for multiple landing systems, robotic and astronaut mobility
- **Permanently Shadowed Regions and Volatiles:** Learning to find and access water ice and other resources for sustainability

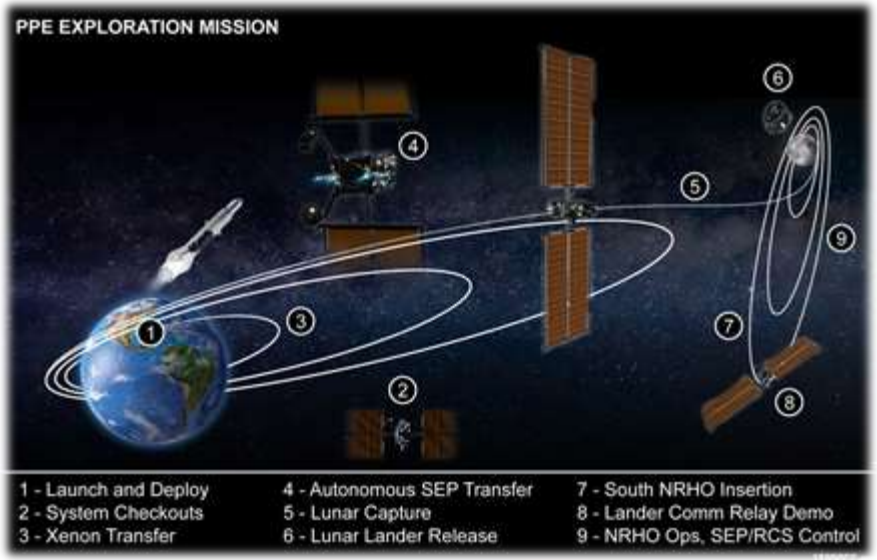
PROGRESS UPDATES

Power and Propulsion Element

Summary of Maxar's PPE approach

Leverage heritage reliability, proven development approach, and the scalable 1300-class platform as the basis for a PPE demonstration mission culminating with delivery of PPE to NASA in the target NRHO

- **Power – 60 kW+ provided by Roll Out Solar Array (ROSA) and Maxar's 1300 commercial power subsystem**
- **Propulsion – Leverage NASA development of 12.5 kW Electric Propulsion (EP), and internal Maxar advanced EP development, with Maxar expertise in system accommodation of EP elements**
- **Communications – Ka-band relay from Lunar vicinity to Earth, accommodations for future optical communications payloads**
- **Guidance Navigation and Control – Utilize proven approaches for station keeping, momentum management, and autonomous low thrust electric orbit transfer**
- **Gateway Interfaces – Support all interfaces with elements of Gateway including docked components, visiting vehicles, robotics, science payloads, Orion, and Human Landing System elements**
- **Payload Transfer – 1000kg for lunar lander or science instruments**



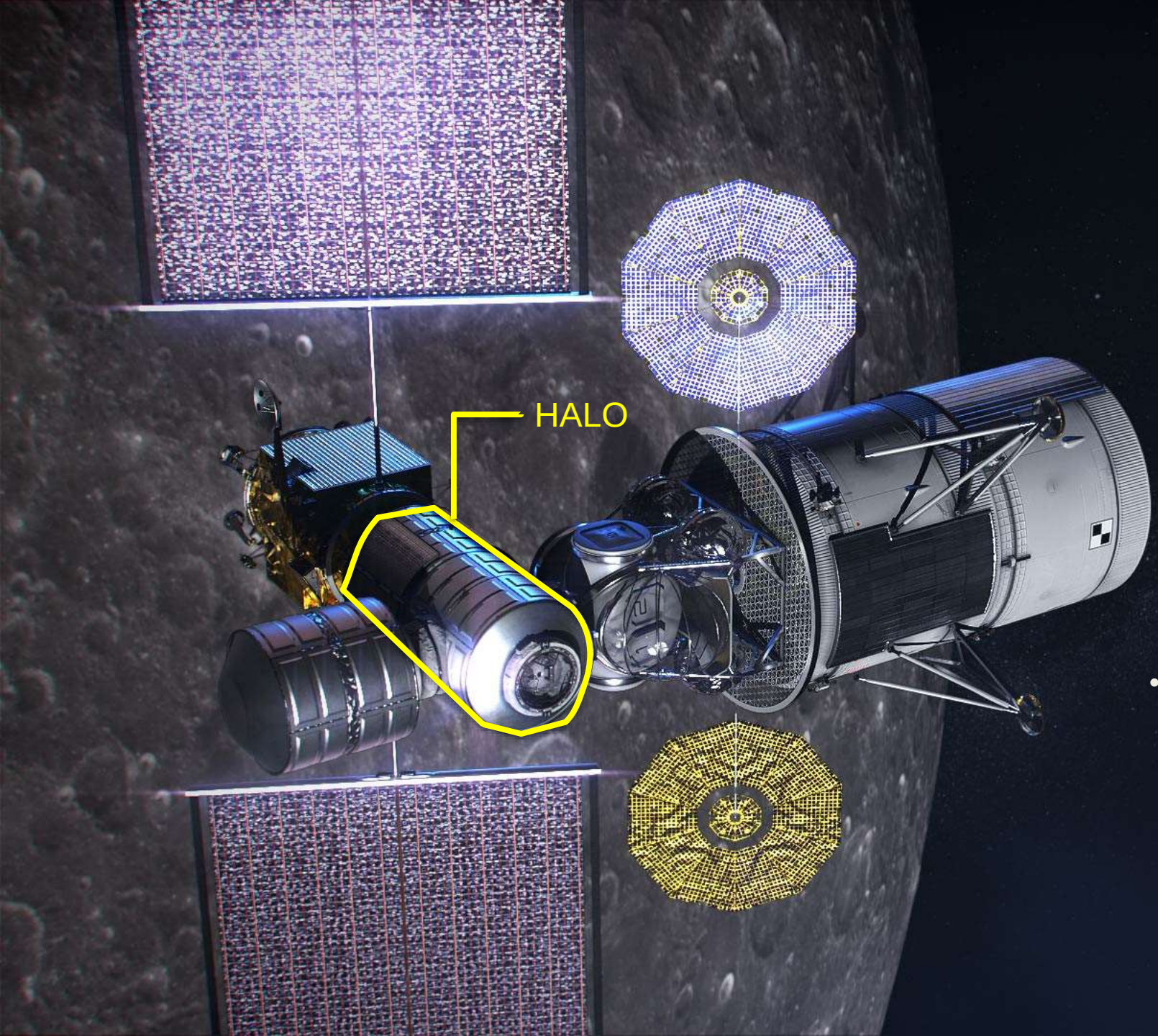
Gateway Logistics Services

U.S. industry to begin delivering cargo, experiments, and supplies to deep space beginning in 2024.

June 14 – Draft RFP issued to U.S. industry

June 26 – Industry forum with media availability

Aug 16 – final solicitation for firm fixed-price contract



Gateway HALO

(Habitation and Logistics Outpost)

- Minimum capability necessary to support a lunar mission, with significant reliance on Orion life support and crew systems

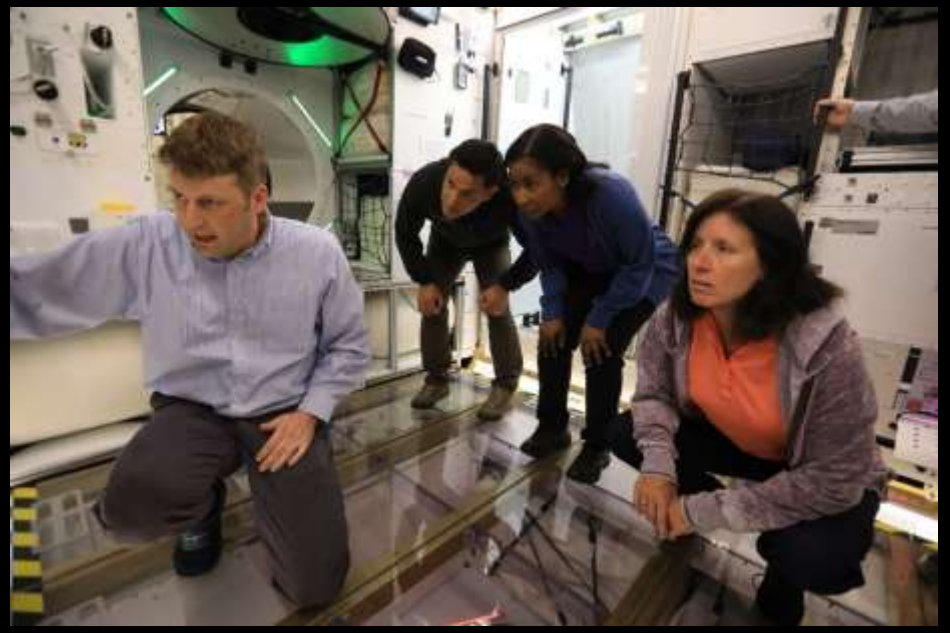
NextSTEP Habitat Prototype Testing

Five full-sized ground prototypes delivered for testing in 2019.

"Because of this prototyping exercise, we are 12-18 months farther along than we would normally be at this stage of concept development. Future programs should go through this approach along with requirements iteration with NASA."

"The NextSTEP approach has been really helpful. The mockup showed us we had more cargo space in our habitat than we originally believed based on the CAD models."

Lockheed Martin – Testing Complete at KSC



Northrop Grumman – Testing Complete at JSC

Boeing – Testing Complete at MSFC

Sierra Nevada Corporation – Testing Complete at JSC

Bigelow Aerospace – Testing Complete at Bigelow, Las Vegas

Current Thoughts on Human Landing System

HLS Notional Transportation Elements

Transfer Ascent Descent Aggregate at Gateway

NextSTEP Appendix E: Human Lander System

- Issued: Feb 7
- Proposals submitted: March 25
- Selections: May
- Awards: July
- Phase A Risk Reduction Studies and prototypes for
  - Descent Element
  - Transfer Element
  - Refueling

Studies expedited via Undefinitized Contract Awards

NextSTEP Appendix H: Human Lander System 2

- Synopsis Issued: April 8, for Ascent Element
- Synopsis updated: April 26, now for development, integration, and crewed demonstration of integrated landing system
- Draft solicitation: July 19
- Second draft solicitation: Aug 30
- Final solicitation: Early fall

Artemis Lunar Surface Suit Plan

- **The Exploration EVA (xEAV) system is a mature design that provides an exploration suit (xEMU), vehicle interfaces, and exploration tools supporting lunar surface and deep space operations**
  - xEMU Core Systems completed Preliminary Design Review in FY19
  - xEVA functional interfaces defined and standardized for all vehicles
  - Extensive ground Design Verification Test of full xEMU slated for 2020
- **Will validate xEMU design applicable to both ISS-based operations and lunar surface exploration via demonstrations at ISS**
  - Thermal loop assembly test article ready for launch in 2019
  - First xEMU spacewalk at ISS in 2023
- **Complete DDT&E and first xEVA flight unit builds in-house**
  - Enable design flexibility as vehicle contracts awarded and con ops matures
  - Early standardization of interfaces across vehicles to streamline integrated systems testing and training
  - Utilize existing NASA facilities, equipment, and experienced team for parallel test series to accelerate schedule
  - Initiate separate fleet production and sustaining contract prior to xEVA CDR to ensure seamless transition into standard operations

xEVA flexible architecture will support a sustainable lunar presence and is adaptable to support multi-programs/roles, as required without system redesign

- Defined physical and functional interfaces simplify component changes to optimize for each mission

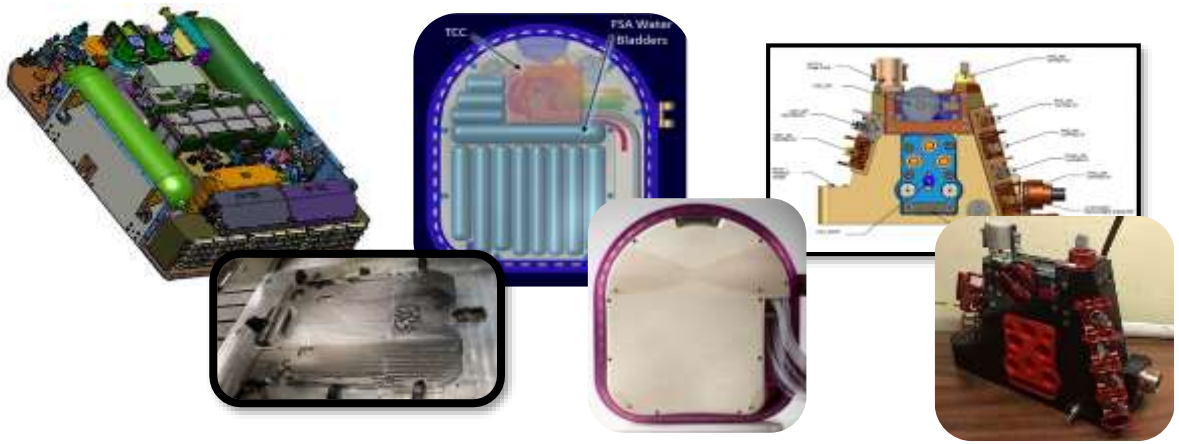
Major Suit Components Status

Portable Life Support Subsystem

- Third generation of components complete for new thermal, regulator, pump, carbon dioxide scrubbing, and fan technologies
- First package system completed 393 hours of integrated testing, including 291 hours of operation in a vacuum environment and 199 hours of simulated EVA time
- Build of flight-like xPLSS will be completed in 2020

Pressure Garment Subsystem

- Third generation of rear-entry adjustable scye spacing upper torso
- Fifth generation multi-bearing hip design for surface exploration and microgravity tasks
- Completed over 25 NBL events with Z-series prototypes to refine upper torso and helmet geometry and validate design for airlock operations
- Build of flight-like xPGS will be completed in 2020



Development of xPLSS hardware from CAD to reality: Backplate with embedded fluid lines; Hatch mounted feedwater assembly and trace contaminant control; Display and Control Unit

Validation of the xPGS design through NBL testing of the Z-series PGS prototype

Lunar Science by 2024

Polar Landers and Rovers

- First direct measurement of polar volatiles, improving understanding of lateral and vertical distribution, physical state, and chemical composition
- Provide geology of the South-Pole Aitken basin, largest impact in the solar system

Non-Polar Landers and Rovers

- Explore scientifically valuable terrains not investigated by Apollo, including landing at a lunar swirl and making first surface magnetic measurement
- Using PI-led instruments to generate Discovery-class science, like establishing a geophysical network and visiting a lunar volcanic region to understand volcanic evolution

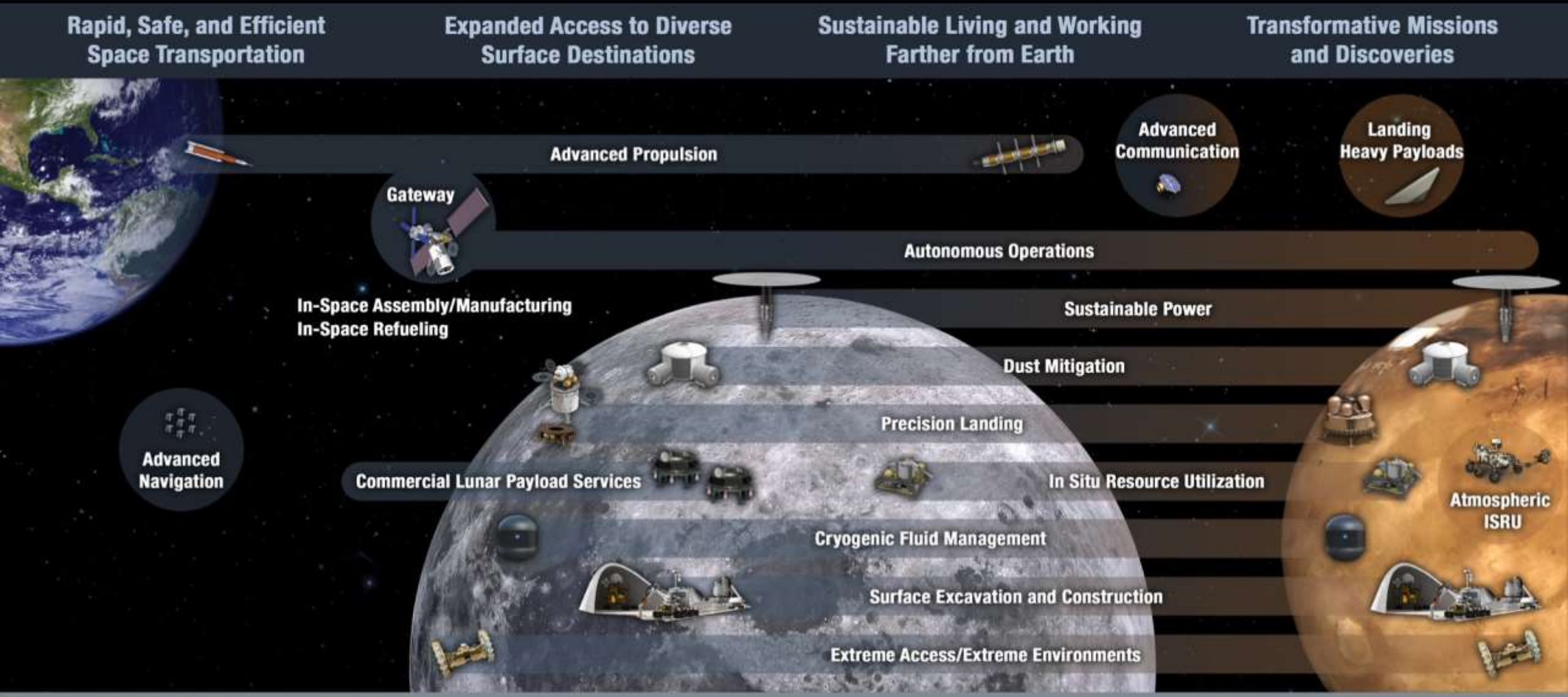
Orbital Data

- Deploy multiple CubeSats with Artemis 1
- Potential to acquire new scientifically valuable datasets through CubeSats delivered by CLPS providers or comm/relay spacecraft
- Global mineral mapping, including resource identification, global elemental maps, and improved volatile mapping

In-Situ Resource Initial Research

- Answering questions on composition and ability to use lunar ice for sustainment and fuel

Reaching The Moon And Mars Faster With NASA Technology



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The Power of SLS and Orion

ORION

The only spacecraft capable of carrying and sustaining crew on missions to deep space, providing emergency abort capability, and safe re-entry from lunar return velocities

SLS

The only rocket with the power and capability required to carry astronauts to deep space onboard the Orion spacecraft

NATIONAL CAPABILITY

The SLS and Orion programs (including Exploration Ground Systems support at Kennedy Space Center) leverages over 3,800 suppliers and over 60,000 workers across all 50 states

ARTEMIS I

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport

1 LAUNCH
SLS and Orion lift off from pad 39B at Kennedy Space Center

2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate

3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safely abort

4 CORE STAGE MAIN ENGINE CUT OFF (MECO) and separation

5 ENTER EARTH ORBIT
Perform the perigee raise maneuver

6 EARTH ORBIT
Systems check and solar panel adjustments

7 TRANS LUNAR INJECTION (TLI) BURN
Burn lasts for approximately 20 minutes

8 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION
The ICPS has committed Orion to TLI

9 OUTBOUND TRANSIT
Requires several attitude maneuvers

A B C D
CUBESATS DEPLOY
ICPS deploys 13 CubeSats total

10 OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS
As necessary adjust trajectory for Lunar flyby to DRO

11 OUTBOUND POWERED FLYBY (OPF)
62 miles from the Moon; targets DRO insertion

Heliocentric Disposal precludes re-contact

12 ORBIT INSERTION
Enter Distant Retrograde Orbit for next 6-23 days

13 DISTANT RETROGRADE ORBIT (DRO)
Orbit Maintenance burns and solar panel adjustments; 38,000 nmi from the surface of the Moon

14 DRO DEPARTURE
Leave DRO and start return to Earth

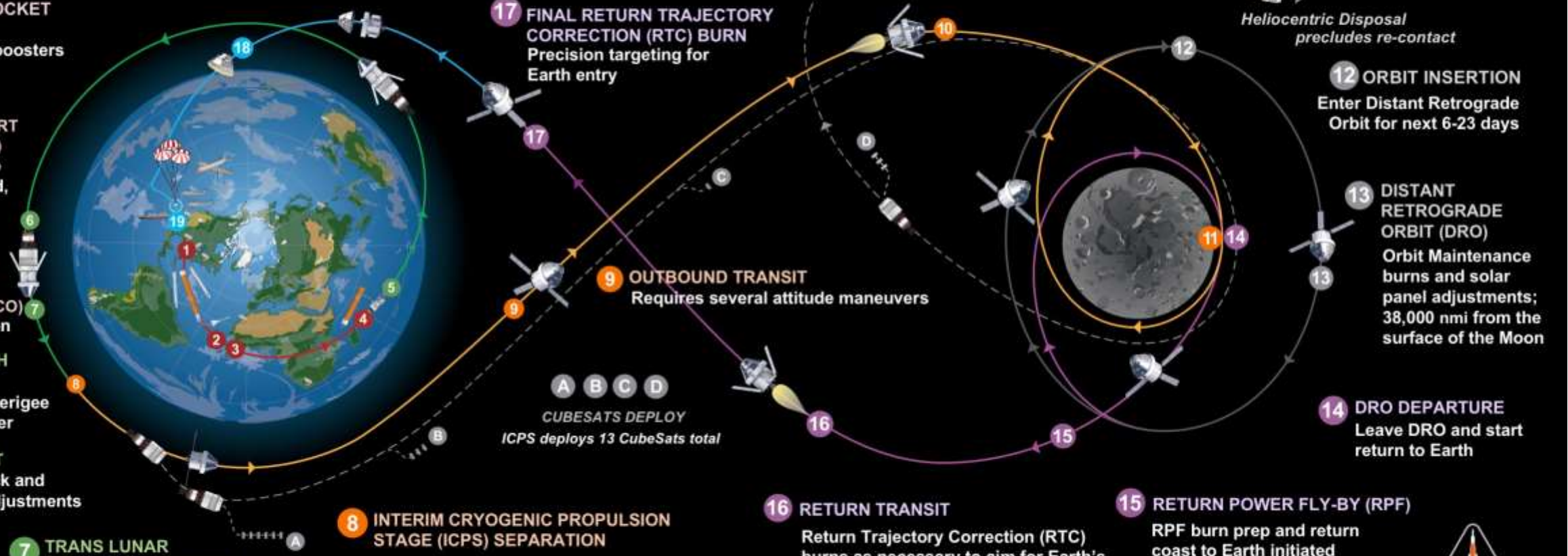
15 RETURN POWER FLY-BY (RPF)
RPF burn prep and return coast to Earth initiated

16 RETURN TRANSIT
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time 3-11 days

17 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN
Precision targeting for Earth entry

18 ENTRY INTERFACE (EI)
Enter Earth's atmosphere

19 SPLASHDOWN
Pacific Ocean landing within view of the U.S. Navy recovery ships



ARTEMIS

ARTEMIS I

Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed