EXPLORE

EXTENDING HUMAN PRESENCE INTO THE SOLAR SYSTEM

William H. Gerstenmaier

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NASA Headquarters
Washington, D.C.

Supporting National Space Policy Directives

SPD-1: Reinvigorating America's Human Space Exploration Program

"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."

SPD-2: Streamlining Regulations on the Commercial Use of Space

"It is the policy of the executive branch to be prudent and responsible when spending taxpayer funds, and to recognize how government actions, including Federal regulations, affect private resources.

It is therefore important that regulations adopted and enforced by the executive branch promote economic growth; minimize uncertainty for taxpayers, investors, and private industry; protect national security, public-safety, and foreign policy interests; and encourage American leadership in space commerce."

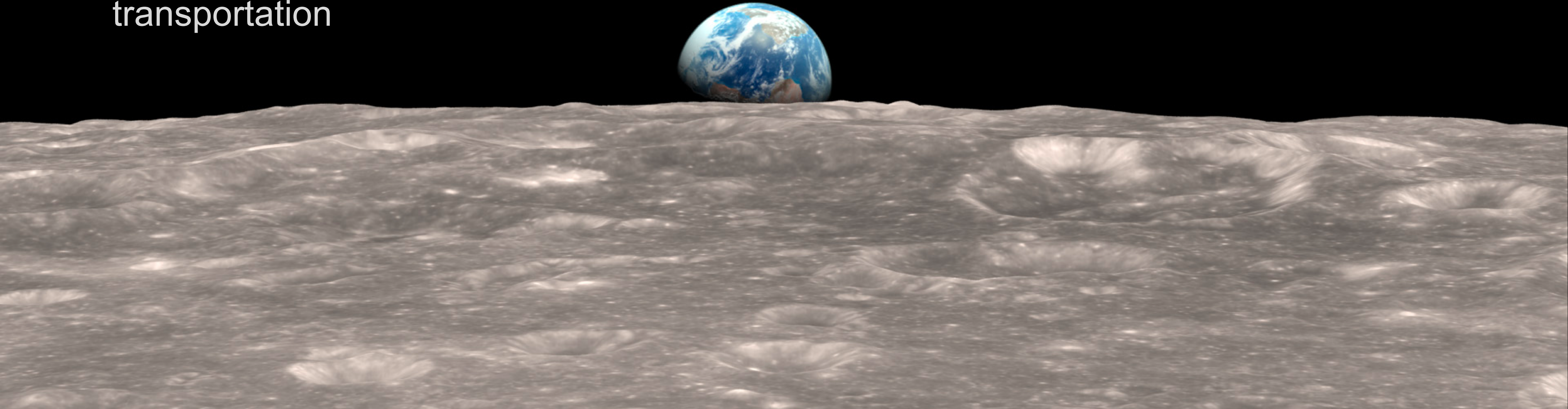
SPD-3: National Space Traffic Management

"For decades, the United States has effectively reaped the benefits of operating in space to enhance our national security, civil, and commercial sectors. Our society now depends on space technologies and space-based capabilities for communications, navigation, weather forecasting, and much more.

Given the significance of space activities, the United States considers the continued unfettered access to and freedom to operate in space of vital interest to advance the security, economic prosperity, and scientific knowledge of the Nation."

NASA’s Path to Moving Human Presence Into The Solar System

- Build an infrastructure that will make deep space accessible to all of humanity
- Develop incremental capabilities during human lunar expeditions that will inform future missions, deeper into the solar system
- Expand our near-Earth economy to establish a sustainable presence in deep space, as we are already doing in low-Earth orbit
- Provide initial backbone crew transportation system augmented with commercial transportation



STRATEGIC PRINCIPLES OF HUMAN SPACE EXPLORATION

Fiscal Realism | Commercial Partnerships | Scientific Exploration
Technology Pull and Push | Gradual Buildup of Capability
Architecture Openness and Resilience
Global Collaboration and Leadership | Continuity of Human Spaceflight

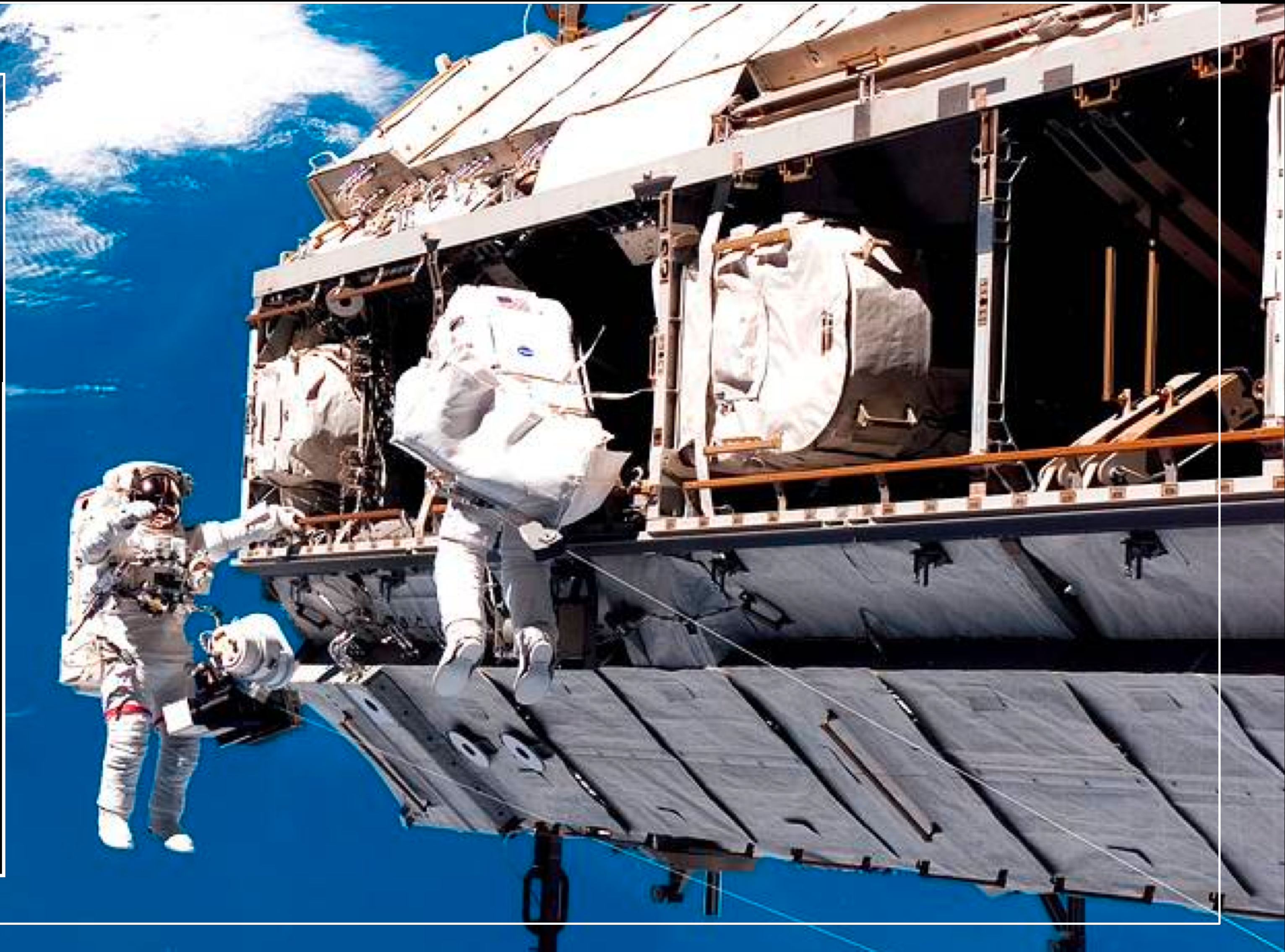
International Interoperability Standards

Preparing for deep space exploration

Draft Deep Space Interoperability System Standards Posted for feedback on March 1, 2018

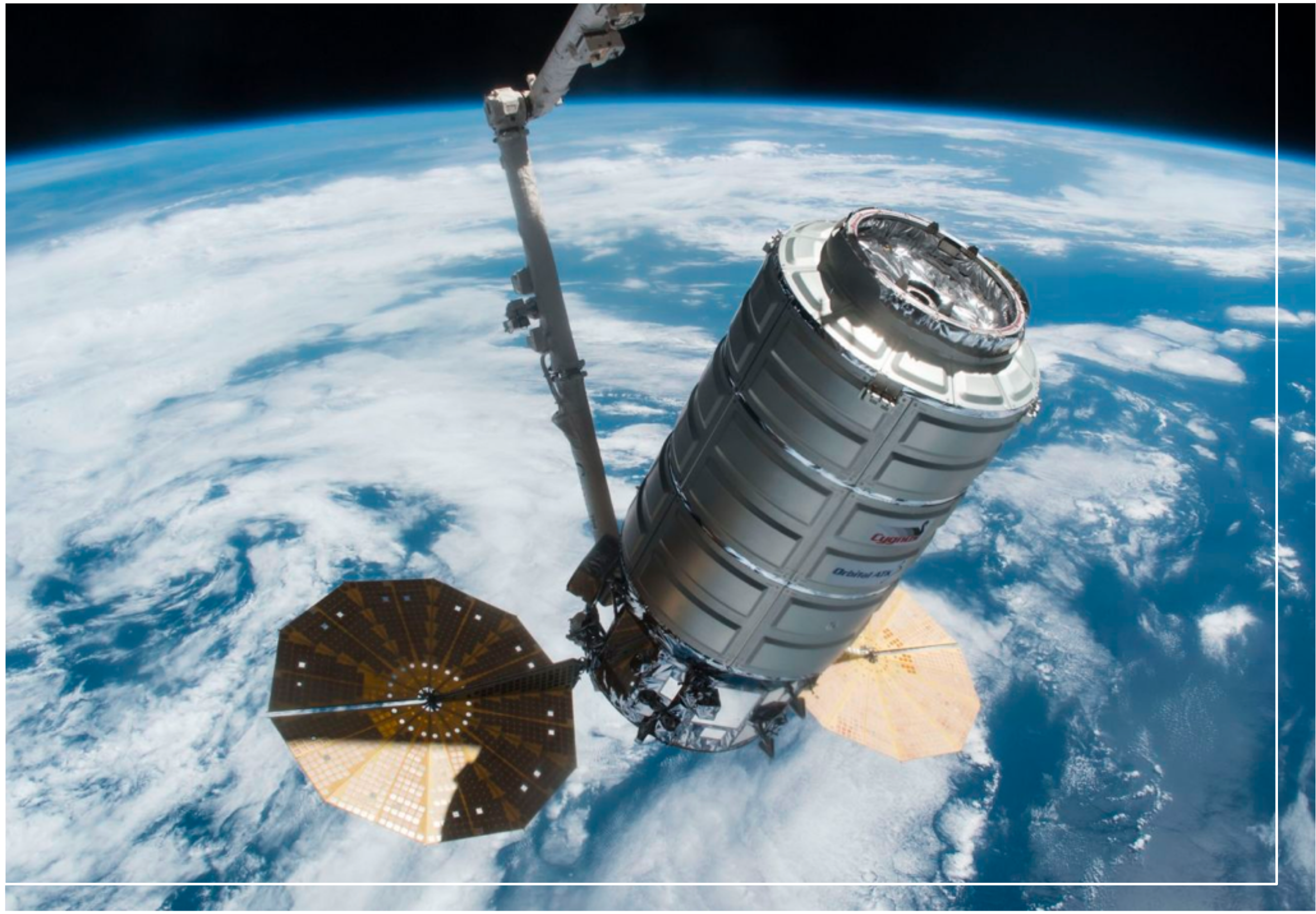
- Avionics
- Communications
- Environmental Control and Life Support Systems
- Power
- Rendezvous
- Robotics
- Thermal

www.InternationalDeepSpaceStandards.com



Commercial Cargo Transportation

Foundation for a low-Earth orbit economy and deep space exploration

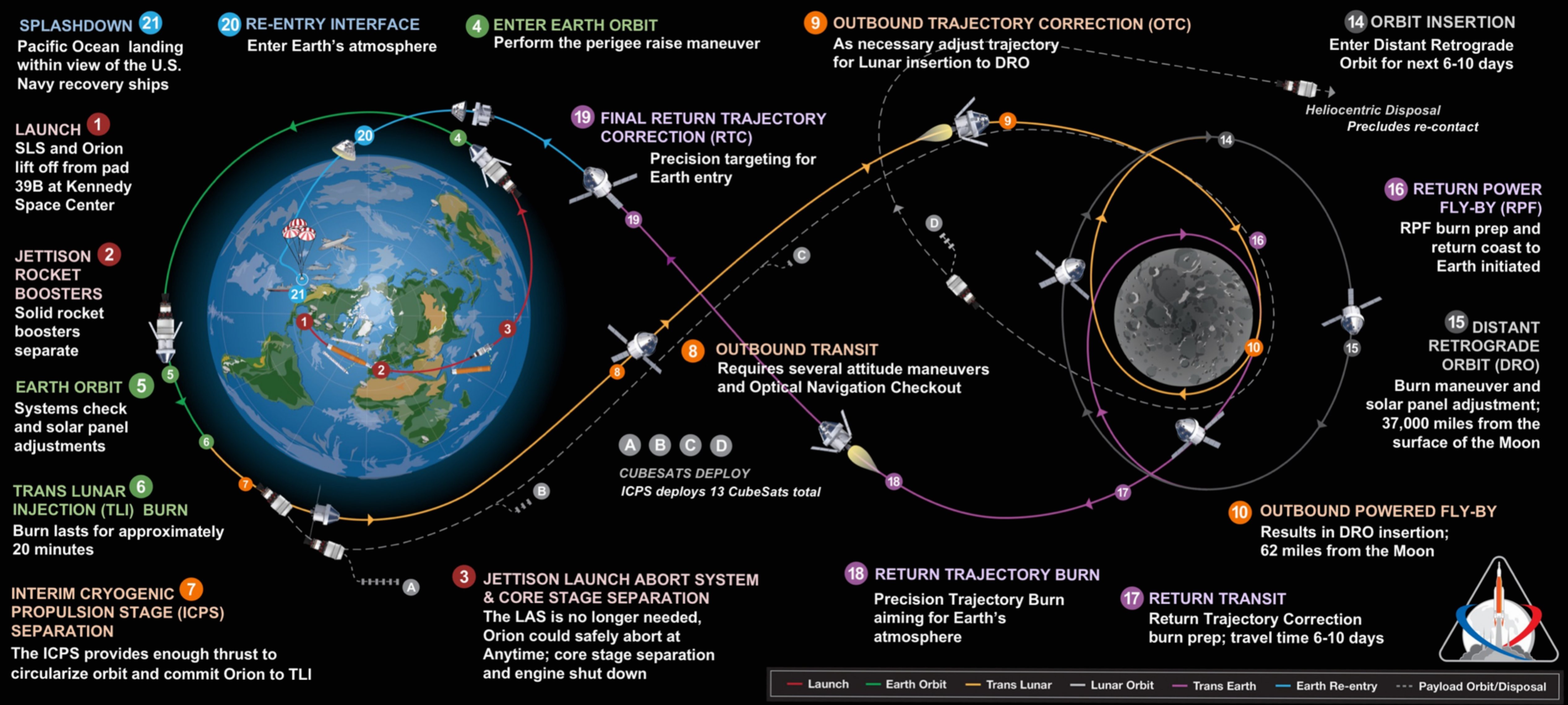


Deep Space Exploration Systems

Building the right system for deep space exploration

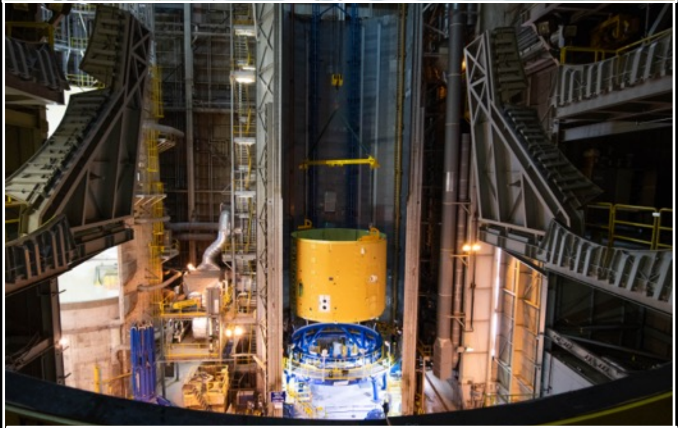
EXPLORATION MISSION-1

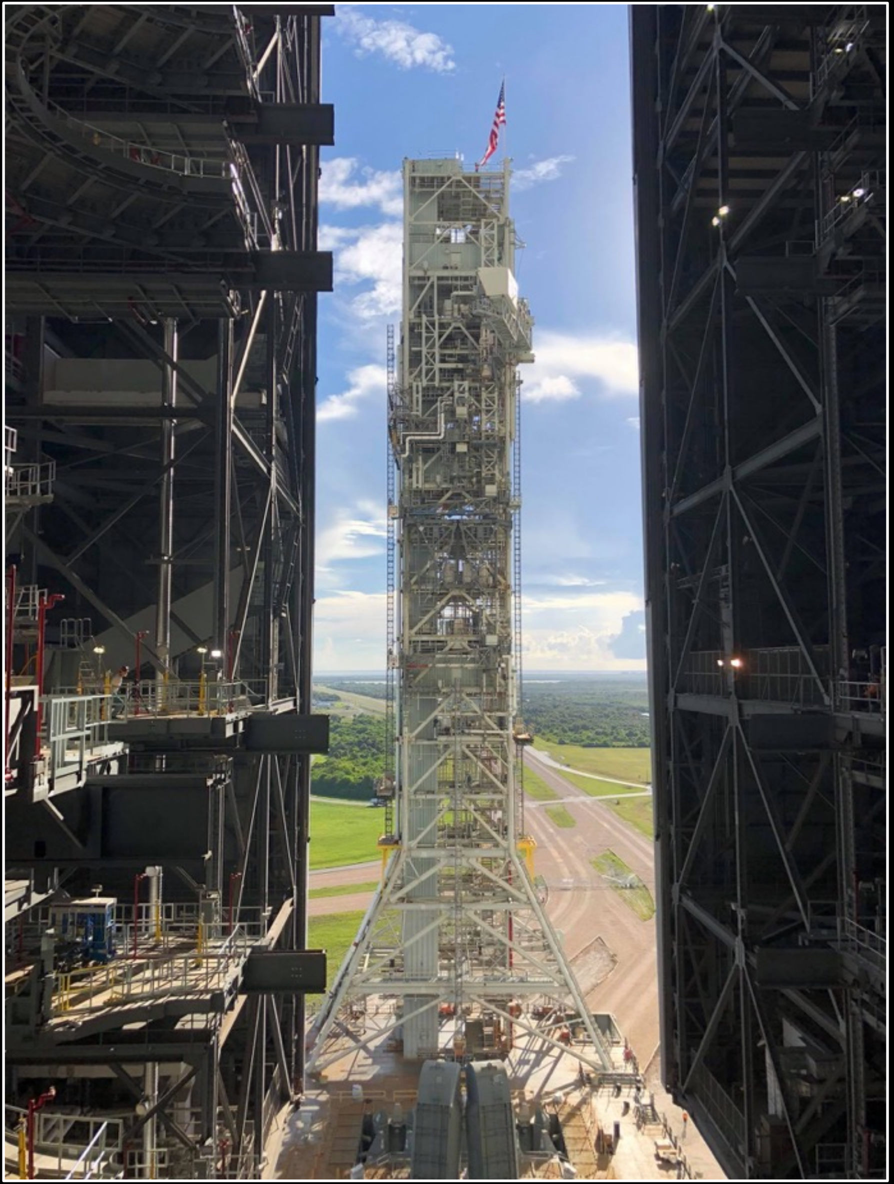
The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport



Total distance traveled: 1.3 million miles – Mission duration: 25.5 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

DEEP SPACE EXPLORATION SYSTEMS

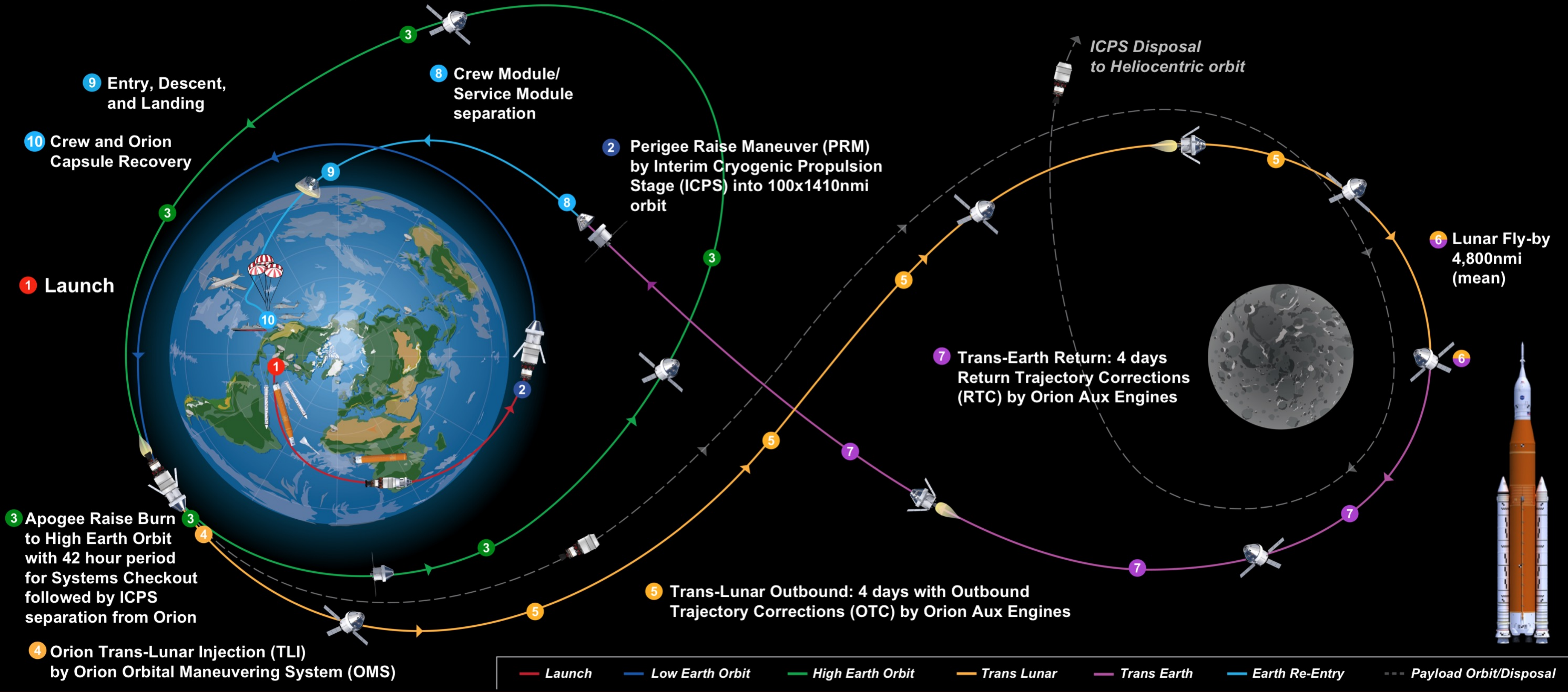




RECENT ACCOMPLISHMENTS

EXPLORATION MISSION-2

Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)

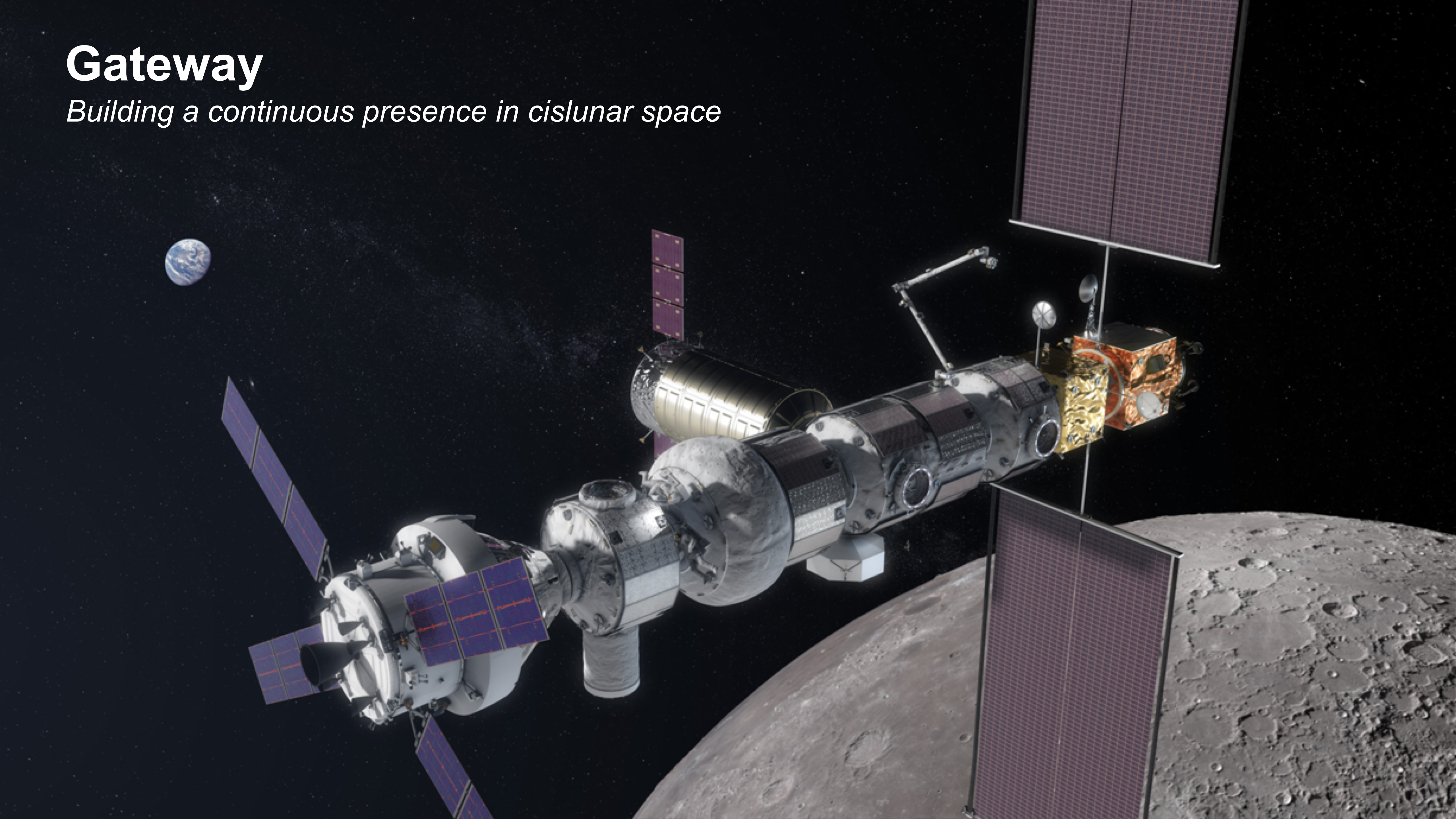


SLS Configuration (Block 1) with Human Rated ICPS | 22x1200nmi (41x2222km) insertion orbit | 28.5 deg inclination

4 astronauts | Mission duration: 10 Days | Re-entry speed: 24,500 mph (Mach 32)

Gateway

Building a continuous presence in cislunar space



Cislunar Space

A deep space harbor for expanded human presence

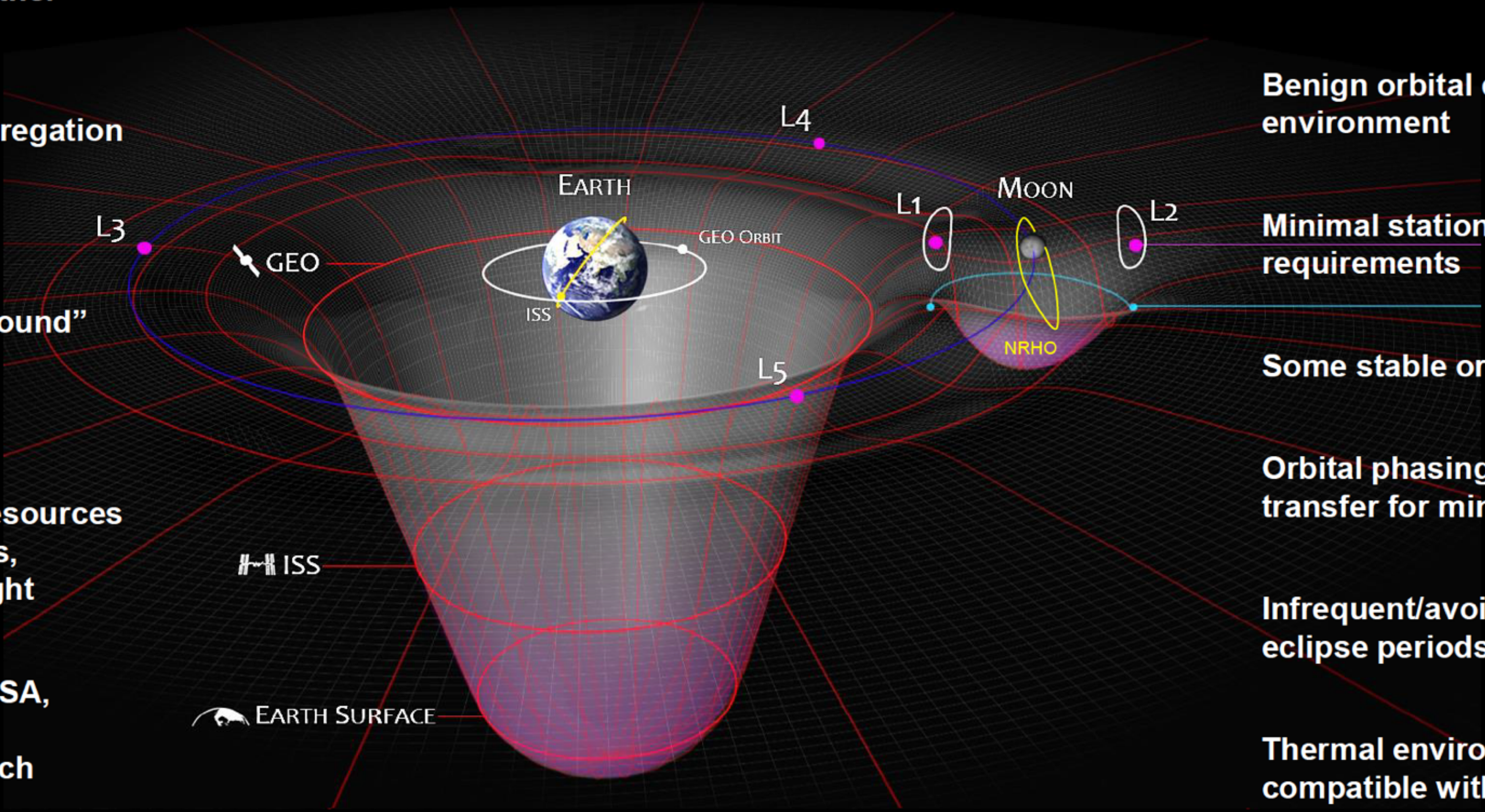
Only ~3 to 5 days away from Earth yet farther than Apollo went

Ideal mission aggregation location

The next "high ground" beyond GEO

Access to local resources including volatiles, gravity and sunlight

Accessible by NASA, commercial, and international launch systems



True deep space radiation environment

Benign orbital debris environment

Minimal station keeping requirements

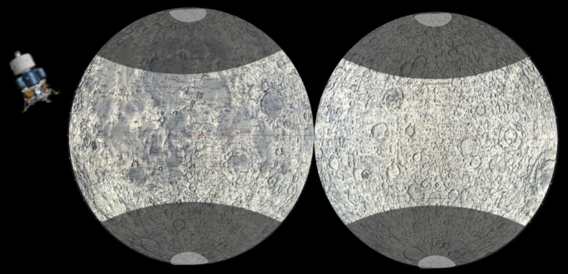
Some stable orbits

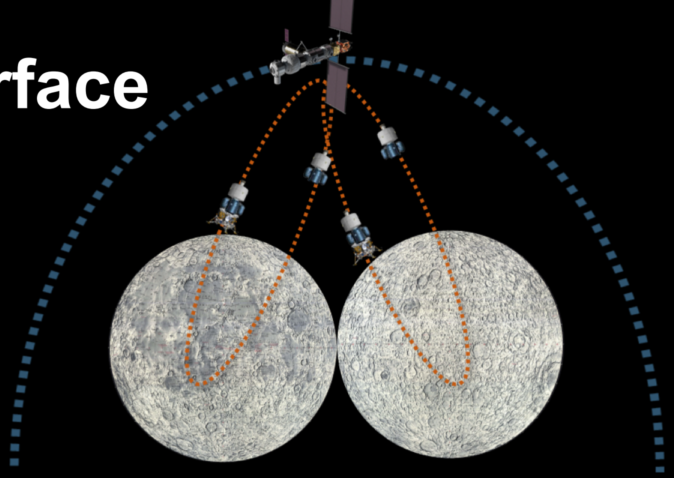
Orbital phasing and transfer for minimal energy

Infrequent/avoidable eclipse periods

Thermal environment compatible with cryogenic oxygen and methane

Two Approaches for Accessing the Lunar Surface





Lunar Surface Direct Apollo-style

- Lacks reusability
- Does not build or test infrastructure necessary for Mars missions
- Delta-v (0-6 %) more efficient for one- and two-way transfers
- Limited opportunities for commercial launch vehicles
- Limited opportunities for international partnerships
- Some vehicle redesign may be required for vehicles under manufacture
- Science and utilization limited by short mission duration
- Limited ability to test and develop Mars systems and capabilities
- Human cis-lunar presence only during surface missions

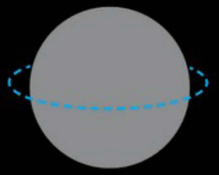
Lunar Surface Through Gateway

- Enables reusable lunar systems
- Enables long-term multiple mission capability (in-space, robotic and human missions across the lunar surface)
- Establishes initial refueling capabilities necessary for Mars
- Lunar vehicle checkout and maintenance at Gateway
- Increased opportunity for international and commercial partnerships reduces political risk
- Longer duration surface missions
- In-space platform for long-duration science
- Deep space testing of Mars-forward systems
- Establishes deep space infrastructure
- Interoperability standards-open architecture
- Lower long-term costs for Mars campaign

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.

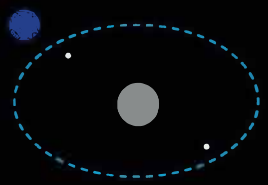
ORBIT TYPES



LOW LUNAR ORBITS

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

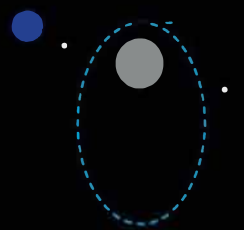
» Orbit period: 2 hours



DISTANT RETRO-GRADE ORBITS

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

» Orbit period: 2 weeks



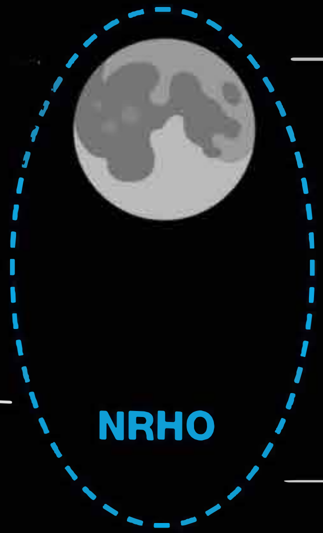
HALO ORBITS

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.

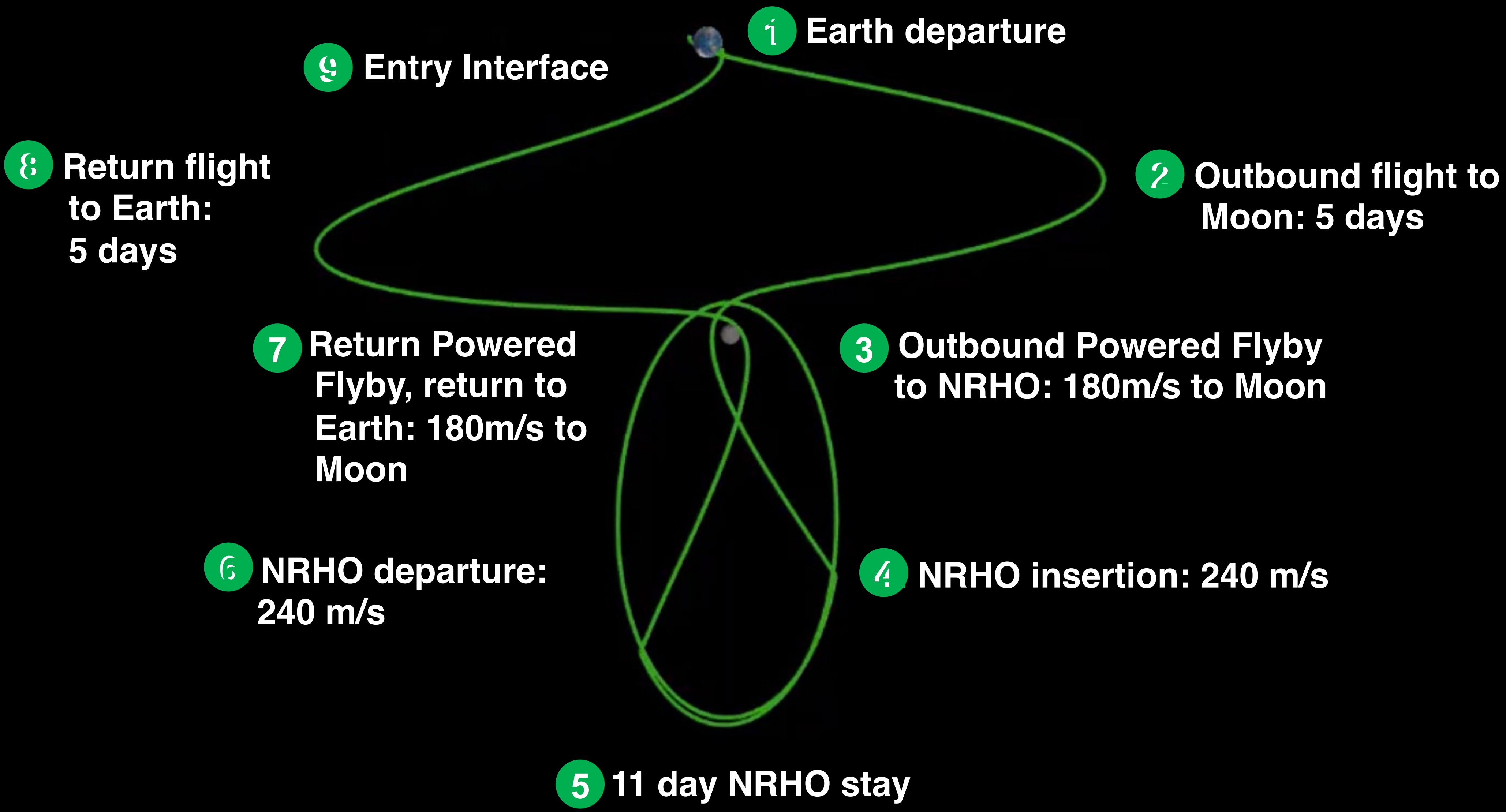
COMMUNICATIONS

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

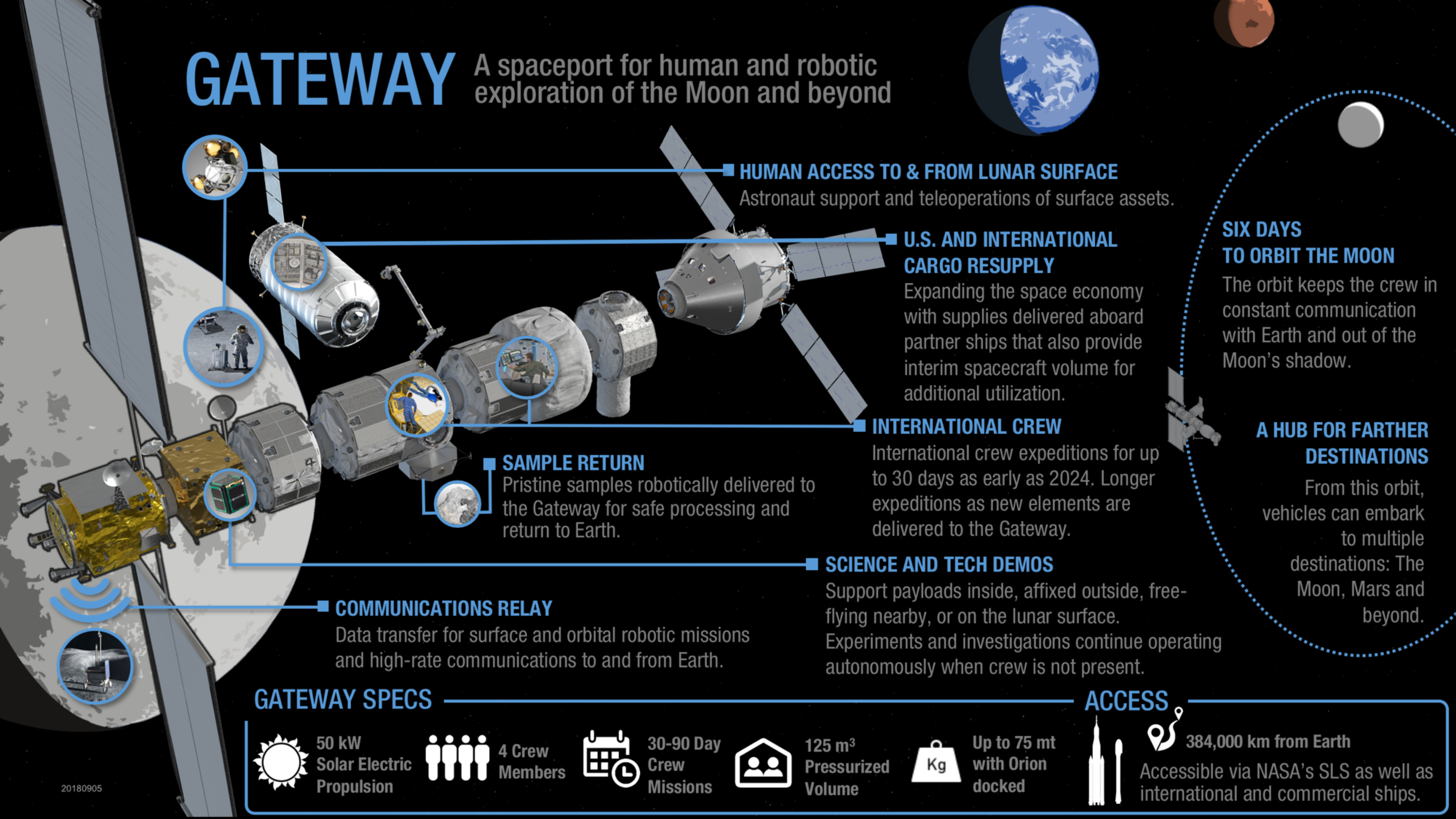
SURFACE OPERATIONS

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

EXPLORATION MISSION-3: *Carrying the first habitable piece to Gateway*



NRHO = Near Rectilinear Halo Orbit


GATEWAY
A spaceport for human and robotic exploration of the Moon and beyond
HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.
U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.
INTERNATIONAL CREW
International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.
SAMPLE RETURN
Pristine samples robotically delivered to the Gateway for safe processing and return to Earth.
SCIENCE AND TECH DEMOS
Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.
COMMUNICATIONS RELAY
Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.
SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon's shadow.
A HUB FOR FARTHER DESTINATIONS
From this orbit, vehicles can embark to multiple destinations: The Moon, Mars and beyond.
GATEWAY SPECS
50 kW Solar Electric Propulsion
4 Crew Members
30-90 Day Crew Missions
125 m³ Pressurized Volume
Kg
Up to 75 mt with Orion docked
ACCESS
384,000 km from Earth
Accessible via NASA's SLS as well as international and commercial ships.
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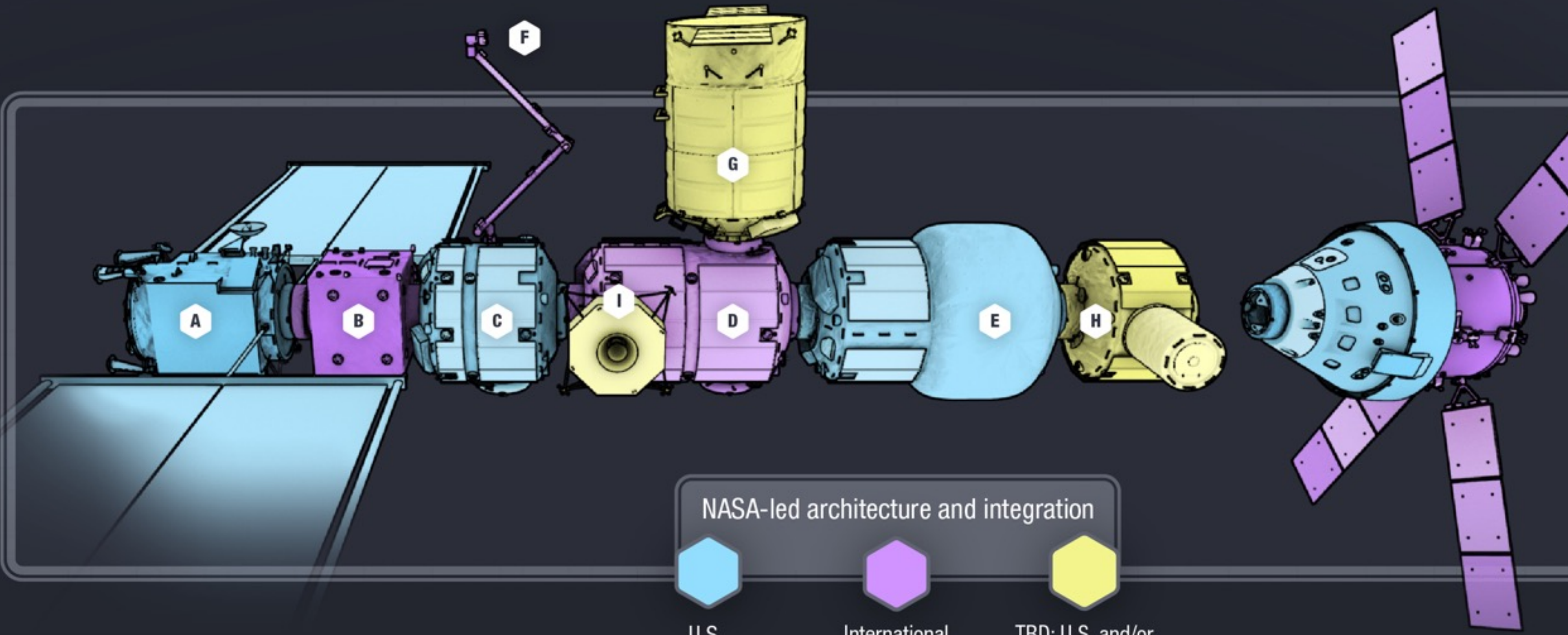
GATEWAY CONFIGURATION CONCEPT

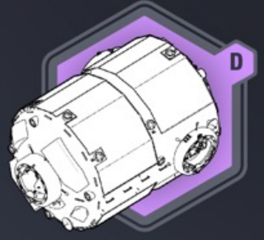
An exploration and science outpost in orbit around the Moon

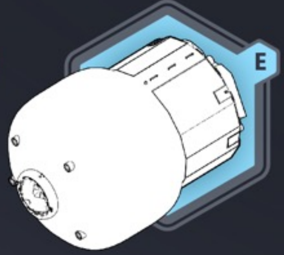


Power and Propulsion Element:
Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.

ESPRIT:
Science airlock, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.

U.S. Utilization Module:
Small pressurized volume for additional habitation capability.





Habitation Modules: Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.

Orion:
U.S. crew module wth ESA service module that will take humans farther into deep space than ever before.

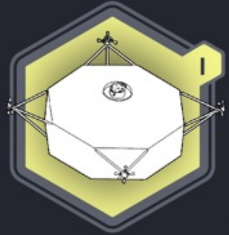
NASA-led architecture and integration

- U.S.
- International
- TBD: U.S. and/or International

Robotic Arm:
Mechanical arm to berth and inspect vehicles, install science payloads.

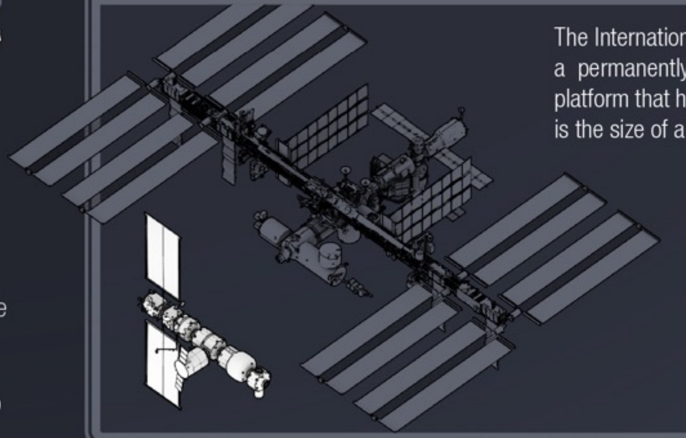
Logistics and Utilization:
Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.

Airlock:
Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:
A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.

Gateway Compared to the International Space Station



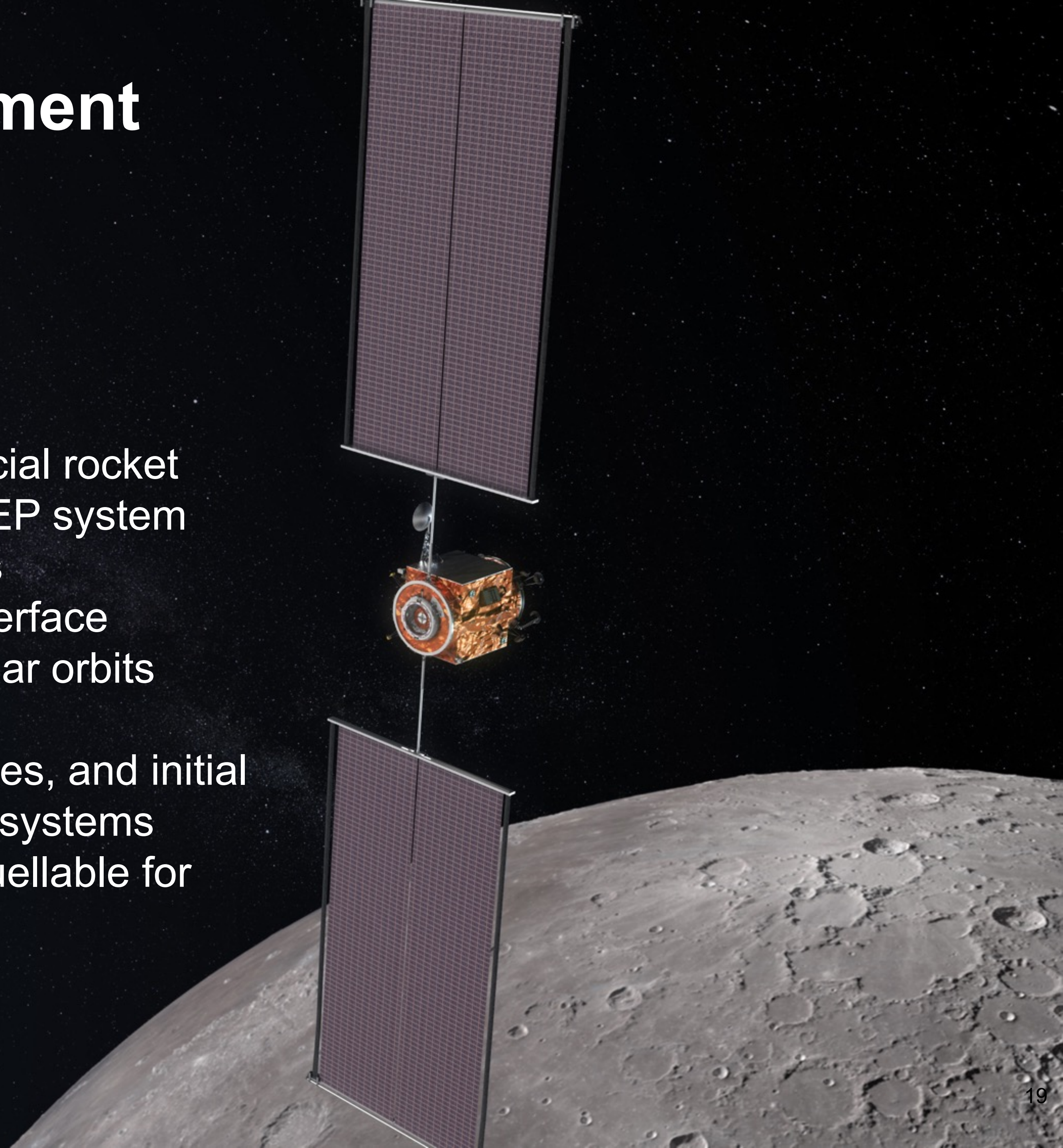
The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.

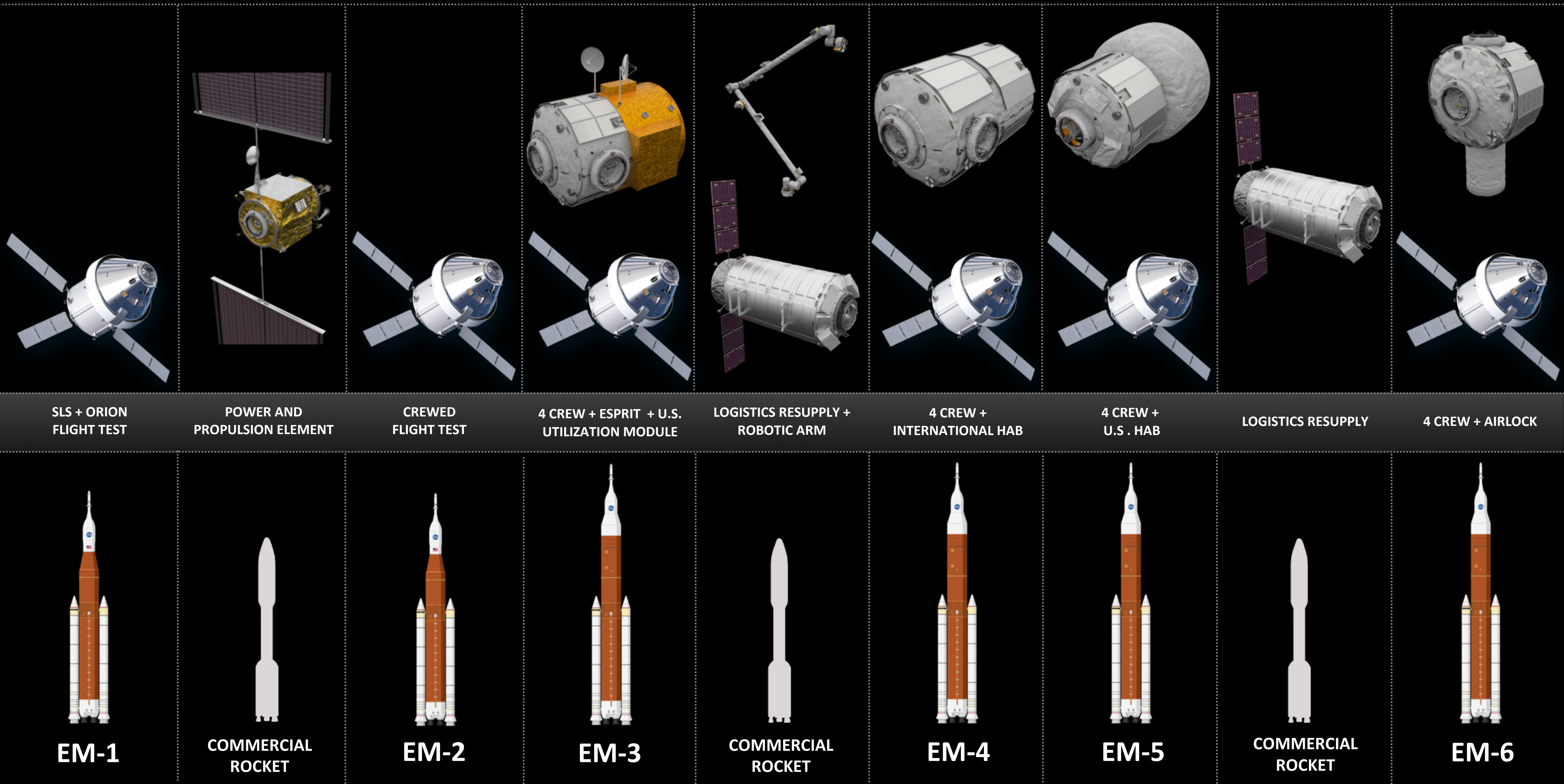
Power and Propulsion Element

First module in lunar orbit for Gateway

- 2022 launch on partner-provided commercial rocket
- 50 kW class spacecraft with 40 kW class EP system
- Power transfer to other Gateway elements
- Passive docking using IDSS compliant interface
- Capability to move gateway to multiple lunar orbits
- Orbit control for gateway stack
- Communications with Earth, visiting vehicles, and initial communications support for lunar surface systems
- 2t class xenon EP propellant capacity, refuellable for both chemical and xenon propellants
- Accommodations for utilization payloads
- 15 year life



Notional Gateway Buildup (2020-2026)



Habitation Development Partnerships

Five full-sized ground prototypes will be delivered for testing in 2019; in final negotiations with NanoRacks for sixth habitat prototype demonstrator

Lockheed Martin
Denver, CO

Refurbishes heritage hardware

Northrop Grumman
Dulles, VA

Builds on proven cargo spacecraft development

Bigelow Aerospace
Las Vegas, NV

Expandable

Boeing
Pasadena, TX

Leverages existing technologies

Sierra Nevada
Louisville, CO

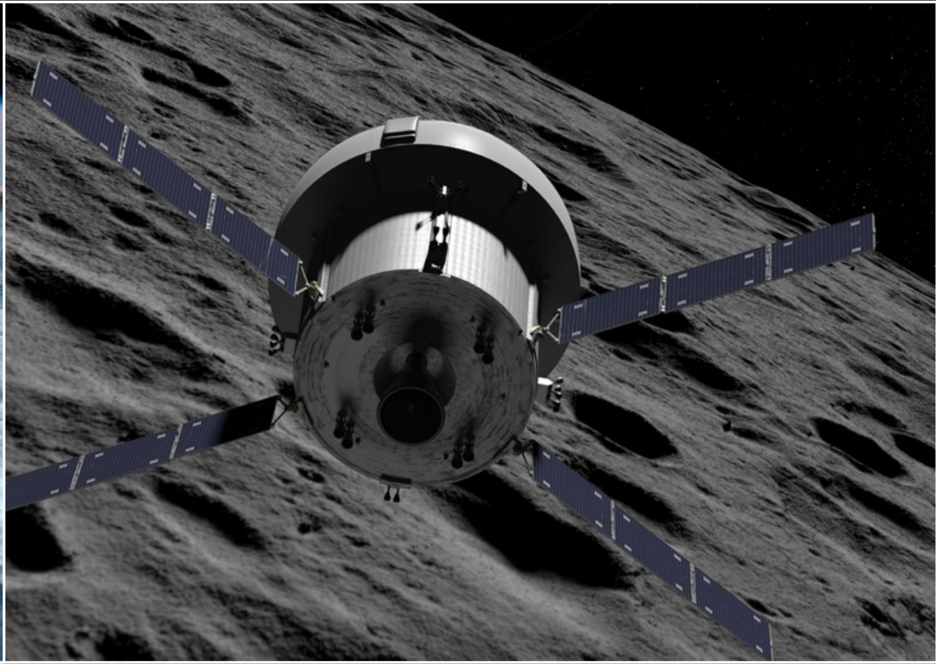
Modular buildup

NanoRacks
Louisville, CO

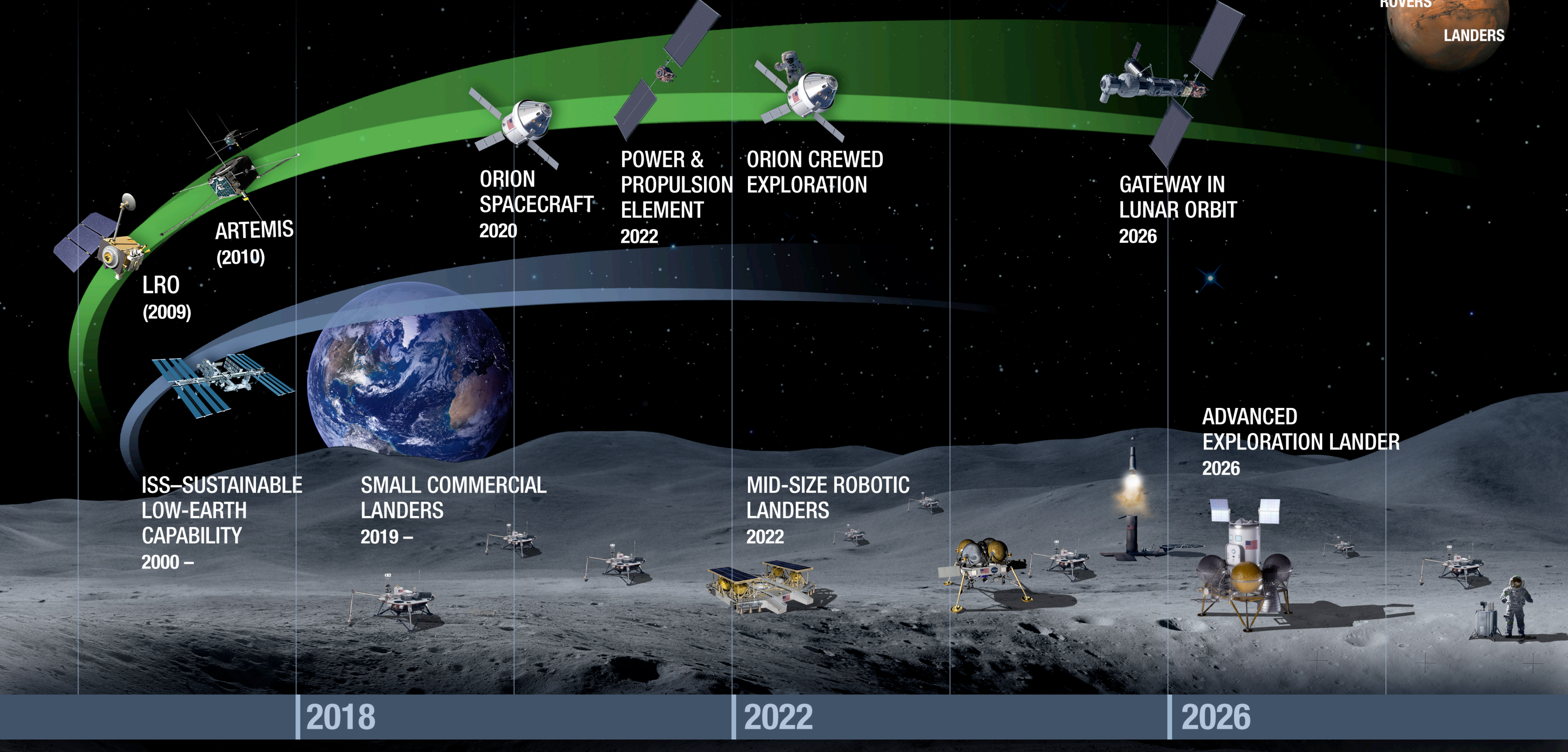
Converted Centaur upper stages

International Cooperation

NASA is leading and facilitating a sustainable open architecture program that is open to and relies on international and commercial partners



Path to the Lunar Surface



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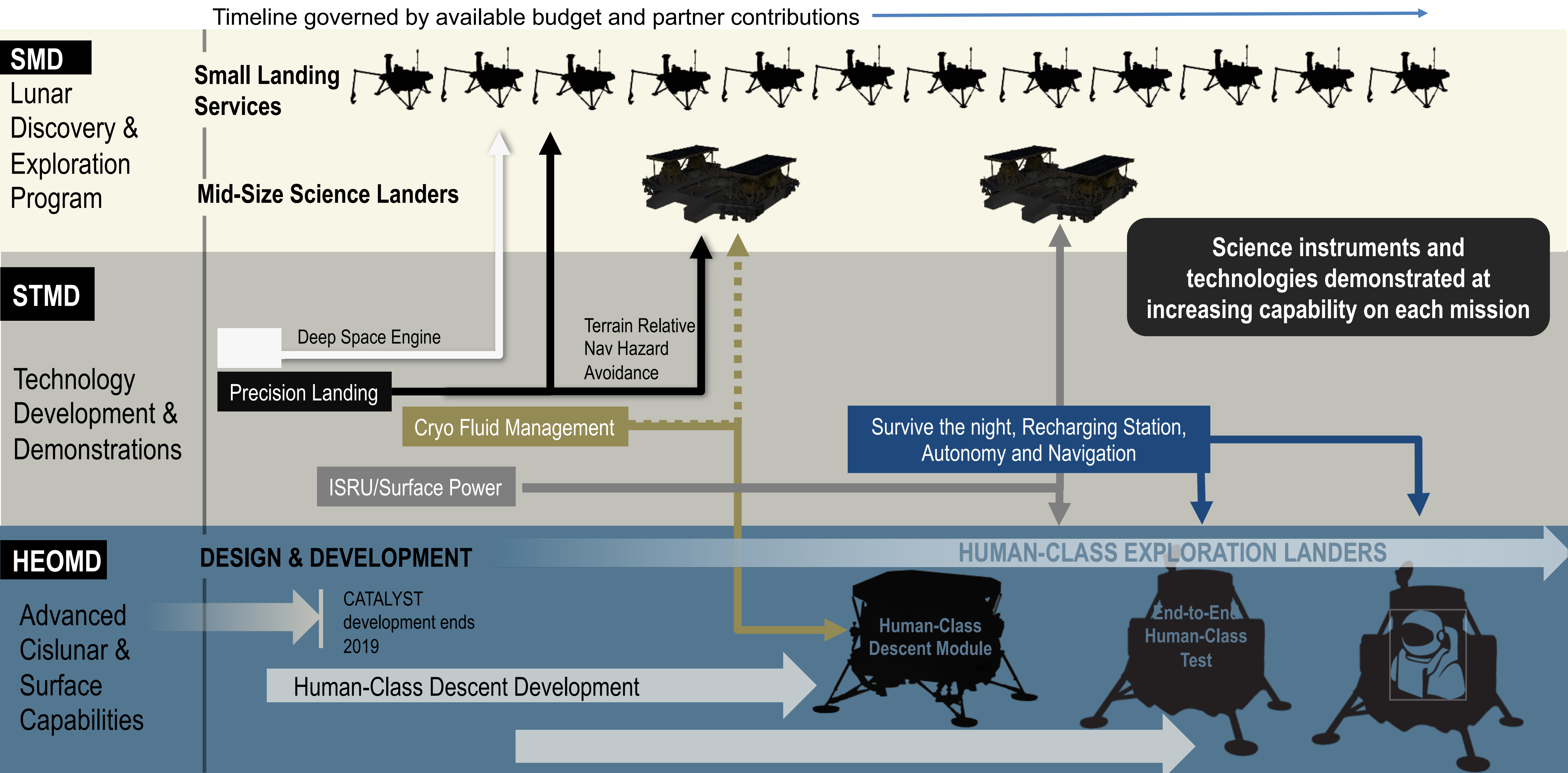
Lunar Transportation Technology Development



Three Stage Lunar Architecture (Planning/Notional)

Approach driven by available launch vehicles and physics

Ascent Element

- Based at Gateway
- Reusable & Refuellable
- Carries a crew of 4

Approx. Delta-v	2,850 m/s
Target Wet Mass	9 mT to 12 mT

Descent Element

- Performs descent propulsion
- Serves as a cargo lander

Approx. Delta-v	2,000 m/s
Target Wet Mass	15 mT to 16 mT

Transfer Vehicle

- Transfers ascent, descent elements (if applicable) from Gateway orbit to lower orbit for landing
- Potential for reusability
- Could be provided as a commercial service

Approx. Delta-v	850 m/s
Target Wet Mass	12 mT to 15 mT

OTHER BENEFITS:

Phased Development

– Spreads costs evenly, achieving capabilities for landing science and exploration lunar payloads in support of future crewed missions.

– Human rating requirements are minimal on the upfront developments, as the ascent element with its full abort capability at any crewed mission phase addresses many of the human rating requirements.

Partnering Opportunities

– Smaller element, enables easier point of entry now and in the future for both commercial and international partners, as long as interoperability standards are established.

– Industry partners can move ahead faster with the capabilities they want to build, while NASA builds and sustains unique competencies related to deep space human systems on the ascent element.

Multi-use Systems

– Elements (or their copies) can be applied to other missions to increase payloads or reduce transportation times (deep space rendezvous with tug for outer planet missions, satellite maneuvering in GEO vicinity, etc.)

– Possible alternate crewed cislunar missions include NEO rendezvous, L4/L5 tour to observe small objects, or L1/L2 missions to deploy or service remote sensing systems.

– The lunar elements may be partially or fully applicable to aspects of future Mars missions (common ascent systems, etc.)

Human Lunar Lander Development

Under the requested funding for Advanced Cislunar and Surface Capabilities (ACSC), along with other Exploration Campaign activities, NASA will re-establish U.S. preeminence to, around, and on the Moon.

Human Lunar Lander funding will invest with industry providers, purchase landed services to test sub-systems, and use innovative acquisition approaches to enable U.S. commercial capabilities to be leveraged toward human exploration of the lunar surface, and will also partner with international partners as appropriate in this endeavor.

The first planned demonstration is 2024 with at least one human-class descent element flight test.

Long-Term Exploration and Utilization of the Moon

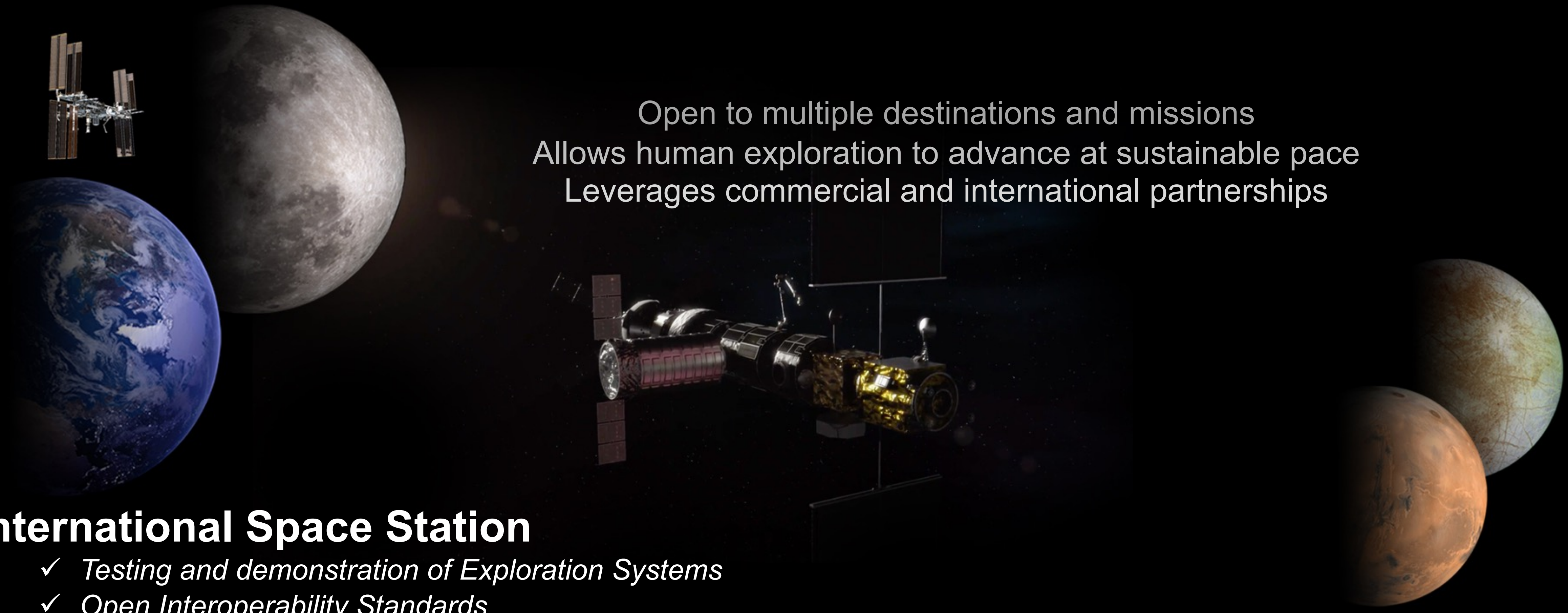
(Planning/Notional)

By 2028, NASA will have :

- Provided opportunities for at least 13 deep space CubeSat missions, including 7 to the Moon (on EM-1)
- Completed 2 Exploration Mission test flights with SLS and Orion
- Completed assembly, and begun supplying, the Gateway with 4 SLS/Orion Exploration Missions and 3 commercial flights
- Flown up to 10 CLPS opportunities, enabling new science and demonstrating new technologies supporting human return to the lunar surface
- Delivered 2 mid-size science landers, including a rover
- Demonstrate human-scale Descent Module by 2024
- Demonstrated, for the first time, a reusable lunar ascent vehicle
- Used, for the first time on the Moon, key exploration technologies including precision landing, cryogenic fluid management, in-situ resource utilization, and surface nuclear power
- Understood the ability of lunar resources and volatiles to be part of human exploration campaign; developed and refined technological capabilities and operational procedures to enable human missions beyond the Earth-moon system
- <u>Returned humans to the lunar surface</u>
- Demonstrated key technologies and operations needed to enable the first human missions to Mars
- Perhaps have a Mars sample return on the way……….

An Open Framework in Space

Developing a new approach to human exploration



Open to multiple destinations and missions
Allows human exploration to advance at sustainable pace
Leverages commercial and international partnerships

International Space Station

- ✓ *Testing and demonstration of Exploration Systems*
- ✓ *Open Interoperability Standards*
- ✓ *Commercial cargo and crew*

Space Launch System – For transportation augmented with commercial capability

Gateway – Enabling reusable in-space operations and opening up commercial opportunities in deep space

Mars

Vistas of opportunity and discovery

Questions?