National Aeronautics and Space Administration

NASA Human Exploration Plans

Space Weather Workshop

April 19, 2018

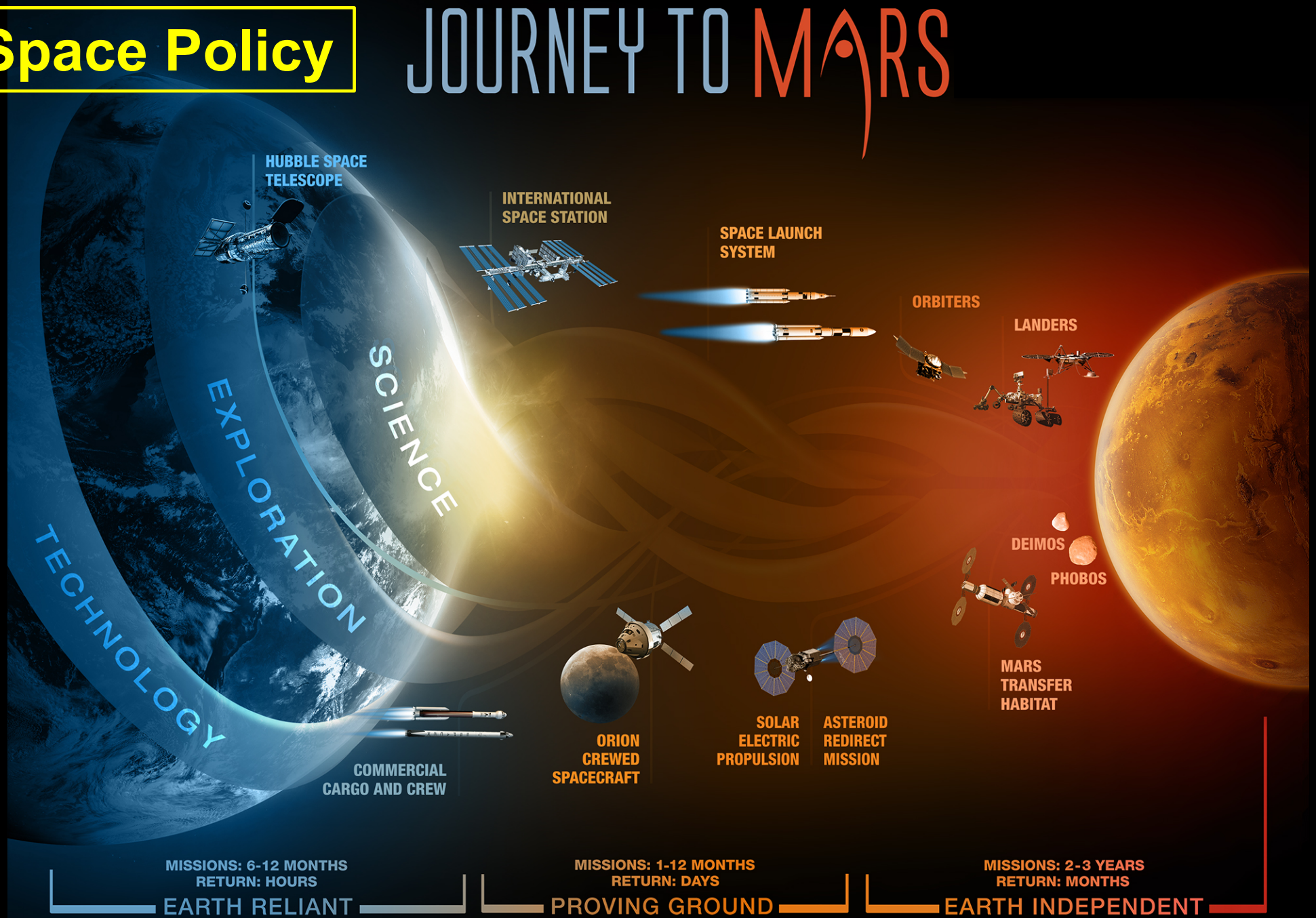
John Guidi

Space Policy Directive-1

“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.”

‘Old’ Space Policy

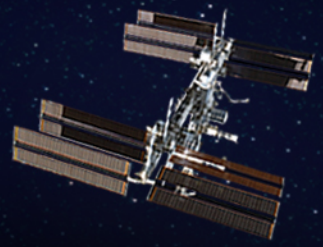


EXPANDING HUMAN PRESENCE IN PARTNERSHIP

CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY

Now

Using the International Space Station



2020s

Operating in the Lunar Vicinity (proving ground)

After 2030

Leaving the Earth-Moon System and Reaching Mars Orbit

2017 Space Policy

Phase 0

Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.

Phase 1

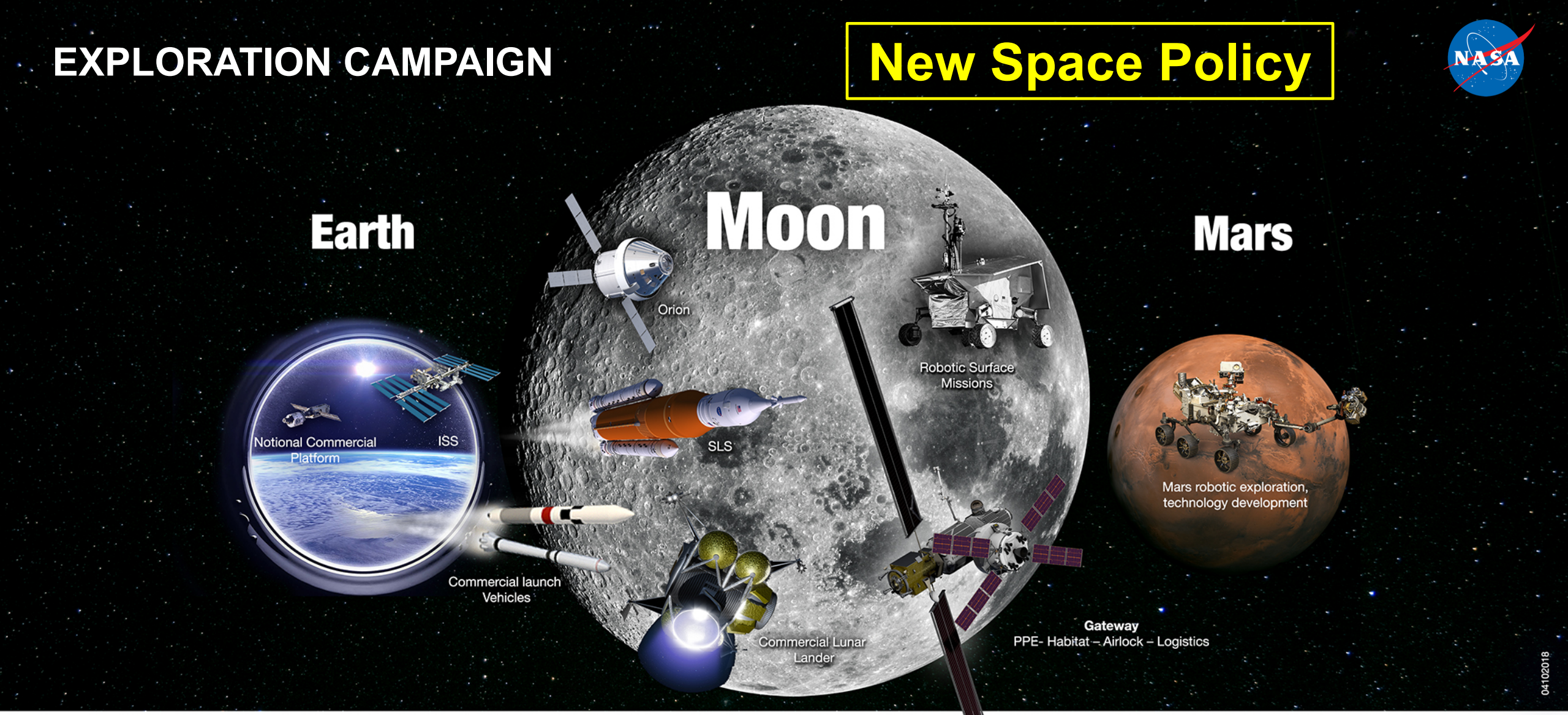
Begin missions in cislunar space. Initiate next key deep space capability.

Phase 2

Complete next deep space capability and checkout.

EXPLORATION CAMPAIGN

New Space Policy



In LEO
Commercial & International partnerships

In Cislunar Space
A return to the moon for long-term exploration

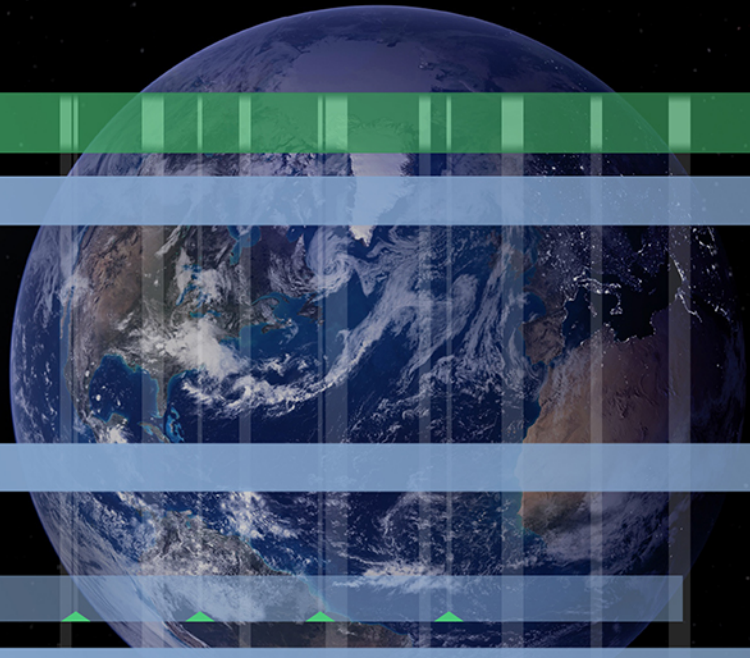
On Mars
Research to inform future crewed missions

Funding: FY2019 Presidential Budget Request Highlights

- Provides $19.9B, including $10.5B to lead an innovative and sustainable campaign of exploration and lead the return of humans to the Moon for long-term exploration and utilization followed by human missions to Mars and other destinations.
- Refocuses existing NASA activities towards exploration, by redirecting funding to innovative new programs and providing additional funding to support new public-private initiatives.
- Conducts uncrewed SLS/Orion first flight in 2020, leading to Americans around the Moon in 2023. This will be the first human mission to the moon since Apollo 17 in 1972, and will establish U.S. leadership in cislunar space.
- Serves as a catalyst for growth of a vibrant American commercial space industry expanding commercial partnerships to strengthen U.S. leadership in space.
- Achieves early Human Exploration milestone by establishing a Lunar Orbital Platform-Gateway in cislunar space; launching a power and propulsion space tug in 2022.
- Develops a series of progressively more capable robotic lunar missions to the surface of the moon using innovative acquisition approaches while meeting national exploration and scientific objectives.
- Begins transition to commercialization of low Earth orbit and ends direct federal government support of the International Space Station in 2025.
- Begins a new $150M program to encourage development of new commercial Low Earth orbital platforms and capabilities for use by the private sector and NASA.
- Focuses and integrates space technology investments to enable new robotic and human exploration capabilities and missions and contribute to economic development and growth by enabling innovative systems and services supporting the emerging space economy.

Lunar focus

NASA Exploration Campaign



NOTIONAL LAUNCHES

EARLY SCIENCE & TECHNOLOGY INITIATIVE

- **SMD**–Pristine Apollo Sample, Virtual Institute
- **HEO/SMD**–Lunar CubeSats
- **SMD**/HEO–Science & Technology Payloads

SMALL COMMERCIAL LANDER INITIATIVE

- **HEO**–Lunar Catalyst & Tipping Point
- **SMD**/HEO–Small Commercial Landers/Payloads

MID TO LARGE LANDER INITIATIVE TOWARD HUMAN-RATED LANDER

- **HEO**/SMD–Mid-sized Landers (~500kg–1000kg)
- **HEO**/SMD–Human Descent Module Lander (5-6000kg)
- **SMD**/HEO–Payloads & Technology/Mobility & Sample Return
- **SMD**–Mars Robotics

LUNAR ORBITAL PLATFORM—GATEWAY

- **HEO**–Orion/SLS (Habitation Elements/Systems)
- **HEO**/SMD–Gateway Elements (PPE, Commercial Logistics)/Crew Support of Lunar Missions
- **HEO**/SMD–Lunar Sample Return Support

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

Timelines are tentative and will be developed further in FY 2019

MARCH 2018

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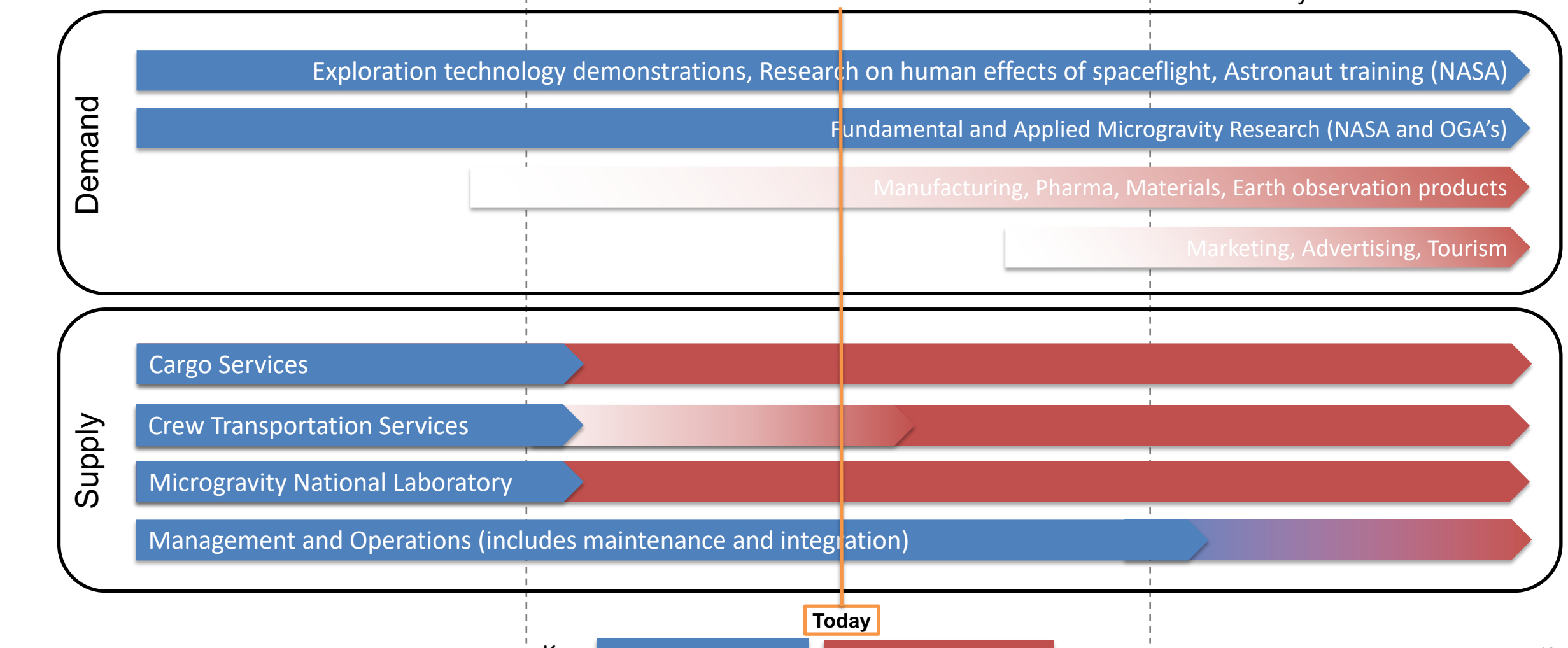
Transition LEO

ISS Utilization and LEO Transition

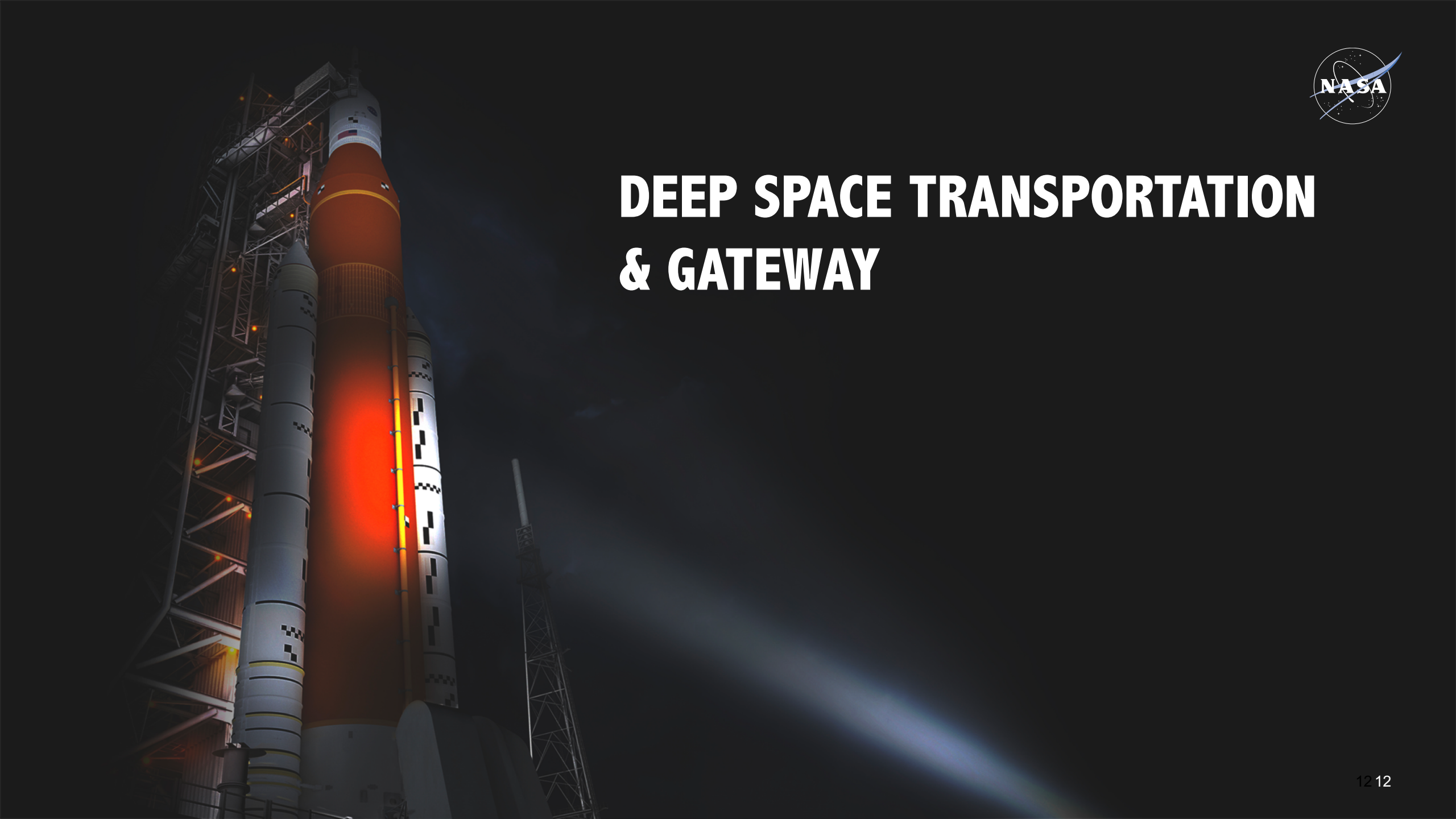
Developing the Domestic LEO Space Economy



ISS Supply Fleet

INTERNATIONAL

COMMERCIAL

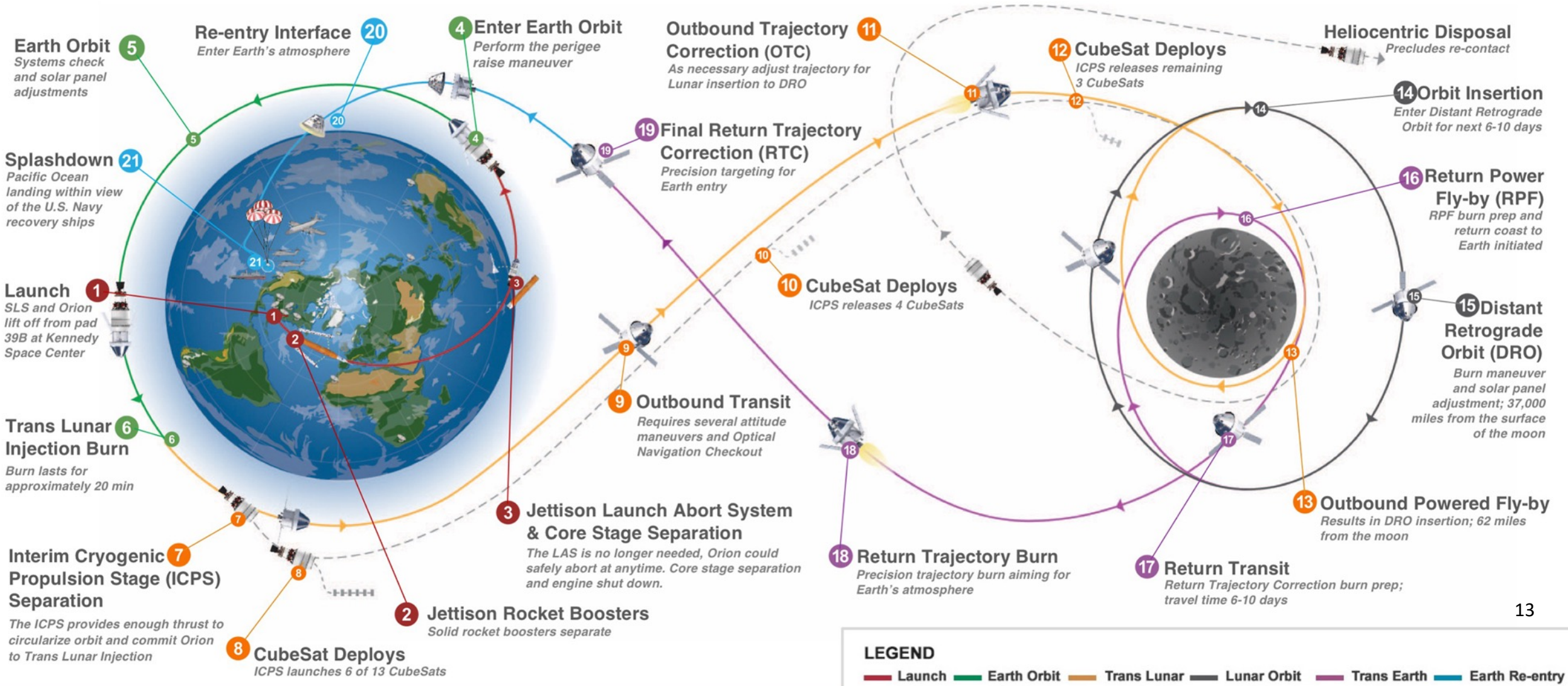


DEEP SPACE TRANSPORTATION & GATEWAY

EXPLORATION MISSION-1

National Aeronautics and Space Administration

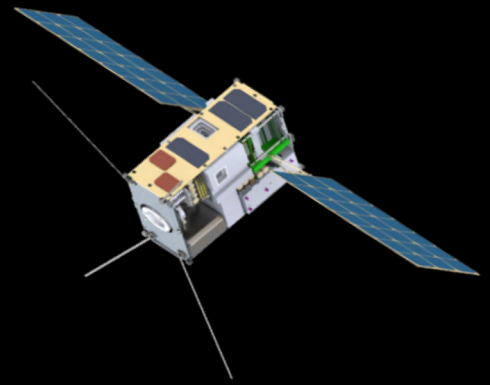
The first uncrewed, integrated flight test of NASA's Deep Space Exploration Systems. The Orion spacecraft and Space Launch System rocket will launch from a modernized Kennedy spaceport.

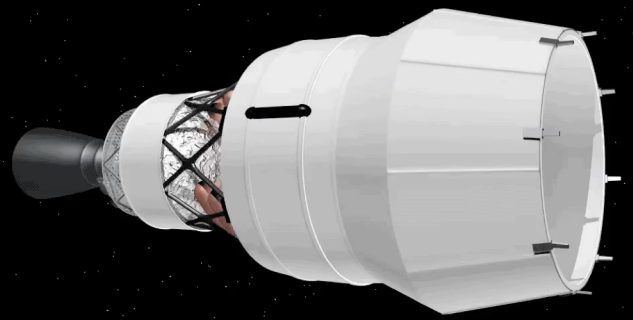


Total distance traveled: 1.3 million miles – Mission duration: 25.5 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

EM-1 Secondary Payloads

INTERIM CRYOGENIC PROPULSION STAGE





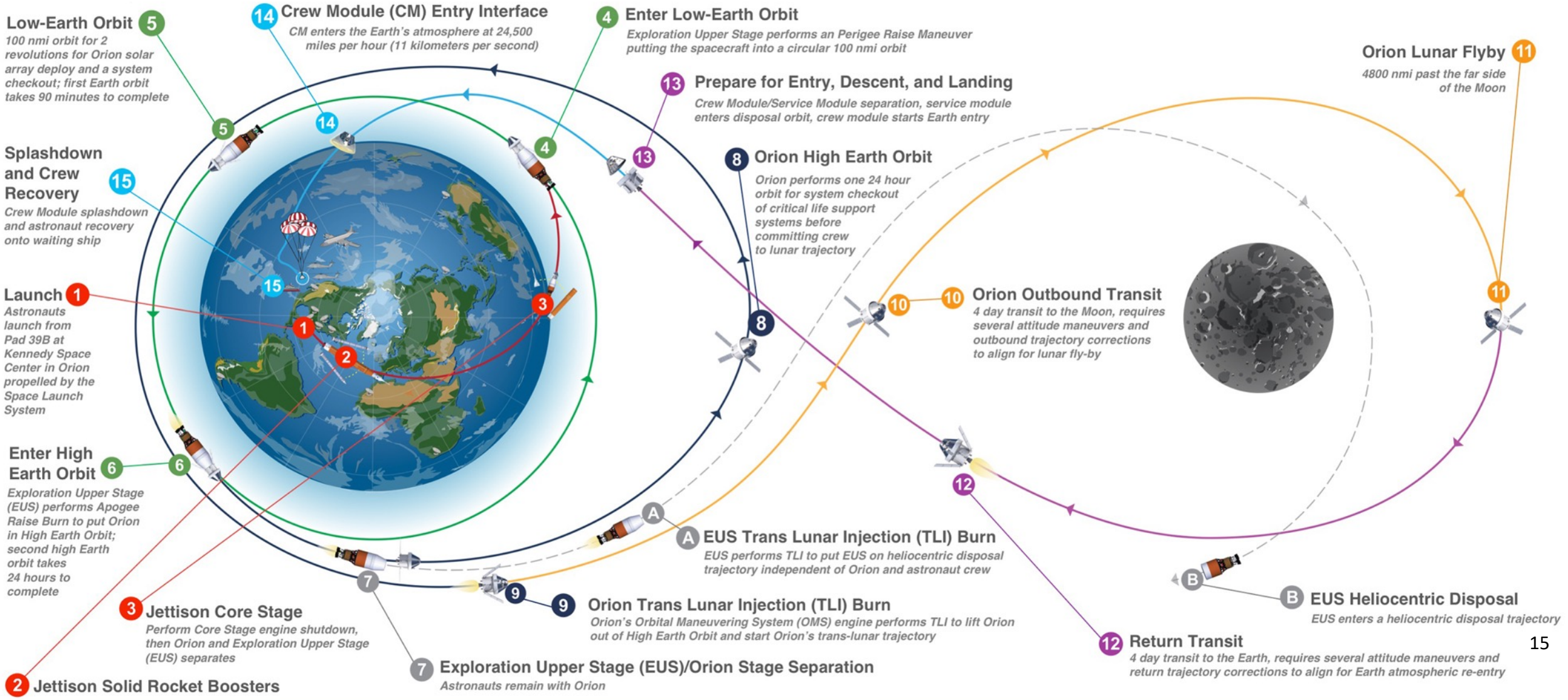
13 CUBESATS SELECTED TO FLY ON EM-1

- Lunar Flashlight
- Near Earth Asteroid Scout
- Bio Sentinel
- LunaH-MAP
- CuSPP
- Lunar IceCube
- LunIR
- EQUULEUS (JAXA)
- OMOTENASHI (JAXA)
- ArgoMoon (ESA)
- STMD Centennial Challenge Winners

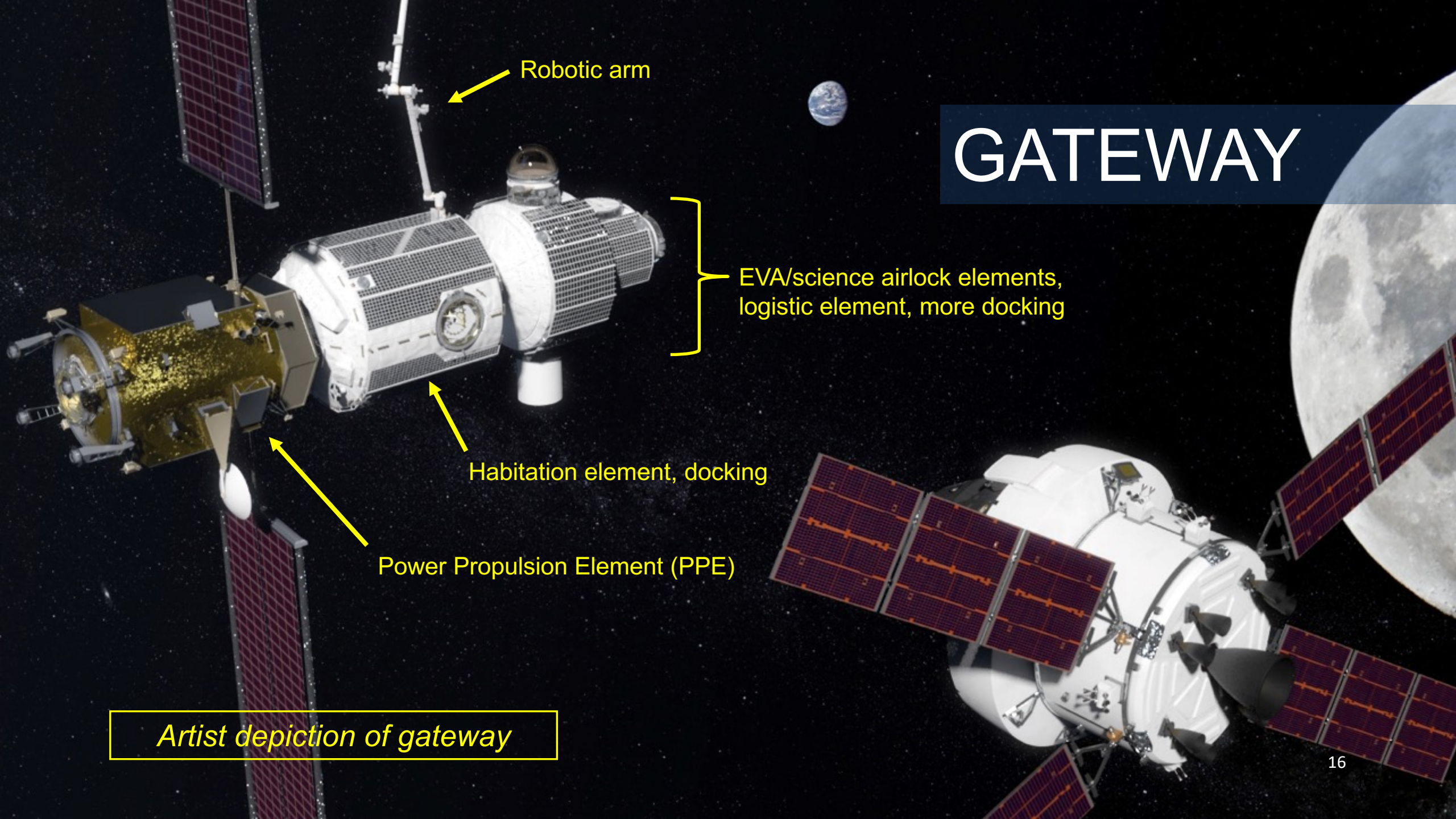
EXPLORATION MISSION-2

National Aeronautics and Space Administration

The first crewed, integrated flight test of NASA's Deep Space Exploration System, the Orion spacecraft and Space Launch System launching from a modernized Kennedy Spaceport.



4 astronauts - Total distance traveled: 1,090,320 km - Mission duration: 9 days – Re-entry speed 24,500 mph (Mach 32) – 9 metric ton Co-Manifested Payload deploy



GATEWAY

Artist depiction of gateway

Lunar Orbital Platform-Gateway: Functions

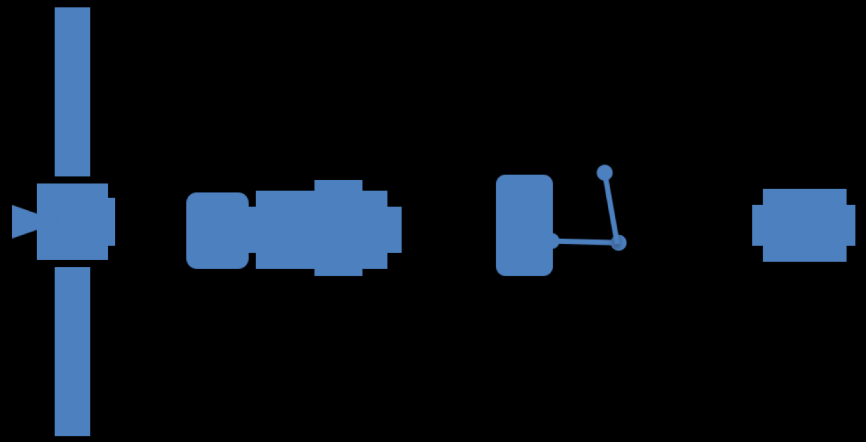
- **Habitation**
  - Provides habitable volume and short-duration life support functions for crew in cislunar space
    - W/Orion: 30 – 60+ days
  - Docking ports allow for attachment to the PPE, other Gateway elements and visiting vehicles
  - Offers attach points for external robotics, external science and technology payloads or rendezvous sensors
  - Provide accommodations for crew exercise, science/utilization and stowage
- **Airlock**
  - Provides capability to enable astronaut EVAs as well as the potential to accommodate docking of additional elements, observation ports, or a science utilization airlock
- **Logistics**
  - Deliver cargo to enable extended crew mission durations, science utilization, exploration technology demonstrations, potential commercial utilization, and other supplies
- **Power and Propulsion**
  - Station keeping, power systems, SEP transfers to different orbits, propulsion system refueling and transfer

GATEWAY DEVELOPMENT

Establishing leadership in deep space and preparing for exploration into the solar system

FOUNDATIONAL GATEWAY CAPABILITIES

2022	2023	2024+



50 kW-class Power & Propulsion Element

Habitation and Utilization

Logistics and Robotic Arm

Airlock

These foundational gateway capabilities can support multiple U.S. and international partner objectives in cislunar space and beyond.

CAPABILITIES

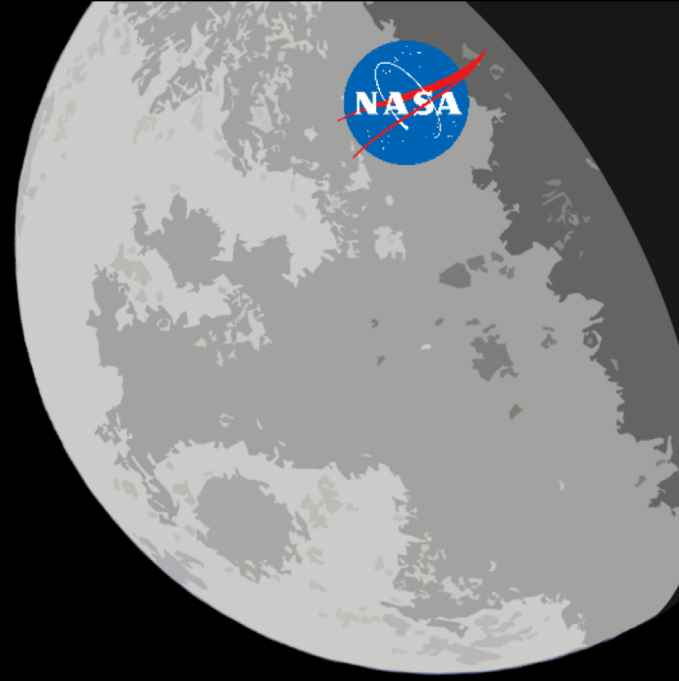
- Supports exploration, science, and commercial activities in cislunar space and beyond
- Includes international and U.S. commercial development of elements and systems
- Provides options to transfer between cislunar orbits when uncrewed
- External robotic arm for berthing, science, exterior payloads, and inspections

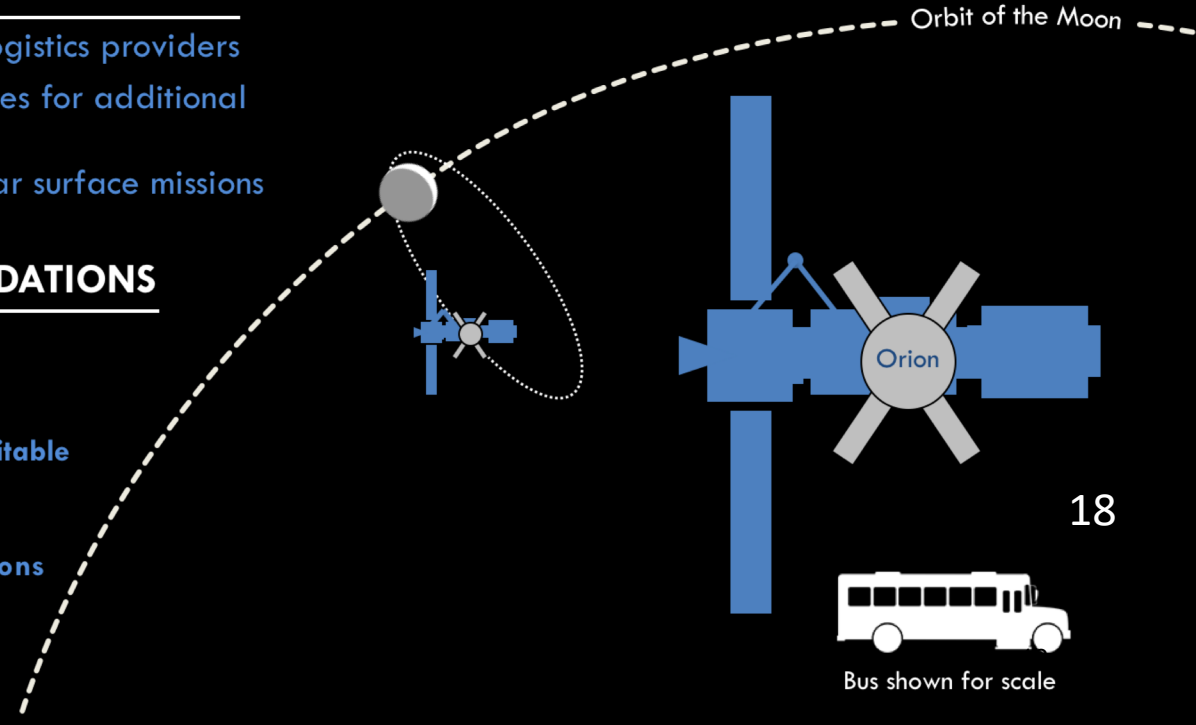
OPPORTUNITIES

- Logistics flights and logistics providers
- Use of logistics modules for additional available volume
- Ability to support lunar surface missions

INITIAL ACCOMMODATIONS

- 4 Crew Members
- At least 55 m^3 Habitable Volume
- 30 Day Crew Missions



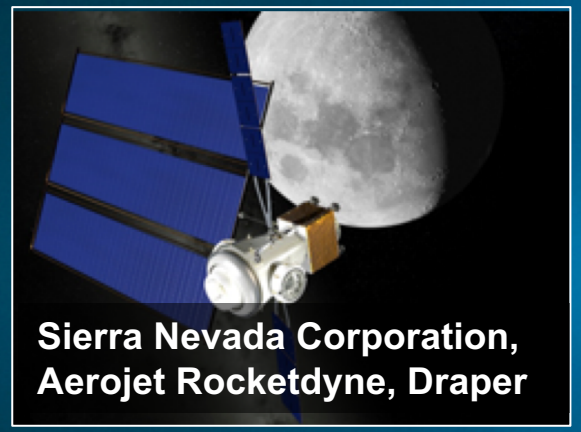


Power & Propulsion: First Element in the Gateway


Boeing


Orbital ATK


Lockheed Martin


Sierra Nevada Corporation, Aerojet Rocketdyne, Draper


SSL, DSS, Draper, University of Illinois-Urbana Champaign

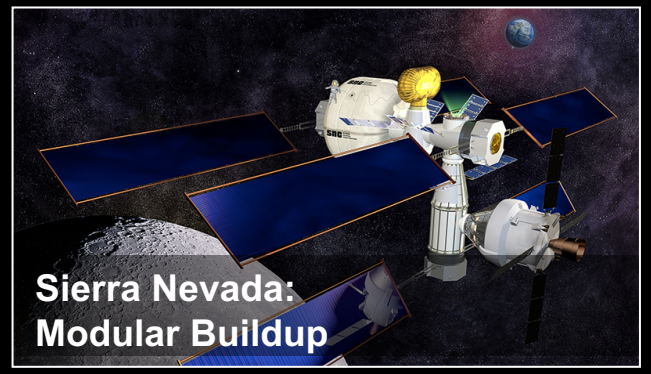
Power and propulsion element industry engagement

- **July 2017:** NASA issued a request for information to capture U.S. industry's capabilities and plans for spacecraft concepts that potentially could be advanced to power an advanced SEP system for the gateway.
- **August 2017:** NASA issued NextSTEP Appendix C, Power and Propulsion Studies seeking U.S. industry-led studies on leveraging commercial spacecraft, plans, and risk reduction for 50 kW-class SEP vehicle capabilities. Five companies began four-month studies in late November 2017.
- **February 2018:** NASA issued synopsis for a Spaceflight Demonstration of a Power and Propulsion Element. Draft BAA to be issued in a few weeks.

HABITATION CAPABILITY

20

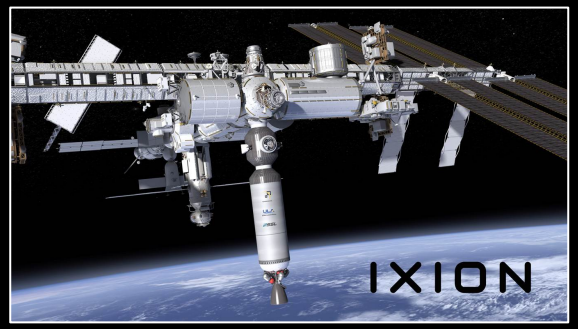
Gateway Concept Investigations

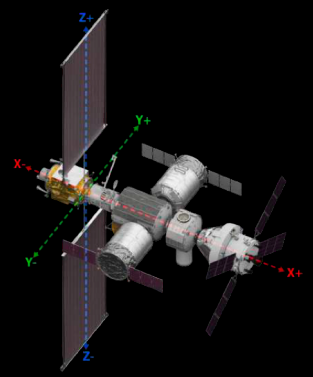


U.S. Industry:

Five full-scale prototypes in development for ground testing across the U.S.

One feasibility study on converting a spent rocket stage.





International Partners:

Concepts for contributions and utilization for gateway buildup in cislunar space

GATEWAY UTILIZATION

Gateway Utilization

- **New development programs balance near term technical and resource challenges with long term goals and system performance**
  - Successfully building the gateway and advancing exploration, science and commercial goals
  - Long term success requires long term value to stakeholders
- **Establishing gateway utilization requirements team during formulation phase**
  - Champion early identification and representation in gateway development
  - Incorporate stakeholder needs early into the gateway design
    - Maximizes return for stakeholders, reduces cost of requirement over later incorporation

Gateway Utilization – Four Focus Areas

- **Technology: Identifying high-priority technologies for gateway demonstration:**
  - Evolve its initial capabilities or enable new capabilities for human exploration.
  - Stimulate the development of commercial capabilities for operations in cislunar space
- **Commercial: Developing overall commercialization strategy for gateway:**
  - Linked with evolving Agency and HEO/SMD planning
  - RFI on commercial uses of a gateway (May)
- **International: Enabling collaboration between interested parties:**
  - International Space Station partner discussions ongoing, working on strategy to involve international, non-ISS partners (ongoing)
- **Science and Research: Identifying potential science opportunities, and how gateway infrastructure can support various investigations:**
  - Identifying science events and forums to raise awareness and obtain insight
  - SMD/HEOMD-hosted event completed – Denver gateway science workshop (February)
    - Revising current gateway utilization ground rules & assumptions

Workshop sponsored by SMD/HEOMD (M. New, B. Bussey)

Three driving rationale for the workshop

- **Engage the science community with respect to the scientific potential of a lunar gateway**
- **Discuss potential scientific investigations leveraging the gateway**
  - including the scope of possible instruments
  - Using the gateway infrastructure
- **Discuss what resources the gateway would have to provide to facilitate different types of scientific investigations**

Science Workshop Format

- **Introductory briefings on NASA plans, ISS lessons learned, gateway orbit options**
- **~180 Talks, ~300 Attendees**
    - Government, academia, industry, international
- **One day of discipline-focused sessions in five parallel venues – 5-20 minutes per abstract**
    - Heliophysics
    - Earth Science
    - Astrophysics & Fundamental Physics
    - Lunar & Planetary
    - Life Sciences and Space Biology
- **Cross-cutting discussions**
    - Orbits, Human exploration, Potential future capabilities
    - External Instruments
    - Samples
    - Telerobotics & Leveraging Infrastructure
    - Internal Instruments

Workshop Space Weather Topics

Dedicated space weather session with 15 presentations

- **Data to support Space Weather Forecasting**
  - Possibly utilize smallsats released from the gateway
  - What observations are required?

- **Observations of different phenomena**
  - Solar Energetic Particle Events
  - X-ray Flares
  - Coronal Mass Ejections (CMEs)
  - Solar Wind Plasma
  - Interplanetary Magnetic Field
  - Galactic Cosmic Rays (GCRs)
  - GCR generated energetic particles from the lunar surface
  - Charged & neutral particle

- **Spacecraft Charging & Space Environment Monitoring**
  - Measure plasma/spacecraft interaction

Workshop Samples Topics

Several sessions discussed different kinds of samples

- **Lunar & Planetary:**
  - Asteroid/mini-moon samples delivered to DSG (2 abstracts)
  - Lunar samples delivered to DSG

- **Heliophysics:**
  - Solar Wind (1 abstract)
    - Genesis–like, long term (10 years)
  - Interstellar dust samples, cosmic dust collected for Earth Return (5 abstracts)
    - Sample collection outside of magnetosphere is key (avoids deflection of particles)
    - Coupled with CDA-like instrument, can both collect for Earth return and characterize
  - Long Duration Exposure for materials tests, micrometeorite cratering (1 abstract)
    - Like LDEF, MISSE experiments

- **SLSPRA: Biological samples**
  - Many sample types (single cell, plants, rodents, organs, systems-on-chip, humans, drugs & food,..)
    - Fixing, preservation, storage, in-situ analysis (instruments, reagents, controls), disposal, crew time

Lunar/Mars Sample Management – Gateway Resources

- **Ability to install, and retrieve dust collectors on the gateway in different look directions, avoiding contamination from the gateway.**
  - Possible need for a boom to avoid contamination
- **Ability to dock, or berth, a sample return vehicle with or without crew present**
  - Need for a science airlock and automation
- **Some internal volume needed of science support equipment, in addition to experiments**
  - Glove box (multi-use) and analytical equipment
  - Emphasis on in-situ analysis. Assumption of limited downmass to Earth via Orion
- **Many Space Biology and HRP return samples will require on-board and return cold stowage capability**
- **External analytical equipment possible**
  - Decrease need to open “dirty” lunar samples inside the gateway

Draft Deep Space Interoperability System Standards

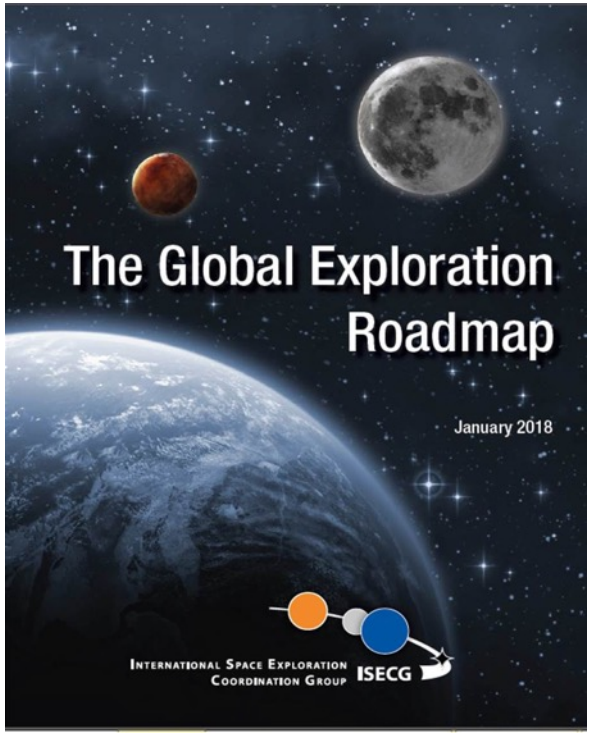
- **NASA, in collaboration with International Space Station partners, has developed a draft set of deep space interoperability system standards in seven prioritized domain areas:**
  - Avionics
  - Communications
  - Environmental Control and Life Support Systems
  - Power
  - Rendezvous
  - Robotics
  - Thermal
- **The draft standards were released for public comment on March 1, 2018, with the goals of:**
  - enabling industry and international entities to **independently develop systems and elements** for deep space that would be compatible aboard any spacecraft, irrelevant of the spacecraft developer;
  - defining interfaces and environments to **facilitate cooperative deep space exploration endeavors**; and
  - engaging the wide-ranging global spaceflight industry, and encourage feedback on the standards **from all potential stakeholder audiences**.

www.internationaldeepspacestandards.com

Global Exploration Roadmap

- **The GER is a human space exploration roadmap developed by 14 space agencies participating in the International Space Exploration Coordination Group (ISECG)**
  - First released in 2011. Updated in 2013 and 2018.

Australia, Canada, China, European Space Agency, France, India, Italy, Japan, Republic of Korea, Russia, Ukraine, United Arab Emirates, United Kingdom, United States



- **The non-binding strategic document reflects consensus on expanding human presence into the Solar System, including**
  - Sustainability Principles
  - Importance of ISS and LEO
  - The Moon: Gateway, Lunar vicinity and Lunar surface
  - Mars: The Driving Horizon Goal

www.globalspaceexploration.org
www.nasa.gov/isecg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