National Aeronautics and Space Administration

Update on Gateway with Science and Technology (Utilization) Discussion

Julie A. Robinson, Ph.D.

NASA Johnson Space Center

Aeronautics and Space Engineering Board, 162nd Meeting, Irvine, CA

October 11, 2018

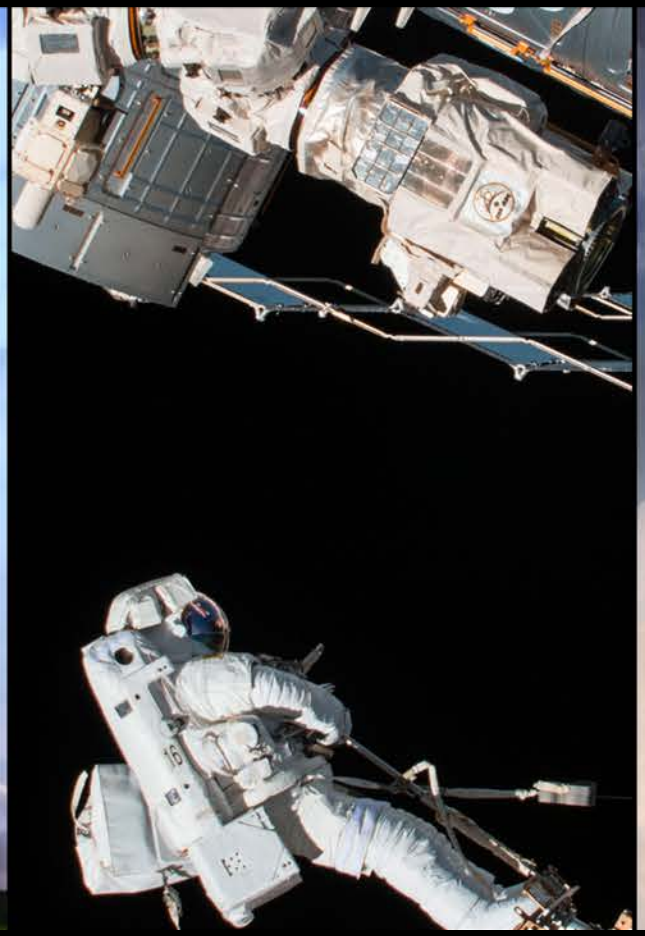
Content approved for public release in presentations by Gerstenmaier, Crusan and Guidi at August 2018 NAC

Space Policy Directive 1

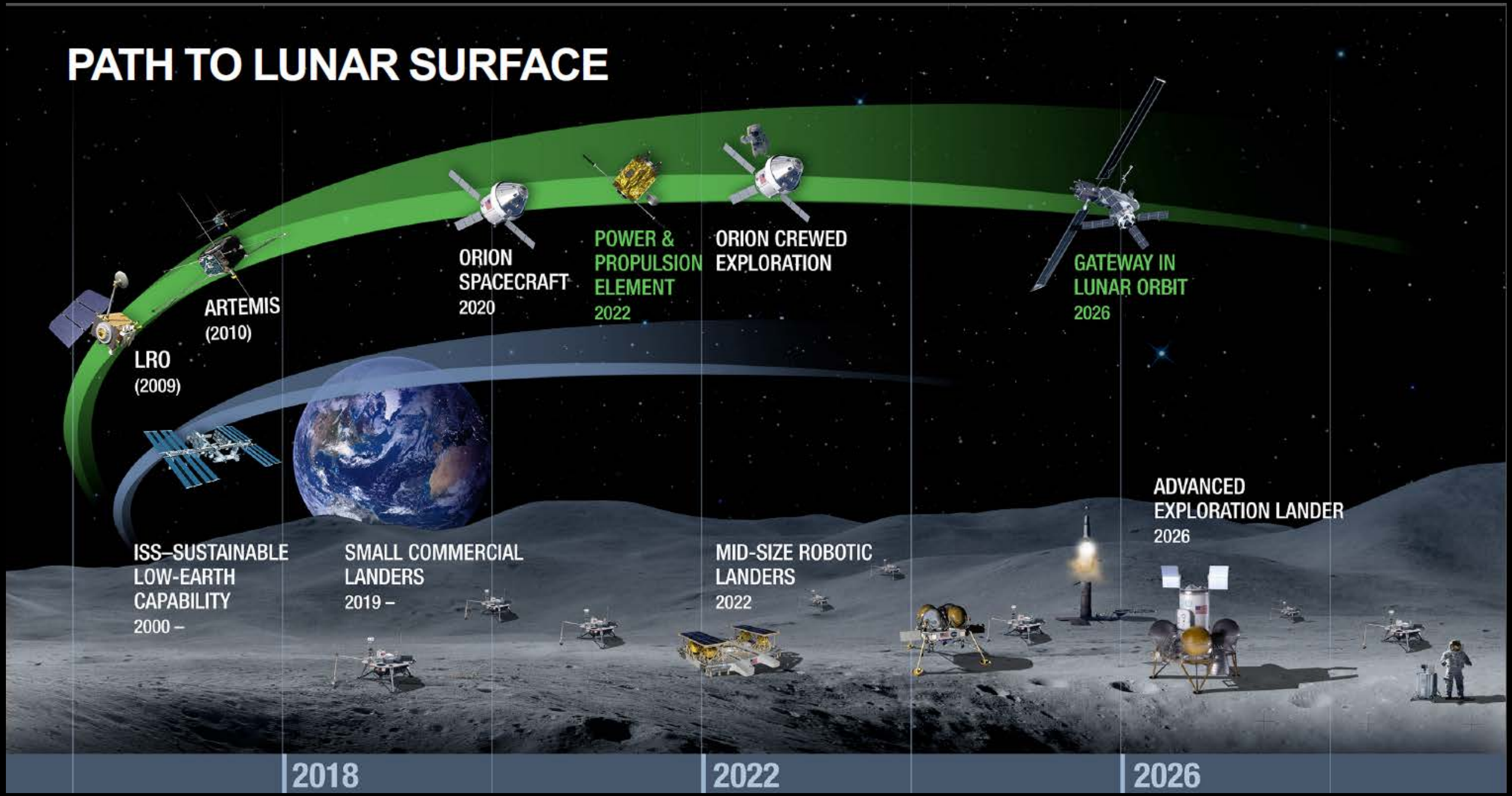
Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of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

11 December 2017

LEADING FUTURE EXPLORATION - STRATEGIC PRINCIPLES



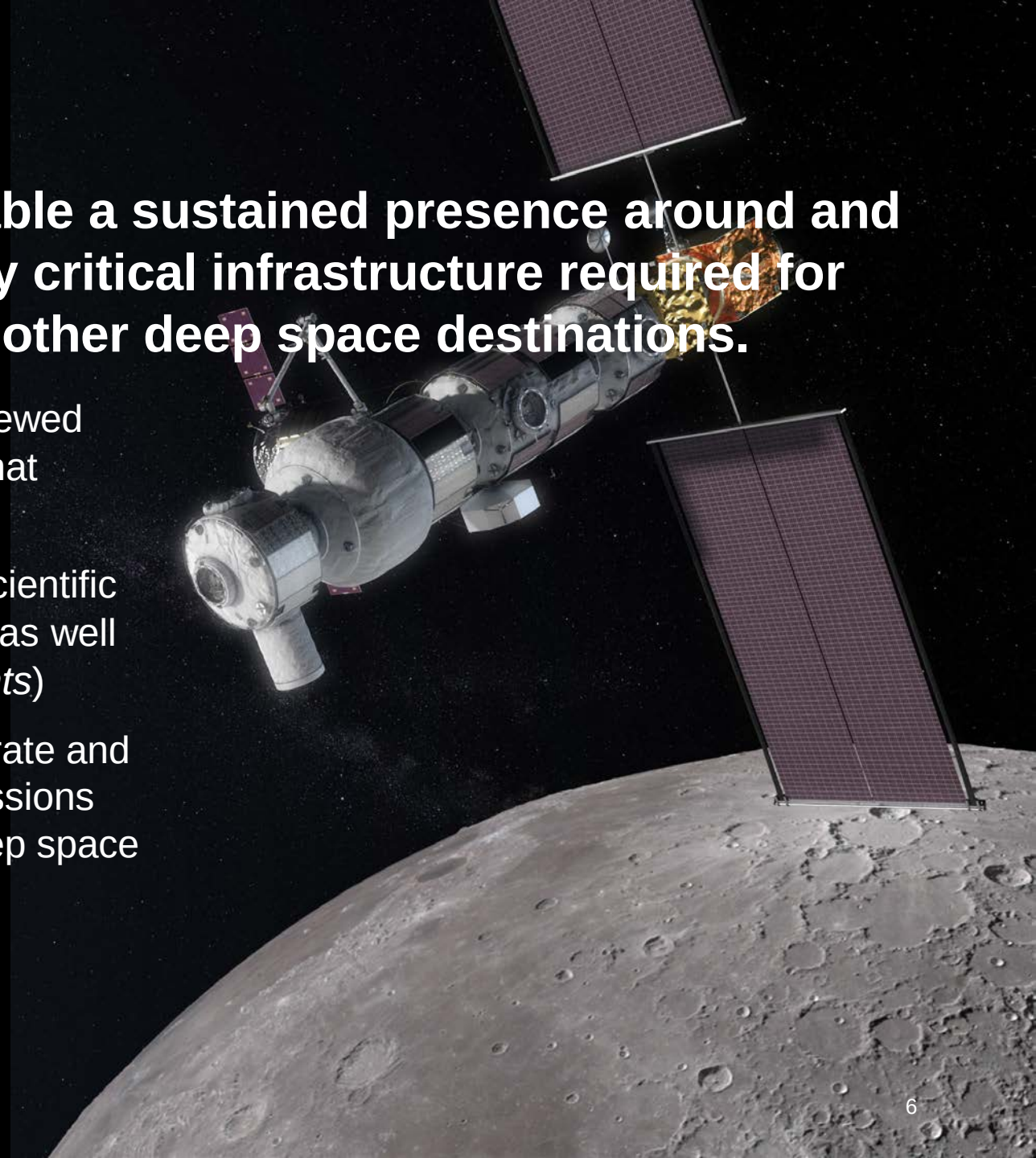
Fiscal Realism | Commercial & International Partnerships | Scientific Exploration
Technology Pull and Push | Gradual Buildup of Capability
Architecture Openness and Resilience
Global Collaboration and Leadership | Continuity of Human Spaceflight


PATH TO LUNAR SURFACE
LRO
(2009)
ARTEMIS
(2010)
ORION
SPACECRAFT
2020
POWER &
PROPULSION
ELEMENT
2022
ORION CREWED
EXPLORATION
GATEWAY IN
LUNAR ORBIT
2026
ISS–SUSTAINABLE
LOW-EARTH
CAPABILITY
2000 –
SMALL COMMERCIAL
LANDERS
2019 –
MID-SIZE ROBOTIC
LANDERS
2022
ADVANCED
EXPLORATION LANDER
2026
2018
2022
2026

Gateway Objectives

NASA shall establish a Gateway to enable a sustained presence around and on the Moon and to develop and deploy critical infrastructure required for operations on the lunar surface and at other deep space destinations.

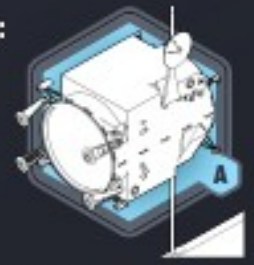
- The Gateway shall be utilized to enable human crewed missions to cislunar space including capabilities that enable surface missions. (*Crewed Missions*)
- The Gateway shall provide capabilities to meet scientific requirements for lunar discovery and exploration, as well as other science objectives. (*Science Requirements*)
- The Gateway shall be utilized to enable, demonstrate and prove technologies that are enabling for Lunar missions and that feed forward to Mars as well as other deep space destinations. (*Proving Ground & Technology Demonstration*)
- NASA shall establish industry and international partnerships to develop and operate the Gateway. (*Partnerships*)



GATEWAY

An exploration and science outpost in orbit around the Moon

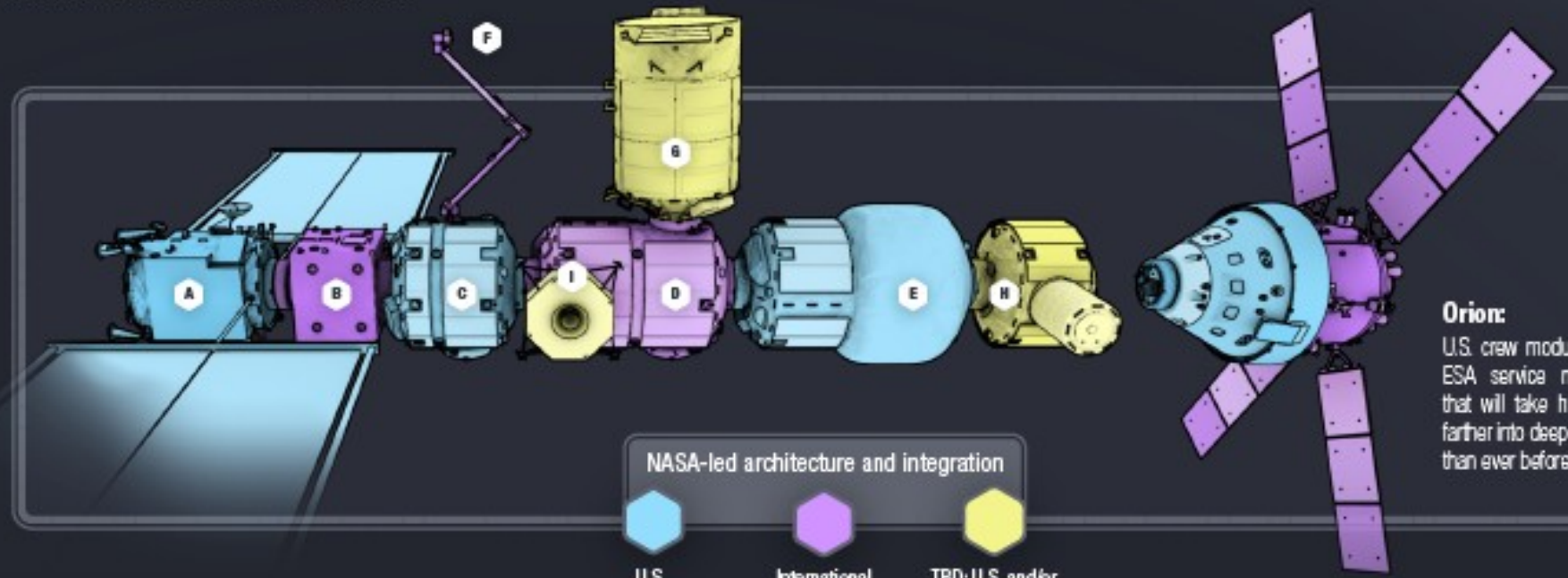
Power and Propulsion Element:
Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.



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 with 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

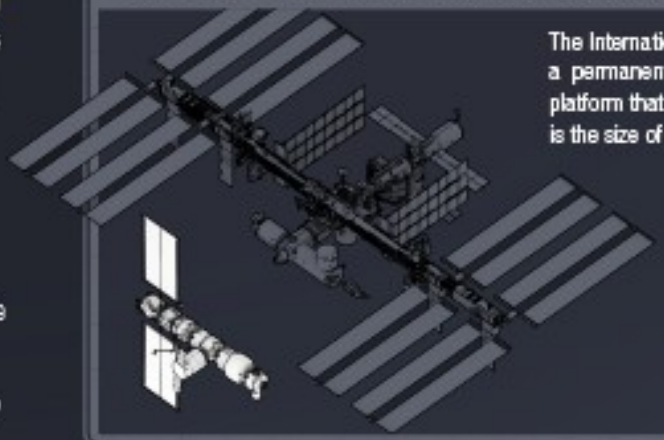
Robotic Arm:
Mechanical arm to berth and inspect vehicles, install science payloads.

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



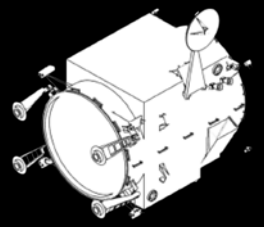
The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

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

Gateway Modules

ADVANCED SEP

Power and Propulsion Element: 2022
Power, in-space transportation, and initial lunar communications



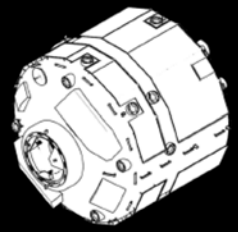
- One or more competitive awards to U.S. industry
- Launching 2022 on partner-provided commercial launch vehicle.
- Acquisition time: 3 years

EARLY OPERATIONAL CAPABILITY

Launch package: ESPRIT and U.S. utilization module: 2023

ESPRIT provides PPE refueling, science airlock and additional lunar communications. The U.S. Utilization Element provides initial habitation volume and logistics for up to 15 days

ESPRIT:
- International partner provided
- Launching NET 2023 on SLS
- Acquisition time: 3-4 years

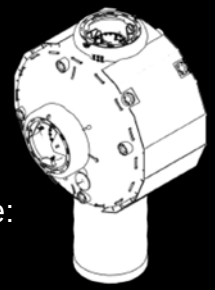


U.S. Utilization Module:
- Provided by NASA
- Launching NET 2023 on SLS
- Acquisition time: 3-4 years

EVA CAPABILITY

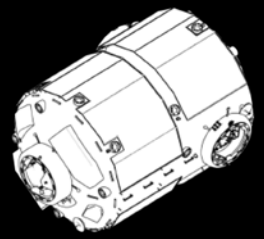
Airlock: *Enables EVAs and additional docking*

- Acquisition approach deferred until 2020
- Acquisition time: 3-6 years

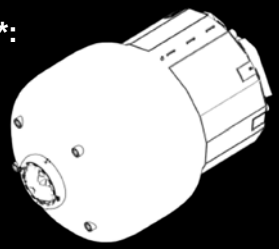


ENHANCED HABITATION

International partner and U.S. habitat modules: 2024 and 2025
Two habitats provide increased volume for crew operations and science.



International Partner Habitat*:
- Launching NET 2024 on SLS
- Acquisition time: 5 years

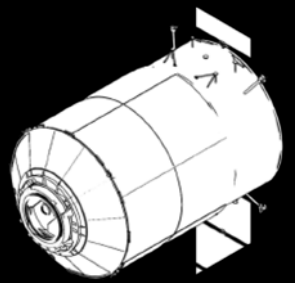


U.S. Habitat*:
- U.S. provided by competitive award to industry
- Launching NET 2025 on SLS
- Acquisition time: 5-6 years

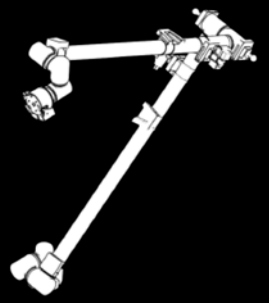
*Habitation functional allocations are currently under review

ENHANCED SCIENCE & OPERATIONS

Launch package: *Provides logistics and utilization payloads, external robotic capabilities*



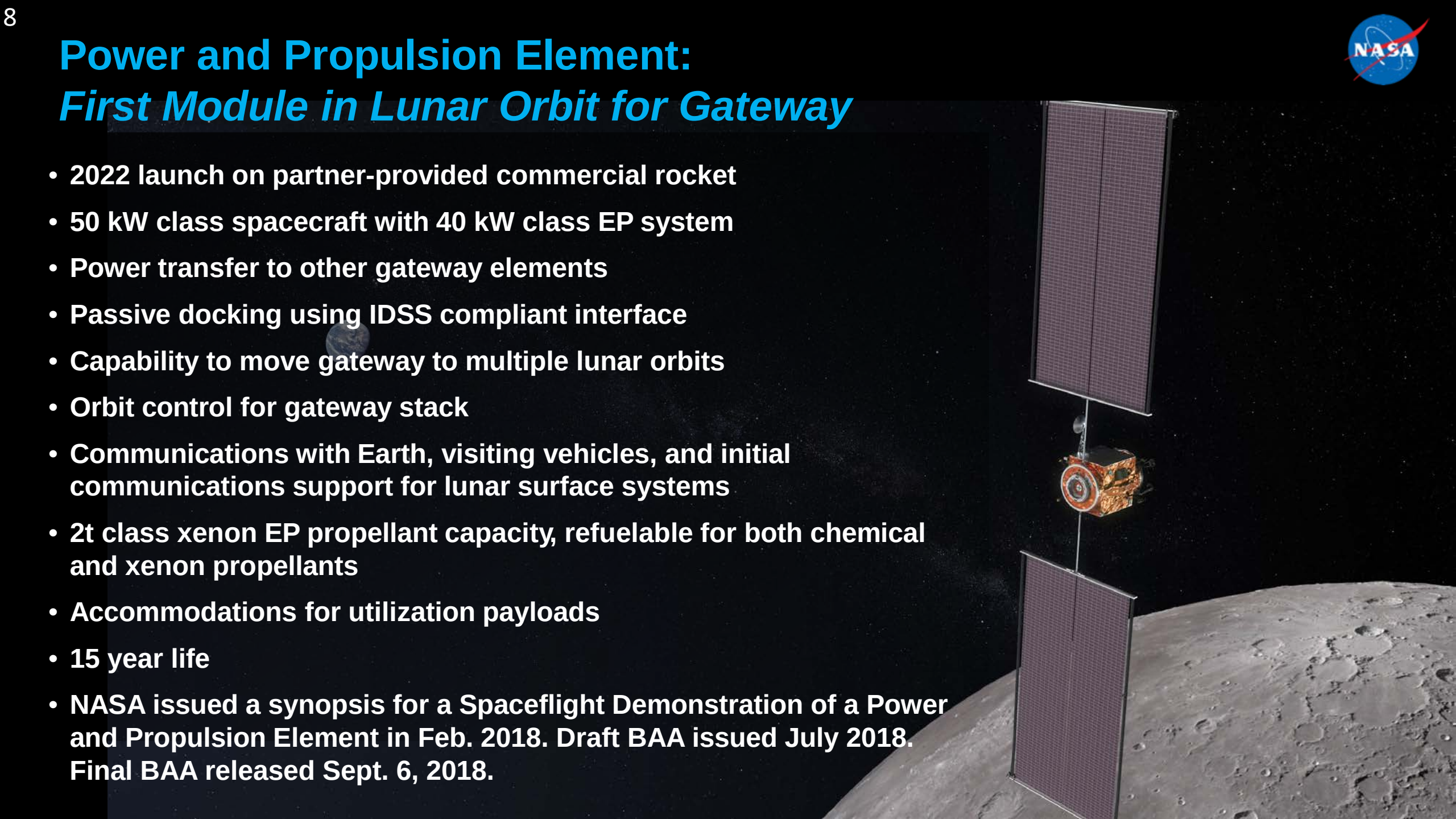
Logistics:
- U.S. and international partner provided
- Earliest delivery 2024
- Acquisition time: 3-4 years



Robotic Arm:
- International partner provided
- Earliest delivery on first logistics flight (2024)

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, refuelable for both chemical and xenon propellants
- Accommodations for utilization payloads
- 15 year life
- NASA issued a synopsis for a Spaceflight Demonstration of a Power and Propulsion Element in Feb. 2018. Draft BAA issued July 2018. Final BAA released Sept. 6, 2018.



U.S. 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

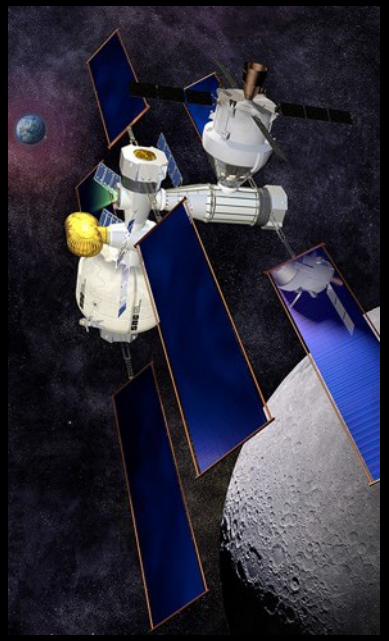
Bigelow Aerospace
Las Vegas, NV

Expandable

Boeing
Pasadena, TX

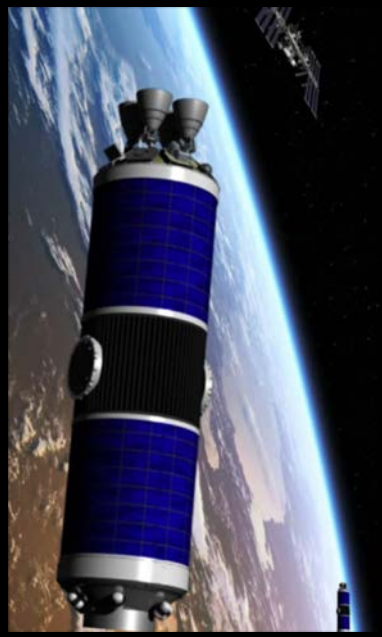
Leverages existing technologies

Sierra Nevada
Louisville, CO



Modular buildup

NanoRacks
Louisville, CO

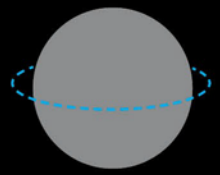


Converted Centaur upper stages

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.

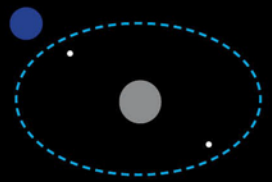
ORBIT TYPES



LOW LUNAR ORBITS

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

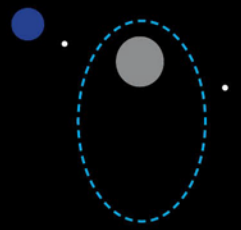
» Orbit period: 2 hours



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)

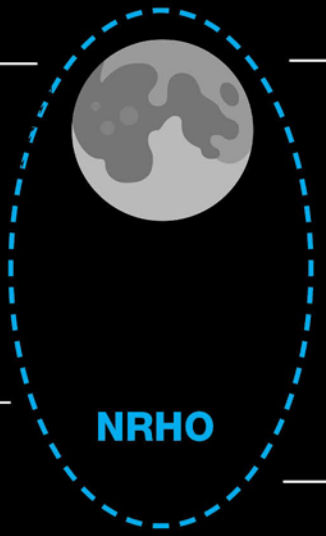
1,500 km (932 miles) at its closest to the lunar surface, 70,000 km (43,495 miles) at its farthest.

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

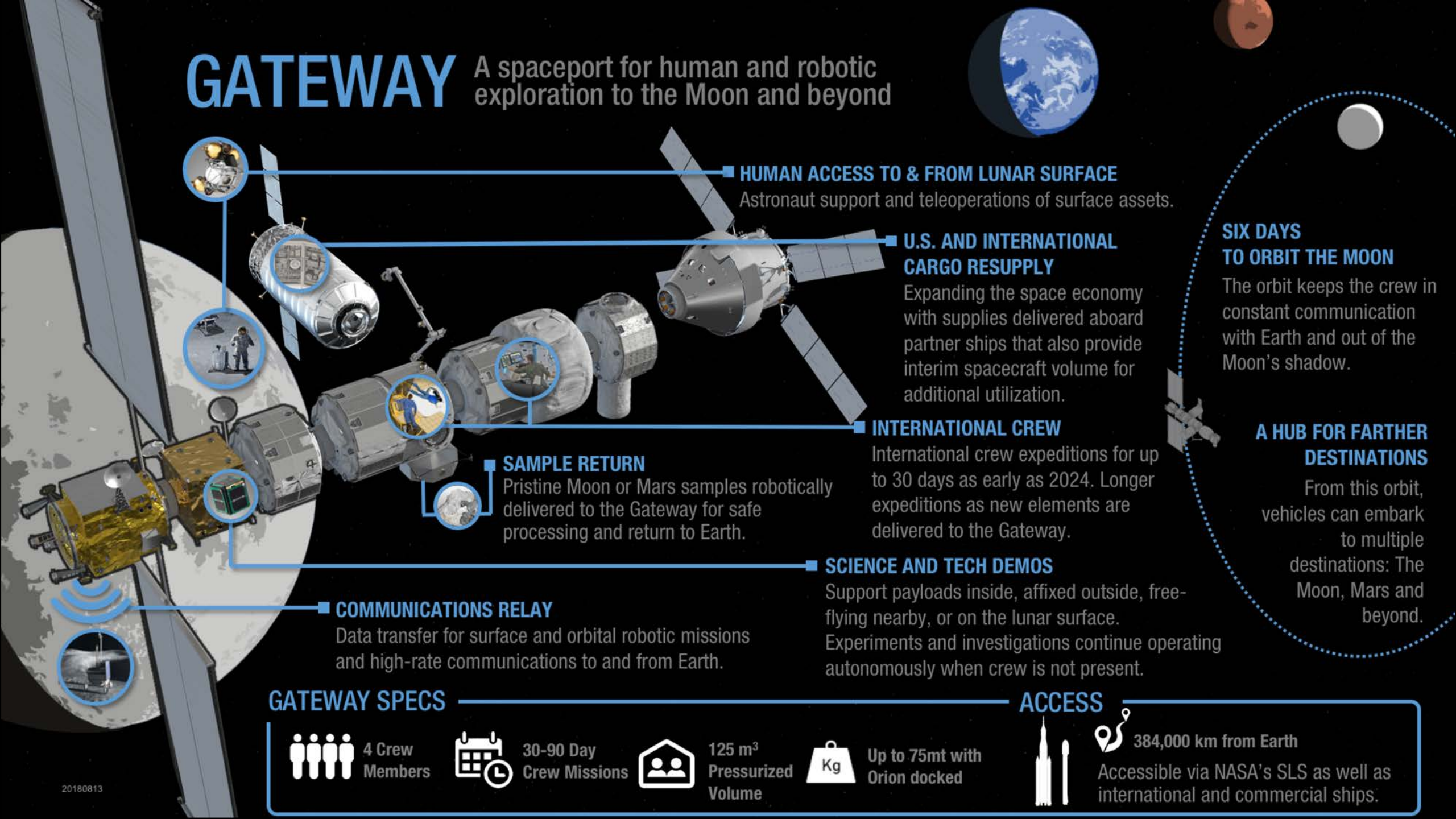
Provides continuous view of Earth and communication relay for lunar farside.

SURFACE OPERATIONS

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

GATEWAY

A spaceport for human and robotic exploration to 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 Moon or Mars 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

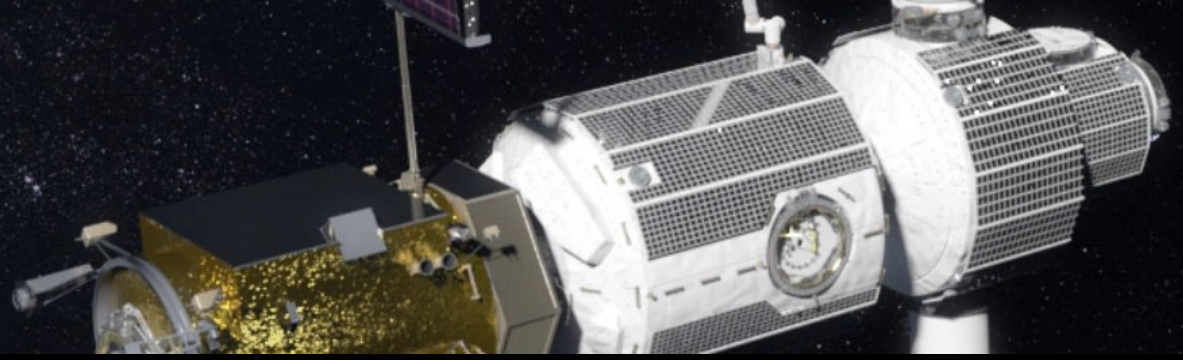
- 4 Crew Members
- 30-90 Day Crew Missions
- 125 m^3 Pressurized Volume
- Up to 75mt with Orion docked

ACCESS

384,000 km from Earth

Accessible via NASA's SLS as well as international and commercial ships.

20180813



DEEP SPACE GATEWAY CONCEPT SCIENCE WORKSHOP

February 27-March 1, 2018
DENVER, COLORADO

Workshop sponsored by NASA HQ (HEOMD & SMD), JSC, MSFC & GSFC

- **All elements will have *external* payload accommodations**
- **All pressurized volumes may have *internal* payload accommodations**

Driving Rationale:

- **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 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, Space Weather
  - External Instruments
  - Samples
  - Telerobotics & Leveraging Infrastructure
  - Internal Instruments

Key ISS Lessons Learned for Gateway

(Presented by Robinson at the Workshop)

1. **Target obtaining science support from key science stakeholder communities**
   - Engage SMD and science communities early
   - Build stakeholder support to aid funding and long term sustainability
   - Align Gateway capabilities with key stakeholder needs (e.g. sample/sample return, astrophysics, heliophysics, human research, Earth/Moon observations)

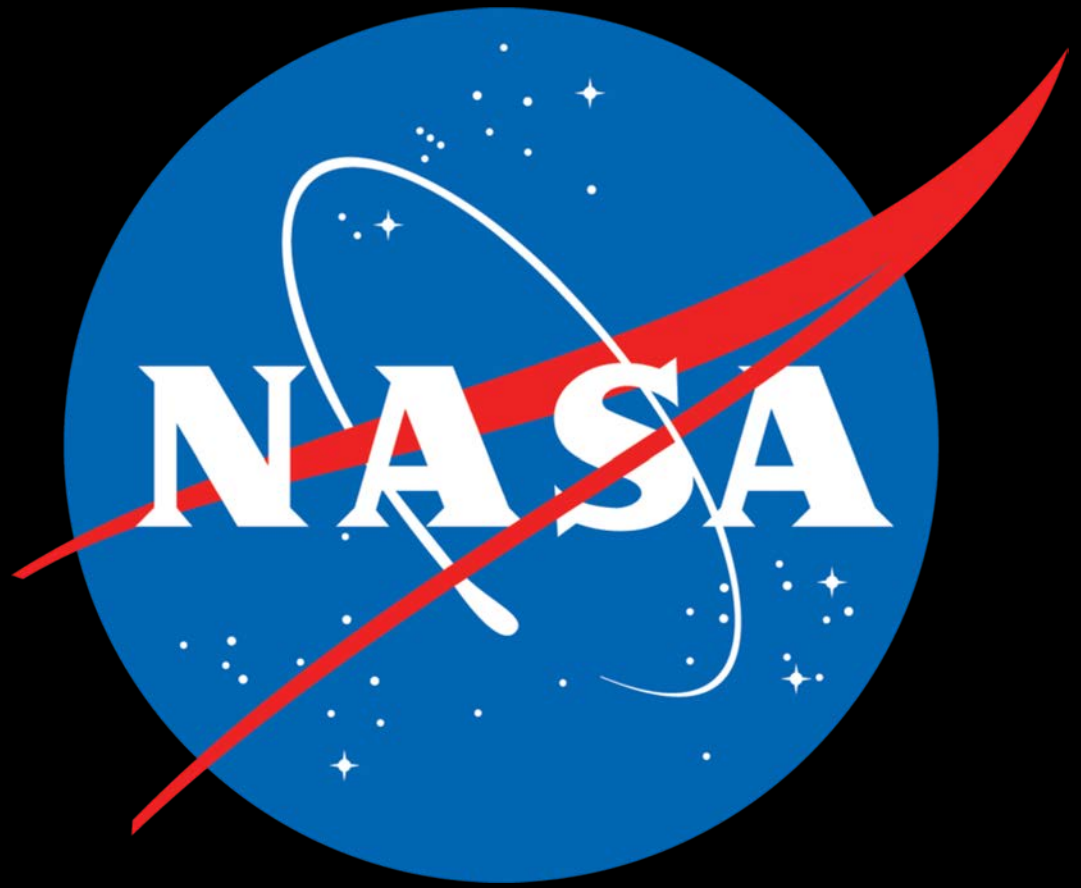
2. **Consider Utilization location within Program Office**
   - Goal of Gateway operations - touches all systems and needs all systems
   - Systems view of Utilization sets up competition with other Gateway systems resources rather than *supported by* other resources

3. **Consider new accommodation of internal experiments (i.e. different than Express Racks)**
   - Incorporate modern improvements – software upgrades, plug and play, standard interfaces, automation, structural improvements
   - Legacy experiment considerations
   - Balance between crew and automation/robotics

4. **Prioritizing science among Gateway users and partners**
   - ISS evolved to current prioritization processes
   - Start defining processes now

Near Term Utilization Activities

- **Providing GPS/Navigation on the Gateway**
  - Precision timing/location for physics experiments, facility capability for instruments or cislunar/surface assets
- **Utilization during uncrewed periods**
  - Defining Gateway internal environmental conditions for experiments - requirements
  - Developing ConOps to optimize automation planning, robotic system potential designs
    - Established Software/Autonomy working group
- **External location of experiments**
  - Field of View studies, vent location designs, shadowing, exosphere analysis (includes NRHO)
- **Logistics**
  - Advocating for dual use logistics vehicles (supply, secondary missions/tugs, experiments)
- **External arm delivery**
  - Protecting earlier delivery in Gateway assembly sequence
- **Internal science accomodations**
  - Detailed studies on potential internal science experiments and identifying common facility lab systems


NASA