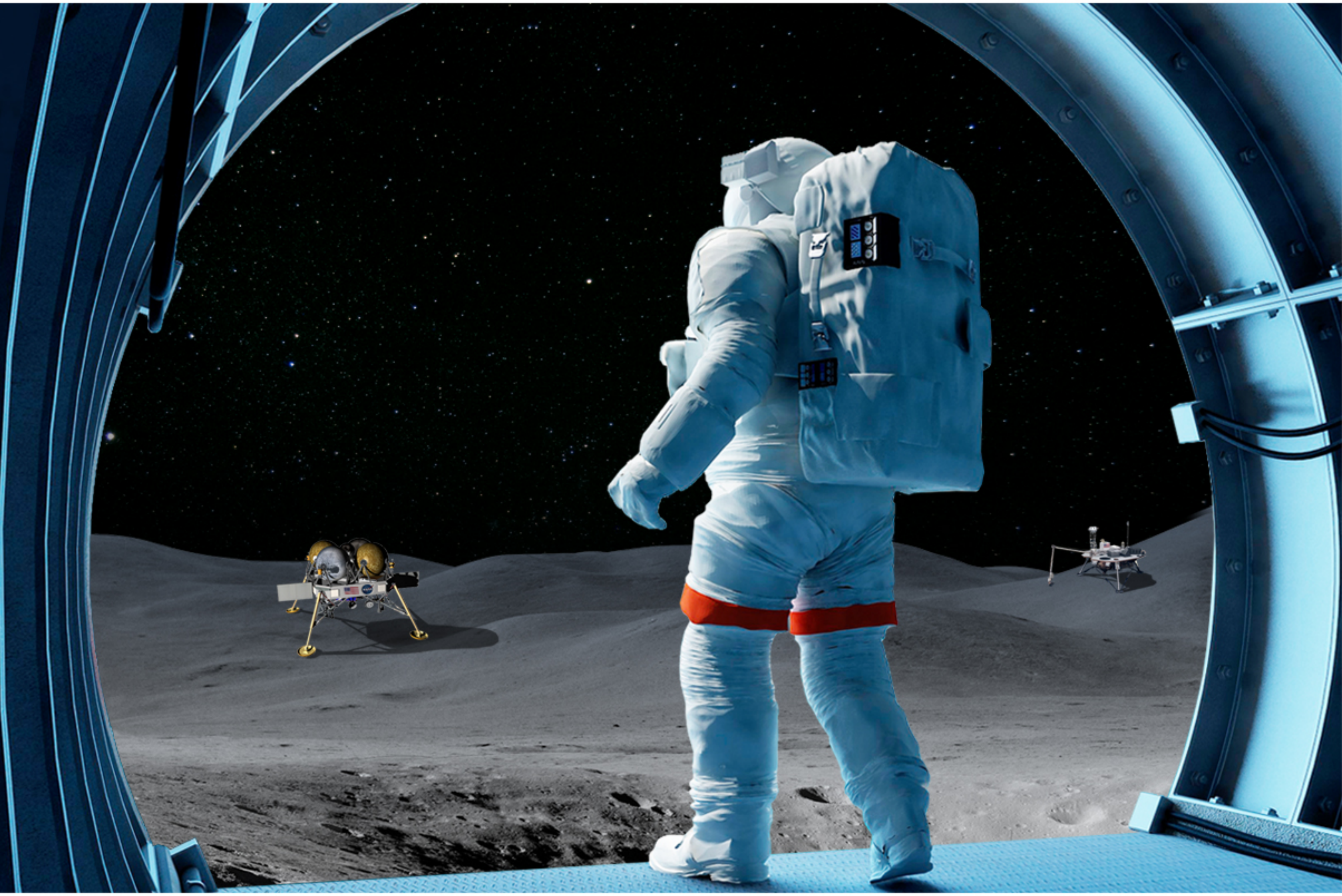
Gateway Update

National Aeronautics and
Space Administration

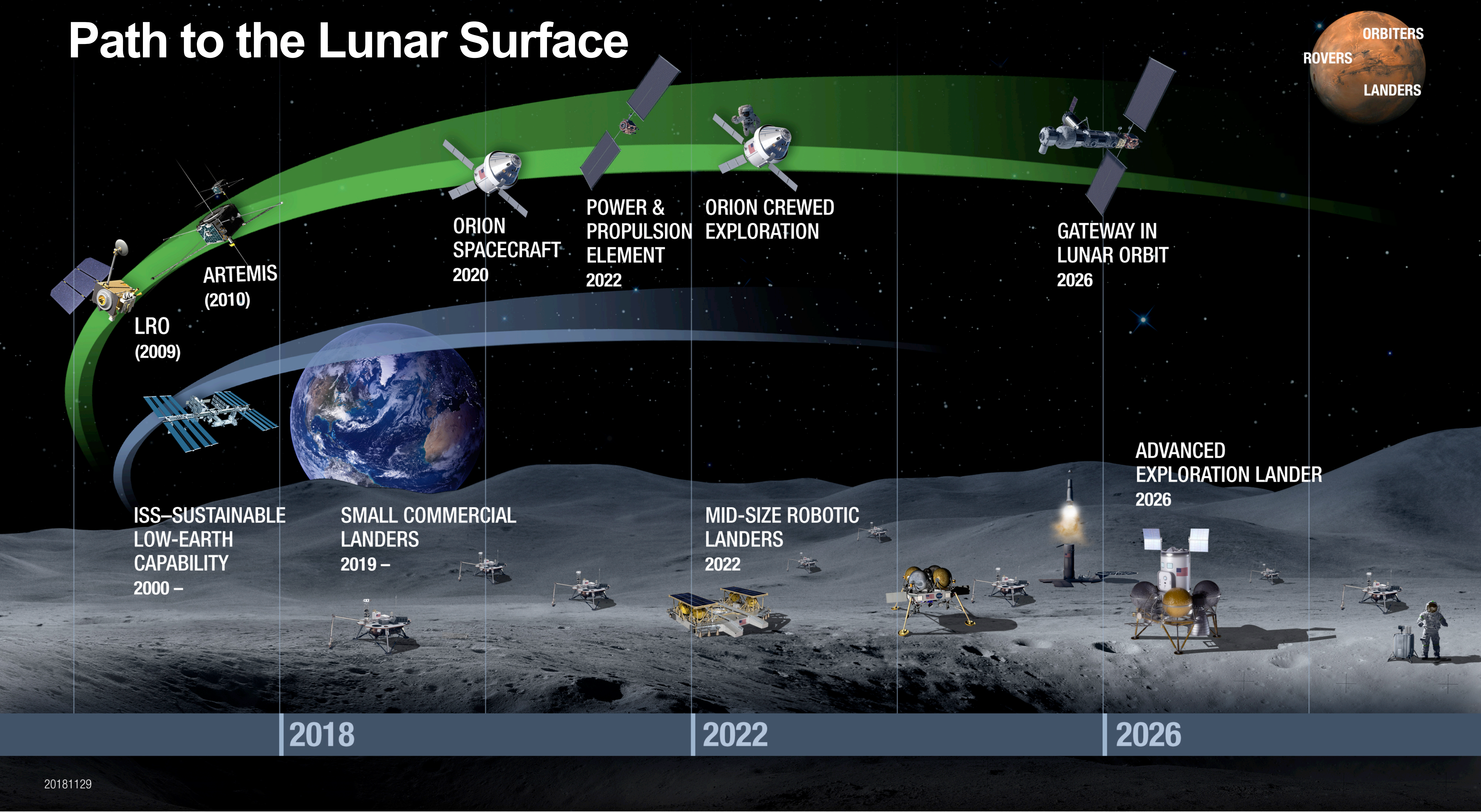


NASA ADVISORY COUNCIL
Human Exploration and
Operations Committee

JASON CRUSAN
Director, Advanced Exploration Systems | NASA HQ

07 December 2018

Path to the Lunar Surface

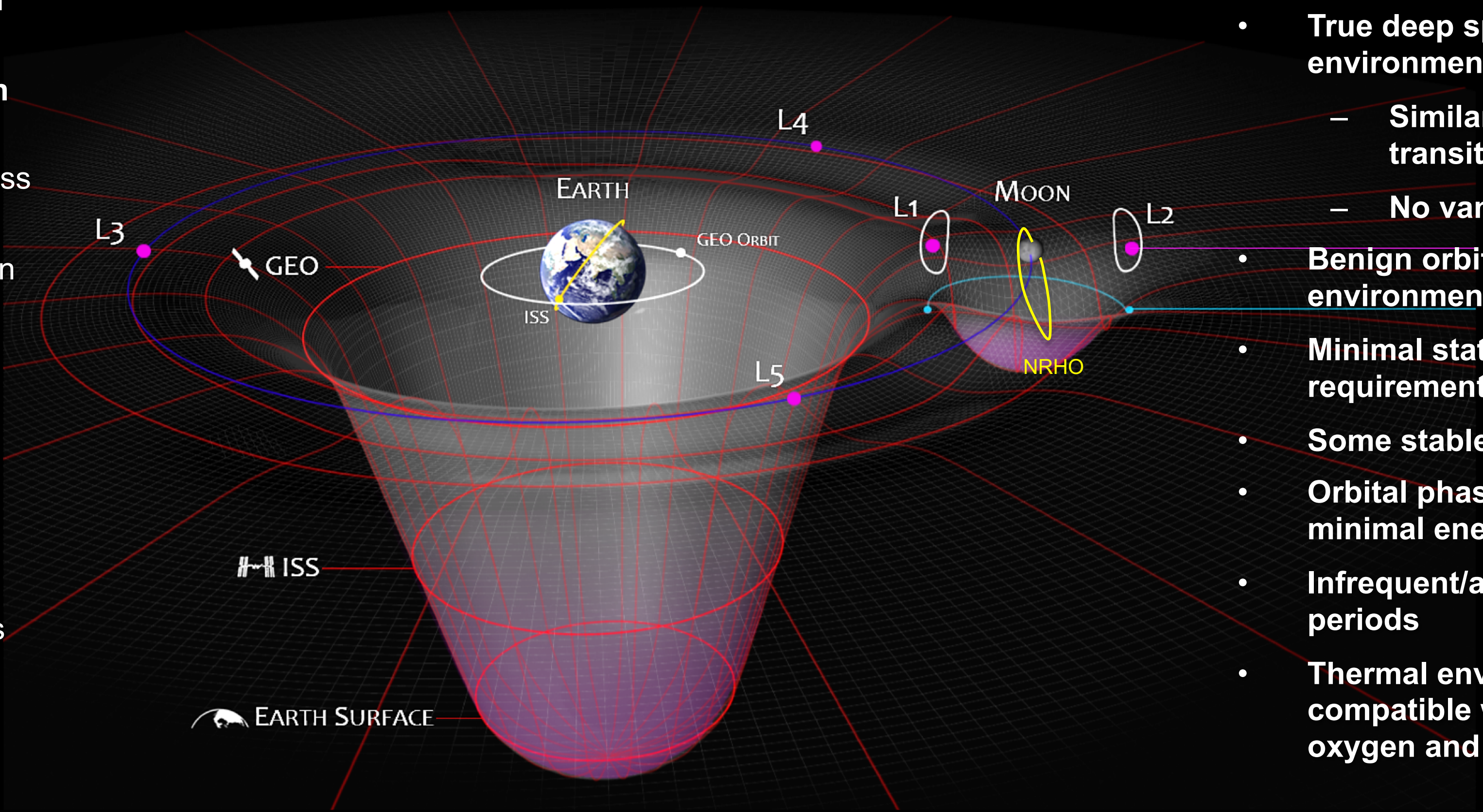


20181129

Cislunar Space: A Deep Space Harbor for Exploration Missions

LOCATION

- **Only ~3 to 5 days away from Earth yet farther than Apollo went**
- **Ideal mission aggregation location**
  - Lunar Surface, Mars and Asteroids all accessible for less than 2.5 km/sec
  - Cryogenic oxygen & hydrogen used to inject to cis-lunar without requiring ZBO
- **The next "high ground" beyond GEO**
  - L2 – Lunar far-side science
  - L1 – Earth observations
  - All cis-lunar – low latency teleoperations of lunar assets
- **Access to local resources (ISRU)**
  - Lunar gravity assists
  - Lunar surface volatiles
  - Asteroidal material
- **Accessible by NASA, commercial, and international launch systems**



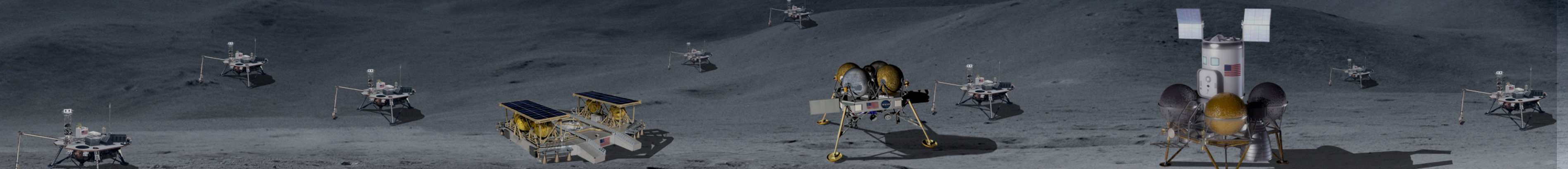
ENVIRONMENT

- **True deep space radiation environment**
  - **Similar to Mars system & transit there**
  - **No van Allen belts**
- **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**

Human Lunar Lander Development

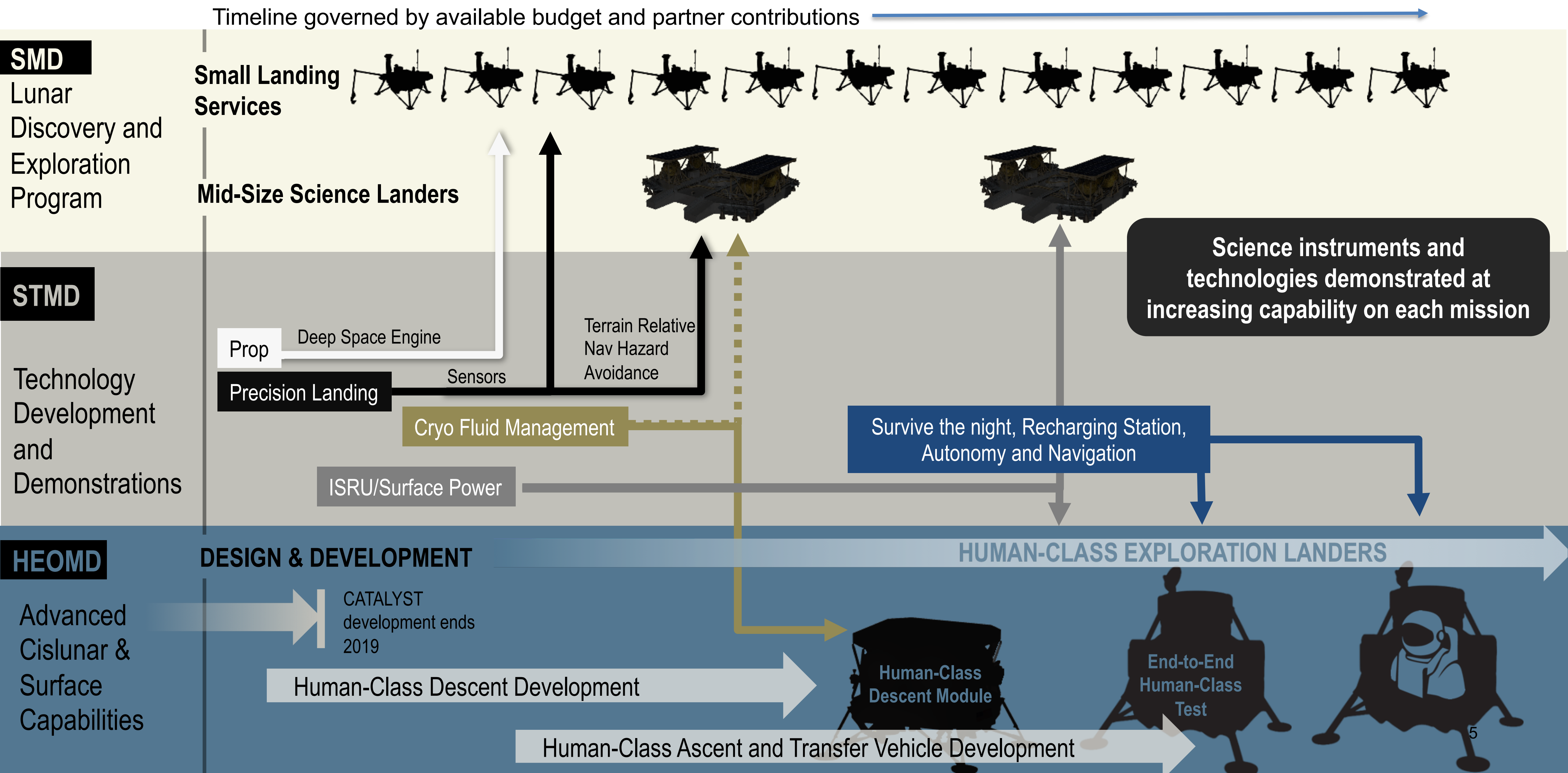
Under the requested funding for Advanced Cislunar and Surface Capabilities (ACSC), along with other Exploration Campaign activities, NASA will re-establish U.S. preeminence to, around, and on the Moon.

To enable human exploration of the lunar surface, NASA will invest with industry providers, purchase landed services to test sub-systems, use innovative acquisition approaches to leverage U.S. commercial capabilities toward a Human Landing System, and 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.

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, enable 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

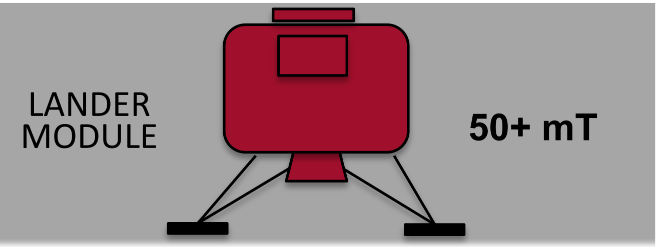
– Elements (or their copies) can be applied to other missions to increase payloads or reduce transportation times (deep space rendezvous with tug for outer planet missions, satellite maneuvering in GEO vicinity, etc.)

– 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.

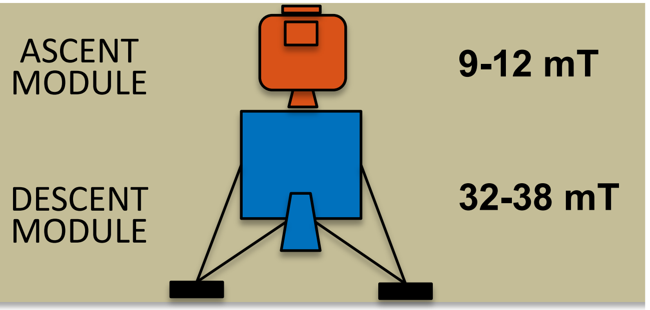
– The lunar elements may be partially or fully applicable to aspects of future Mars missions (common ascent systems, etc.)

Key Takeaways from Initial Internal Architecture Approach Studies

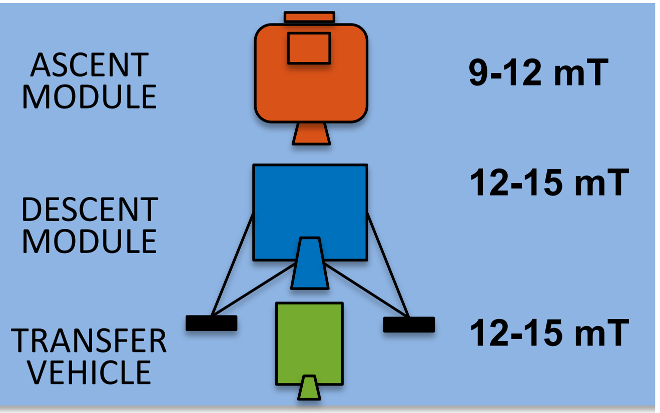
To deliver humans to the Moon, several lander vehicle options were assessed



- **Single-stage human lander**
  - Does not fit on any launch vehicle, including SLS Block 1B Cargo



- **Two-stage options**
  - Ascent Module fits on commercial launch vehicles expected to be available
  - Descent Module does not fit on commercial launch vehicles

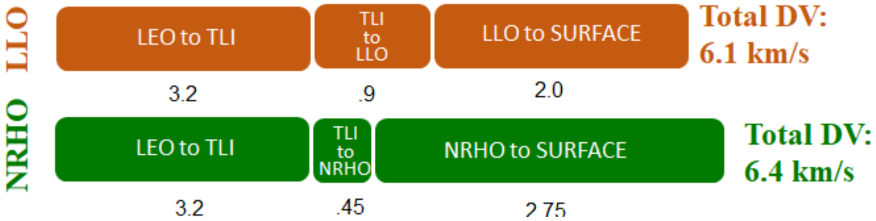


- **Three-stage options**
  - Fits on commercial launch vehicles expected to be available
  - Single elements potentially can be co-manifested payload on SLS
  - Allows increased partnering opportunities

A review of Delta-v of Using Gateway vs. Direct to Moon

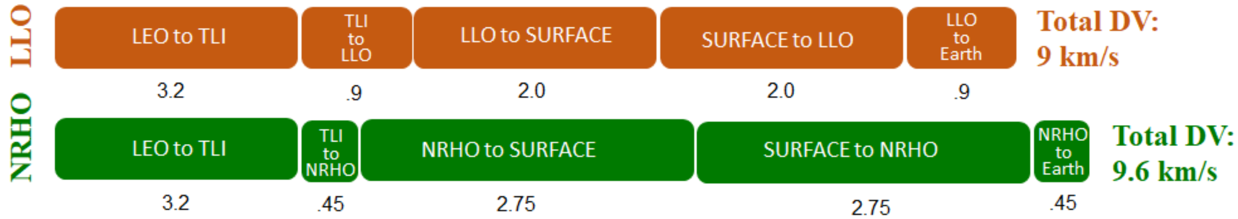
- Fast one way transits to the surface incur about .3 km/s penalty to go through Gateway as opposed to LLO (4.9% of total).
- Round trip transits where everything is delivered fast on a single launch incur about .6 km/s penalty (6.7% of total).

Fast Transit One Way (km/s) (Crew)

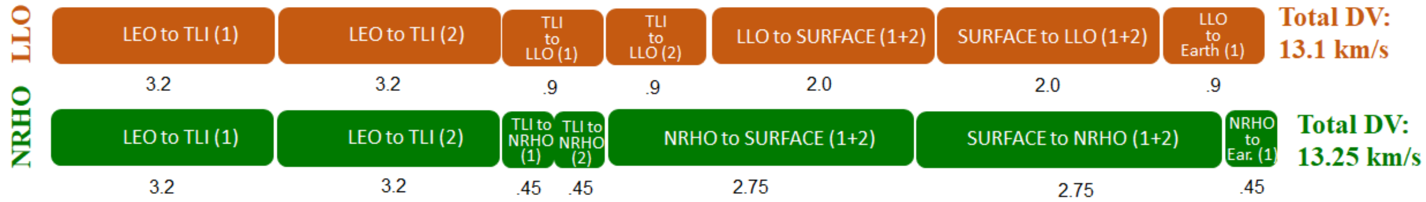


- Round trip fast transits for 2 launches incur only a .15 km/s penalty (1.1% of total).
- Round trip transits for 2 launches where cargo is delivered on ballistic lunar transfer incurs 0 km/s penalty (0% of total).

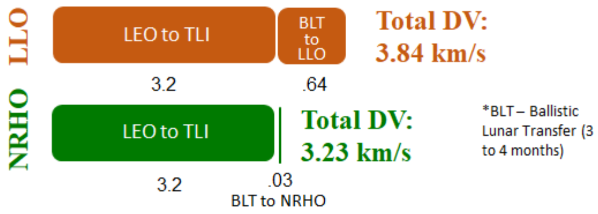
Fast Transit Roundtrip (km/s) (Crew)



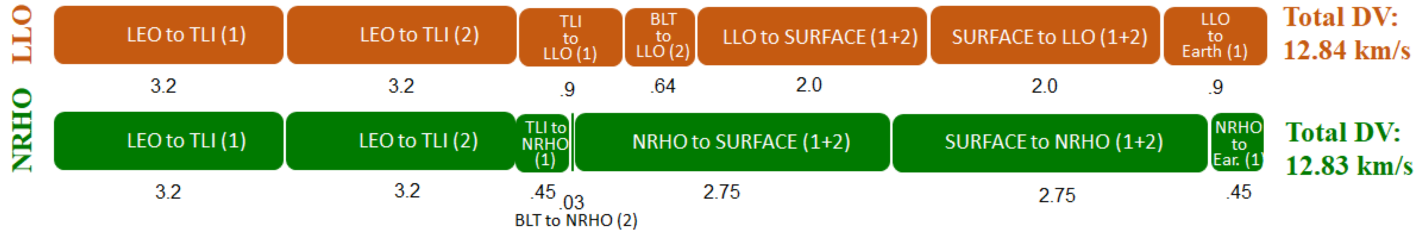
2-Launch Roundtrip (km/s) (1. Crew + 2. Cargo)

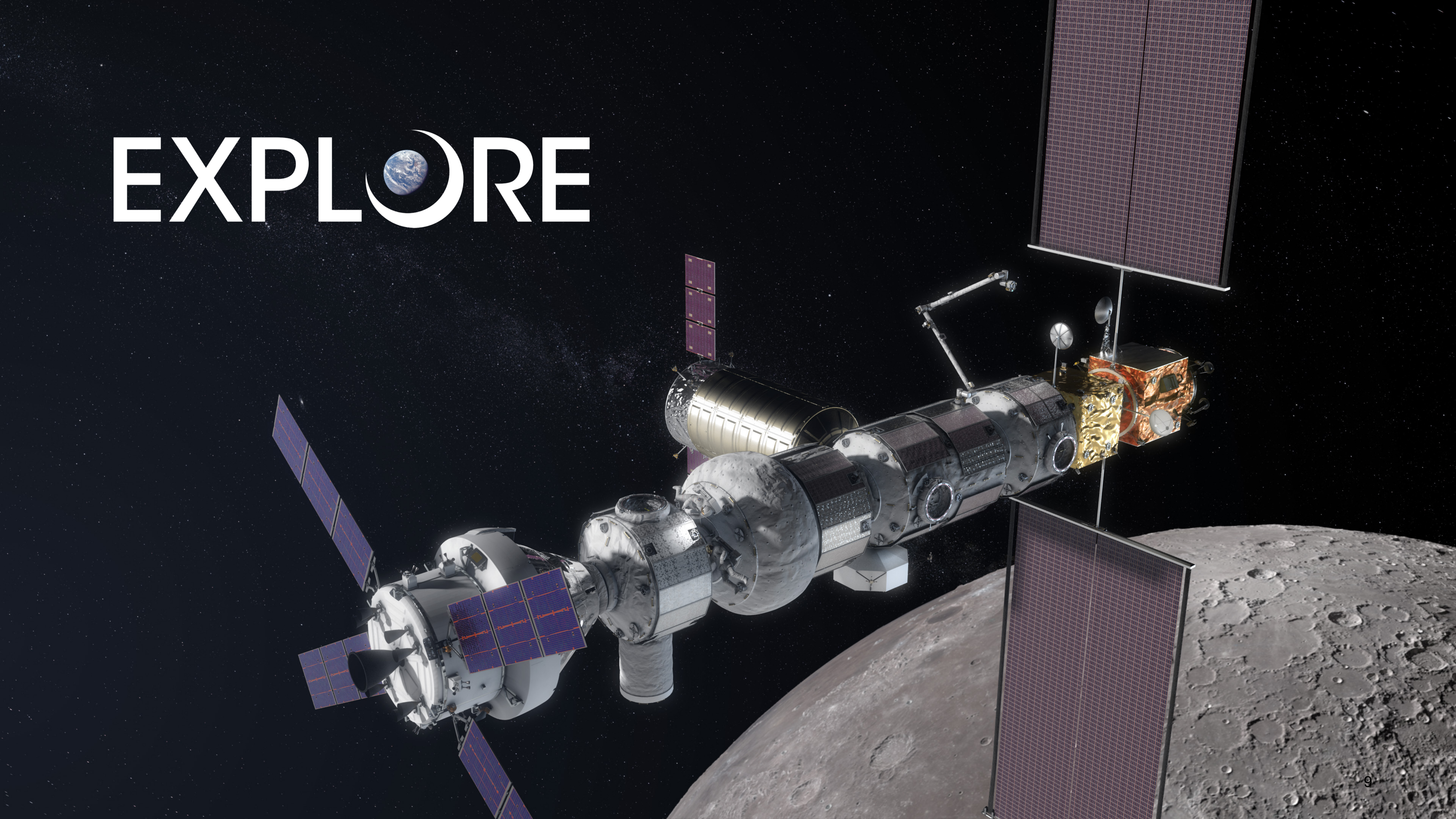


Slow Transit One Way to Orbit (km/s) (Cargo)



2-Launch Roundtrip (km/s) (1. Crew + 2. Cargo)

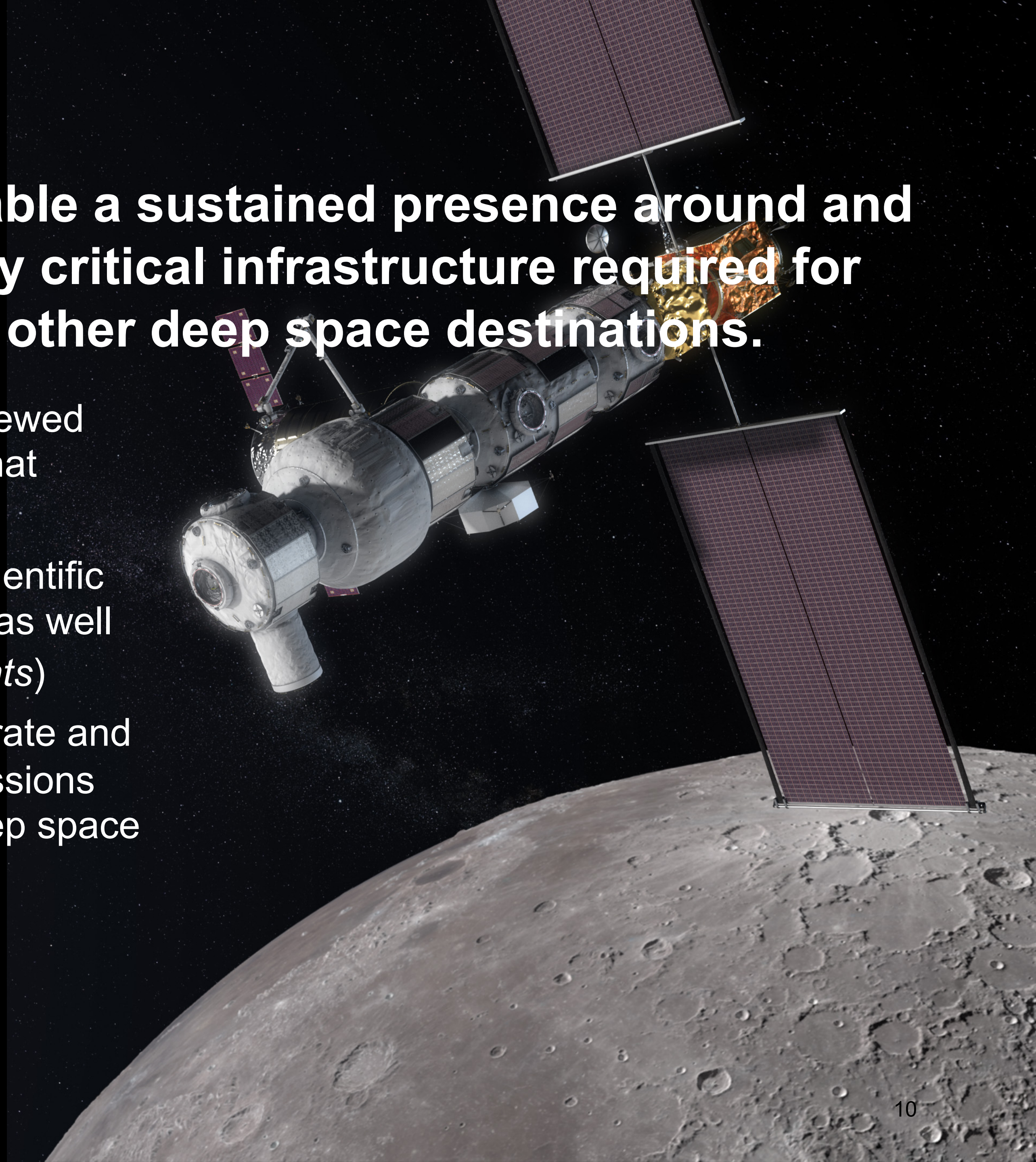



EXPLORE

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.

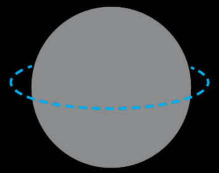
- The Gateway shall be utilized to enable human crewed missions to cislunar space including capabilities that enable surface missions. (*Crewed Missions*)
- The Gateway shall provide capabilities to meet scientific requirements for lunar discovery and exploration, as well as other science objectives. (*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 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.

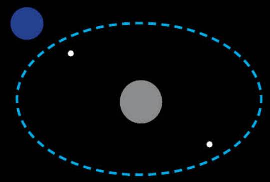
ORBIT TYPES



LOW LUNAR ORBITS

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

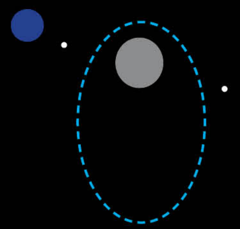
» Orbit period: 2 hours



DISTANT RETRO-GRADE ORBITS

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

» Orbit period: 2 weeks



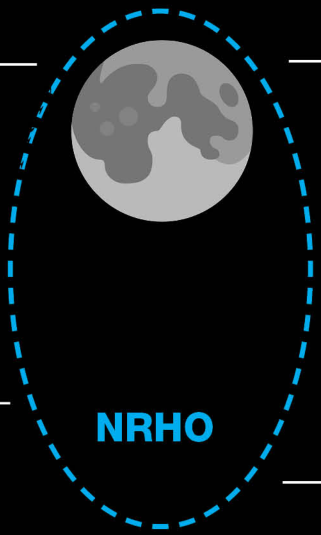
HALO ORBITS

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.

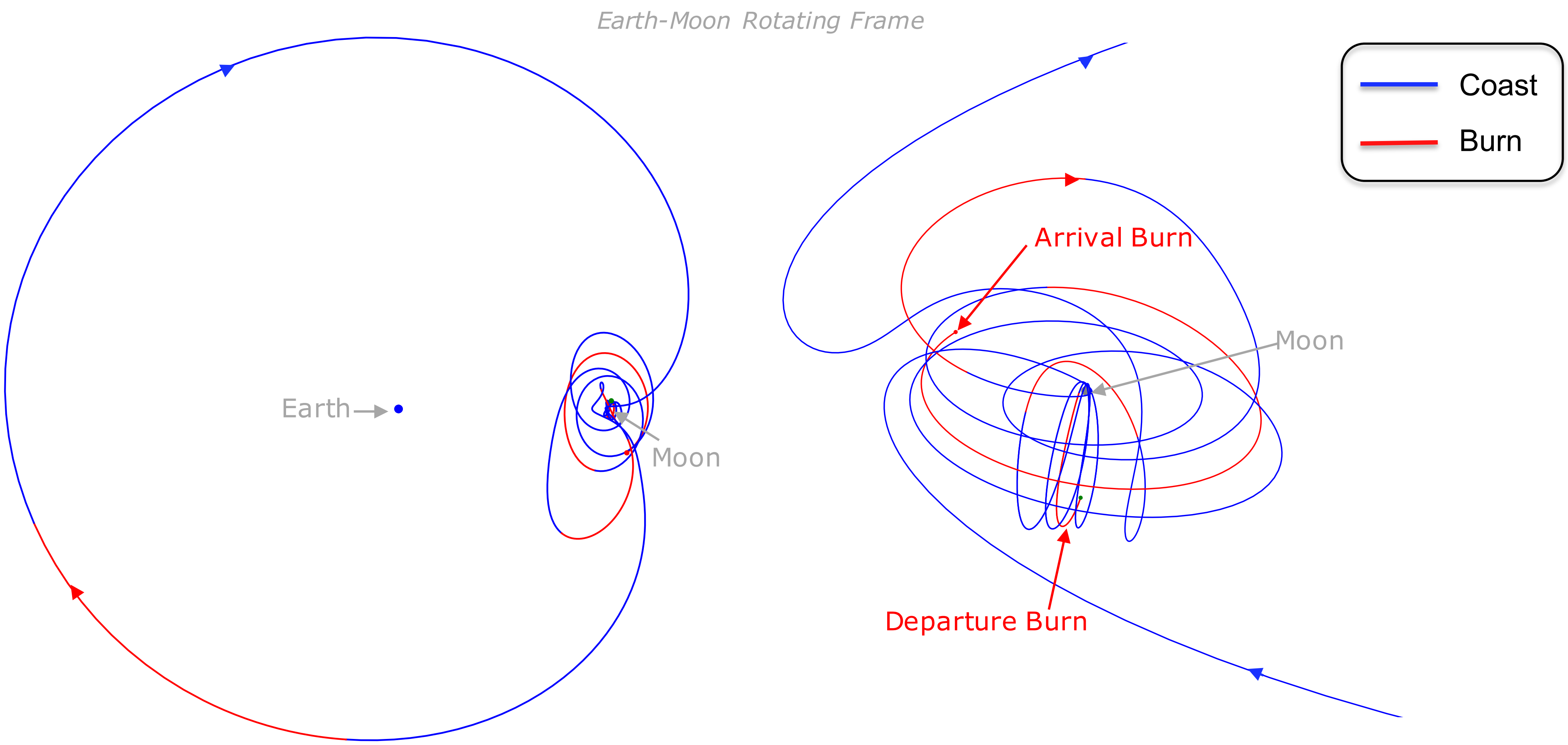
COMMUNICATIONS

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.

DRO Transfer (1-way)



Xe Mass (kg)	TOF (days)	SEP ΔV (m/s)
135	156	85

Note: Margin Not Included

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 electric propulsion (EP) system**
- **Power transfer to other gateway elements**
- **Passive docking using International Docking Systems Standard (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 Broad Agency Announcement (BAA) issued July 2018. Final BAA released Sept. 6, 2018. Proposals received Nov. 15. Selections targeted for early 2019.**

Gateway Logistics Sources Sought Notice (1/2)

- NASA issued a Sources Sought Notice on Oct. 23, asking U.S. companies to provide the agency with information regarding options to transport cargo, equipment and other goods like food to and from the Gateway near the Moon. Responses were due Nov. 2.
- NASA is planning to release a Request for Proposals for the Gateway's logistics module in the spring, with an award in late 2019.
- The first two logistics modules will likely launch on commercial rockets, but after Gateway assembly, NASA's Space Launch System will be available as well.
- This upcoming procurement from NASA is for U.S. domestic provided logistics module services only. NASA is anticipating future international Gateway partners to contribute logistic services as well, with details to be worked out at a later date.

Gateway Logistics Sources Sought Notice (2/2)

1. Describe preference between an acquisition using contract by negotiations procedures (Federal Acquisition Regulation (FAR) Part 15), commercial acquisition procedures (FAR Part 12) and one conducted via a broad agency announcement (BAA) (FAR Part 35) [i.e., Commercial Resupply Services-2 commercial approach versus the Gateway Power Propulsion Element BAA approach].
2. Describe the effect on pricing if more than one contract is awarded. How many logistic missions are needed on contract to meet anticipated business case?
3. Should the Gateway Logistics Services be split into two separate acquisitions, one for the Logistics Module and one for the launch services? Why or why not?
4. Identify significant technical and cost drivers associated with providing the logistic service (e.g. target launch date, interoperability standards, human rating requirements, NASA standards, etc.). Are there any commercial approaches which may mitigate these concerns while maintaining the requisite level of Gateway safety?
5. Summarize the cost, schedule, and technical challenges associated with the Logistics Module performing functions in support of the other Gateway elements (e.g., providing and/or receiving power, attitude control, orbital adjustment, communications, environmental control/life support, etc.).
6. Are there any impacts in requiring an ability to manifest on multiple launch vehicles to include a co-manifested configuration on SLS?

NextSTEP-2: Deep Space Habitation Prototypes

Five full-sized ground prototypes will be delivered for testing in 2019. A sixth company, NanoRacks, is conducting a feasibility study and is under final negotiations to also deliver a ground prototype.

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

Selected Aug 2016

Formulation Sync Review (FSR) Kickoff Summary

- Gateway conducted a kickoff for a Systems Requirement Review (SRR) equivalent review called FSR, Sept 10-13, 2018 in Orlando, FL
- Purpose was to evaluate whether the functional and performance requirements defined for the system are responsive to requirements and represent achievable capabilities

Snapshot Status of FSR Kick-Off:
- 39 Presentations
- 36 FSR Products
- 40 Reference Products
- 14 pre-declared RFAs

- Throughout 2018, Gateway has been developing the products and processes necessary for a Program SRR review
- The FSR included independent assessment via an Independent Review Team (IRT)
- Prior to the kickoff, Gateway held an internal readiness assessment and conducted a readiness to proceed checkpoint with the IRT
- The kickoff was built around demonstrating that entrance and success criteria have been met
- Forward work includes conducting table top reviews with the IRT, closing actions, addressing Requests for Action (RFAs)

Gateway Milestones

- ✓ September 6: PPE Final Solicitation Released
- ✓ September 9: Schedule TIM with International Partners
- ✓ September 10-14: FSR Kickoff
- ✓ October 2 – 5: International Habitat Technical Interchange Meeting (TIM) @ ESTEC
- ✓ October 4: FSR RFAs due
- ✓ October: ESPRIT Virtual TIM
- ✓ October 23: Logistics Services SSN Issued
- ✓ December 17: Habitation Element and Logistics Element PSMs

Looking Ahead

- Gateway program transition from formulation to center program management
- PPE Selection(s) – March 2019
- Science/Utilization Workshop – Spring 2019
- Gateway U.S. Logistics and U.S. Habitation solicitations – Spring/Summer 2019


EXPLORE
MOON to MARS
MOON LIGHTS THE WAY