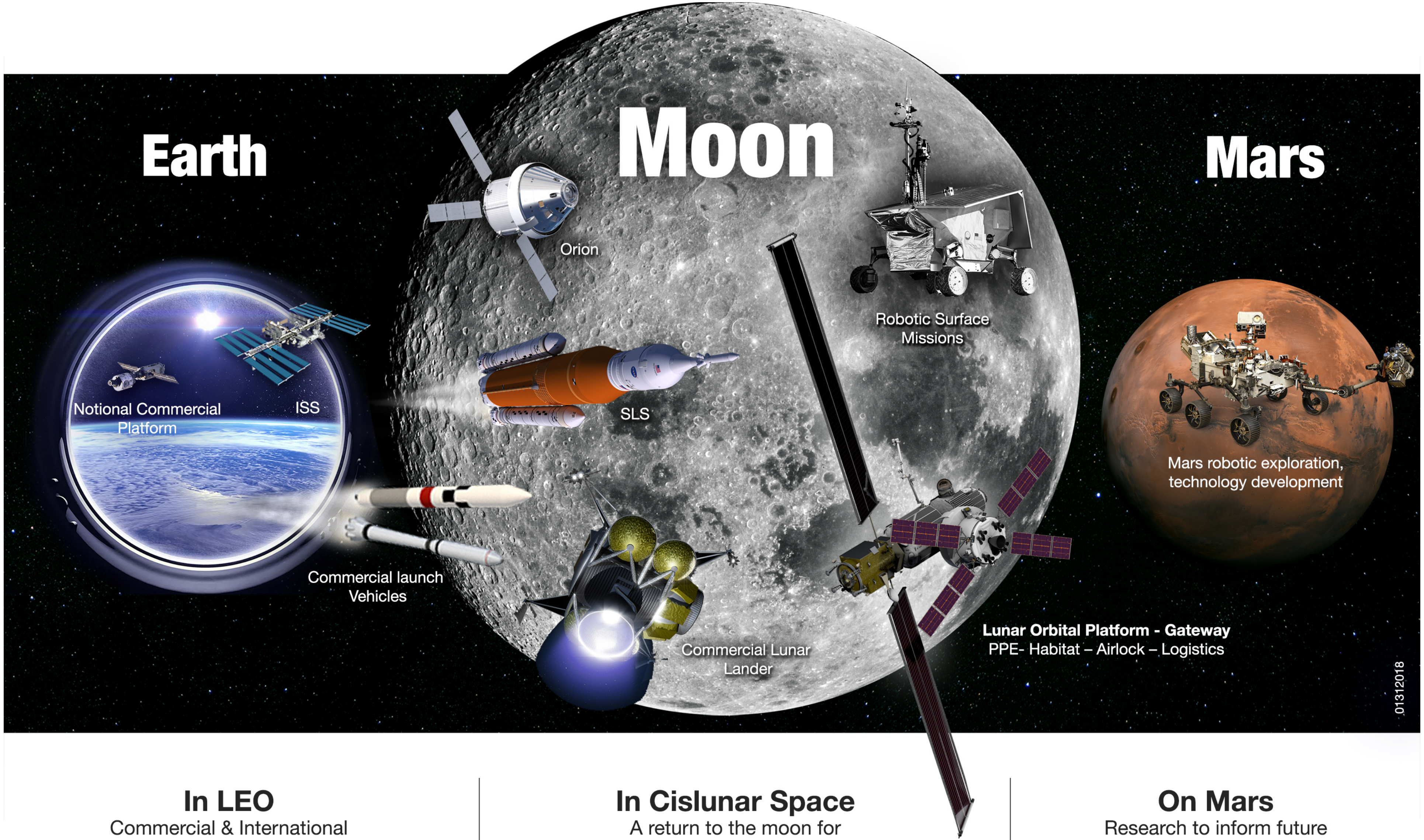
Future Human Exploration Planning: Lunar Orbital Platform-Gateway and Science Workshop Findings

JASON CRUSAN, ADVANCED EXPLORATION SYSTEMS, NASA HQ

March 27, 2018

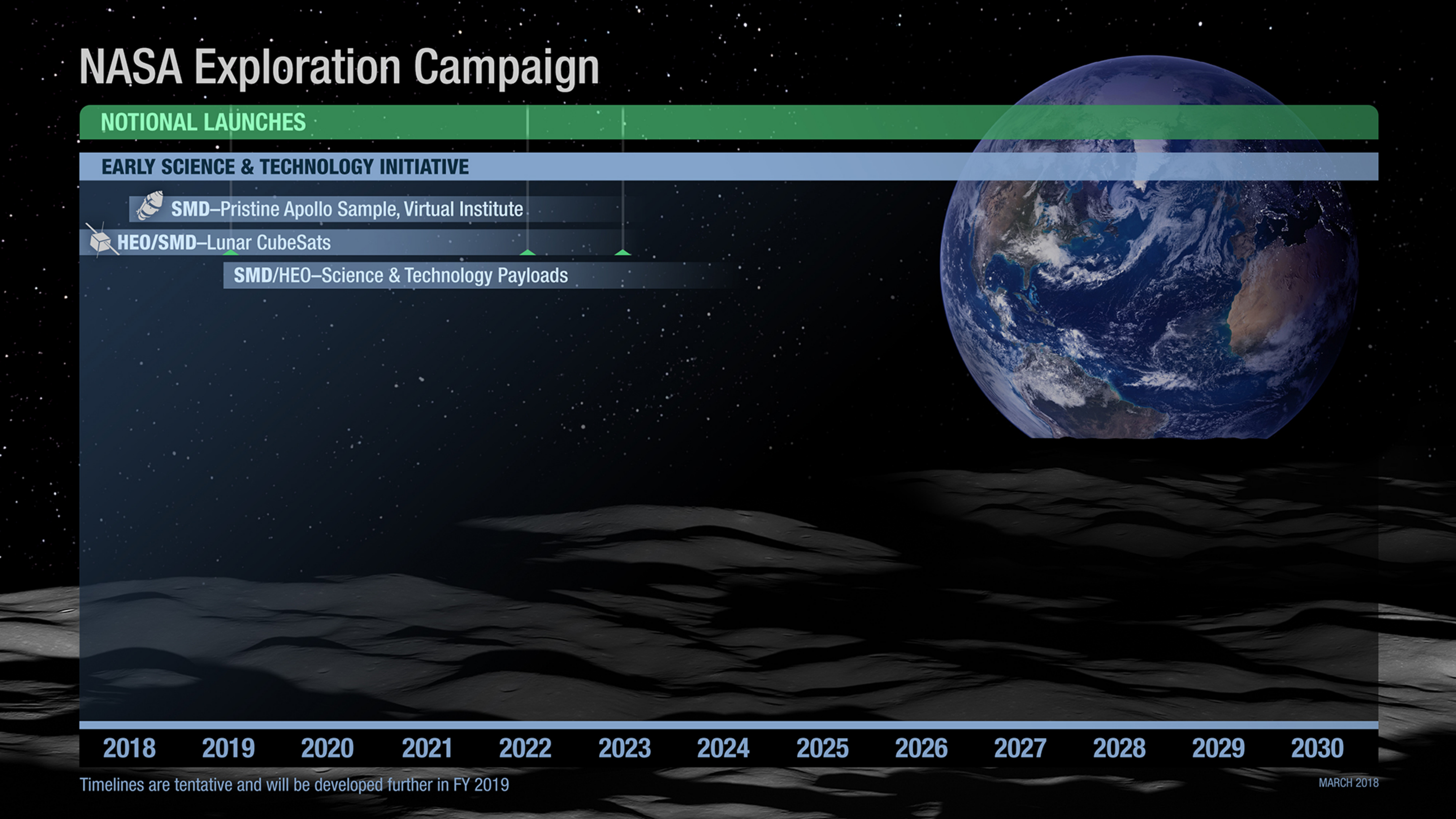
EXPLORATION CAMPAIGN



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



NASA Exploration Campaign
NOTIONAL LAUNCHES
EARLY SCIENCE & TECHNOLOGY INITIATIVE
SMD–Pristine Apollo Sample, Virtual Institute
HEO/SMD–Lunar CubeSats
SMD/HEO–Science & Technology Payloads
2018
2019
2020
2021
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2026
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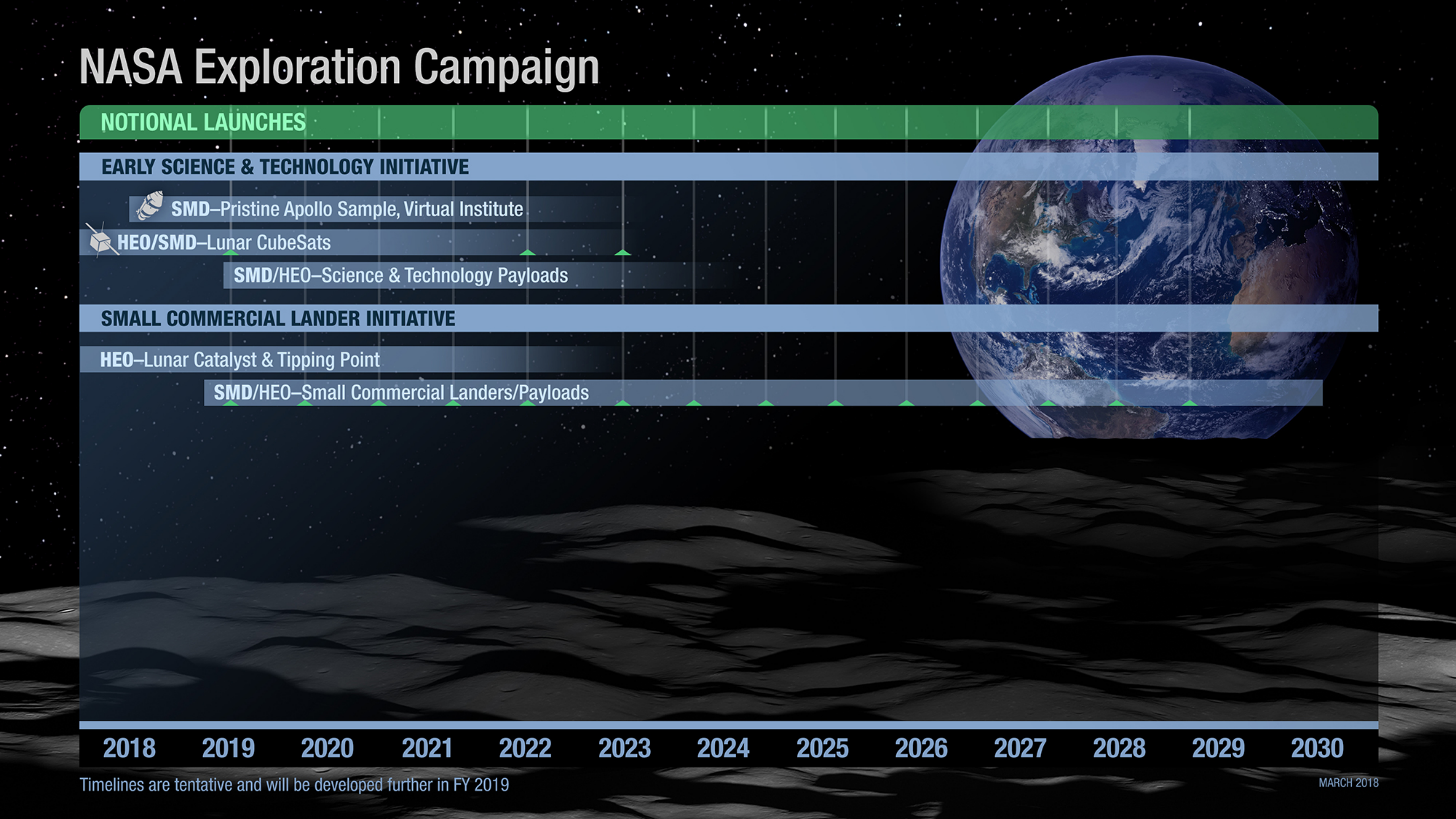
2028
2029
2030
Timelines are tentative and will be developed further in FY 2019
MARCH 2018



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SMALL COMMERCIAL LANDER INITIATIVE
HEO–Lunar Catalyst & Tipping Point
SMD/HEO–Small Commercial Landers/Payloads
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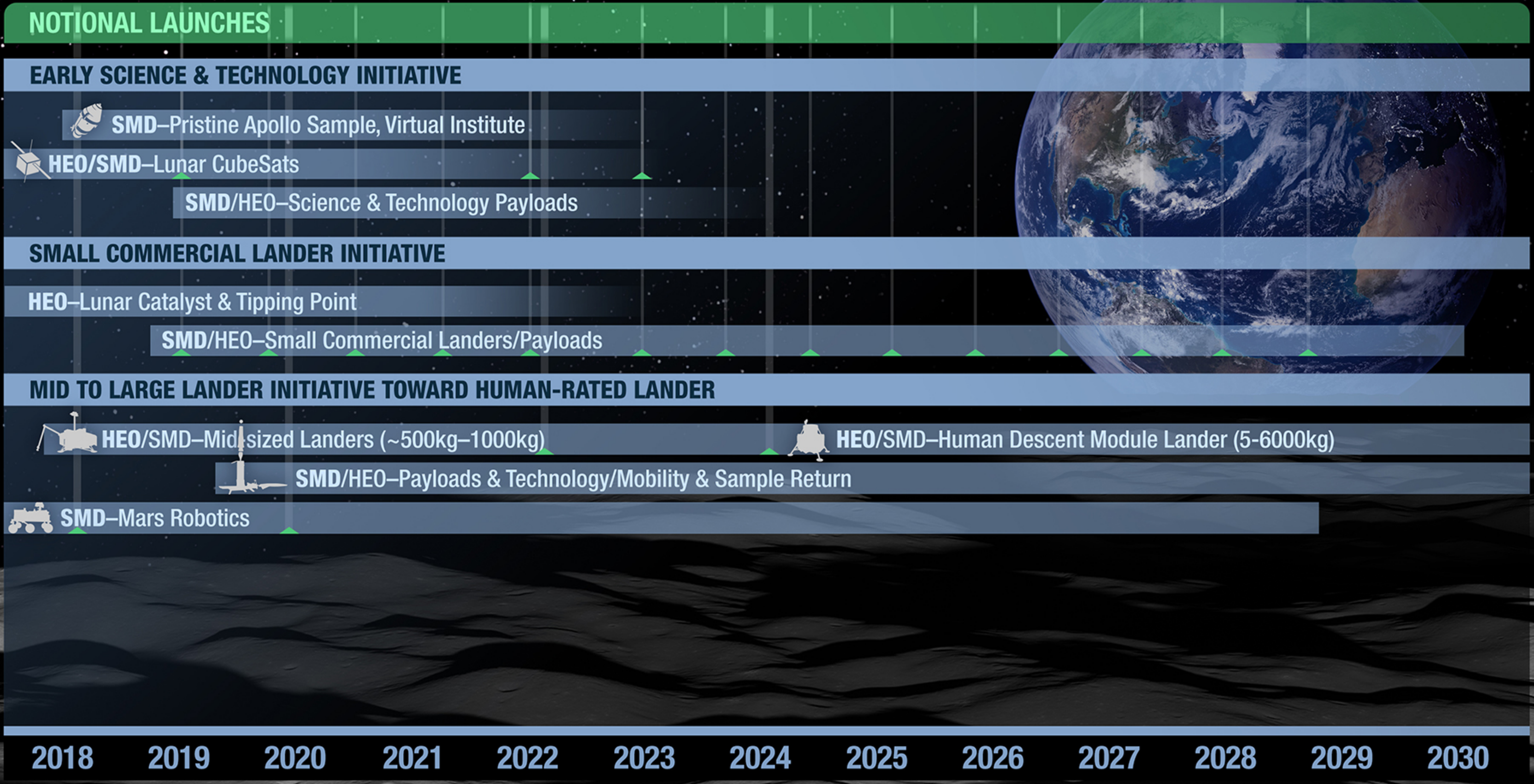

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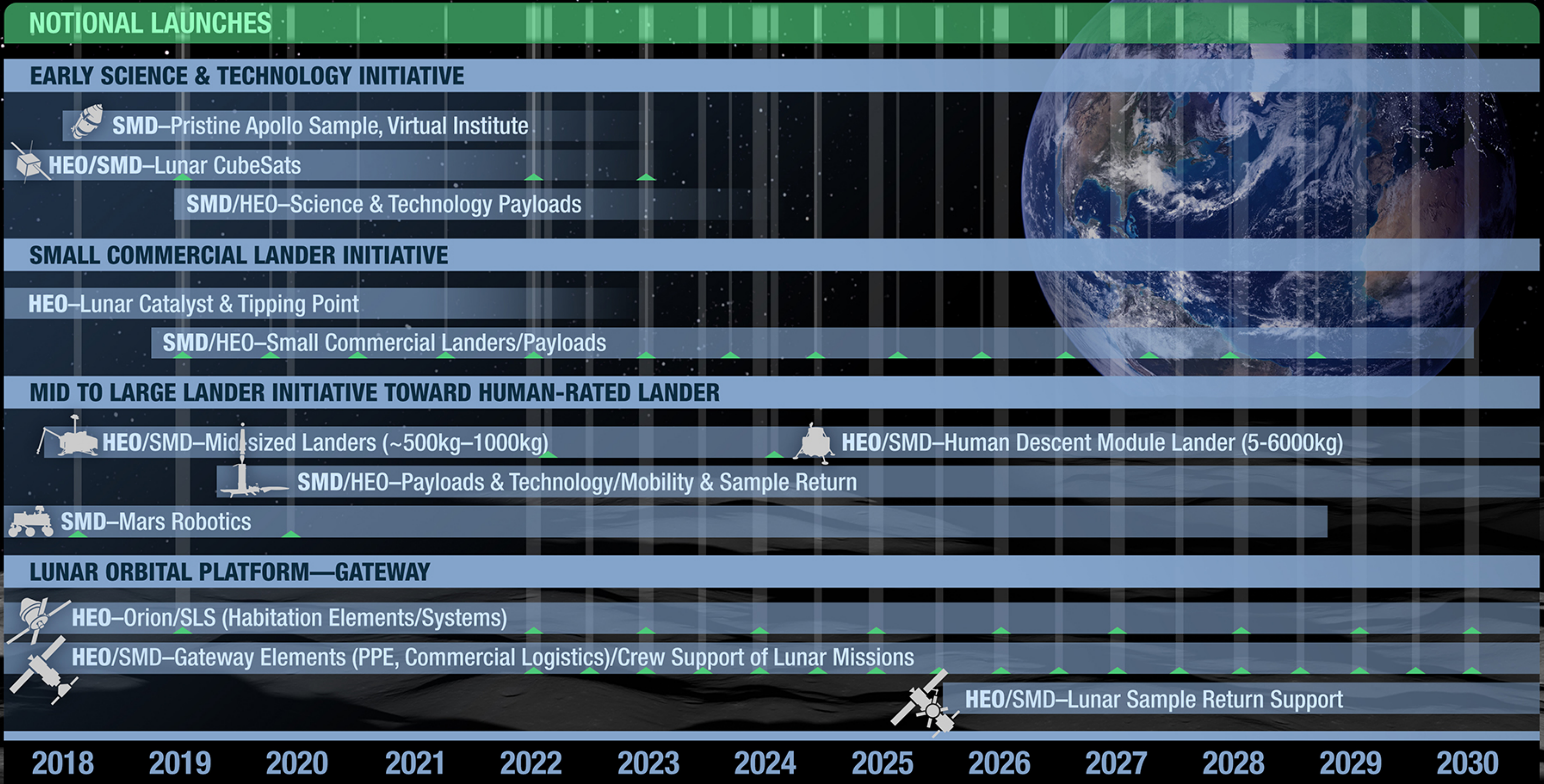

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MARCH 2018

Near-Term Engagement (March 19–May 31, 2018)

MARCH

HEO–RFI: Advancing Lander Capabilities

SMD–Commercial Lunar Payload Services (CLPS) Draft SOW

HEO–Power & Propulsion Element Studies Complete

STMD–Tipping Point preliminary proposals down-select (EDL/ Precision Landing & Propulsion topics)

HEO–RFI: Commercial Utilization of Gateway

HEO–NextSTEP Habitation First Analysis Cycle: 5 Partner Design Cycle Results

APRIL

SMD–SIMPLEX SmallSat AO

HEO–RFI: Potential Tech-nological Considerations & Utilization of the Gateway

SMD–Development & Advancement of Lunar instrumentation (DALI) Step 1 Proposals Due

HEO–RFI: Acquisition Approaches for Gateway Implementation

SMD–Enhanced Lunar Sample Analysis Campaign Announced

HEO–Draft Broad Agency Announcement: Power & Propulsion Element

HEO: ISS Commercial Acquisition Strategy Meeting

SMD–CLPS Draft RFP

HEO–Determination of Solicitation Mechanism for Advance Lunar Capabilities Engagement

MAY

SMD–SSERVI CAN3 Draft

SMD–CLPS Industry Day

STMD–Tipping Point Full Proposals Due May 31

LUNAR ORBITAL PLATFORM-GATEWAY

LOW EARTH ORBIT

LUNAR

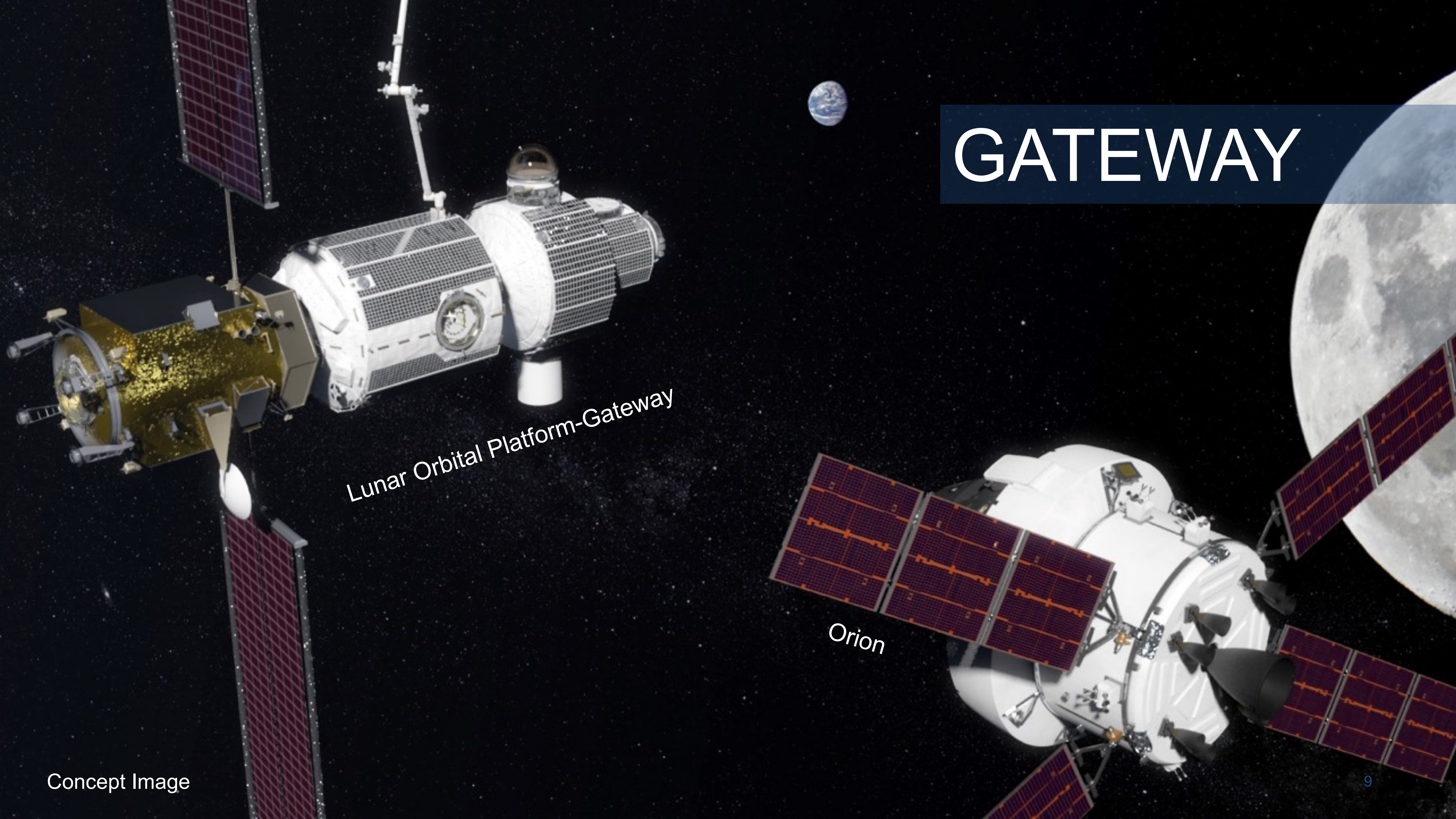
Human Exploration and Operations

Advanced Exploration Systems: Overview

FY 2019 BUDGET	REQUEST	NOTIONAL			
Budget Authority (in $ millions)	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Lunar Orbital Platform-Gateway (gateway)	504.2	662.0	540.0	558.9	459.1
Advanced Cislunar and Surface Capabilities (ACSC)	116.5	146.0	163.7	300.0	320.3
Exploration Advanced Systems	268.2	260.7	240.6	186.1	144.7
Total Budget	**889.0**	**1068.6**	**944.3**	**1045.0**	**924.1**

- **Gateway be assembled in orbit around the Moon**
  - Can also be used as a staging point for missions to the lunar surface and to destinations in deep space
- **ACSC will once again establish U.S. preeminence to, around, and on the Moon.**
  - Leveraging initial flights of the Space Launch System, Orion, and elements of the gateway, ACSC will harness U.S. industry and international partnerships to enhance U.S. leadership on the lunar neighborhood.
- **Exploration Advanced Systems will design, develop, and demonstrate exploration habitation capabilities technologies to reduce risk, lower life cycle cost and validate operational concepts needed for future deep space habitation elements, including those on the gateway.**

GATEWAY

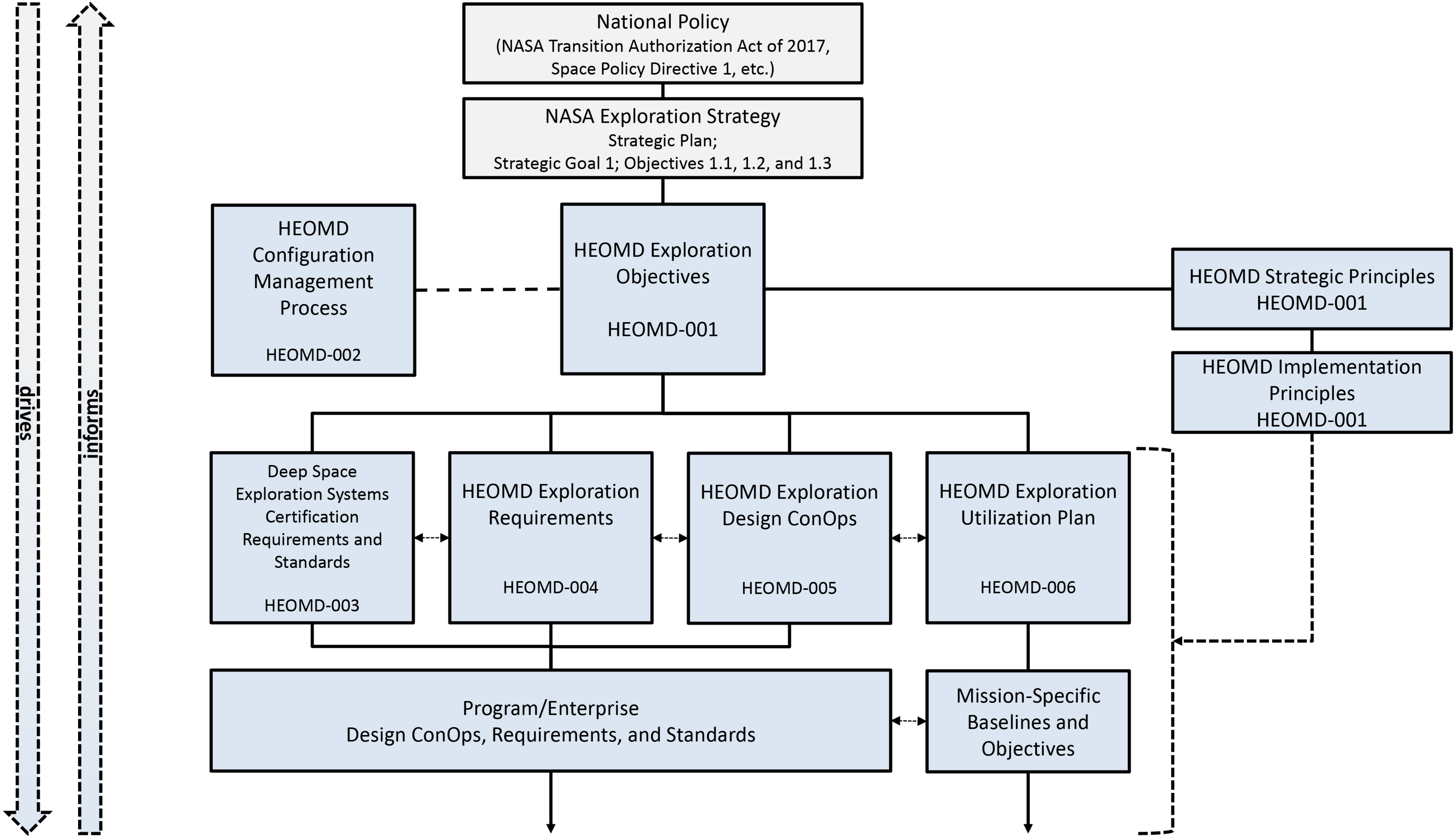


Concept Image

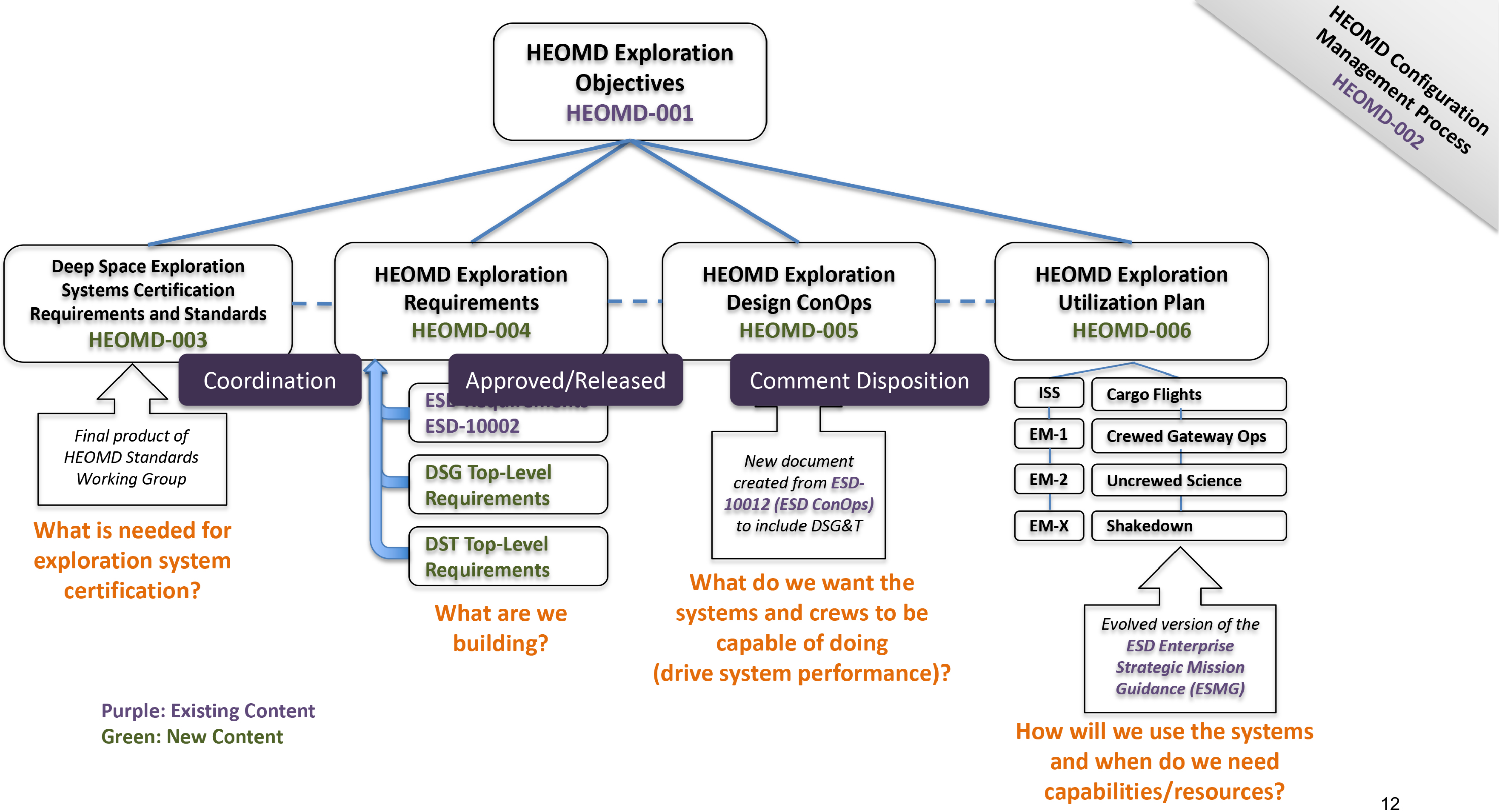
Human Exploration and Operations

Gateway Functionality

- **Assumptions**
  - Lunar Orbital Platform-Gateway provides ability to support multiple NASA, U.S. commercial, and international partner objectives in cislunar space and beyond
  - The gateway is designed for deep space environments
    - Supports crew of 4 for a minimum of 30 days
    - Supports staging of other assets including landers
- **Emphasis on defining early elements – functional allocations are still being traded**
  - Power Propulsion Element
  - Habitat
  - Logistics Strategy
  - Airlock
- **Feasibility trades and future work**
  - Partner-provided elements
  - Lunar Landers
  - Mars Extensibility


drives
informs
National Policy
(NASA Transition Authorization Act of 2017,
Space Policy Directive 1, etc.)
NASA Exploration Strategy
Strategic Plan;
Strategic Goal 1; Objectives 1.1, 1.2, and 1.3
HEOMD Configuration Management Process
HEOMD-002
HEOMD Exploration Objectives
HEOMD-001
HEOMD Strategic Principles
HEOMD-001
HEOMD Implementation Principles
HEOMD-001
Deep Space Exploration Systems Certification Requirements and Standards
HEOMD-003
HEOMD Exploration Requirements
HEOMD-004
HEOMD Exploration Design ConOps
HEOMD-005
HEOMD Exploration Utilization Plan
HEOMD-006
Program/Enterprise
Design ConOps, Requirements, and Standards
Mission-Specific Baselines and Objectives

HEO Strategy/Document Structure and Current Status

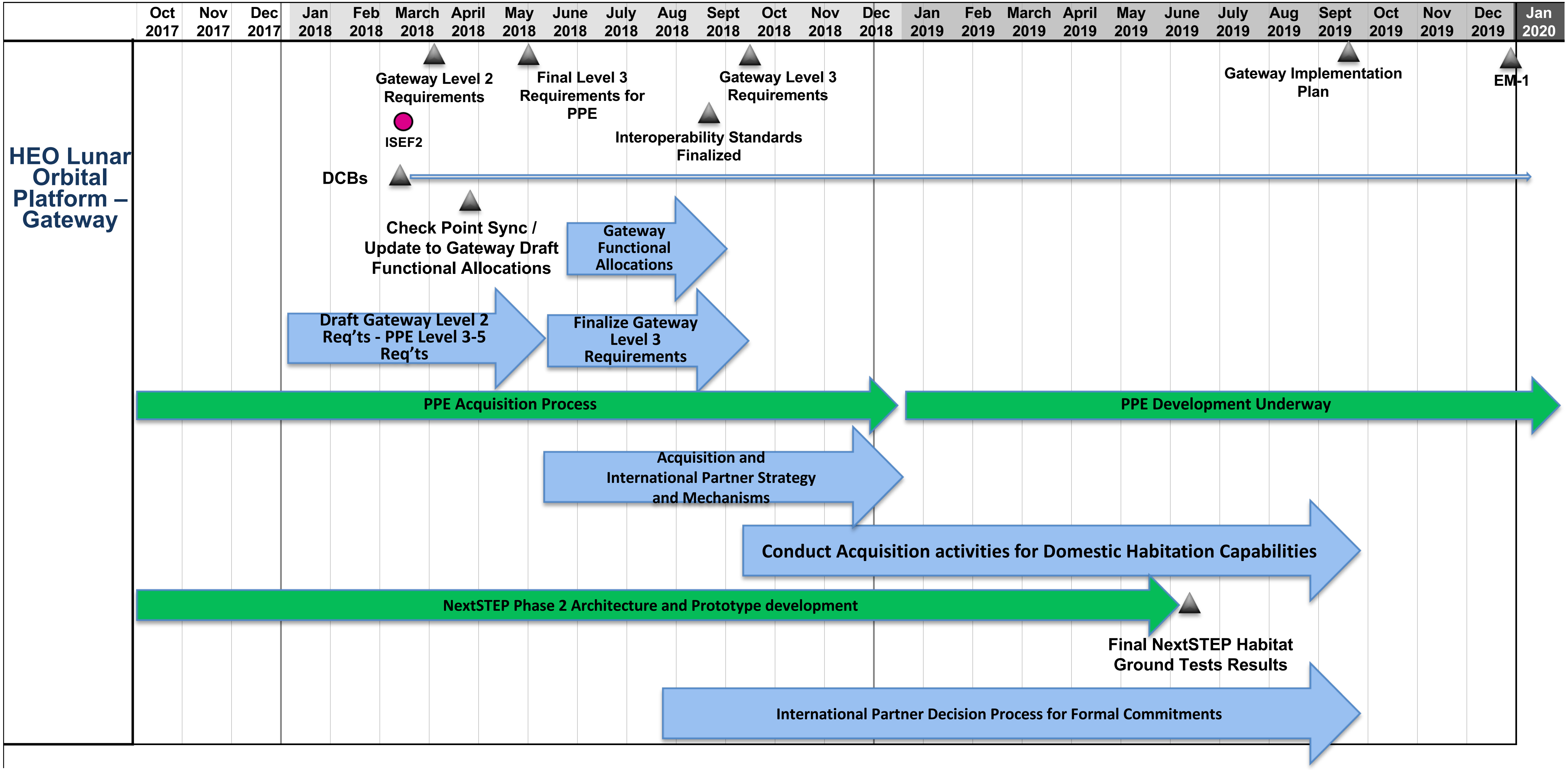


Draft Deep Space Interoperability System Standards – Posted for Feedback on March 1, 2018

- **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**.

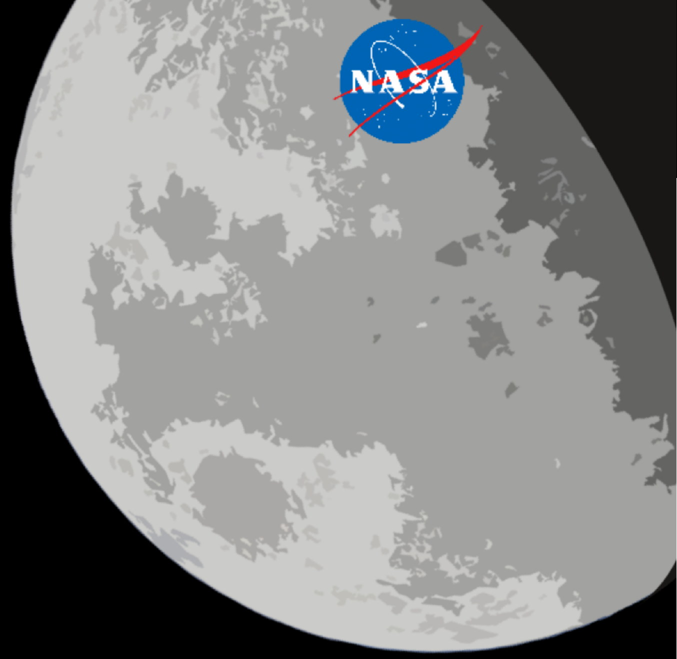
www.internationaldeepspacestandards.com

Lunar Orbital Platform – Gateway Top Level Schedule



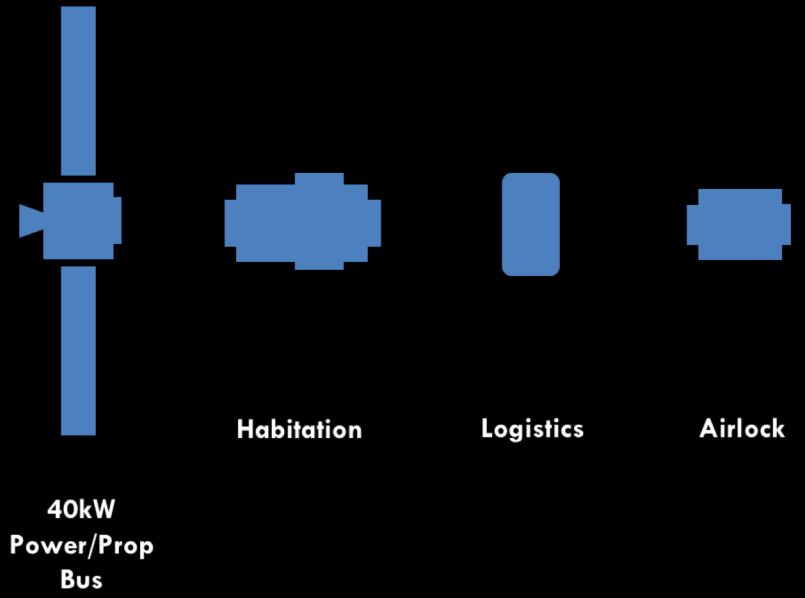
LUNAR ORBITAL PLATFORM-GATEWAY DEVELOPMENT

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



FOUNDATIONAL GATEWAY ELEMENTS

2022	2023	2024+



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

CAPABILITIES

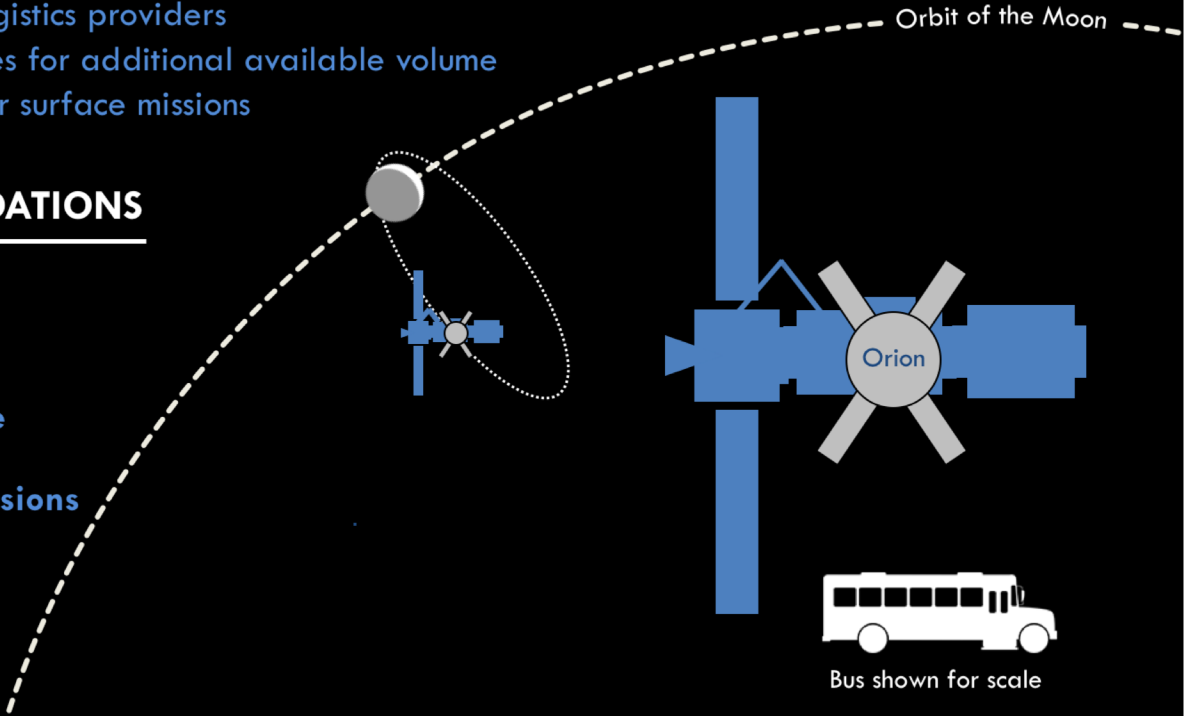
- Supports exploration, science, and commercial activities in cislunar space and beyond
- Includes international and U.S. commercial development of elements and systems
- Provides options to transfer between cislunar orbits when uncrewed

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



Gateway Core Functionality

- **Power and Propulsion Element**
  - First gateway capability targeted for launch readiness in 2022
  - Spaceflight demonstration of advanced solar electric propulsion spacecraft for industry and NASA objectives; developed through public-private partnership
  - Power to gateway and externally accommodated elements
  - Orbital maintenance and potential to transport the uncrewed gateway between cislunar orbits
  - Attitude control for the gateway in multiple configurations
  - Communications with Earth, space-to-space communications, and radio frequency relay capability in support of extra-vehicular activity (EVA) communications; accommodations for an optical communications demonstration in the future
- **Habitation**
  - Provides habitable volume and short-duration life support functions for crew in cislunar space
  - 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 & 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 April 2018.

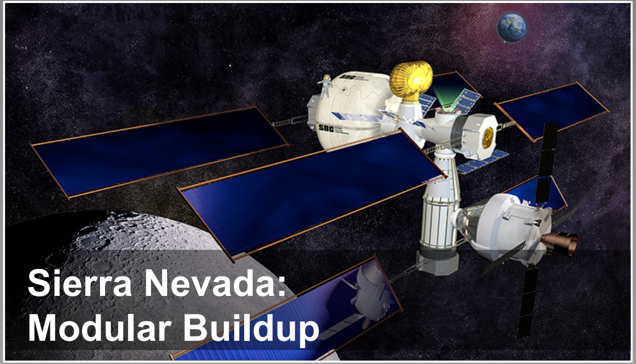
Gateway Concept Investigations


Bigelow: Expandable


Boeing: Leverages Existing Technologies


Orbital ATK: Builds on proven cargo spacecraft development

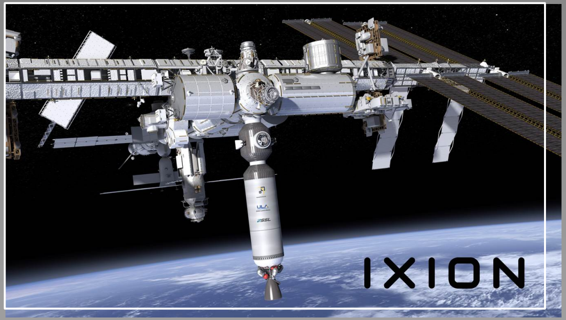

Lockheed: Refurbishes Heritage Hardware

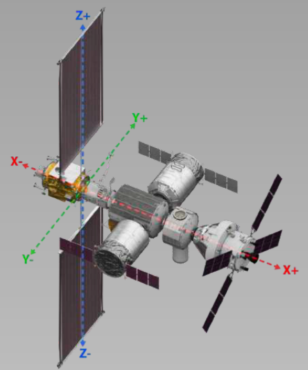

Sierra Nevada: Modular Buildup

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 – 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
  - NASA Working Group – Cross Center/technology organizations (workshop 28 March)
  - Evaluating Request For Information (RFI) to obtain non-NASA technology insights (April)
- **Commercial: Developing overall commercialization strategy for gateway:**
  - Linked with evolving Agency and HEO/SMD planning
  - RFI on commercial uses of a gateway (early summer)
- **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
  - NASA-hosted event completed – Denver gateway science workshop (February)
    - Revising current gateway utilization ground rules & assumptions

GATEWAY SCIENCE WORKSHOP
February 27-March 1, 2018
DENVER, COLORADO

Three driving rationale for the workshop, sponsored by HEOMD/SMD:

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

Workshop Format

- **Introductory briefings on NASA plans, ISS lessons learned, gateway orbit options**
- **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
  - External Instruments
  - Samples
  - Telerobotics & Leveraging Infrastructure
  - Internal Instruments
- **~180 Talks, ~300 Attendees**
  - Government, academia, industry

Top Science Takeaways

- **Science utilization extremely constrained until the presence of an external robotic arm**
  - Arm is the de facto external experiment installer
  - Some small-scale initial science might be possible with instruments on PPE
- **Gateway, in a NRHO, offers unique opportunities for some Earth, Heliophysics, Astrophysics and fundamental physics investigations**
- **With the addition of additional transportation infrastructure (LLO tug/pallet, surface access, sample return capability) gateway can enable additional important lunar science**
- **Externally mounted sample collection with controlled pointing can collect samples and provide important science about cometary material, solar composition, interstellar particles, and near Earth objects**
- **Radiation environment of the gateway can provide important tests of the effects of radiation on biological organisms.**

Top Resource Takeaways

- **External payloads need multiple look directions, and long duration stare capability**
- **Ability for external (i.e., in vacuum) delivery of science elements**
- **Desire for significant amount of internal analysis equipment (multi-use, flexible and configurable)**
- **Automation of internal payload interactions**
- **Science will generate LARGE amounts of data**
- **Farside of the Moon is a unique radio science location, need to consider how noisy the gateway is**
- **Contamination concerns (gateway exosphere & optical payloads passing through the hab)**
- **Enhancement of generic gateway capabilities can facilitate science**

<u>Lunar</u> science needs significant transportation infrastructure investment

External Payloads – Resources (1/2)

- **External payloads need multiple look directions, and long duration stare capability**
  - Optical instruments desire Sun, Moon, Earth, none-of-the-above
  - Potential benefit of utilizing shared gimbal/pointing mounting platforms
  - Need to consider mounting point location, gateway orientation during an orbit, resultant FOV
- **Size and/or contamination concerns may require external delivery and installation**
- **Need to better understand the contamination risk from the gateway's exosphere. This might require mounting points further away from gateway, possibly even requiring a boom for certain payloads**
- **Assume a central data recorder**
  - Instruments send to central SSDR, gateway handles downlink
- **Onboard data computing capability**
- **Need to determine the gateway's vibrational environment (crewed and uncrewed)**
  - Vibration isolation potentially required for majority of optical payloads

External Payloads – Resources (2/2)

- **Large amounts of data**
  - Need laser com?
  - Potential option to send hard drives back to Earth
- **Potentially consider generic telescope facility**
  - Photons sent to multiple sensors
  - Sensors possibly inside gateway (easier to swap with improved/different sensors)
  - Might require optically pure window
- **Assume robotic arm installation of external payloads**
  - Con ops for delivery and installation should be fleshed out to identify specific robotic needs and any potential impacts to the payloads

Internal Payloads

- **Significant amount of volume could be utilized for internal experiments**
  - Neutron/radiation detection, neurocognitive function, radiation and microgravity effects, behavioral health, gardening and food evaluation, waste reclamation
  - *Need / opportunity for a separate (international?) science module?*
- **Possible need for a significant amount of multi-use analytical equipment**
  - Multi-use glove box, configurable
  - Partly a result of assumed limited downmass capability
- **Need for internal robotics for instrument interactions whilst gateway is uncrewed**
- **Adding automation capability**
  - Otherwise crew time is going to be at a premium; set up, tending etc
- **Significant downlink data requirements**
- **On-board storage and distribution of space radiation environmental data (external/internal) from payloads as available meta-data for other payloads, especially Space Biology and possibly HRP.**

Gateway Capabilities for Infrastructure (CubeSats, Comms)

- **Capability to deploy CubeSats/SmallSats from the Gateway – both from the interior via a science airlock and externally using the robotic arm to remove a satellite/pre-packaged deployer from an unpressurized logistics module.**
  - CubeSat deployment capabilities currently available on ISS are similar to needs indicated for cislunar space operations.
  - Deployment of CubeSats up to 12U identified as likely candidates, though deployment of larger small payloads may be desirable in the future.
  - Both crew-operated and automated deployment capabilities enable CubeSat deployment during both crewed and uncrewed modes of Gateway operation.
- **Capability to uplink/downlink extensive volumes of data to/from the Gateway (on order of terabytes daily feasible required depending on science payloads). Optical comm could meet these needs as well as provide precise position data of the Gateway.**
- **Provide communication relay for other orbiting assets as well as lunar surface assets, within the bounds available given the Gateway orbit.**
- **Maintain RF quiescence on lunar farside, possibly by using cabling and wiring that limits release of RF noise.**

Gateway Capabilities for Infrastructure (Telerobotics)

- **For internal ops, telerobotics operated from Earth could extend lifetime of internal Gateway experiments into uncrewed Gateway modes.**
  - For example, capabilities could include autosampling, programmed fluid delivery or fluid/water delivery, programmed or human-in-the-loop measurements, and general maintenance.
- **For prox ops, telerobotics enables the installation, assembly, and deployment of external instruments, as well as the return of samples collected from free flyers and robotic landed missions.**
- **Teleops of assets in space or on the lunar surface could be conducted by a Gateway crew member or by payload operators on Earth when crew time is unavailable.**
- **The Gateway as a comm relay enables teleops in locations on the lunar surface that may not be feasible with direct comm between Earth and the Moon (such as the farside, polar regions, and steep terrain).**
- **A workstation that can evolve to accommodate telerobotics ops as Gateway capabilities progress enables these capabilities.**
- **The Gateway can provide infrastructure for telerobotics**
  - Communications relay: provide (or increase) link availability and bandwidth to the surface – particularly polar regions and the far side
  - “Orbital computing” (space equivalent of “cloud computing”)
    - Off-load processing from rover – potentially much higher performance
    - Off-board storage from rover – for later triage, downlink, or retrieval
  - Mapping from orbit: provide site maps
  - Positioning & timing: assist rover localization

Samples - 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

- **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

- **Many Space Biology and HRP return samples will require on-board and return cold stowage capability**

- **External analytical equipment mooted**
  - Decrease need to open “dirty” lunar samples inside the gateway

Leveraging the Gateway for Destinations Farther Into the Solar System

Operating for long durations in a deep space environment pushes the boundaries of science, opens opportunities for partnerships and prepares us for robotic and human missions to other destinations, farther into the solar system.

- Advancing planetary lander capabilities
- Honing sample return operations
- Deploying CubeSats, small sats and other science platforms
- Provides opportunities for commercial ventures and international partnerships
- Informing Mars transportation

NASA