Feb 28th, 9:00 AM

NASA's Lunar Orbital Platform-Gatway

Tracy Gill
NASA/KSC Technology Strategy Manager

NASA's Lunar Orbital Platform-Gateway

Tracy Gill
NASA/Kennedy Space Center
Exploration Research & Technology Programs

February 28, 2018

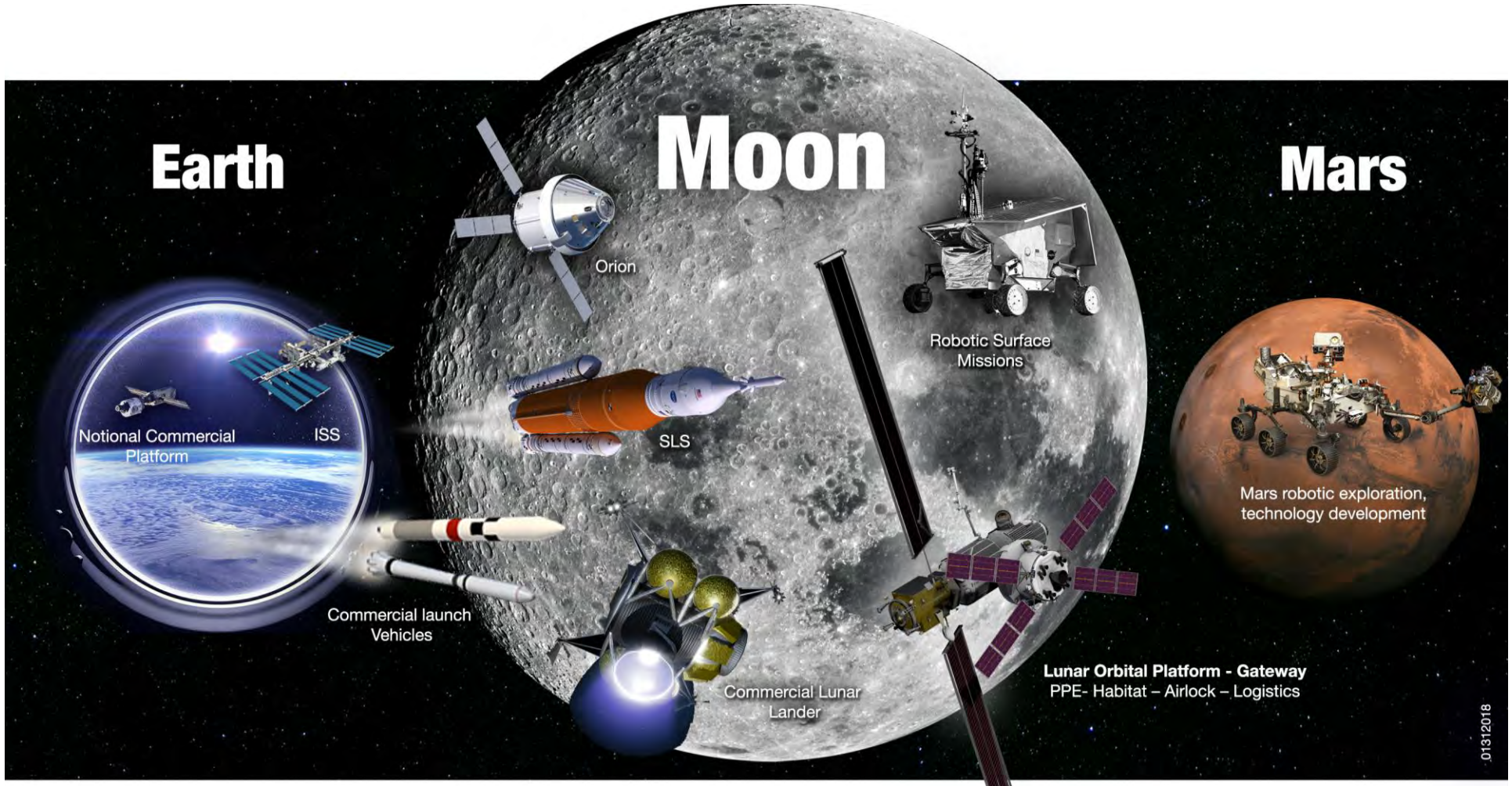
45th Space Congress

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.”

LUNAR EXPLORATION CAMPAIGN

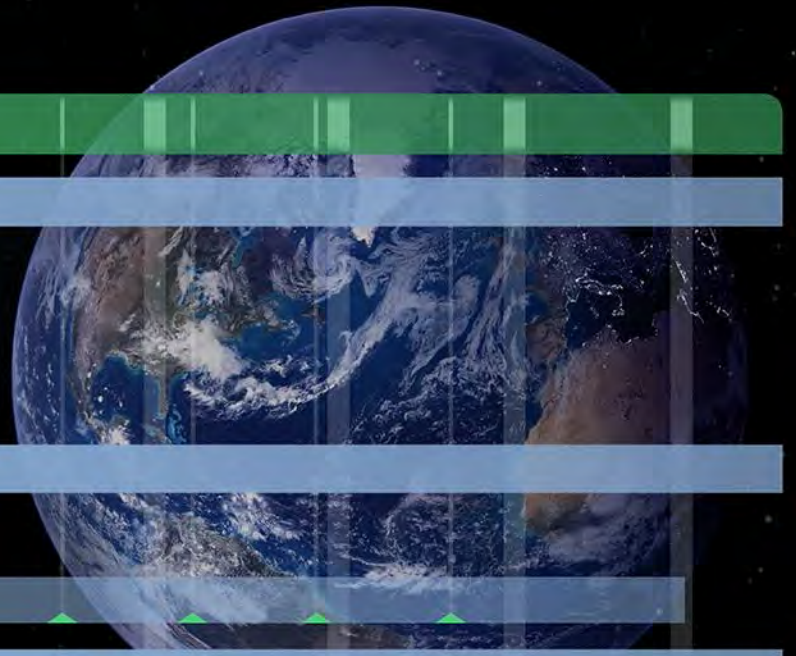


In LEO
Commercial & International partnerships

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

On Mars
Research to inform future crewed missions

NASA Lunar 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 COMMERCIAL LANDER INITIATIVE TOWARD HUMAN-RATED LANDER

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

LUNAR ORBITAL PLATFORM—GATEWAY

- **HEO**/SMD–Power & Propulsion Element/Communication Relay
- **HEO**/SMD–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

02.05.18

STRATEGIC PRINCIPLES FOR SUSTAINABLE EXPLORATION

- **FISCAL REALISM**
  Implementable in the near-term with the buying power of current budgets and in the longer term with budgets commensurate with economic growth;

- **SCIENTIFIC EXPLORATION**
  Exploration enables science and science enables exploration; leveraging scientific expertise for human exploration of the solar system.

- **TECHNOLOGY PULL AND PUSH**
  Application of high TRL technologies for near term missions, while focusing sustained investments on technologies and capabilities to address the challenges of future missions;

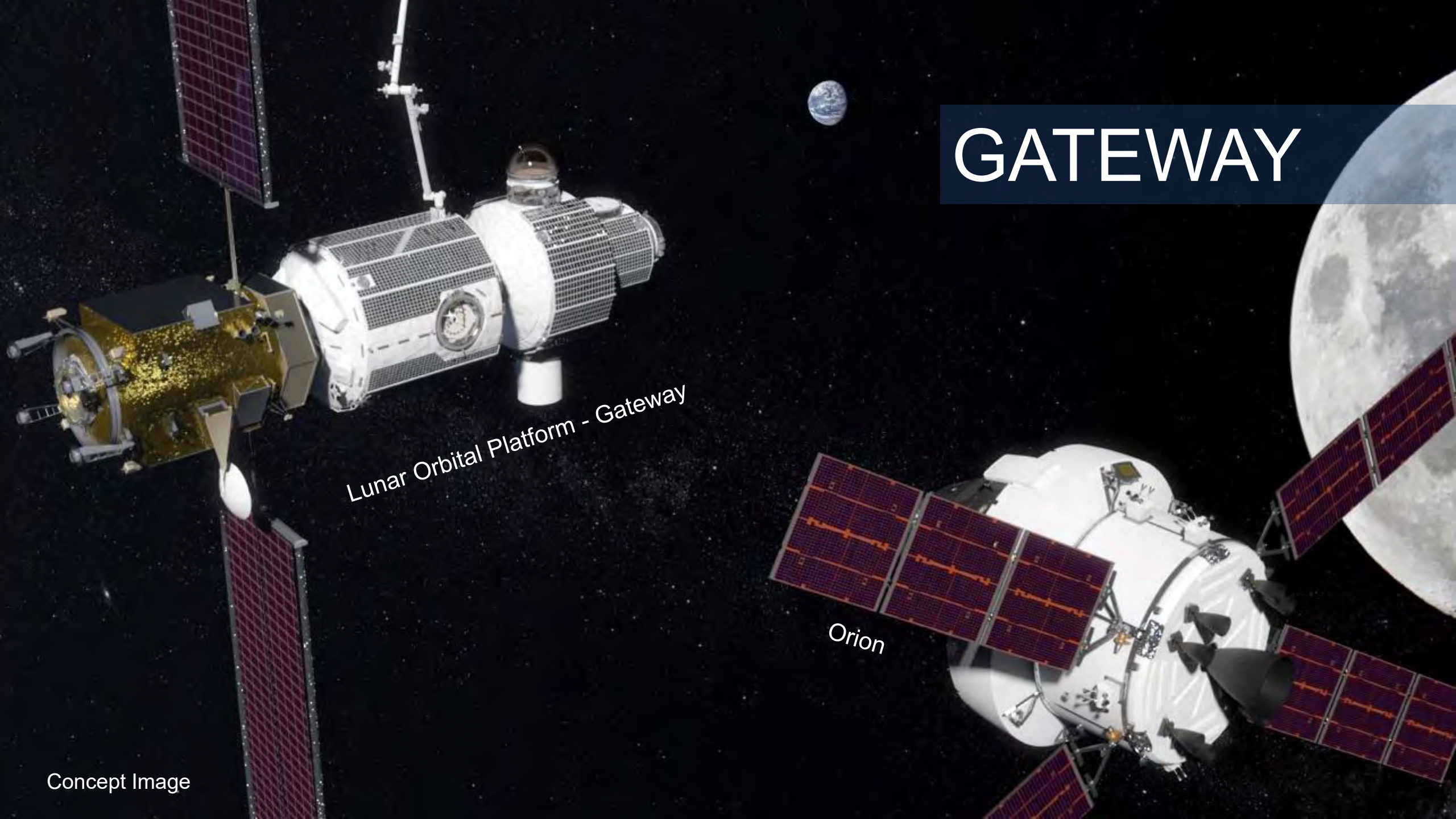
- **GRADUAL BUILD UP OF CAPABILITY**
  Near-term mission opportunities with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;

- **ECONOMIC OPPORTUNITY**
  Opportunities for U.S. commercial business to further enhance their experience and business base;

- **ARCHITECTURE OPENNESS AND RESILIENCE**
  Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;

- **GLOBAL COLLABORATION AND LEADERSHIP**
  Substantial new international and commercial partnerships, leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and

- **CONTINUITY OF HUMAN SPACEFLIGHT**
  Uninterrupted expansion of human presence into the solar system by establishing a regular cadence of crewed missions to cis-lunar space during ISS lifetime.


GATEWAY
Lunar Orbital Platform - Gateway
Orion
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**
  - Power Propulsion Element
  - Habitat
  - Logistics Strategy
  - Airlock
- **Feasibility trades and future work**
  - Partner-provided elements
  - Deep Space Transport

Draft Deep Space Interoperability System Standards – Open for Feedback March 1-29, 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 will be 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 (live starting March 1)

Next Space Technologies for Exploration Partnerships (NextSTEP):
Industry Partnerships in Pursuit of NASA's Strategic Goals

- **NextSTEP solicits studies, concepts and technologies to demonstrate key capabilities on the International Space Station and for future human missions in deep space. Focus areas include:**
  - deep space habitation concepts, life support systems, advanced electric propulsion systems, small satellites, commercial lunar landers, advanced manufacturing, and in-situ resource utilization (ISRU) measurements and systems
- **Most NextSTEP efforts require some level of corporate contributions.**
- **This model of public-private partnerships stimulates the economy and fosters a stronger industrial base and commercial space market.**

Approach to Power and Propulsion Element Development

- **PPE will leverage advanced solar electric propulsion (SEP) technologies developed and matured during Asteroid Redirect Mission activities:**
  - 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
  - Leverage with U.S. industry current capabilities and future plans for future use of SEP
  - Will provide transportation and controls for lunar orbital operations, power to future lunar orbiting elements, and communications

Power & Propulsion: First Element in the Gateway

- **The PPE would provide key functionality for the gateway including:**
  - 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; and
  - accommodations for an optical communications demonstration.

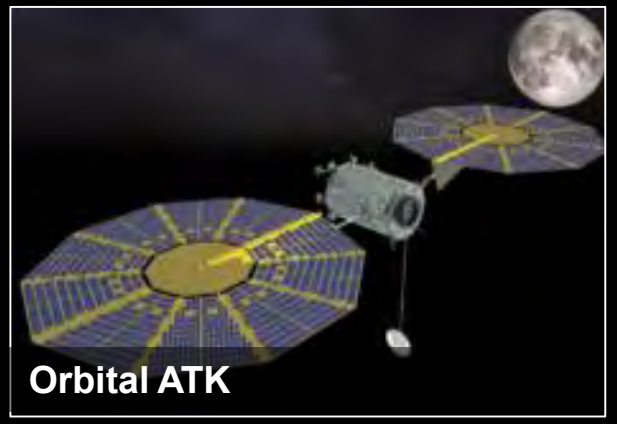
PPE Industry Engagement

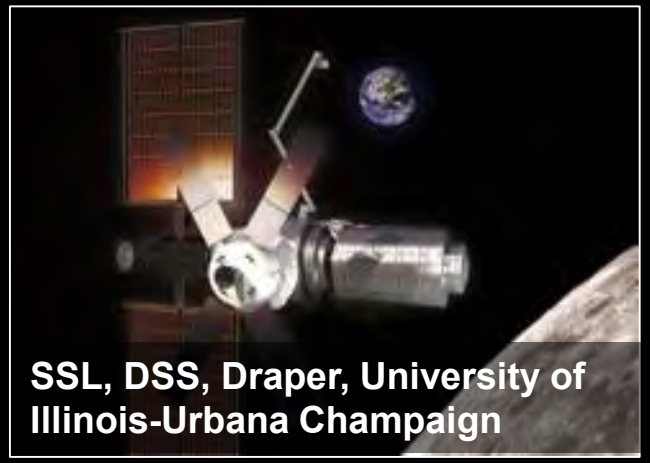
- **Summer 2017:** NASA issued a request for information to capture U.S. industry's capabilities and plans for spacecraft concepts that potentially could be advanced to power an advanced SEP system for the gateway.
- **August 2017:** NASA issued NextSTEP Appendix C, Power and Propulsion Studies seeking 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 Nov. 2017.
- **Feb. 2018:** NASA issued synopsis for a Spaceflight Demonstration of a Power and Propulsion Element

Power and Propulsion Element Studies

<u>NextSTEP Appendix C:</u> Issued Aug 11, 2017 | Selections announced Nov. 1, 2017

- U.S. industry-led studies for an advanced solar electric propulsion (SEP) vehicle capability.
- Four-month studies commenced late Nov 2017.





HABITATION CAPABILITY

Systems to enable the crews to live and work safely in deep space. Capabilities and systems for use in conjunction with Orion and SLS on exploration missions in cislunar space and beyond.

NextSTEP Habitation

NextSTEP Phase 1: 2015-2016

Cislunar habitation concepts that leverage commercialization plans for LEO


LOCKHEED MARTIN


BIGELOW AEROSPACE


ORBITAL ATK


BOEING

FOUR SIGNIFICANTLY DIFFERENT CONCEPTS RECEIVED

Partners develop required deliverables, including concept descriptions with concept of operations, NextSTEP Phase 2 proposals, and statements of work.

NextSTEP Phase 2: 2016-2019

- Partners refine concepts and develop ground prototypes.
- NASA leads standards and common interfaces development.

FIVE GROUND PROTOTYPES BY 2019


BIGELOW AEROSPACE

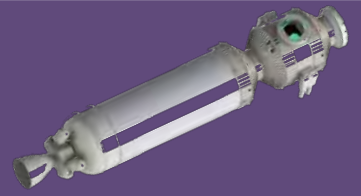

BOEING


LOCKHEED MARTIN


SIERRA NEVADA CORPORATION


ORBITAL ATK

ONE CONCEPT STUDY


NANORACKS

Define reference habitat architecture in preparation for Phase 3.

Initial discussions with international partners

Phase 3: 2019+

- Partnership and Acquisition approach, leveraging domestic and international capabilities
- Development of deep space habitation capabilities
- Deliverables: flight unit(s)

- **NASA plans to host a workshop Feb. 27-March 1, 2018** to investigate concepts that could advance scientific discoveries near the Moon by leveraging potential capabilities provided by the gateway. The workshop will evaluate concepts submitted by the global science community through a call for abstracts, issued Nov. 7, 2017.
- **Attendance will be by invitation only based on an open call for presentations**
  - Scientists, engineers, and program managers from NASA, academia, industry, and international organizations
- **Two types of sessions: discipline-focused splinter sessions and cross-cutting discussions**
  - The bulk of the workshop will consist of parallel discipline-focused sessions, where potential science areas enabled by exploration are presented, discussed, and eventually synthesized to instrument concepts
    - Heliophysics, Earth Science, Astrophysics & Fundamental Physics, Planetary Science, Life Sciences and Space Biology
  - Also have cross-cutting sessions, e.g., CubeSats, external payloads
  - Final plenary session will summarize results and discuss the next strategic steps for how workshop content will be captured and disseminated

In-Situ Resource Utilization (ISRU)

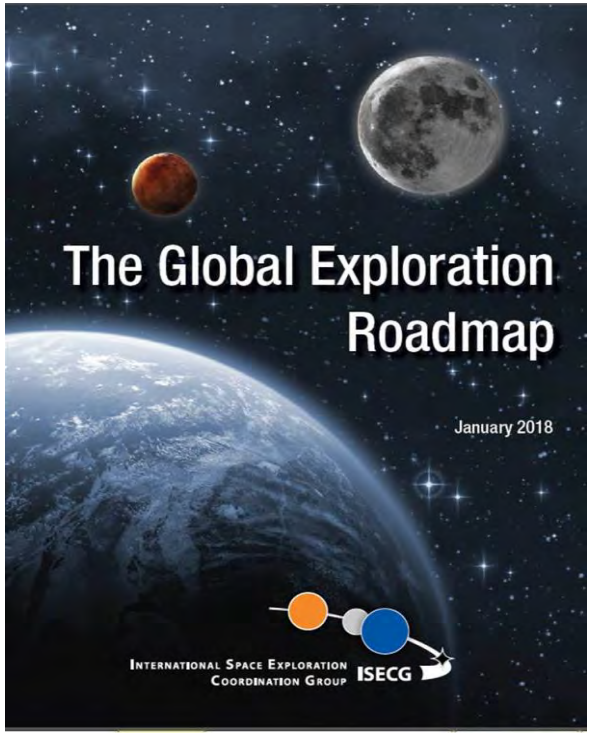
NextSTEP Appendix D: Issued Dec. 4, 2017 | Proposals Due March 12, 2018
Seeking proposals to advance ISRU technologies for extracting and processing resources from the Mars atmosphere and soil from deep space destinations such as the Moon and Mars.


NASA

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



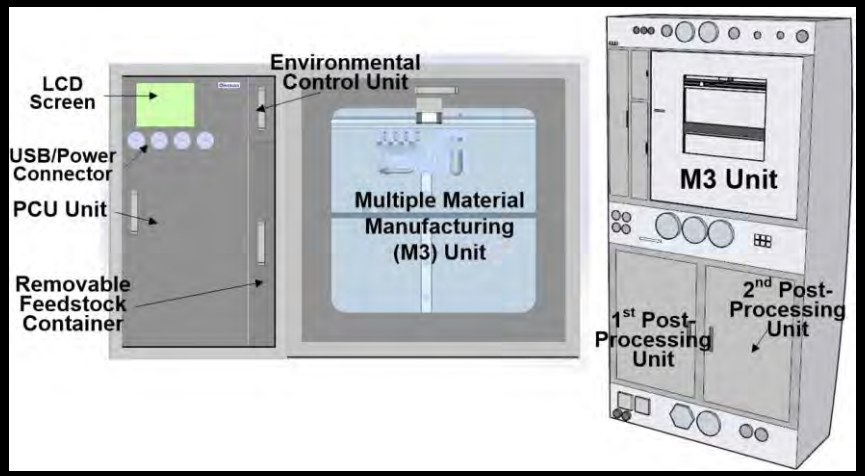
- **The non-binding strategic document reflects consensus on expanding human presence into the Solar System, including**
  - Sustainability Principles
  - Importance of ISS and LEO
  - The Moon: Lunar vicinity and Lunar surface
  - Mars: The Driving Horizon Goal

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

FabLab

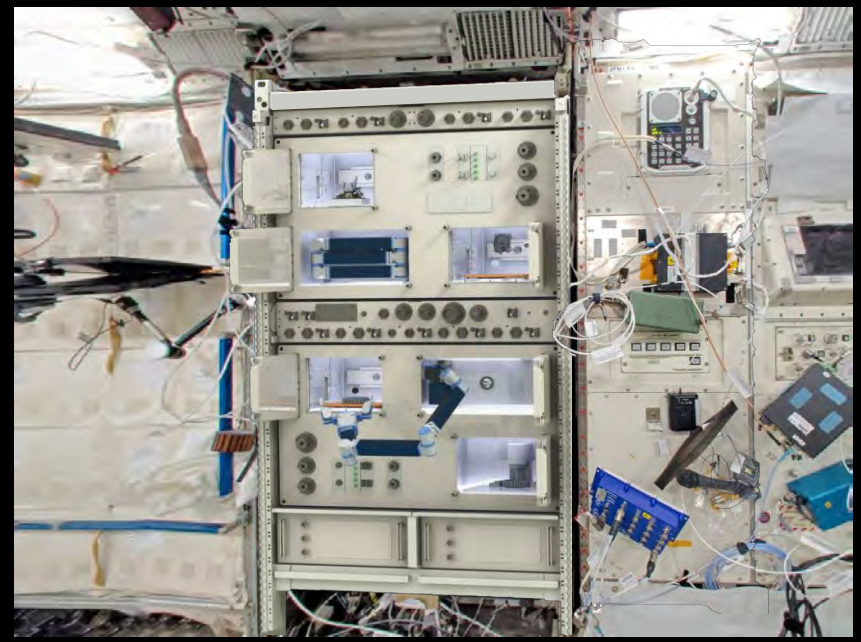
NextSTEP Appendix B: Issued May 3, 2017 | Selections announced Dec. 7, 2017

- Three companies selected to develop a multi-material fabrication laboratory (FabLab) capable of end-to-end manufacturing during space missions.



Interlog Corporation of Anaheim, California

Techshot, Inc. of Greeneville, Indiana



Tethers Unlimited, Inc. of Bothell, Washington

Full-Sized Ground Prototype Habitation Development

NextSTEP Appendix A: Issued April 19, 2016 | Selections announced Aug. 9, 2016
Five full-sized ground prototypes will be delivered for testing beginning early 2019

NextSTEP Phase II
Bigelow Aerospace B330 / XBASE

OBJECTIVES & TECHNICAL APPROACH

- 330 m^3 habitat that will attach to the ISS as a testing platform for deep space exploration technologies and procedures.
- Technical approach includes refinement of the concept of operations, a series of tests including structural tests and ECLSS prototype tests, full scale prototype development activities, and integration studies in Virtual Reality.
- Phase II will involve active support from Bigelow Aerospace for standards and common interfaces working groups.

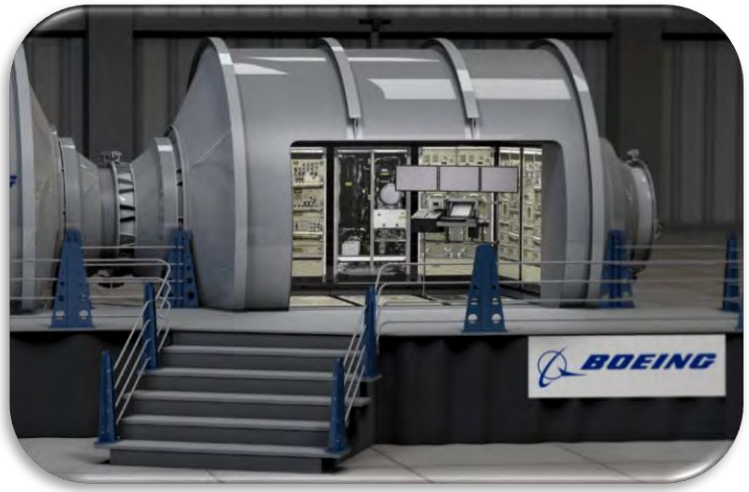
TEAM

- **Robert Bigelow:** President of Bigelow Aerospace / Program Manager
- **Colm Kelleher, PhD:** Deputy Program Manager and Chief Scientist ECLSS
- **Lisa Thomas:** Deputy Program Manager
- **Uy Duong:** Deputy Program Manager – Structures

KEY ATTRIBUTES

- Provides opportunity to develop and test an inflatable-based integrated deep-space Spaceship that incorporates new structures and exploration capabilities (e.g. Liquid Processing System, CO2 Removal systems)
- Supports both LEO Commercialization and future human exploration mission objectives
  - Provides opportunity to test NASA exploration class ECLSS and other exploration systems while docked to ISS
  - Once exploration systems validated, the module could then be detached from ISS and become a LEO free flyer and continue to test exploration systems while supporting commercial needs
  - Second copy of module could be developed as the Spaceship Habitat and flown to Spaceport for assembly and outfitting
- 2018 Ground Test to be performed at BA facilities

NextSTEP Phase II
The Boeing Company



TEAM

- Boeing leads a global team of companies, each contributing valuable habitat systems experience, subject matter expertise, and services
- The Boeing NextSTEP-2 team includes support from NASA centers, including JPL, JSC, KSC, and MSFC
- Boeing has engaged industry and university partners focused on advanced concepts and exploration technologies for joint study and collaboration

KEY ATTRIBUTES

- Concept uses existing technology
  - Already developed ISS assets
  - Boeing's commercial GEO satellite bus for power/propulsion module
- Provides innovative modular approach for subsystem integration into habitat module
- Performs long duration missions in cislunar space when fully assembled
- Good leverage of NASA workforce
- 2018 Ground Test to be performed at MSFC facilities

OBJECTIVES

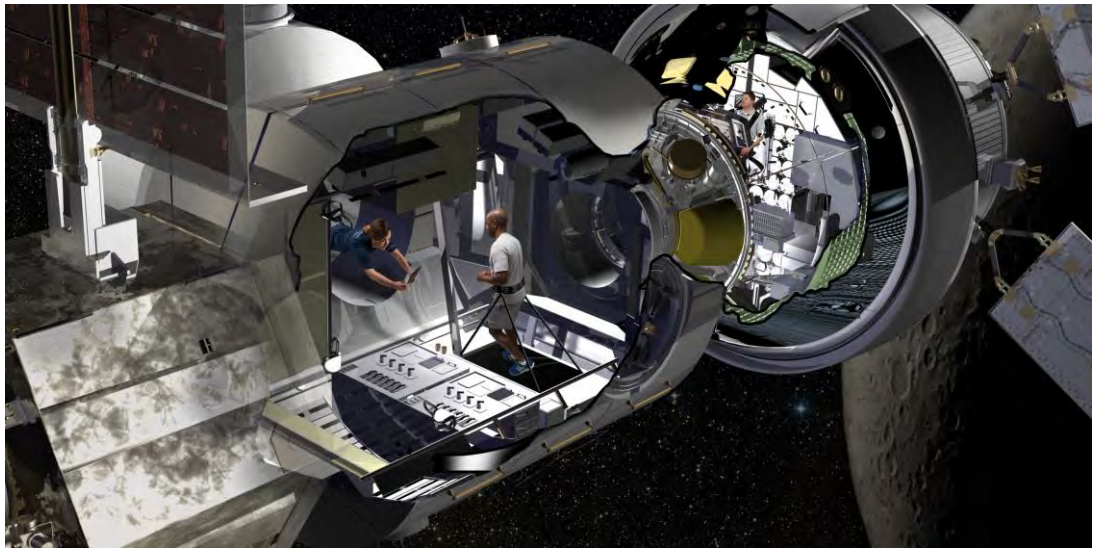
Develop input to NASA's reference architecture for long duration, deep space human spaceflight exploration missions and develop habitation element concepts for cislunar space

- Build a full scale ground demonstrator prototype habitat
- Define standards and common interfaces
- Describe intersections between the NextSTEP-2 partnership and industry interest in commercial activities in LEO

TECHNICAL APPROACH

- Design and analyze modular habitation system concepts and assess requirements relative to NASA's exploration architecture
- Validate designs and interface standards
- Test habitat functionality in Boeing's full scale ground prototype demonstrator

NextSTEP Phase II
Lockheed Martin



OBJECTIVES

- Refine design concept over three design and analysis cycles. Utilize virtual prototyping in order to rapidly iterate on core design. Incorporate lessons learned from IWG and prototype builds. Identify LEO and cislunar commercialization intersections.
- Work with NASA to define common interface standards.
- Refurbish NASA provided MPLM as a full-scale habitat module prototype, with integrated avionics and ECLSS, to provide risk reduction and form/fit testing.
- Prove out command and data handling between HSV and Orion. Demonstrate crew interface commonality between DSTH and Orion.
- Build and test a high-fidelity prototype to demonstrate the integrated habitat and Orion operations and to characterize subsystem performance, interactions, and behaviors when the modules share a common atmosphere.

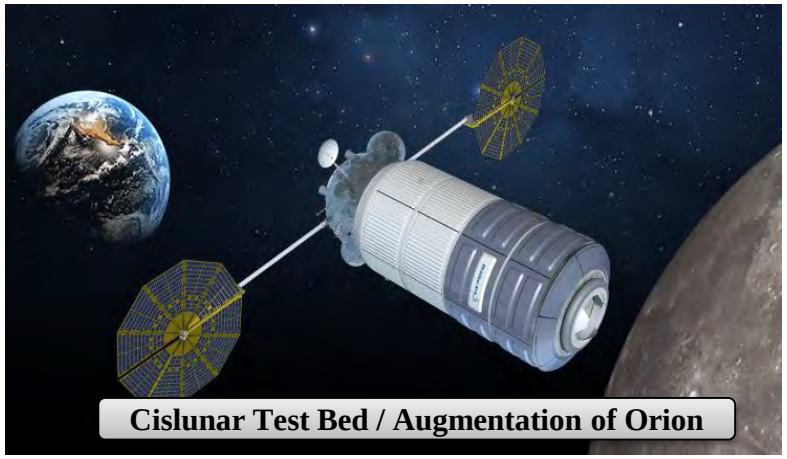
KEY ATTRIBUTES

- Provides a concept using existing technology
  - Use existing ISS assets (e.g., MPLM) for the primary module concept
  - Leverages LM's commercial and deep space bus heritage for power/propulsion module
  - Uses Orion command and control capability to leverage NASA investment
- Concept provides innovative approach for EVA module and airlock functions
- Once fully assembled, can perform long duration missions in cislunar space, serving as a lunar space portal and construction platform for Mars elements (flexible design)
- Provides good leverage of NASA workforce
- 2018 Ground Test to be performed at KSC facilities
  - Leverages ISS Donatello MPLM as prototype module

TEAM

- **Lockheed Martin:** Prime contractor responsible for entire system concept and prototypes
- **Thales Alenia Space – Italy:** Habitat module primary and secondary structure
- **ILC Dover:** ECLSS engineering services, EVA, inflatable technologies integration
- **Thin Red Line Aerospace:** Inflatable Technologies
- **Airbus Defense & Space:** Habitat science integration lunar surface exploration, advanced habitation systems integration
- **Made in Space:** in-space material recycling
- **MDA:** Habitat robotic systems
- **NASA JSC:** ECLSS, EVA, power avionics and software, crew displays and controls
- **NASA LaRC:** Radiation mitigation and inflatable technologies

NextSTEP Phase II
Orbital ATK


Cislunar Test Bed / Augmentation of Orion

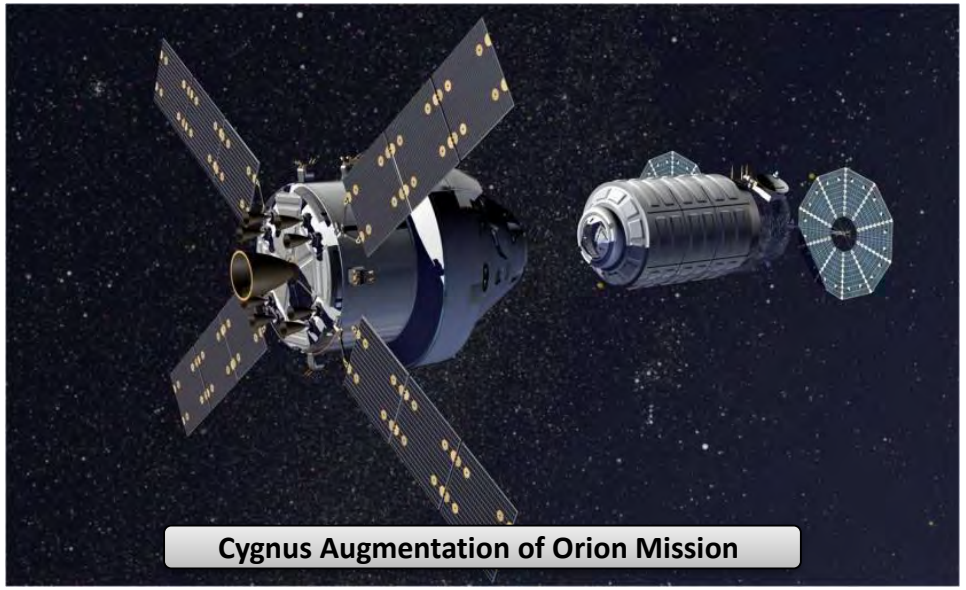
KEY ATTRIBUTES

- Designed to perform long duration missions in cislunar space
- Utilizes existing technology in vehicle design
- Leverages Orbital ATK's human-rated and operational commercial cargo spacecraft
- Provides innovative approach for EVA module and airlock functions
- Supports 2018 Ground Test to be performed at NASA facilities
- Evolvable to support future Exploration needs

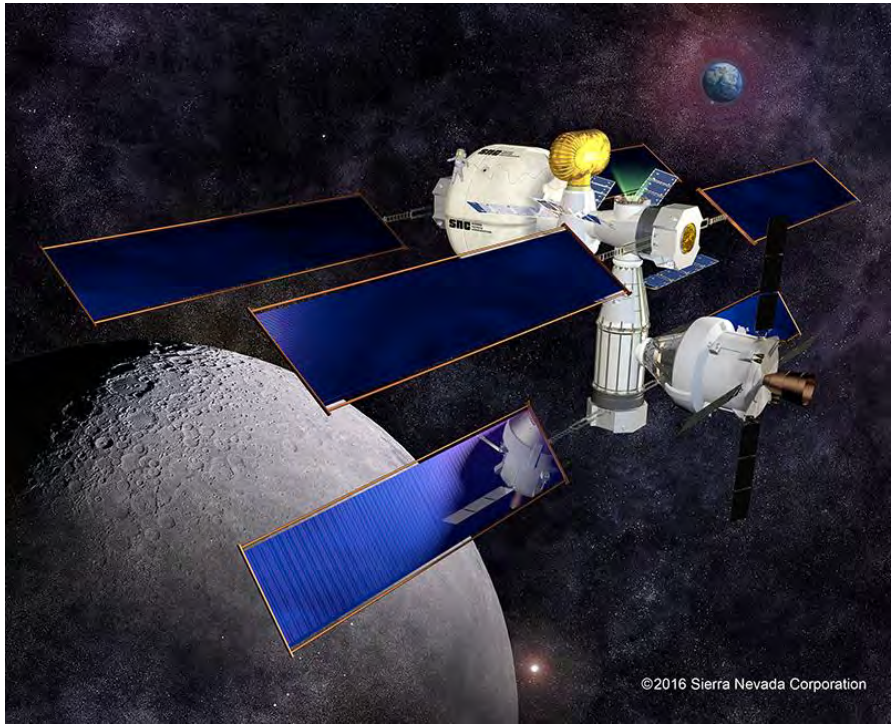
OBJECTIVES

Develop long-duration deep space habitation capabilities that enable the deployment of a deep space transit habitat in the early 2020s

- Advance the long duration deep space habitation system concepts and mature the design and development of the integrated system(s)
- Apply standards and common interfaces defined by the NASA-led standards working group during Phase 2
- Develop high fidelity ground prototype units and deliver to NASA for additional testing and integration
- Further define and develop deep space habitation and logistics capabilities that can be flown as co-manifested payloads on SLS Block 1 B or on other independent launch vehicles
- Identify options to maximize NASA and commercial LEO opportunities such as demonstration missions at the ISS or in cislunar space


Cygnus Augmentation of Orion Mission

NextSTEP Phase II
Sierra Nevada Corporation



KEY ATTRIBUTES

- New to NextSTEP Hab activity – will have to accelerate concept refinement to meet milestones
- Provides innovative solution for deep space habitation
  - Leverages off of SNC's cargo resupply development activities
  - Uses advanced inflatable materials for habitat
  - Flies initial habitat to ISS for assembly and check-out and then meets up with remaining elements in LEO and is then sent to cislunar space
- 2018 Ground Test to be performed at JSC facilities

OBJECTIVES & TECHNICAL APPROACH

- Matures and refines SNC's deep space habitat concept through system trades and full-scale ground prototyping and testing
- Leverages a modular and flexible architecture that builds on NextSTEP-1, CRS2 and cooperative commercial investments.
- Requires four launches to complete the mission; able to co-manifest with SLS/CRS2 or utilize commercial launch vehicles to provide NASA flexibility in assembling habitat that supports Orion mission timelines
- Uses mature system building blocks and evolving capabilities to achieve long-duration mission objectives
- Includes ongoing technology evaluation to further LEO and deep space commercialization

TEAM

- **SNC** – CCDev, CCiCap, and CRS2 contracts with NASA to deliver a human-rated flight systems for LEO
- **ORBITEC** – SNC business unit, provides ECLSS subsystem for CRS2 contract, and also awarded NextSTEP-1 contract to develop a habitat plant growth system.
- **Aerojet Rocketdyne** – Awarded NextSTEP-1 contract to advance electric propulsion capabilities through EP thruster development
- **ILC Dover** – Applies TransHab, Lunar Habitat Study and Resilient Tunnel Plug technology to develop inflatable habitat for SNC's concept
- **NASA LaRC** – Considerate experience with inflatables and long-duration radiation mitigation.

NextSTEP Phase II
NanoRacks

OBJECTIVES

- Leverage proven, affordable, and safe flight hardware by converting a Centaur and other rocket stage into a habitat;
- Perform feasibility assessment of habitat outfitting via robotics;
- Transform the LEO commercial marketplace by combining Nanoracks and SSL's unique private sector experience and customer base for next-generation orbital satellite manufacturing, assembly, and deployment; space tourism; media activities; and orbital experiments.
- Explore cost/benefit analysis in differing space regimes of this proposed approach in comparison to other current approaches/technologies

KEY ATTRIBUTES

- Provides study to look at feasibility of converting spent upper-stages into habitats while in space
- Uses advances in robotics to perform the upper-stage safing and outfitting
- Leverages partners' extensive knowledge in robotics, launch vehicle upper-stages, and commercial use of low-earth-orbit
- Concept provides innovative approach for development of future large habitats at a potentially great cost savings
- Study will finish in four months, contractor to continue afterwards to support interface and standards working group
- Activity will not result in development of a ground prototype unit

TEAM

- **NanoRacks, LLC**
  - Prime contractor, habitat systems design, LEO commercial operations
- **Space Systems Loral**
  - Robotics, Solar Electric Propulsion, LEO/GEO commercial satellite manufacturing
- **United Launch Alliance**
  - Centaur tank, launch services, and mission design