Boots on Moon: Going Forward to the Moon to Stay

International Space University Space Studies Program
Strasbourg, France – July 24, 2019

Michael Johansen/NASA Kennedy Space Center
Kim Ellis/Earth Space Technology Pty Ltd
Tracy Gill/NASA Kennedy Space Center

Introductions

Overview

- Introduction and Overview (Kim)
- Vision & NASA plans (Tracy and Michael)
- Capabilities and Enablers
  - Technology Needs (Michael)
  - Legal framework/other factors (Kim)
- Barriers and Challenges (Michael)
- Team Activity
- Presentations

Workshop Deliverables

- Develop a vision for future of “Pioneering on the Moon”
- Identify the single greatest challenge to achieving that vision
- Draft an RFT response which supplies a solution to the greatest challenge that your team identifies
- Present the vision, challenge, and solution to your peers and evaluation team

Lunar Exploration Plans

NextSTEP E: Human Landing Sy Reduction, Development, and D

Solicitation Number: NNH19ZCQ001K_APP-E

Dec. 13, 2018 - Synopsis Issued | Announcement

Dec. 20, 2018 - Synopsis Updated | Page Updated with new BAA Rel

Jan. 28, 2019 - Page updated with BAA Release and Industry Forum

Feb. 5, 2019 - Synopsis Updated | Page updated with new BAA Rele

Feb. 7, 2019 - Solicitation Released | Updated Announcement

Feb. 14, 2019 - NASA hosted an Industry Forum at NASA HQ to prov (HLS) BAA.

- The briefing is available here:
  NextSTEP-2 HLS BAA Industry Forum Briefing
- A list of industry representatives who participated in the Industry facilitate partnering among potential proposers:
  HLS BAA Industry Forum Participant List
- Video of NASA TV Portion of the Industry Forum: Industry Forur

Feb. 28, 2019 - Q&A Log Posted

March 26, 2019
RELEASE 19-022

NASA Administrator Stateme Next Five Years

NextSTEP H: Human Landing System - Integrated Lander

Solicitation Number: NNH19ZCQ001K_APP-H

Apr. May 13, 2019
April RELEASE 19-039

NASA Highlights Moon 2024 Mission with FY 2020 Budget Amendment

NASA Administrator Jim Bridenstine sent a video message to agency employees Monday about the president's fiscal year 2020 budget amendment, which will support accelerated plans to land astronauts on the Moon by 2024.

Artist's rendering of an ascent vehicle separating from a descent vehicle and departing the lunar surface.
Credits: NASA

This update signals intent by the end of May 2019 to seek proposals from industry in support of rapid development of an integrated human lunar landing system, including elements such as a descent element, ascent element, and transfer vehicle. NASA will seek proposals from U.S. industry for the development, integration, and crewed demonstration of these elements as a functional human landing system that can fulfill NASA and industry requirements, and meet the challenge to send the next man, and the first woman, to the Moon by 2024.

Activities under NextSTEP E, Human Landing Systems Studies, Risk Reduction, Development and Demonstration will be integrated with the proposed activities under NextSTEP H.

Commercial Lunar Payload Services

CLPS Providers

- Astrobotic Technologies
- Deep Space Systems
- Draper
- Firefly Aerospace
- Intuitive Machines
- Lockheed Martin Space
- Masten Space Systems
- Orbit Beyond

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NASA Provided Lunar Payloads

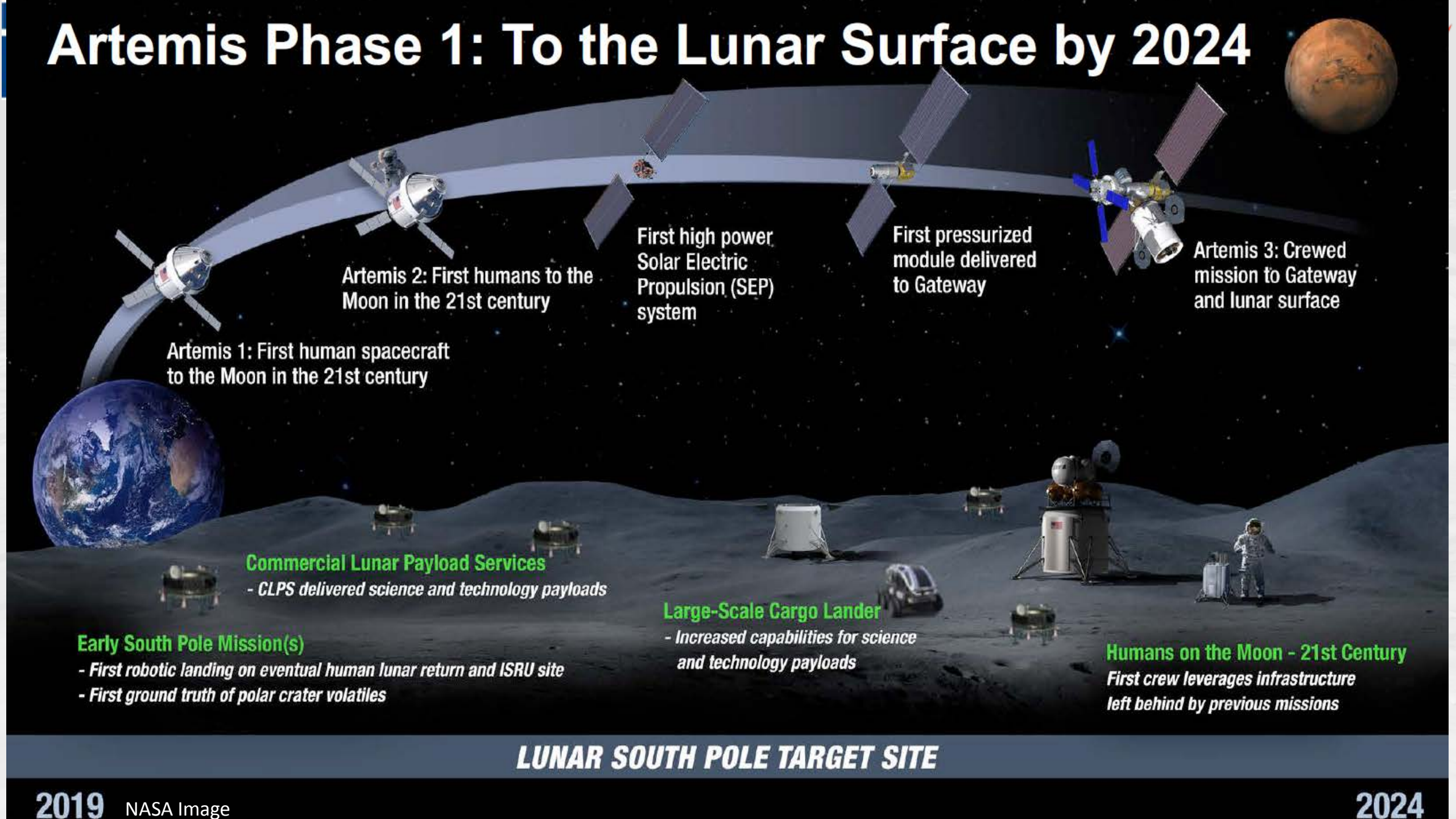
- Surface and Exosphere Alterations by Landers (SEAL)
- Linear Energy Transfer Spectrometer
- Stereo Cameras for Lunar Plume-Surface Studies (SCALPSS)
- Solar Cell Demonstration Platform for Enabling Long-Term Lunar Surface Power
- Near-Infrared Volatile Spectrometer System
- Neutron Spectrometer System
- Lunar Node 1 (LN-1) Navigation Demonstrator
- Neutron Measurements at the Lunar Surface
- PROSPECT ion-Trap Mass Spectrometer (PITMS) for Lunar Surface Volatiles
- Fluxgate Magnetometer
- Low-frequency Radio Observations from the Near Side Lunar Surface
- Navigation Doppler Lidar (NDL) for Precise Velocity and Range Sensing
- Mass Spectrometer observing lunar operations (MSolo)

How do we start and what is it called?

Deep Space Gateway

Lunar Orbital Platform - Gateway

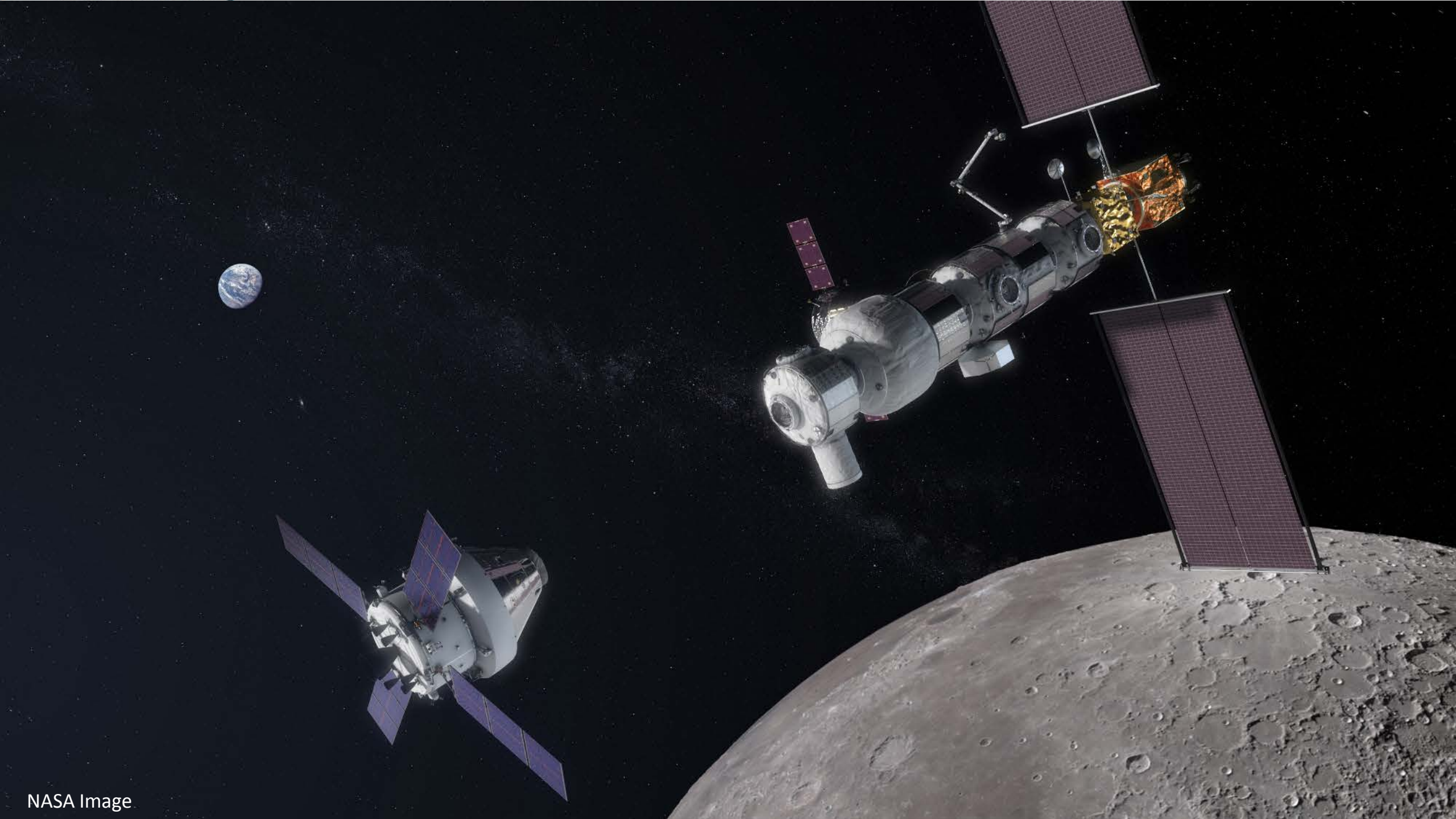
Gateway


Artemis Phase 1: To the Lunar Surface by 2024
Artemis 1: First human spacecraft to the Moon in the 21st century
Artemis 2: First humans to the Moon in the 21st century
First high power Solar Electric Propulsion (SEP) system
First pressurized module delivered to Gateway
Artemis 3: Crewed mission to Gateway and lunar surface
Commercial Lunar Payload Services
- CLPS delivered science and technology payloads
Early South Pole Mission(s)
- First robotic landing on eventual human lunar return and ISRU site
- First ground truth of polar crater volatiles
Large-Scale Cargo Lander
- Increased capabilities for science and technology payloads
Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions
LUNAR SOUTH POLE TARGET SITE
2019
2024
NASA Image

Gateway is Essential for 2024 Landing

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2
- Provides command center and aggregation point for 2024 human landing
- Establishes strategic presence around the Moon – US in the leadership role
- Creates resilience and robustness in the lunar architecture
- Open architecture and interoperability standards provides building blocks for partnerships and future expansion

NASA Image



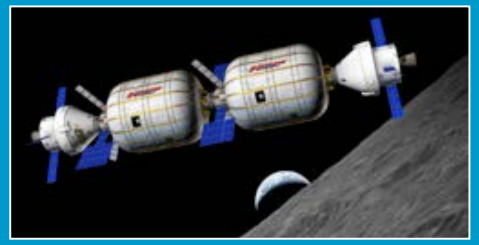
NASA Image

NextSTEP Habitation – Model for Commercial Engagement

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.


BIGELOW AEROSPACE


BOEING


LOCKHEED MARTIN


SIERRA NEVADA CORPORATION


NORTHROP GRUMMAN


NANORACKS

NASA defines reference habitat architecture in preparation for Phase 3.

Phase 3: 2019+

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

15

Habitation Development Partnerships

Five full-sized ground prototypes will be delivered for testing in 2019. In negotiations with NanoRacks for prototype concept demonstration.

Lockheed Martin
Denver, CO

Refurbishes heritage hardware

KSC (March 2019)

Northrop Grumman
Dulles, VA

Builds on proven cargo spacecraft development

JSC (May 2019)

Bigelow Aerospace
Las Vegas, NV

Expandable

Las Vegas (Sept 2019)

Boeing
Pasadena, TX

Leverages existing technologies

MSFC (June 2019)

Sierra Nevada
Louisville, CO

Modular buildup

JSC (July 2019)

NanoRacks
Louisville, CO

Converted Centaur upper stages

MSFC

Government Evaluation Location:

INTERNATIONAL INTEROPERABILITY STANDARDS

Draft Deep Space Interoperability System Standards

- **Posted for public feedback on March 1, 2018.**
- **Planned for Baseline in 2019.**

www.InternationalDeepSpaceStandards.com

- **Avionics**
- **Communications**
- **Environmental Control and Life Support Systems**
- **Power**
- **Rendezvous**
- **Robotics**
- **Thermal**

NextSTEP Phase 2 Parameters

- Each contractor has approximately a 2 year window from contract start
- 18 months to
  - Develop deep space architecture and allocate needed functions to modules
  - Design concept habitat and then design and build ground prototype demonstrator emphasizing features of merit using avionics test beds, physical mockups, augmented reality and virtual reality, modeling and simulation tools, and more…
- Contractors determine design process and recommend milestones
- After the 18 month contractor period, the government has up to 6 months to evaluate the architecture

Intellectual Property (IP)

- Developed a program specific best practices guide for handling sensitive information, additional engagement with data IP attorneys
- Incorporating additional training on IP and data rights for personnel engaging with the contractors
- Implemented custom IP clauses in the contracts
- To protect sensitive information, the NextSTEP contracts include the standard Federal Acquisition and NASA regulations that require marking the data as “Limited Rights Data/Information in Accordance with FAR 52.227-14 as Modified by NFS 1852.227-14.”
- Civil servants are bound by the United States Trade Secrets Act, which requires that civil servants protect proprietary information they receive in their official capacity and carries criminal sanctions.

Value of the NextSTEP Habitat Phase 2 Contracts

- First NextSTEP Phase 2 work has informed NASA of diverse architecture and concept of operations approaches and afford an opportunity to assess those approaches.
- Next, these contracts have provided options for acquisition strategies because the Phase 2 work was competitively awarded.
- The Phase 2 work has resulted in better standards and interfaces because of the collaborative efforts across the contractors as well as the public input.
- It also helped inform and confirm NASA trades during NASA requirements development.
- The work is expected to contributed to developing realistic cost and schedule targets for Gateway, and it has enabled testing of different habitat and integration concepts.
- The Phase 2 contract work has enhanced the experience base both in NASA and contractors in design, development, and testing of space habitat systems.
- The Gateway is still evolving as concepts, partnerships, and mission objectives mature and this model allows for that flexibility
- Now this same approach is being applied to lander systems as well via NextSTEP Appendices E and H!

An International Enterprise

Canada Commits to Joining NASA at the Moon

Jim Bridenstine
February 28, 2019
Moon to Mars

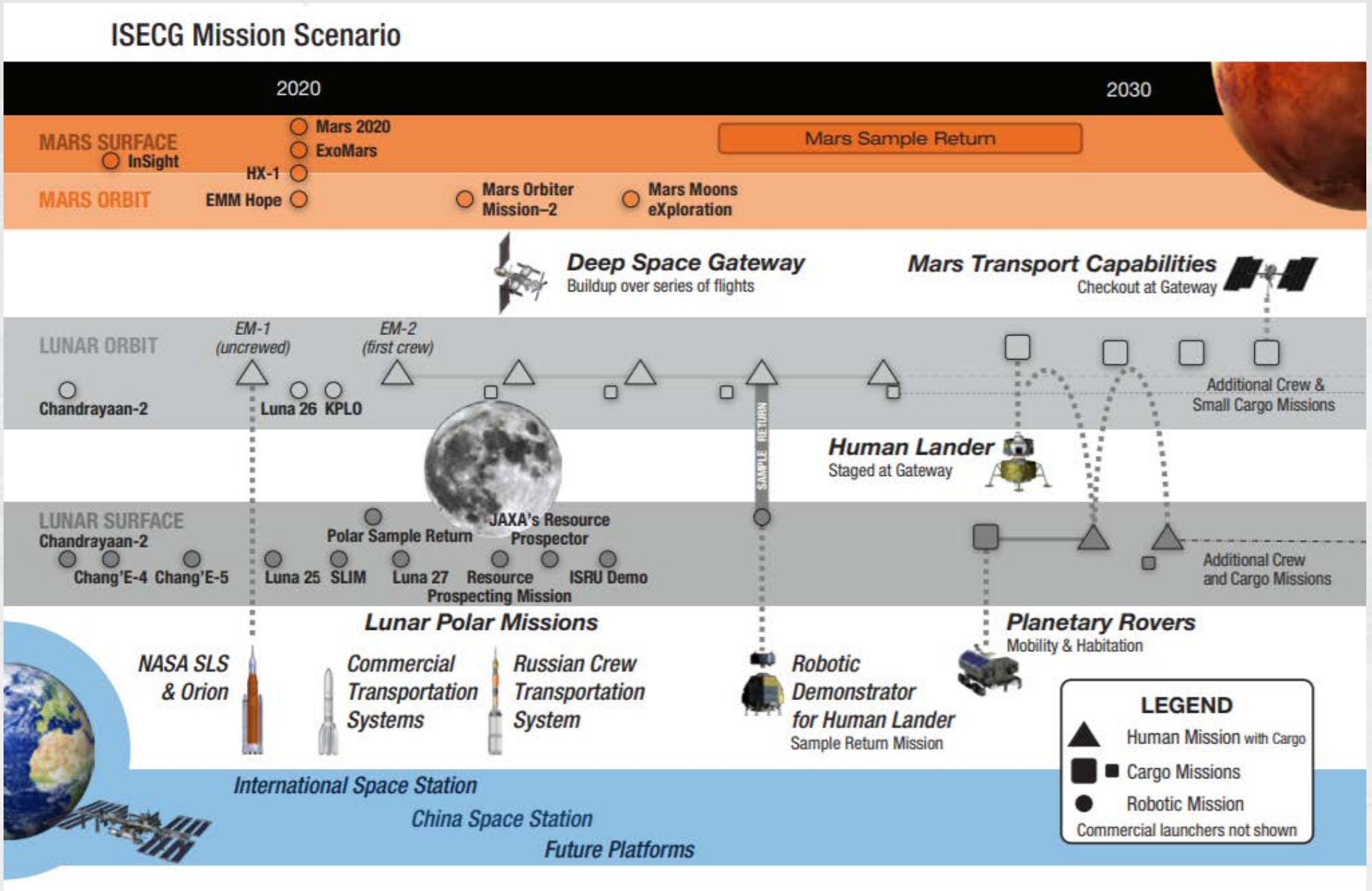
NASA is going back to the Moon to stay. It's part of a bold directive from the President for the U.S. to lead a worldwide endeavor to open a new era of space exploration in a measured, sustainable way. This work is going to take collaboration with international partners, industry, and other stakeholders, and I'm delighted by Canada's commitment today to join us in our work to go forward to the Moon and Mars.

We are excited that Canada will be a vital ally in this lunar journey as they become the first international partner for the Gateway lunar outpost with their 24 year commitment to deep space exploration and collaboration.

International Space Exploration Coordination Group
https://www.globalspaceexploration.org


INTERNATIONAL SPACE UNIVERSITY
Earth Space Tech
NASA
Australian Space Agency
CSIRO
Australia
CSA ASC
Canada
CNSA
China
esa
European Space Agency
cnes
France
इसरो isro
India
Italy
JAXA
Japan
KARI
Republic of Korea
ROSCOSMOS
Russia
STATE SPACE AGENCY OF UKRAINE
Ukraine
وكالة الإمارات للفضاء
UAE SPACE AGENCY
United Arab Emirates
UK SPACE AGENCY
United Kingdom
NASA
United States
THE GLOBAL EXPLORATION ROADMAP
POLISH SPACE AGENCY

ISECG Image


ISECG Mission Scenario
2020
2030
MARS SURFACE
InSight
Mars 2020
ExoMars
HX-1
EMM Hope
MARS ORBIT
Mars Orbiter Mission–2
Mars Moons eXploration
Mars Sample Return
Deep Space Gateway
Buildup over series of flights
Mars Transport Capabilities
Checkout at Gateway
LUNAR ORBIT
EM-1 (uncrewed)
EM-2 (first crew)
Chandrayaan-2
Luna 26
KPLO
Additional Crew & Small Cargo Missions
SAMPLE RETURN
Human Lander
Staged at Gateway
LUNAR SURFACE
Chandrayaan-2
Chang'E-4
Chang'E-5
Luna 25
SLIM
Polar Sample Return
Luna 27
Resource Prospecting Mission
JAXA's Resource Prospector
ISRU Demo
Additional Crew and Cargo Missions
Lunar Polar Missions
Planetary Rovers
Mobility & Habitation
NASA SLS & Orion
Commercial Transportation Systems
Russian Crew Transportation System
Robotic Demonstrator for Human Lander
Sample Return Mission
LEGEND
Human Mission with Cargo
Cargo Missions
Robotic Mission
Commercial launchers not shown
International Space Station
China Space Station
Future Platforms

ISECG Image

Future Lunar Robotic Missions

Mission	Agencies/Launch Date	Objectives/Strategic Knowledge Gaps Addressed
Chandrayaan-2	ISRO/2018	Polar scientific orbiter, lander, and rover.
Chang'E-4	CNSA/2018	Far side scientific lander and rover. Communications relay satellite.
Chang'E-5	CNSA/2019	Near side sample return.
KPLO	KARI/2020	Polar scientific orbiter.
Luna 25/Luna Glob	Roscosmos/2020	Lunar volatile prospecting. Soft landing technology demonstration.
SLIM	JAXA/2020	Technology demonstration.
Polar Sample Return	CNSA/around 2020	Polar volatiles sample return.
Luna 26/Luna-Resurs Orbiter	Roscosmos/2022	Polar scientific orbiter. Polar volatiles mapping.
Resource Prospecting Mission	NASA/early 2020's	Polar science, volatile prospecting and acquisition. Drill technology demonstration.
JAXA's Resource Prospector	JAXA/early 2020's	Polar lander and rover. Polar science and volatiles prospecting.
Luna 27/Luna-Resurs Lander	Roscosmos, with ESA/2023	Polar science, volatile prospecting and acquisition. Drill technology demonstration.
ISRU Demo	ESA/2025	ISRU technology demonstration.
Korea Lunar Lander	KARI	Technology demonstration.
Luna 28/Luna Grunt	Roscosmos	Cryogenic polar volatiles sample return.

ISECG Image

Future Mars Robotic Missions

Mission	Agencies/Launch Date	Objectives/Strategic Knowledge Gaps Addressed
InSight	NASA, with CNES, CSA, DLR/2018	Subsurface geothermal gradient/seismology and internal structure of the planet. Identification of seismic risk at the location. Weather station to monitor weather conditions.
ExoMars	ESA/Roscosmos, with ASI, CNES, DLR, NASA, UKSA and Spain/2020	Rover with 1.5m drill with instruments to search for bio-signatures, subsurface hydrated materials and very shallow ice.
Mars 2020	NASA, with CNES, ASI, Norway and Spain/2020	Oxygen processing demonstration, caching samples for later return to Earth.
EMM Hope	UAE Space Agency/2020	Synoptic weather views moving through all times of day.
HX-1	China/2020	Orbit, landing and roving mission. Investigate topographical and geological features, physical fields and internal structure, atmosphere, ionosphere, climate and environment.
Mars Orbiter Mission-2	ISRO/2022	Orbiter to study the surface and sub-surface features, mineralogy composition and upper atmospheric processes.
Mars Moons eXploration	JAXA with CNES, NASA and other agencies/2024	Sample return from one of the two moons to progress our understanding of planetary system formation and primordial material transport.

ISECG Image

Technology Needs

NASA Image

Lunar Surface Innovation Initiative

Technology Needs - Propulsion

- Solid Rocket Propulsion - Increase performance and safety while reducing cost
- Liquid Rocket Propulsion - Improve the production and manufacturability of large booster engines
- Other Propulsion Systems – Provide affordable launch on demand capability in nano and micro satellite markets

Technology Needs – Power and Energy Storage

- Power Generation – Provide the highest possible specific power with sufficient durability
- Energy Storage – Store energy at the highest possible specific energy with sufficient durability in the mission environment and sufficient lifecycle
- Power management and distribution – Support high-power electric propulsion missions into deep space. Support low-power operations in extreme environments

Technology Needs – Robotics

- Sensing and Perception – Provide situational awareness for exploration robots, autonomous spacecraft
- Mobility – Reach and operate at sites of scientific interest in extreme surface terrain
- Manipulation – Increase manipulator dexterity and reactivity to external forces

Technology Needs – Exploration Systems

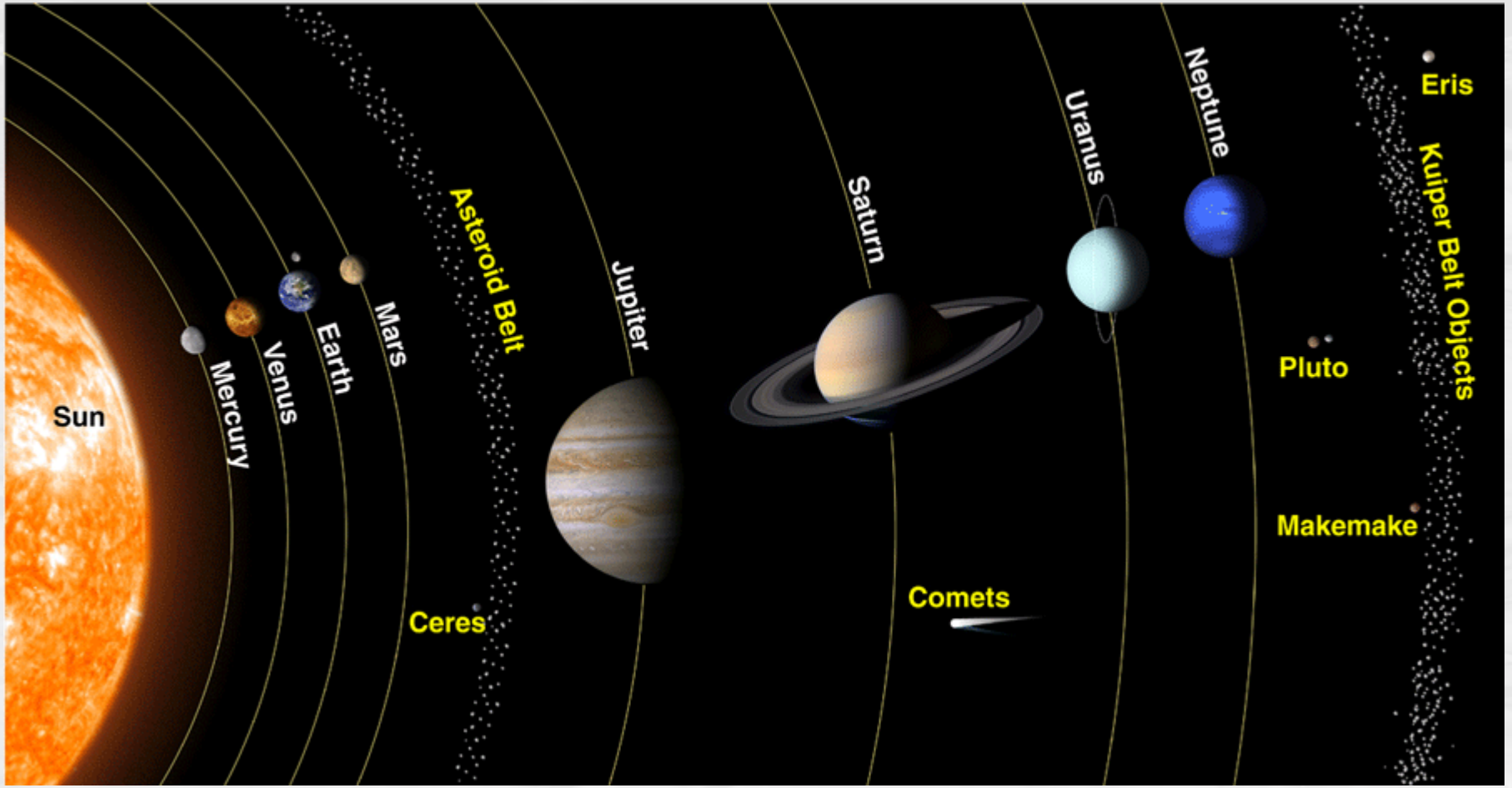
- ISRU – Dramatically reduce launch mass and cost of human exploration
- Habitat Systems – Develop autonomously operating spacecraft that promotes crew health and well being while reducing crew requirements
- Cross-cutting systems – Manage particulate contamination by operations, plume ejecta, and larger scale construction and assembly technologies

Boots on the Moon - Legal Overview

Overview of Legal Concepts;

- The relationship between the Space Law and the Solar System
- Lunar Space Law - Law and the Moon
- Gateway Legal Issues

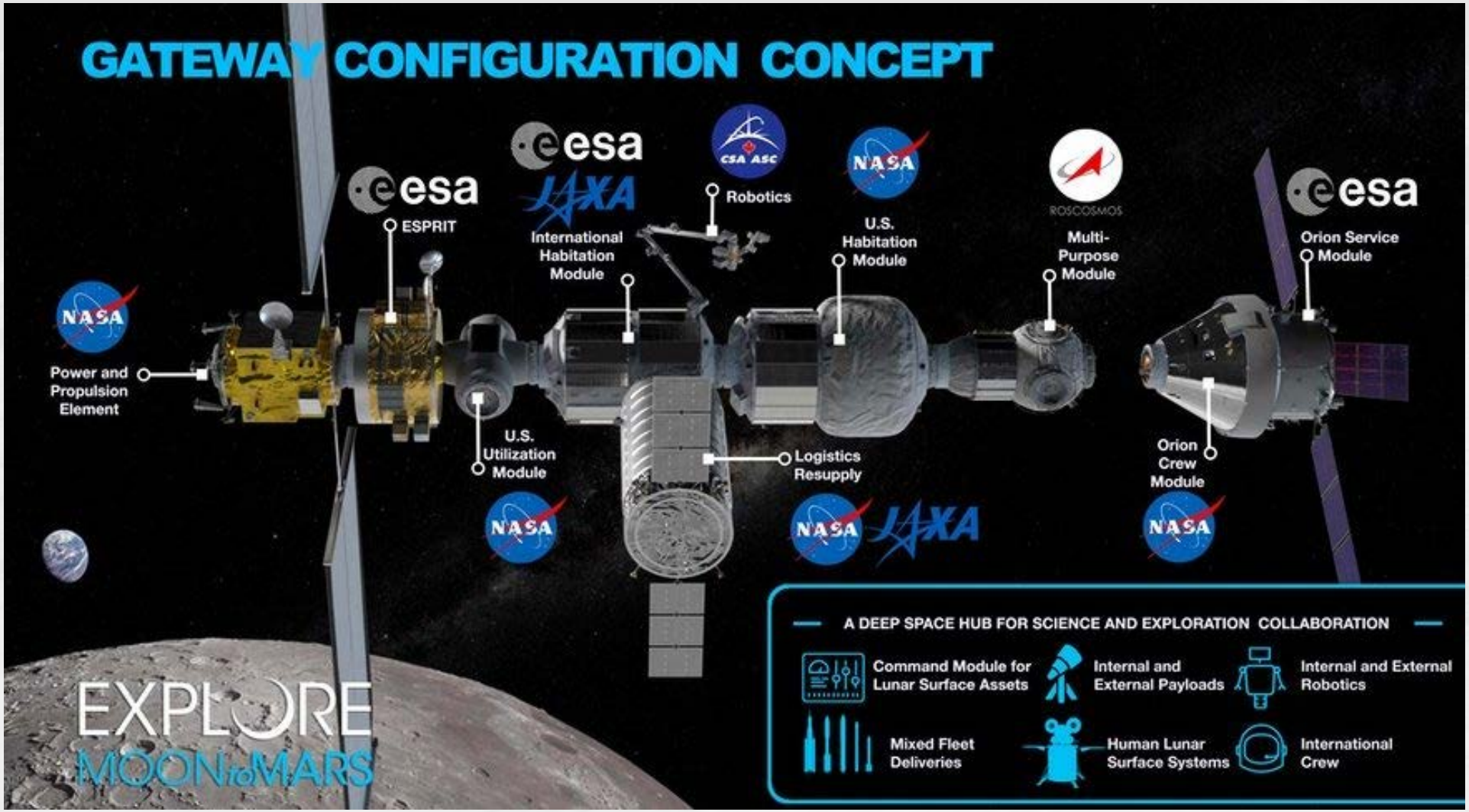
Law v Solar System



NASA Image

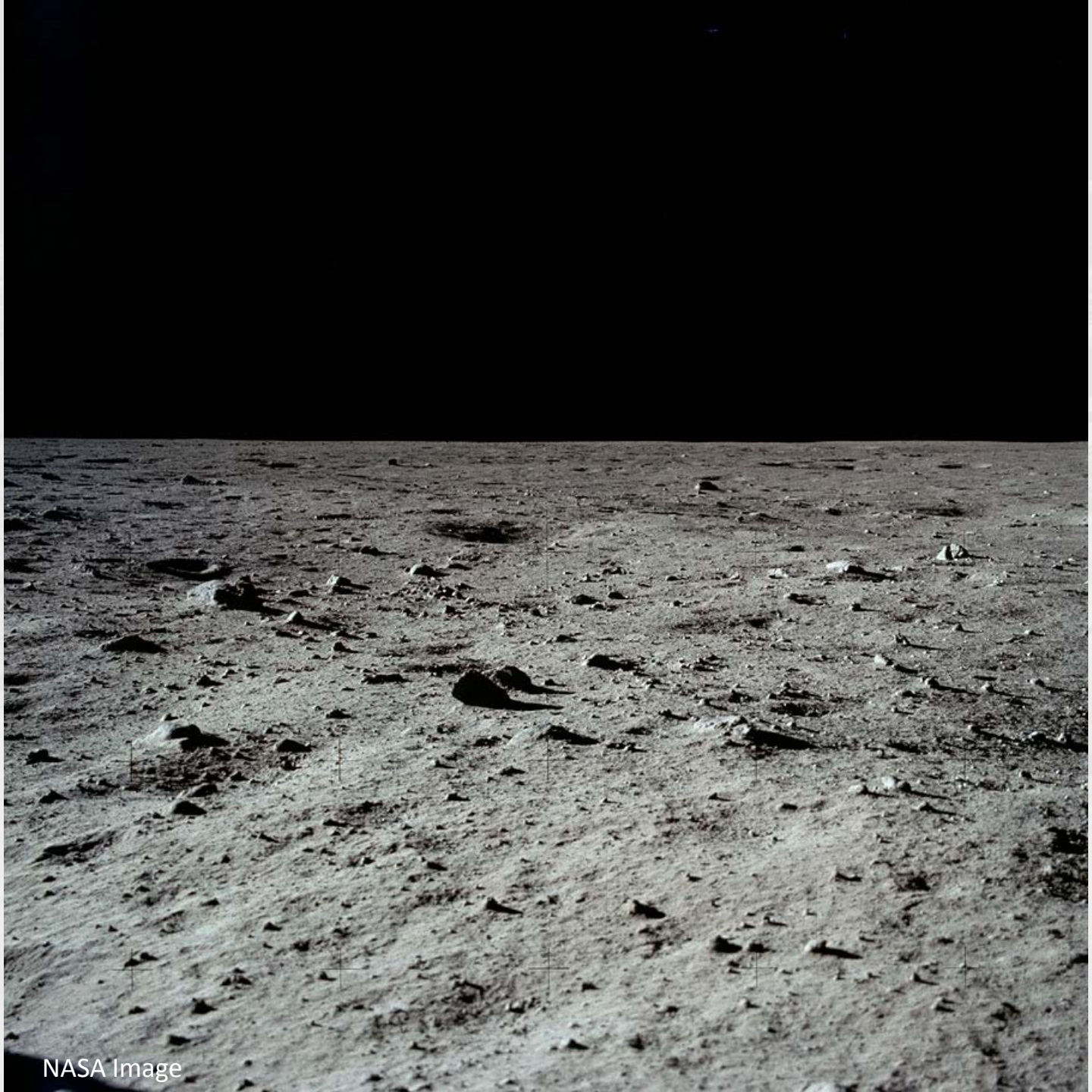
Law on the Moon

Image of ESA Moon Village concept
(Ref: ISECG/Global Exploration Roadmap Ver 3)


GATEWAY CONFIGURATION CONCEPT
esa
ESPRIT
esa
JAXA
International Habitation Module
CSA ASC
Robotics
NASA
U.S. Habitation Module
ROSCOSMOS
Multi-Purpose Module
esa
Orion Service Module
NASA
Power and Propulsion Element
U.S. Utilization Module
Logistics Resupply
Orion Crew Module
NASA
NASA JAXA
NASA
EXPLORE MOON to MARS
A DEEP SPACE HUB FOR SCIENCE AND EXPLORATION COLLABORATION
Command Module for Lunar Surface Assets
Internal and External Payloads
Internal and External Robotics
Mixed Fleet Deliveries
Human Lunar Surface Systems
International Crew

NASA Image

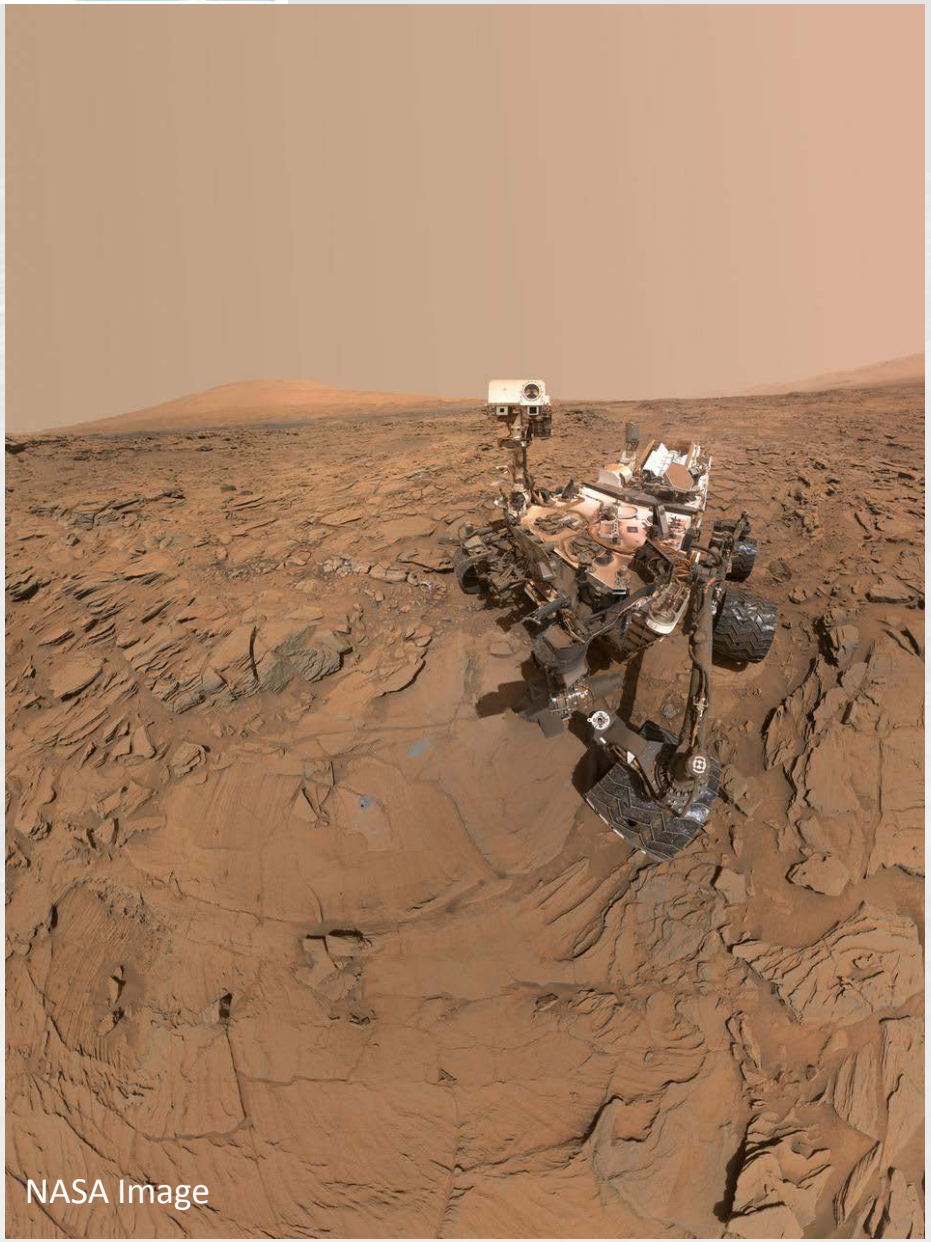
Set the Scene



NASA Image

NASA Image

NASA Image



NASA Image

NASA Image

Barriers and Challenges

- How do we get from present day to sustainable operations on the lunar surface?
- What do we do there to make it worthwhile?
- What technological advances are needed?
- What is required to support the identified technological advances?
- What is the environment like in 2030? Think through the 7 departments

➢ Be concise yet sufficiently detailed in your response to the RFP

➢ Practice your elevator pitch – you have only a few moments to sell your idea

Request for Proposals

RFP 07312017-SOL-001-003 Mars
NASA Pioneering Mars

RFP
Issued under: Commercial and Financial Advisory Services Panel for Infrastructure and Capital Asset Projects, and Commercial Transactions NASA Pioneering Mars Earth Independent Program

Engagement details:
DTF Authorization Number: RFP 7312017-SOL-001-003 Mars NASA Pioneering Mars

This Request for Proposal ("RFP") is issued in accordance with clause 7.1 of the Open Standing Offer Agreement ("OSOA") between your organization and the Department of Treasury and Finance for the "Commercial and Financial Advisory Services Panel for Infrastructure and Capital Asset Projects, and Commercial Transactions".

You are requested to submit a response to Pioneering Mars, Earth Independent Program (PMEIP) RFP Statement of Work in accordance with this request

SECTION A. Project Brief – For the Provision of Pioneering Mars, Earth Independent Program (PMEIP) solutions

A.1 Section 1 – General Information

A.1.1 A. PROJECT OVERVIEW

Project Background

No outpost currently exists.

Project Objectives

To identify a vision for pioneering mars and to address challenges to establishing Earth Independent Human settlement on Mars within Exploration Zones.

Proposed Deliverables of the Engagement

1. Develop a vision for future "Pioneering on Mars"
2. Identify the single greatest challenge to achieving that vision
3. Draft a RFT response which supplies a solution to the greatest challenge that your team identifies
4. Present the vision, challenge and solution to the RFT evaluation team.

Group Details
(To be submitted by Service Provider with its Plan)

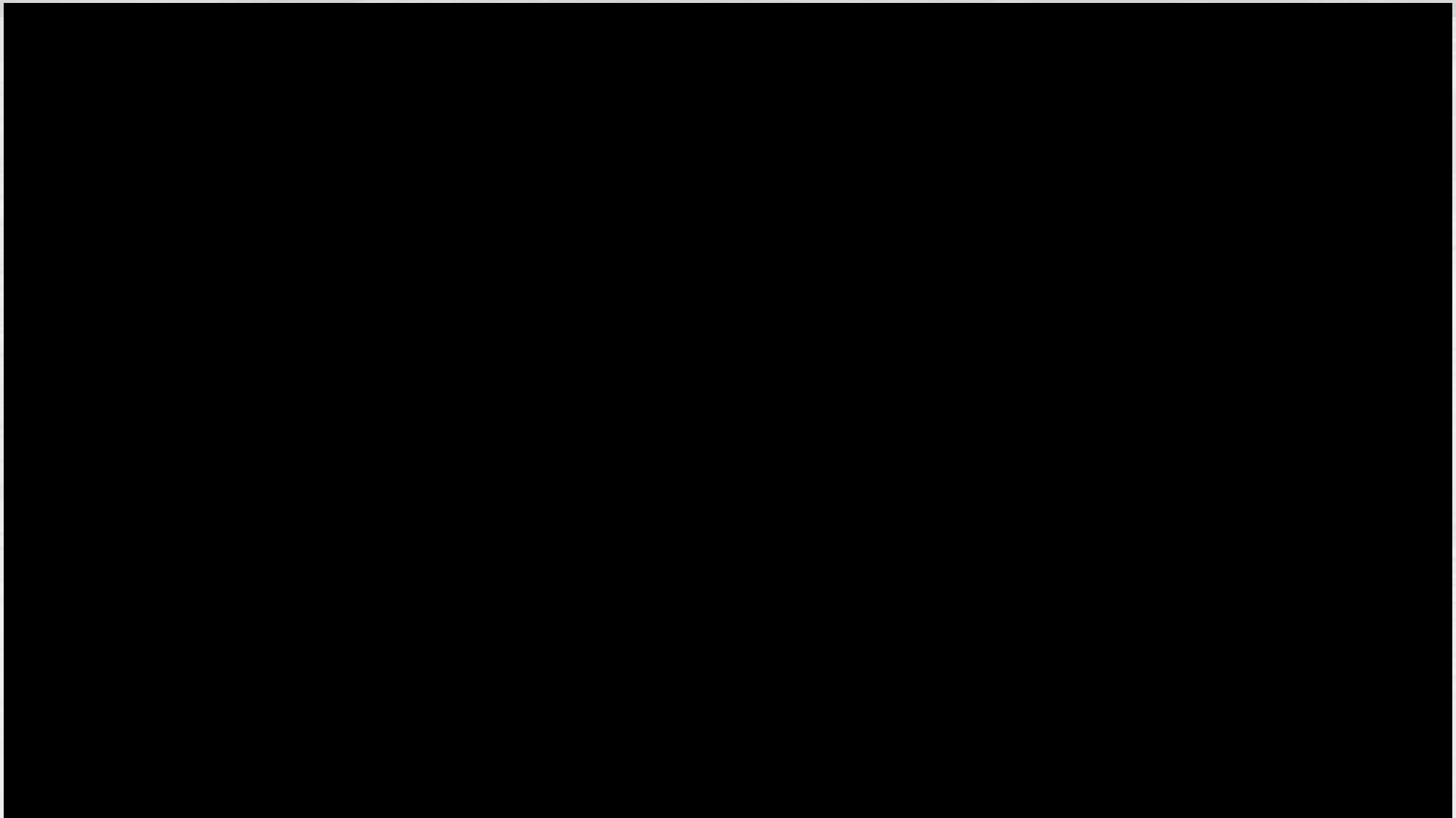
I/We offer to supply the Services specified in the Plan and Request for Proposal; at the fees and charges offered; within the period offered; and in accordance with the terms and conditions in our Open Standing Offer Agreement executed with the Department of Treasury and Finance for the 'Commercial and Financial Advisory Services Panel for Infrastructure and Capital Asset Projects, and Commercial Transactions'.

Service Provider's Names:

Workshop Deliverables

- Develop a vision for future of (many) “Boots on the Moon”
- Identify the single greatest challenge to achieving that vision
- Draft an RFT response which supplies a solution to the greatest challenge that your team identifies
- Present the vision, challenge, and solution to your peers and evaluation team

We Are Going!



Backup

Achieving 2024 – A Parallel Path to Success

Artemis will see government and commercial systems moving in parallel to complete the architecture and deliver crew

CREW

NASA Programs SLS and Orion

Artemis 1

First flight test of SLS and Orion as an integrated system

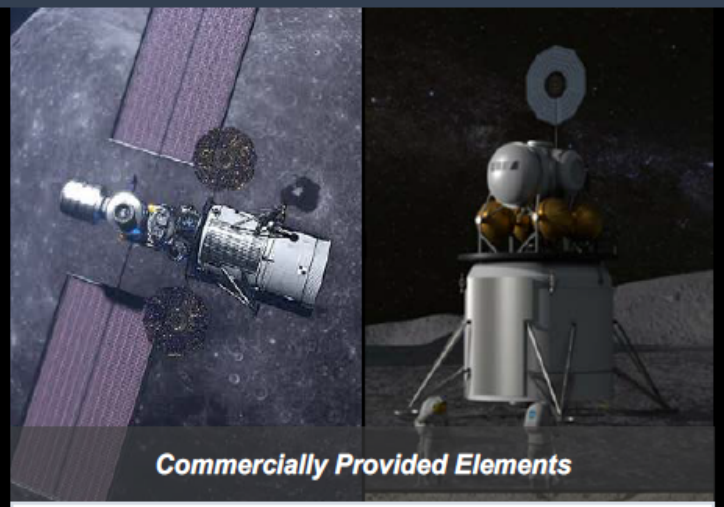
Artemis 2

First flight of crew to the Moon aboard SLS and Orion

Artemis 3

First crew to the lunar surface; Logistics delivered for 2024 surface mission

Between now and 2024, U.S. industry delivers the launches and human landing system necessary for a faster return to the Moon and sustainability through Gateway.



Commercially Provided Elements

CARGO

PPE

Power Propulsion Element arrives at NRHO via commercial rocket

Pressurized Module

Small area for crew to check out systems prior to lunar transfer and decent

Human Landing System

Transfer

Transfers lander from Gateway to low lunar orbit

Descent

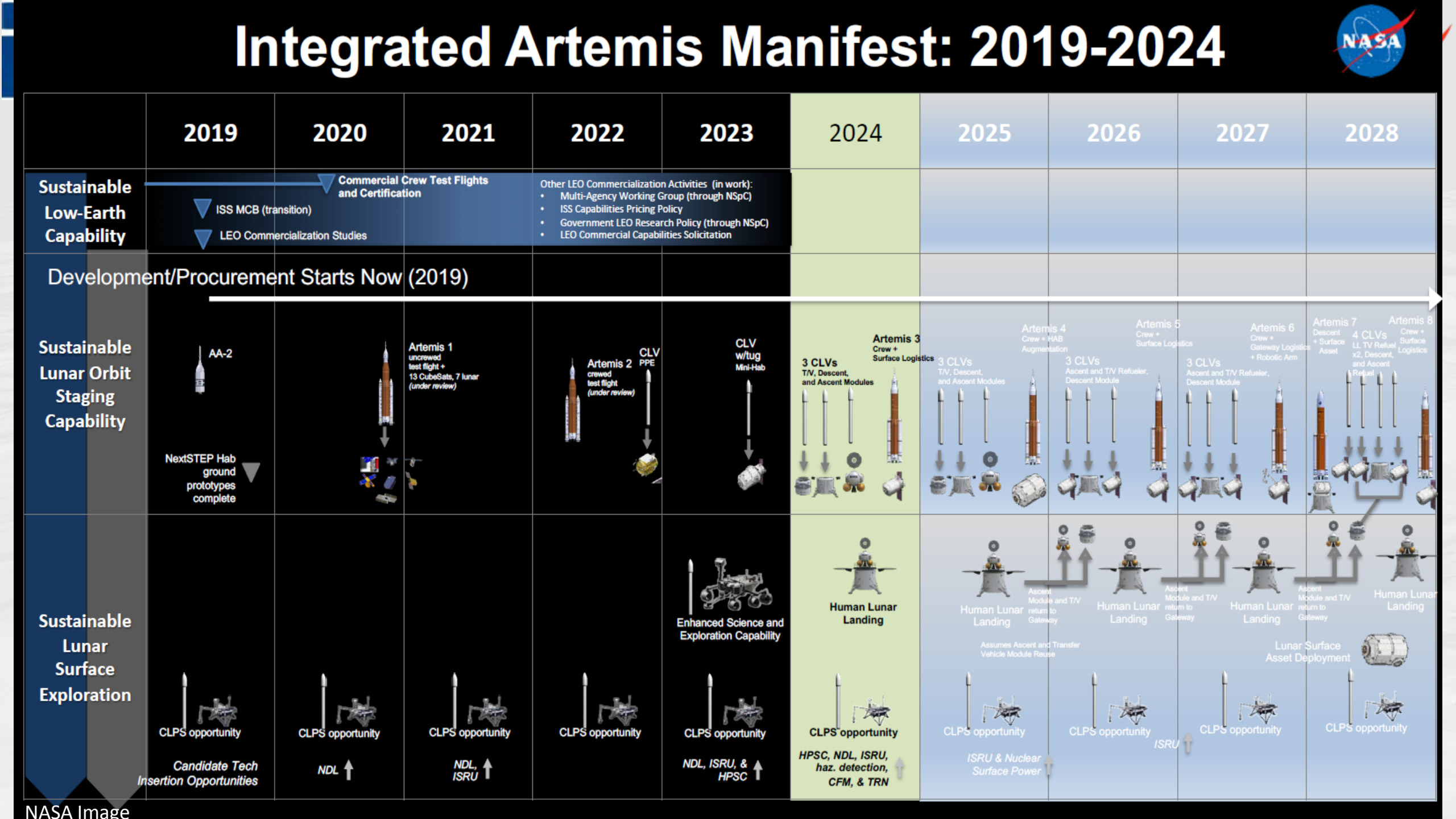
Descends from Transfer Vehicle to lunar surface

Ascent

Ascends from lunar surface to Gateway

Up to three commercial rocket launches, depending on distribution of the Transfer, Descent, and Ascent functions.

Integrated Artemis Manifest: 2019-2024



NASA Image

References

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- ISECG Global Exploration Roadmap (3rd edition) https://www.globalspaceexploration.org/wordpress/wp-content/isecg/GER_2018_small_mobile.pdf. NP-2018-01-2502-HQ G-327035
- Gill, T., Gordon, R., Moore, E.C., Shull, S., Ching, M., *A Novel Approach in Public Private Partnership Execution with NextSTEP-2 Habitat,* AIAA Space 2018 Conference and Exposition, Orlando FL, September 17-19, 2018.