

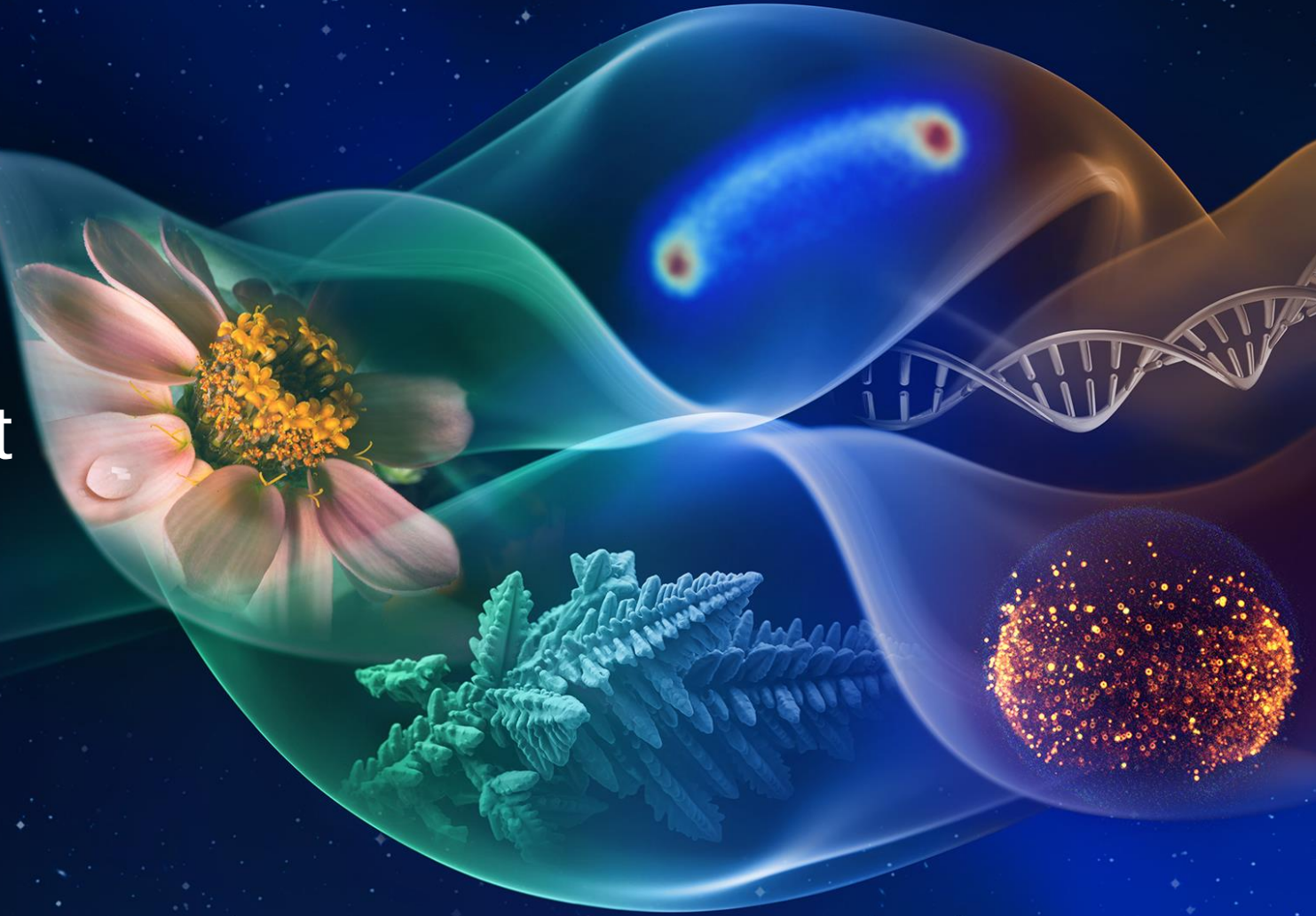
Biological and Physical Sciences Division

National Aeronautics and
Space Administration



Artemis: Biological and Physical Sciences Next Big Step for Scientific Research

Kevin Sato, Ph.D.
Program Scientist for Exploration
Biological Sciences Division
NASA Science Mission Directorate, NASA HQ NASA
Ames Research Center



NAS CBPSS Fall Meeting, Oct. 20, 2022



Topics to be Covered

1. Artemis Status
2. Commercial Lunar Payload Services Status
3. BPS Division – Progress and Challenges

Artemis: a Foundation for Deep Space Exploration



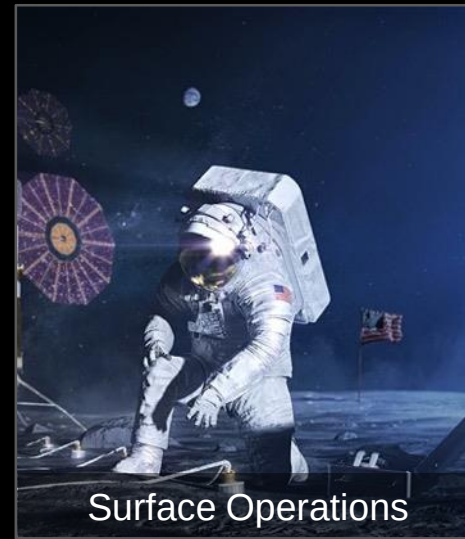
Space Launch System



Orion spacecraft



Human Landing System



Surface Operations



Gateway



Exploration Ground Systems



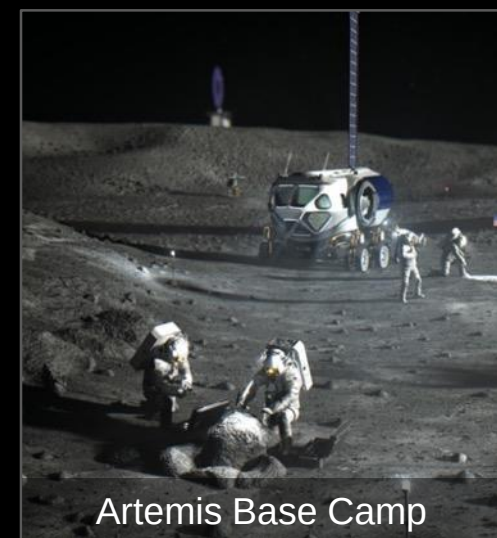
Space Communications
& Navigation



Surface Mobility



Space Suits



Artemis Base Camp

The Principal Organizations Responsible for Artemis Architecture, Strategies, Tactics, Planning, and Implementation of Science Utilization

Exploration Systems Development Mission Directorate (ESDMD)

- Technology and Integration Office
 - Science and Technology Utilization
- Artemis Campaign Development Division (ACD; formerly Advanced Exploration Systems)
 - Gateway Program
 - Human Landing Systems Program (HLS)
 - Extravehicular Activity and Human Surface Mobility Program
- Common Exploration Systems Development Division (CESD)
 - Orion Program

Science Mission Directorate

- Exploration Science Strategy and Integration Office (ESSIO)
- Planetary Sciences Division: Lunar Discovery and Exploration Program (LDEP)
- Biological and Physical Science Division: Exploration Program (principally Moon and Mars)

Science & Technology Utilization (S&TU)

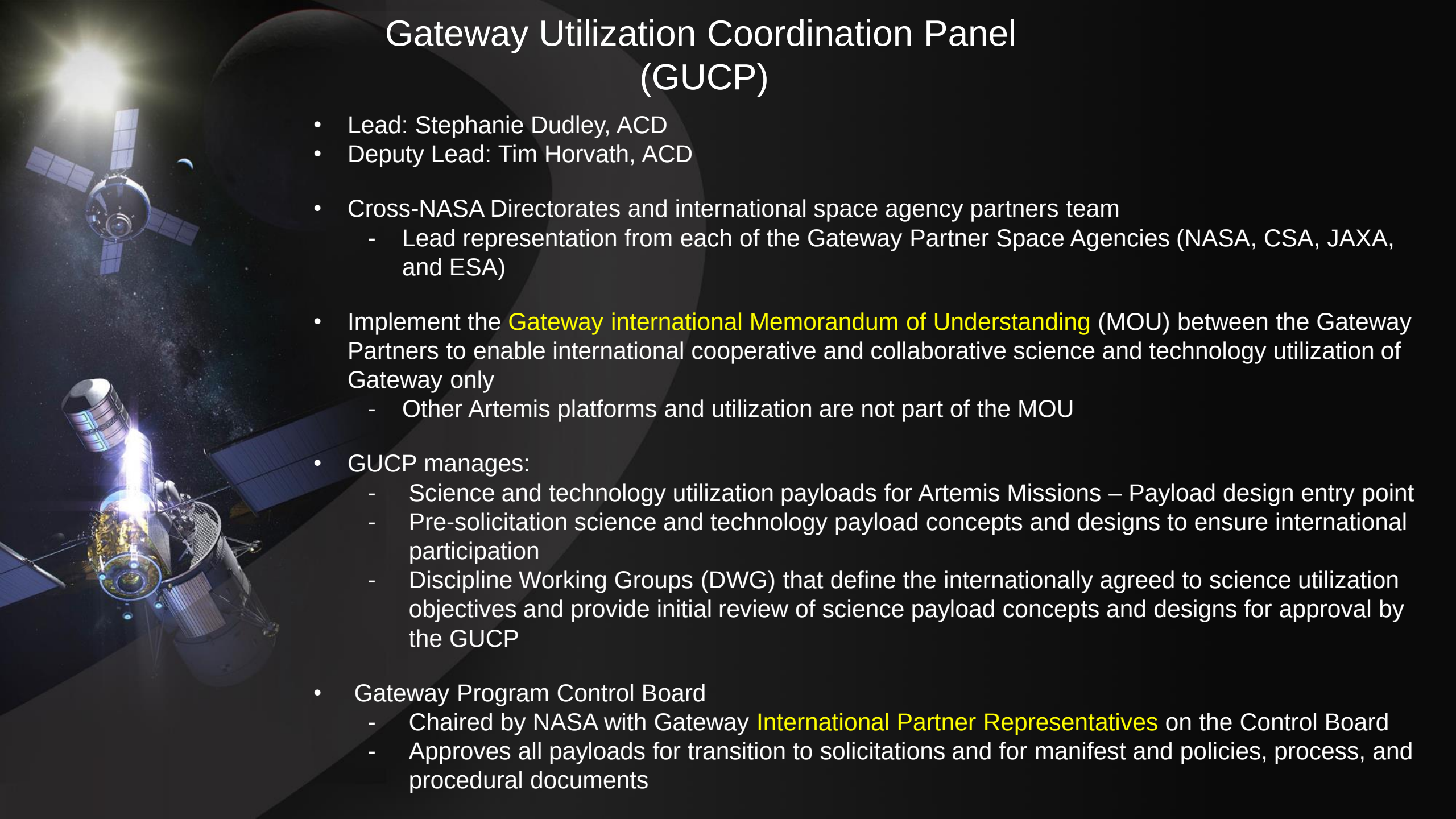
Manager: Jacob Bleacher, Ph.D., Chief Scientist for Exploration, ESDMD

- Provides cross-NASA mission directorates integration and documentation of science and technology utilization for human spaceflight within SE&I
- Cross-platform relevance for Artemis, ISS, and LEO focused on lunar and Mars science
- **Utilization Coordination and Integration Group (UCIG)**
 - Chair: Jacob Bleacher, Ph.D.
 - Co-Chair and Lead Coordinator: Tim Lewis
 - ESDMD/SOMD/SMD/STMD Co-Chaired Working Group
 - Defines and develops use-case and design reference missions
 - Develops products and documents that:
 - Strategic planning (HEOMD-006)
 - Defines strategic utilization requirements in HEOMD-006, Annex 4)
 - Annex 4 are mission specific requirements and allocations
 - Provide science and technology subject matter expertise for other development of other ESDMD documents for Artemis missions and architecture

A detailed illustration of the Artemis spacecraft on the lunar surface. The spacecraft, with its solar panels extended, is positioned in the lower-left foreground. The rugged, cratered terrain of the Moon slopes upwards towards the right. In the background, the Earth is visible as a large, blue and white sphere against the blackness of space. The title 'Artemis Utilization Coordination Panel (AUCP)' is overlaid in white text on the right side of the image.

Artemis Utilization Coordination Panel (AUCP)

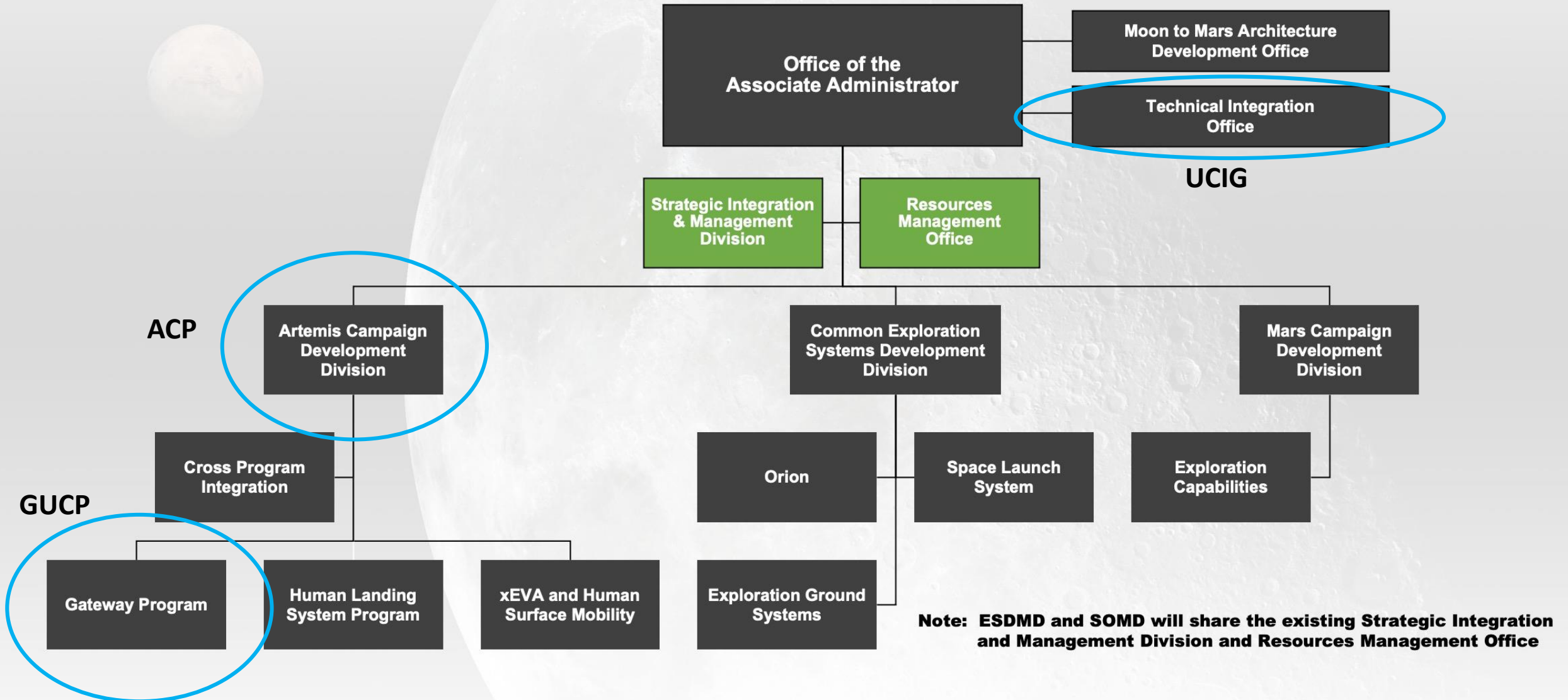
- Chair: Stephanie Dudley, ACD
- Alternate Chair: Tim Horvath, ACD
- Cross-NASA Directorates integrated team
- Feasibility and implementation of strategic utilization requirements are reviewed and coordinated
- ACD Internal NASA committee focused on science and technology utilization payloads and Artemis Missions
- Review, comment, and input on documents, processes, and procedures for Artemis platforms resources, capabilities, requirements, and configuration specifications

The background of the slide features a dark space scene. In the upper left, a satellite with four solar panel arms is visible against a bright light source, possibly the sun. In the lower left, a rocket is shown in the process of launching, with a large plume of fire and smoke at its base. The overall aesthetic is high-tech and futuristic.

Gateway Utilization Coordination Panel (GUCP)

- Lead: Stephanie Dudley, ACD
- Deputy Lead: Tim Horvath, ACD
- Cross-NASA Directorates and international space agency partners team
 - Lead representation from each of the Gateway Partner Space Agencies (NASA, CSA, JAXA, and ESA)
- Implement the **Gateway international Memorandum of Understanding** (MOU) between the Gateway Partners to enable international cooperative and collaborative science and technology utilization of Gateway only
 - Other Artemis platforms and utilization are not part of the MOU
- GUCP manages:
 - Science and technology utilization payloads for Artemis Missions – Payload design entry point
 - Pre-solicitation science and technology payload concepts and designs to ensure international participation
 - Discipline Working Groups (DWG) that define the internationally agreed to science utilization objectives and provide initial review of science payload concepts and designs for approval by the GUCP
- Gateway Program Control Board
 - Chaired by NASA with Gateway **International Partner Representatives** on the Control Board
 - Approves all payloads for transition to solicitations and for manifest and policies, process, and procedural documents

EXPLORATION SYSTEMS DEVELOPMENT MISSION DIRECTORATE



Vision

- Define and lead the science strategy for Artemis and Moon to Mars
- Exploration science integration between SMD Divisions, SMD/STMD/HEOMD, other government agencies, and international partners
- Promote a lunar economy to produce rapid, frequent, and affordable access to the lunar surface and cislunar space

ESSIO supports and enables the BPS place at the Artemis table and voice

Lunar Discovery and Exploration Program

The Lunar Discovery and Exploration Program (LDEP):

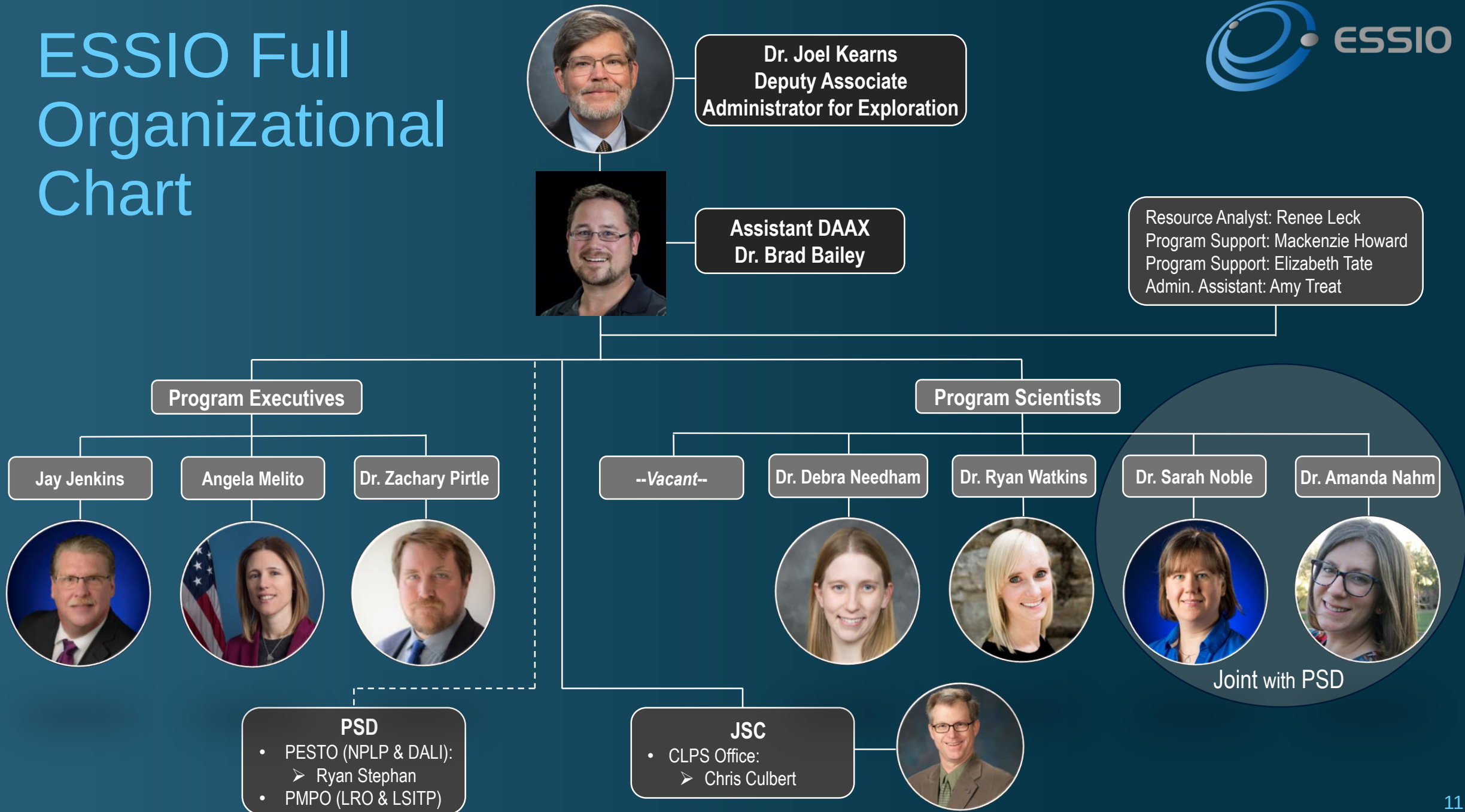
- Develops lunar surface science instruments that address Decadal and other community document science priorities
 - NASA-internal payloads, Community-developed payloads, PRISM, DALI
- Uses commercial companies to deliver payloads to the Moon (CLPS)
- Develops mobility systems to expand and enhance science investigations on the lunar surface
- Leverages international partnerships for additional opportunities (e.g., instruments, rovers)
- Defines, integrates and leads Artemis science efforts across SMD, other NASA mission directorates, and with other US and international agencies

”

...Infusing decadal-level science goals into both the Lunar Discovery and Exploration Program in general, and into the Artemis program in particular, is viewed by the committee as an essential priority for the next decade.

- *Origins, Worlds, and Life:
A Decadal Strategy for Planetary
Science and Astrobiology 2023-2032*

ESSIO Full Organizational Chart



Upcoming U.S. Lunar Solicitations



2022

Artemis
III/V

Lunar Terrain
Vehicle

PRISM 3

The following are expected solicitations out of SMD's Lunar Discovery and Exploration Program (LDEP) within the calendar year*

Artemis III

- Artemis III Geology Team
- BPS Space Biology and Physical Sciences topics are included in the call
- Deployed Instruments/Hardware Call – Includes Surface deployed instruments, lander mounted instruments, and/or Astronaut-utilized instruments, science investigations

Lunar Terrain Vehicle (LTV)

- LTV Mounted Instruments – May include chassis-, mast-, and/or arm-mounted instruments
- Potential interest for BPS scientists who want to conduct environmental monitoring and analyses

F.10 Payloads and Research Investigations on the Surface of the Moon (PRISM 3)

- Platform: Commercial Lunar Payload Services Lander
- BPS Space Biology and Physical Sciences are included in the call
- Instruments and science research hardware/science investigation
- Step-1 Proposals due October 24, 2022
- Step-2 Proposals due December 20, 2022



LTV mounted



Astronaut Utilized



Lander mounted



Astronaut Deployed

**A community announcement will be released ~3 months prior to all solicitations*

Release of Two Key Artemis Documents

National Aeronautics and
Space Administration



MOON TO MARS OBJECTIVES

SEPTEMBER 2022

The purpose of NASA's Moon to Mars Objectives effort is to develop and document an objectives-based approach to its human deep space exploration efforts.

Executive Summary:

<https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf>

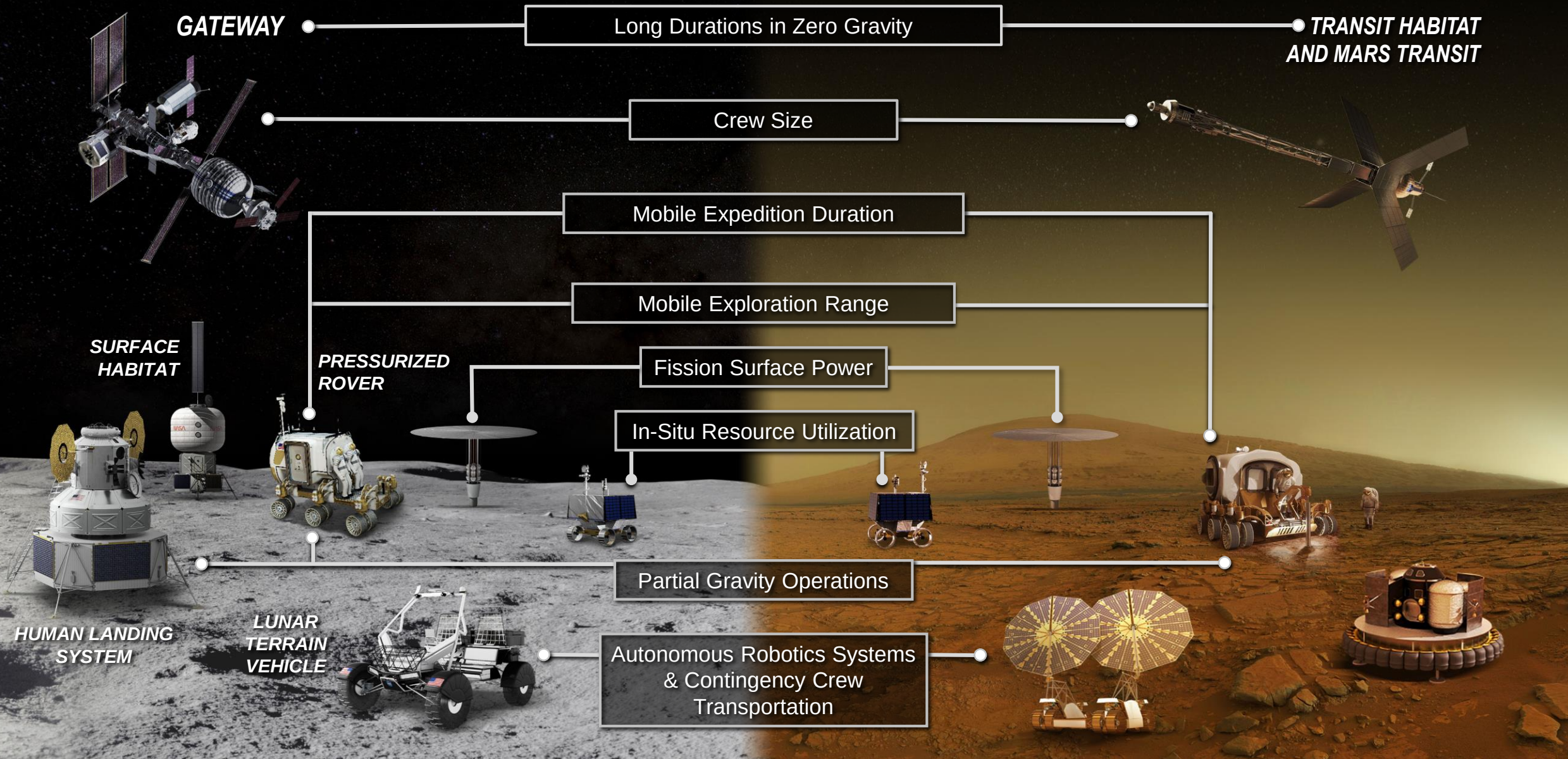
Full Presentation:

<https://www.nasa.gov/press-release/update-nasa-seeks-comments-on-moon-to-mars-objectives-by-june-3>



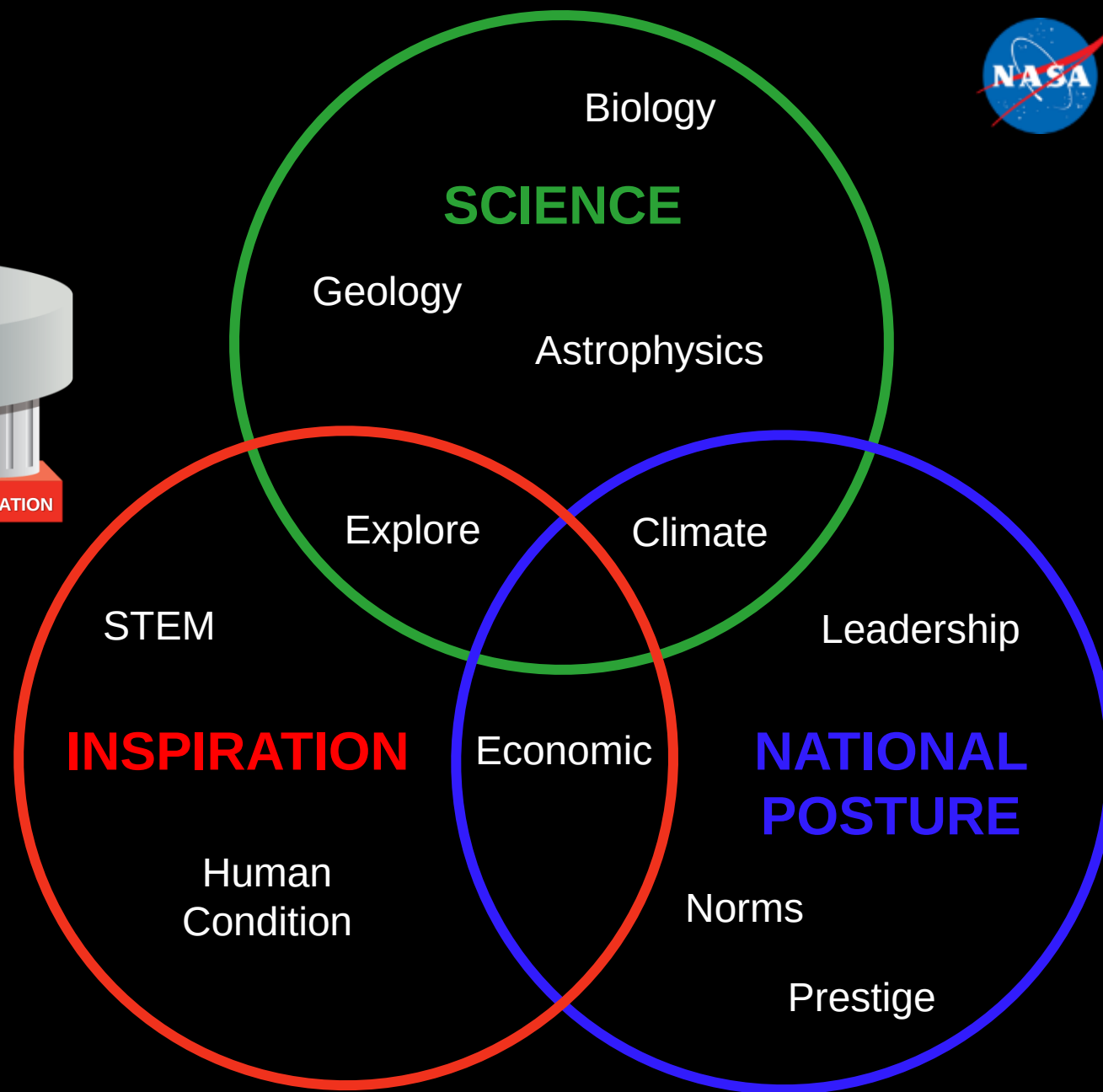
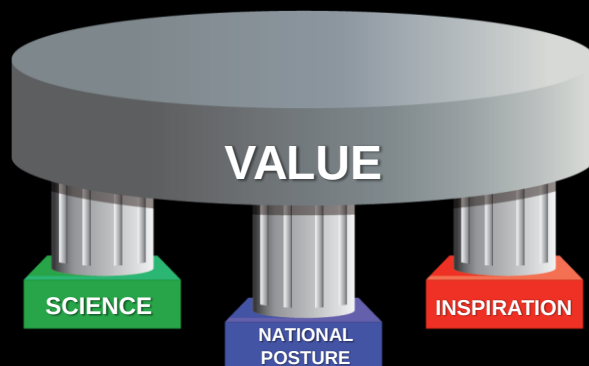
Moon to Mars Exploration Strategy

Operations on and around the Moon will help prepare for the first human mission to Mars

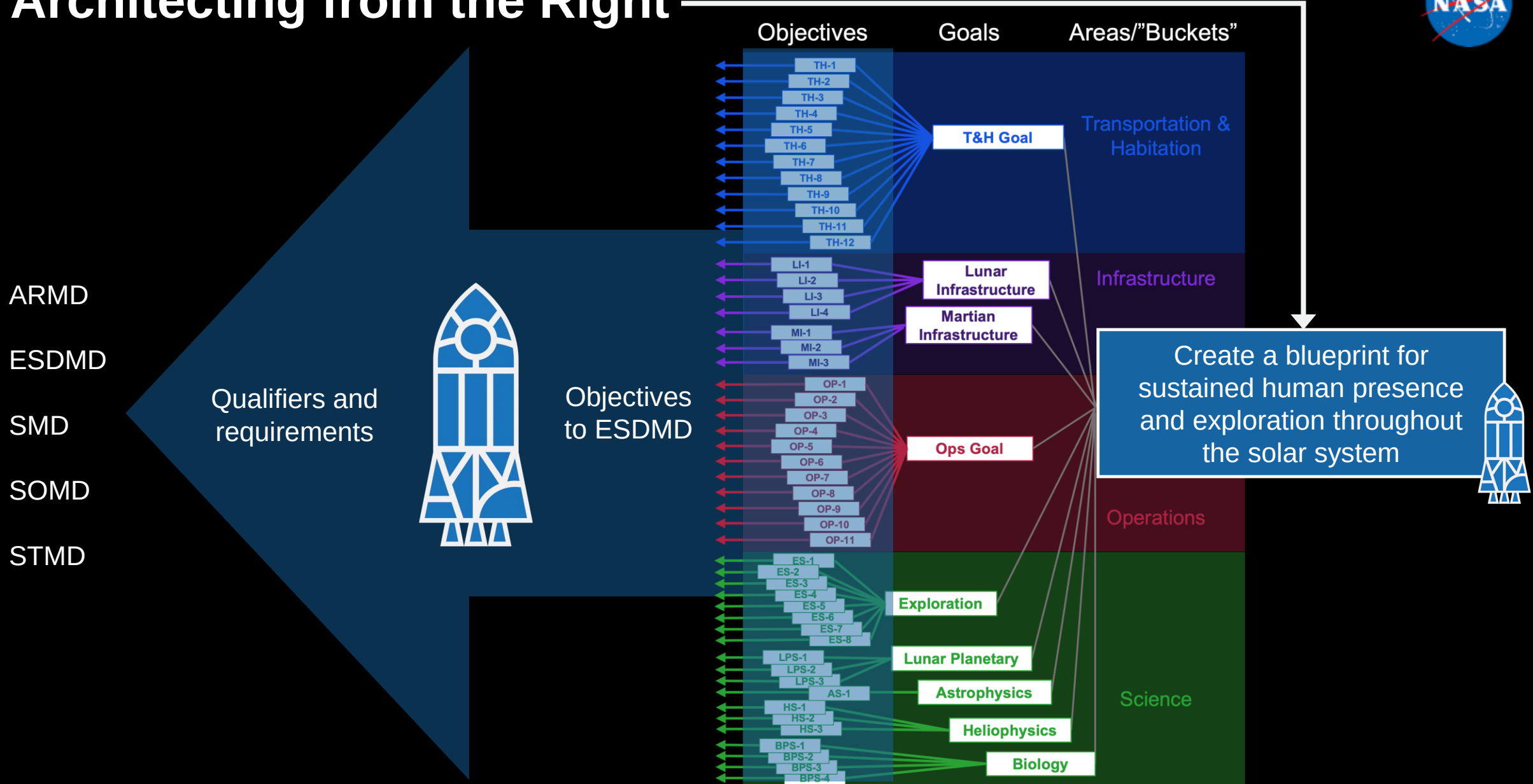


Why Go?

Benefit to Citizens



Architecting from the Right



Moon to Mars Strategy Objectives

- Recurring Tenets (Common Themes Across the Objectives)
- Lunar and Planetary, Heliophysics Science Objectives
- Human and Biological, Physics and Physical Science Objectives
- Science-Enabling and Applied Science Objectives
- Lunar and Mars Infrastructure Objectives
- Transportation and Habitation
- Operations

Human and Biological Science (HBS) Goal: Advance understanding of how biology responds to the environments of the Moon, Mars, and deep space to advance fundamental knowledge, support safe, productive human space missions and reduce risks for future exploration.

- HBA-3LM: Understand the effects of short- and long-duration exposure to the environments of the Moon, Mars, and deep space on biological systems and health, using humans, model organisms, systems of human physiology, and plants

Physics and Physical Science (PPS) Goal: Address high priority physics and physical science questions that are best accomplished by using unique attributes of the lunar environment.

- PPS-2LM: Advance the understanding of physical systems and fundamental physics by utilizing the unique environments of the Moon, Mars, and deep space



Exploration Systems Development
Mission Directorate (ESDMD)
HEOMD-006
REVISION A
RELEASE DATE: 03/30/2022

EXPLORATION SYSTEMS DEVELOPMENT MISSION
DIRECTORATE
UTILIZATION PLAN

This document has been reviewed for Proprietary, CUI, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA #20220005087

This document was approved by NASA's Exploration Systems Development Mission Directorate (ESDMD), Space Operations Mission Directorate (SOMD), Science Mission Directorate (SMD), Space Technology Mission Directorate (STMD)

The purpose of the Human Exploration and Operations (HEO) Utilization Plan is to identify and describe NASA's science and technology utilization goals and objectives that will be enabled by human missions.

Developed by the UCIG

<https://ntrs.nasa.gov/citations/20220005087>

Key Sections and Annexes:

- Human Exploration Utilization Goals and Objectives
- Cornerstone Capabilities that Enable Multiple Objectives
- Phasing of Capabilities and Facility Requirements
- Integrated LEO Mission-Specific Utilization Requirements
- **Integrated Artemis Mission Utilization Objectives (Annex 4)**
 - **Strategic requirements for a specific Artemis Mission**
- Integrated Mars Mission-Specific Utilization Requirements

This document has been approved for public release per DAA #20220005087.

ACD In-Work:

- Artemis Interface Configuration Document for Payload Developers
- Artemis User's Guide (in consideration)

ACD Artemis Utilization Planning Process



Mission parameters: vehicles, Sortie/ABC, #crew, #EVAs, launch date

Strategic Planning

Tactical Planning

Solicitation & Selection for utilization w/ new HW

Solicitation & Selection for utilization using existing HW

Late selection w/agreement

Execute Planning & Training

- ACD determines resource estimates
- **ESDMD-SOMD-SMD-STMD co-chaired working group** releases call for Artemis utilization and negotiates resource allocations between Mission Directorates
- Results documented in **HEOMD-006 Annex 4** which is approved by Quad DPMC

~L-5 to 4 years

- **Mission Directorates / Payload Sponsors** release solicitations and make selections or direct research
- ACD assists with feasibility consultations as needed

~L-4.5 to 1.5 years

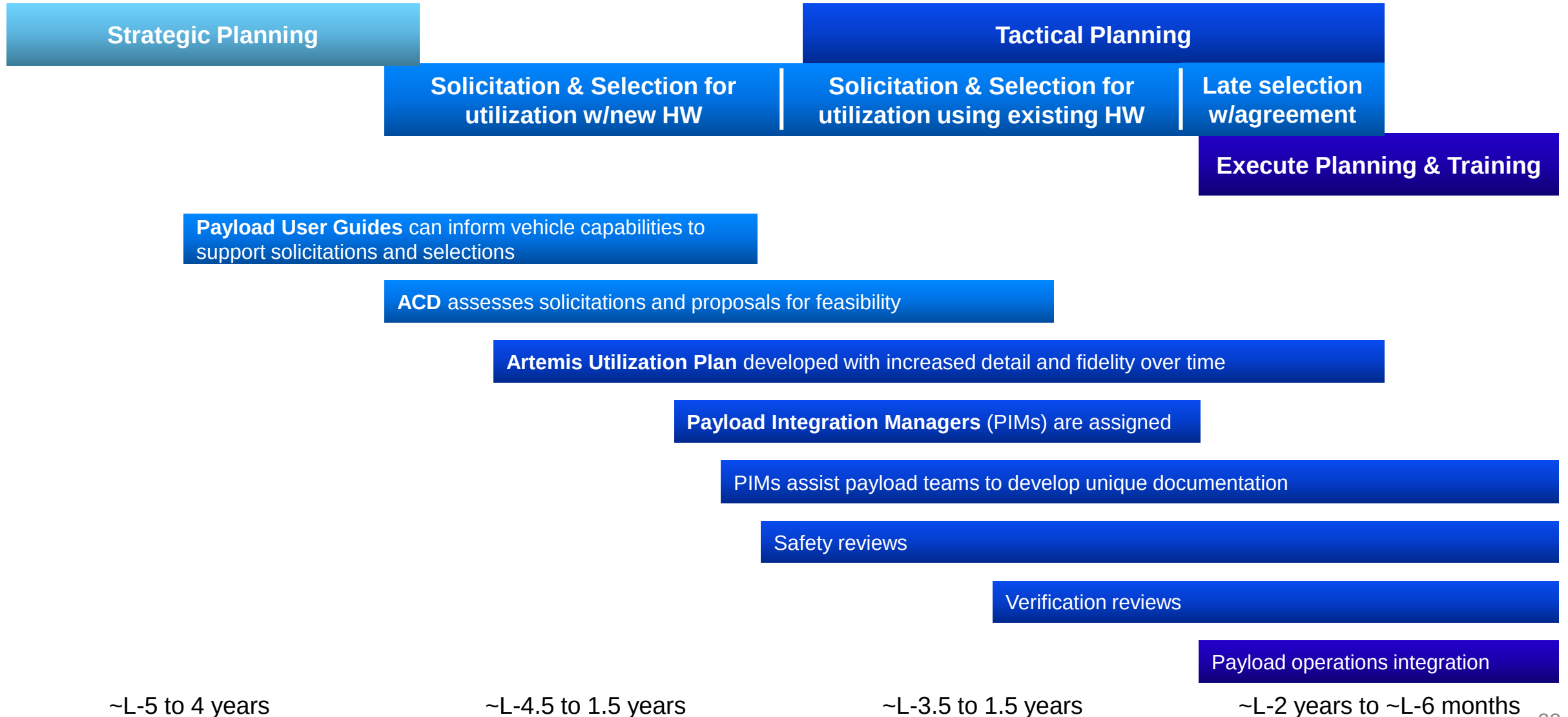
- ACD coordinates detailed resource needs with selected teams and represents the selected payloads to Artemis forums
- **Artemis Utilization Plan** documents each selected payload's detailed resource needs and relative priority and is approved by joint ACB/ECB

~L-3.5 to 1.5 years

- Crew assignment and training
- Procedures, manifest, and timeline matures
- Flight and operations readiness reviews occur

~L-2 years to ~L-6 months

Artemis Payload Integration Process





Artemis Mission Launch Dates

Artemis I	No Earlier than 14 November 2022 Launch Window closes on 27 November 2022 25.5 days – uncrewed, lunar orbit only (actual duration is dependent on the launch date)
Artemis II	2024 - Crewed Mission around the Moon
Artemis III	2025 - Human Landing on the Moon
Artemis IV	2027 - Gateway Only
Artemis V	2028 - Human Landing on the Moon



A B C
CUBESATS DEPLOY
ICPS deploys 10
CubeSats total

MISSION DURATIONS:
Total: 28–42 days
Outbound Transit: 8–14 days
DRO Stay: 6–19 days
Return Transit: 9–19 days



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

- | | | | | | |
|---|---|--|---|--|---|
| 1 LAUNCH
SLS and Orion lift off from pad 39B at Kennedy Space Center. | 4 PERIGEE RAISE MANEUVER | 7 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL
ICPS commits Orion to moon at TLI. | 9 OUTBOUND POWERED FLYBY (OPF)
60 nmi from the Moon; targets DRO insertion. | 12 DRO DEPARTURE
Leave DRO and start return to Earth. | 15 CREW MODULE SEPARATION FROM SERVICE MODULE |
| 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM | 5 EARTH ORBIT
Systems check with solar panel adjustments. | 8 OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS
As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO). | 10 LUNAR ORBIT INSERTION
Enter Distant Retrograde Orbit. | 13 RETURN POWERED FLYBY (RPF)
RPF burn prep and return coast to Earth initiated. | 16 ENTRY INTERFACE (EI)
Enter Earth's atmosphere. |
| 3 CORE STAGE MAIN ENGINE CUT OFF
With separation. | 6 TRANS LUNAR INJECTION (TLI) BURN
Maneuver lasts for approximately 20 minutes. | | 11 DISTANT RETROGRADE ORBIT
Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon. | 14 RETURN TRANSIT
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere. | 17 SPLASHDOWN
Pacific Ocean landing within view of the U.S. Navy recovery ship. |

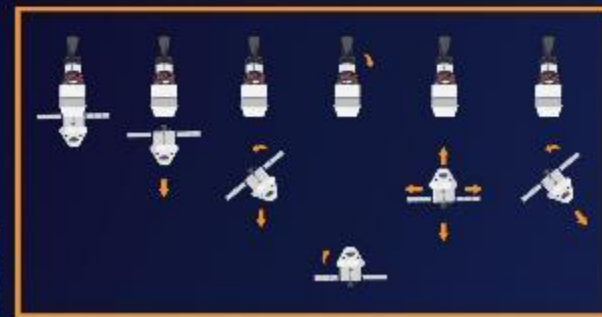


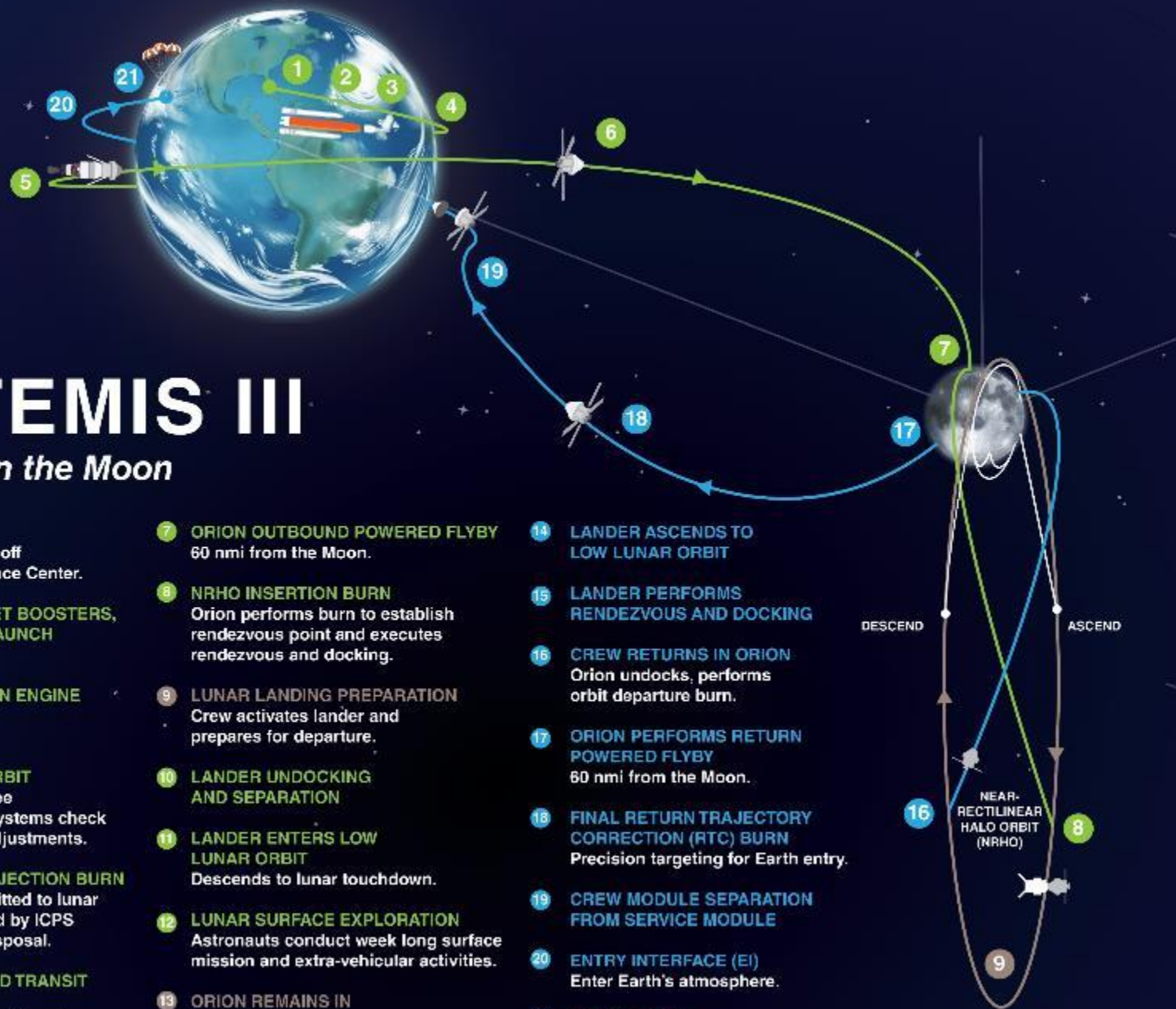
ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

- 1 LAUNCH**
Astronauts lift off from pad 39B at Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 PERIGEE RAISE MANEUVER**
- 5 APOGEE RAISE BURN TO HIGH EARTH ORBIT**
Begin 24 hour checkout of spacecraft.
- 6 PROX OPS DEMONSTRATION**
Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.
- 7 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN**
- 8 HIGH EARTH ORBIT CHECKOUT**
Life support, exercise, and habitation equipment evaluations.
- 9 TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
Lunar free return trajectory initiated with European service module.
- 10 OUTBOUND TRANSIT TO MOON**
4 days outbound transit along free return trajectory.
- 11 LUNAR FLYBY**
4,000 nmi (mean) lunar farside altitude.
- 12 TRANS-EARTH RETURN**
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
- 13 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 14 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 15 SPLASHDOWN**
Ship recovers astronauts and capsule.

PROXIMITY
OPERATIONS
DEMONSTRATION
SEQUENCE

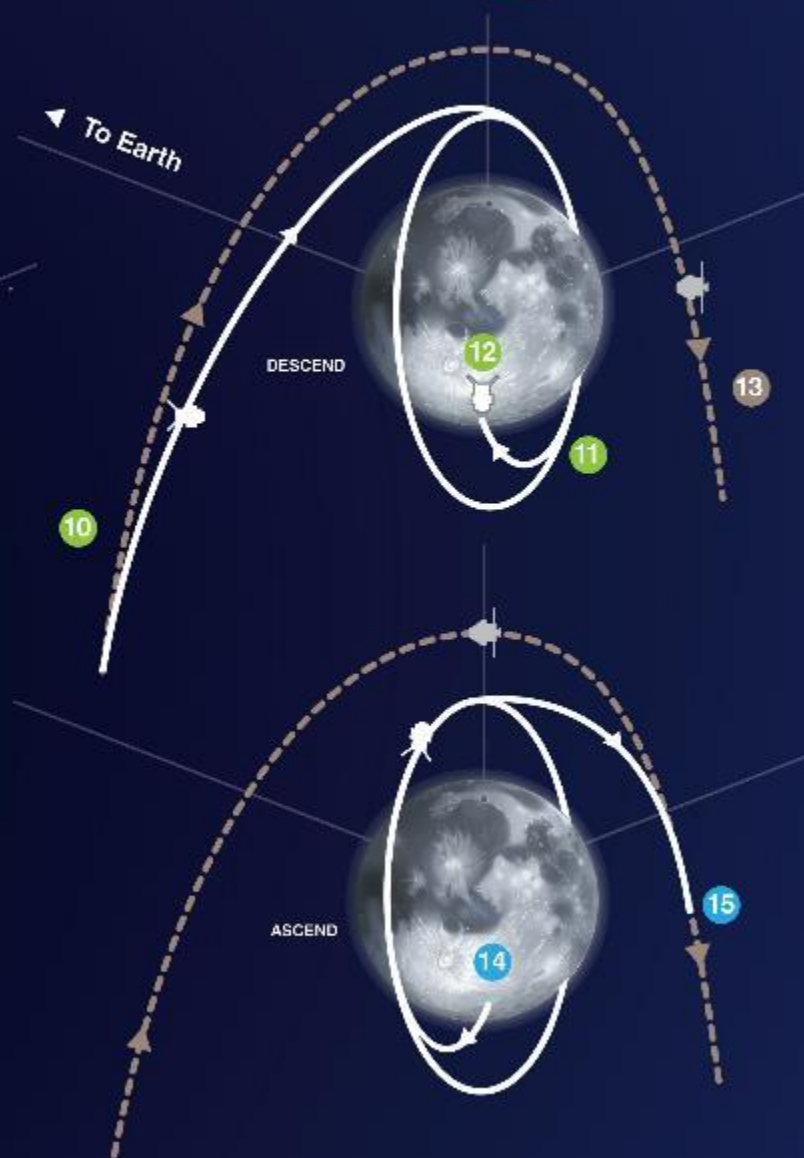




ARTEMIS III

Landing on the Moon

- 1 LAUNCH**
SLS and Orion lift off from Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 ENTER EARTH ORBIT**
Perform the perigee raise maneuver. Systems check and solar panel adjustments.
- 5 TRANS LUNAR INJECTION BURN**
Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
- 6 ORION OUTBOUND TRANSIT TO MOON**
Requires several outbound trajectory burns.
- 7 ORION OUTBOUND POWERED FLYBY**
60 nmi from the Moon.
- 8 NRHO INSERTION BURN**
Orion performs burn to establish rendezvous point and executes rendezvous and docking.
- 9 LUNAR LANDING PREPARATION**
Crew activates lander and prepares for departure.
- 10 LANDER UNDOCKING AND SEPARATION**
- 11 LANDER ENTERS LOW LUNAR ORBIT**
Descends to lunar touchdown.
- 12 LUNAR SURFACE EXPLORATION**
Astronauts conduct week long surface mission and extra-vehicular activities.
- 13 ORION REMAINS IN NRHO ORBIT**
During lunar surface mission.
- 14 LANDER ASCENDS TO LOW LUNAR ORBIT**
- 15 LANDER PERFORMS RENDEZVOUS AND DOCKING**
- 16 CREW RETURNS IN ORION**
Orion undocks, performs orbit departure burn.
- 17 ORION PERFORMS RETURN POWERED FLYBY**
60 nmi from the Moon.
- 18 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
Precision targeting for Earth entry.
- 19 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 20 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 21 SPLASHDOWN**
Ship recovers astronauts and capsule.



Artemis III Candidate Landing Regions

KEY LANDING REGION CHARACTERISTICS

Close proximity to the geographic South Pole

Gentle slope for landing and moonwalks

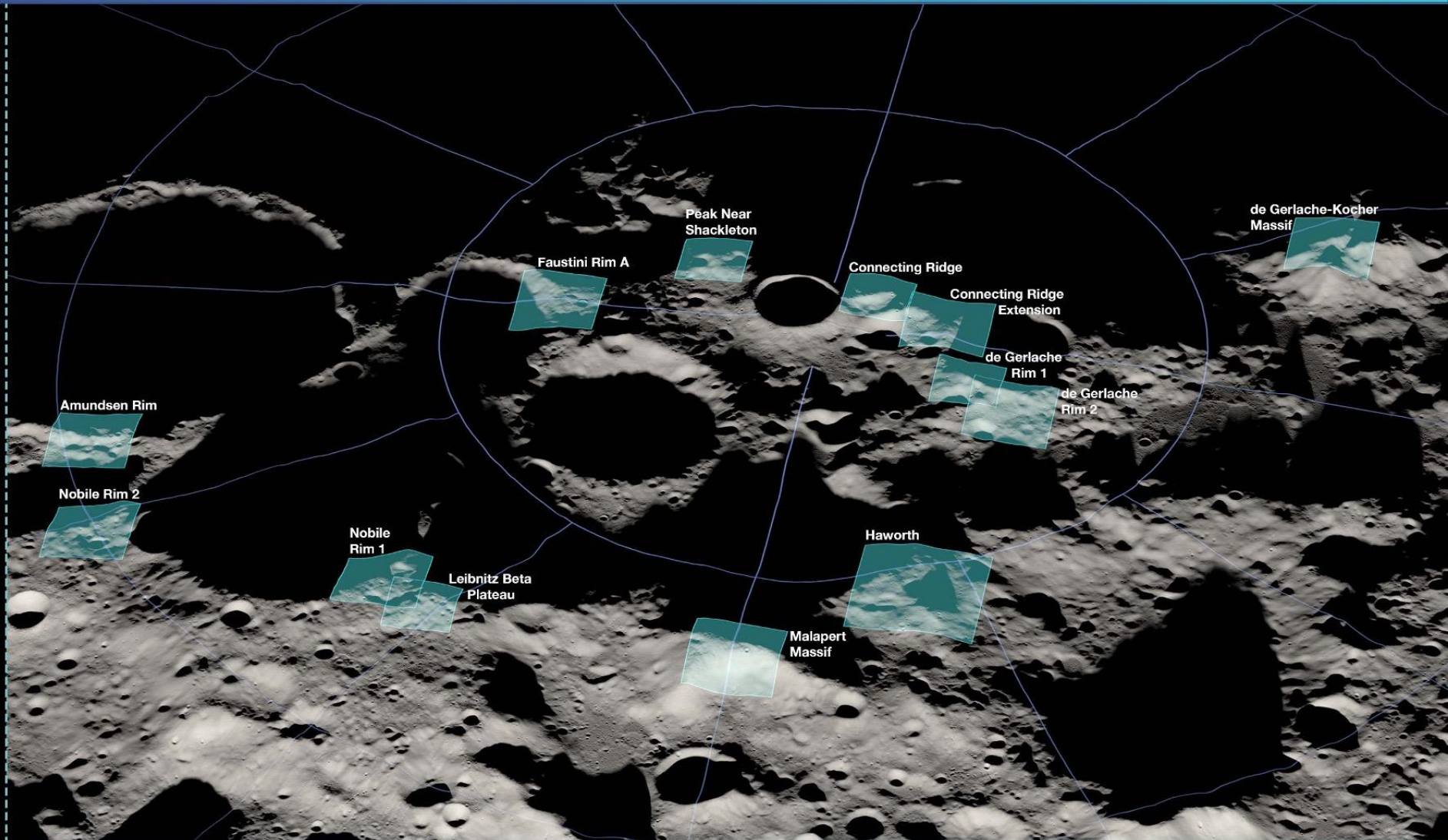
Constant view to Earth for communications

Continuous sunlight throughout the surface expedition of about 6.5 days

Surface data resolution

Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

A landing *region* is approximately 15 km². Each landing region includes multiple potential landing sites.





Human Landing System

HLS

Sustaining Lunar Transport

Using proven commercial partnership strategies, NASA is working with U.S. industry to build towards regular human lunar landings.

Companies will develop human landing systems and NASA will purchase transport services, while maintaining oversight to ensure safety standards are met.

Initial Human Landing System

HLS

NASA has awarded SpaceX a contract to develop its HLS Starship for use on Artemis III, the mission that will put the next two Americans on the surface of the Moon.

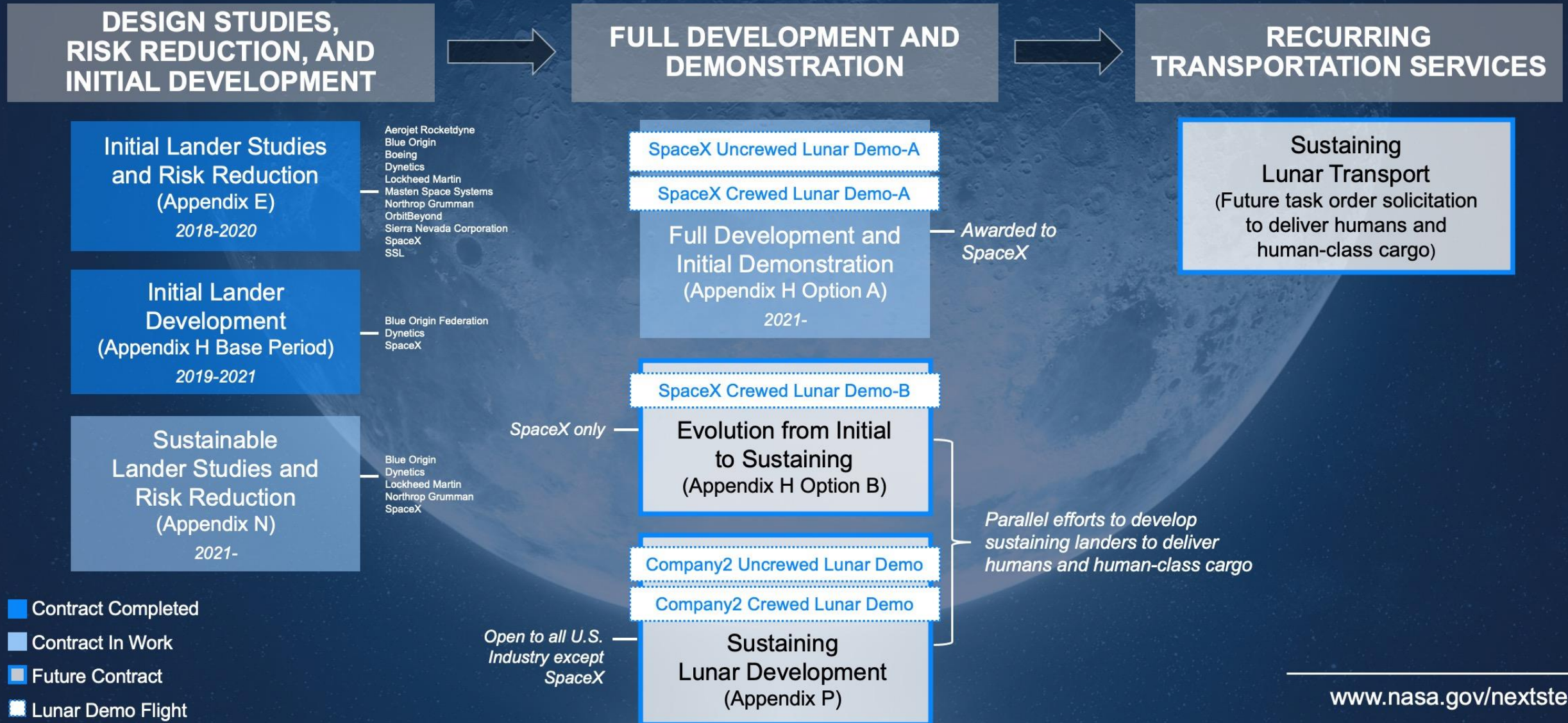
The contract includes two surface missions:

- SpaceX Uncrewed Lunar Demo-A
- SpaceX Crewed Lunar Demo-A

Image Credit: SpaceX



Human Landing System (HLS) Procurement Path



Questions To Guide Future Objectives



- What **human/robotic exploration hybrid modalities** can be employed during Artemis surface missions to maximize scientific value and productivity in addressing high priority Planetary Science and Astrobiology decadal survey questions?
- Should astronauts focus on tradition field geology or making in-situ measurements while on the surface of the moon? How does this compare to modern field work in other, earth-based remote locations?
- What is the role of the astronaut as “explorer” on the lunar surface, and how is this different from the astronaut role on the International Space Station or in Low Earth Orbit?
- What is the **framework for science done by humans on the surface vs. robotic presence?** Is there value to having remote-sensing data made available to the astronauts in near real-time?
- What types of measurements should be done in-situ during the **astronaut surface EVAs, and what matter or samples specifically needs to be brought back to Earth for analyses?** What equipment should astronauts have available to make those measurements?
- How can NASA optimize between robotic capability or remote sensing and use of valuable crew time on the surface?
- What will the concepts of operations be for combined humans-in-the-loop and robotic/teleoperated explorers?

GATEWAY



Expanded Capability

NASA and its international partners will add modules and capabilities, evolving a robust orbiting laboratory and a home away from home for astronauts on their way to and from the lunar surface. The Gateway will serve as a test bed and staging point for future human exploration into deep space.



Canadian Space Agency (CSA):

External robotics system, robotic interfaces, and end-to-end robotic operations



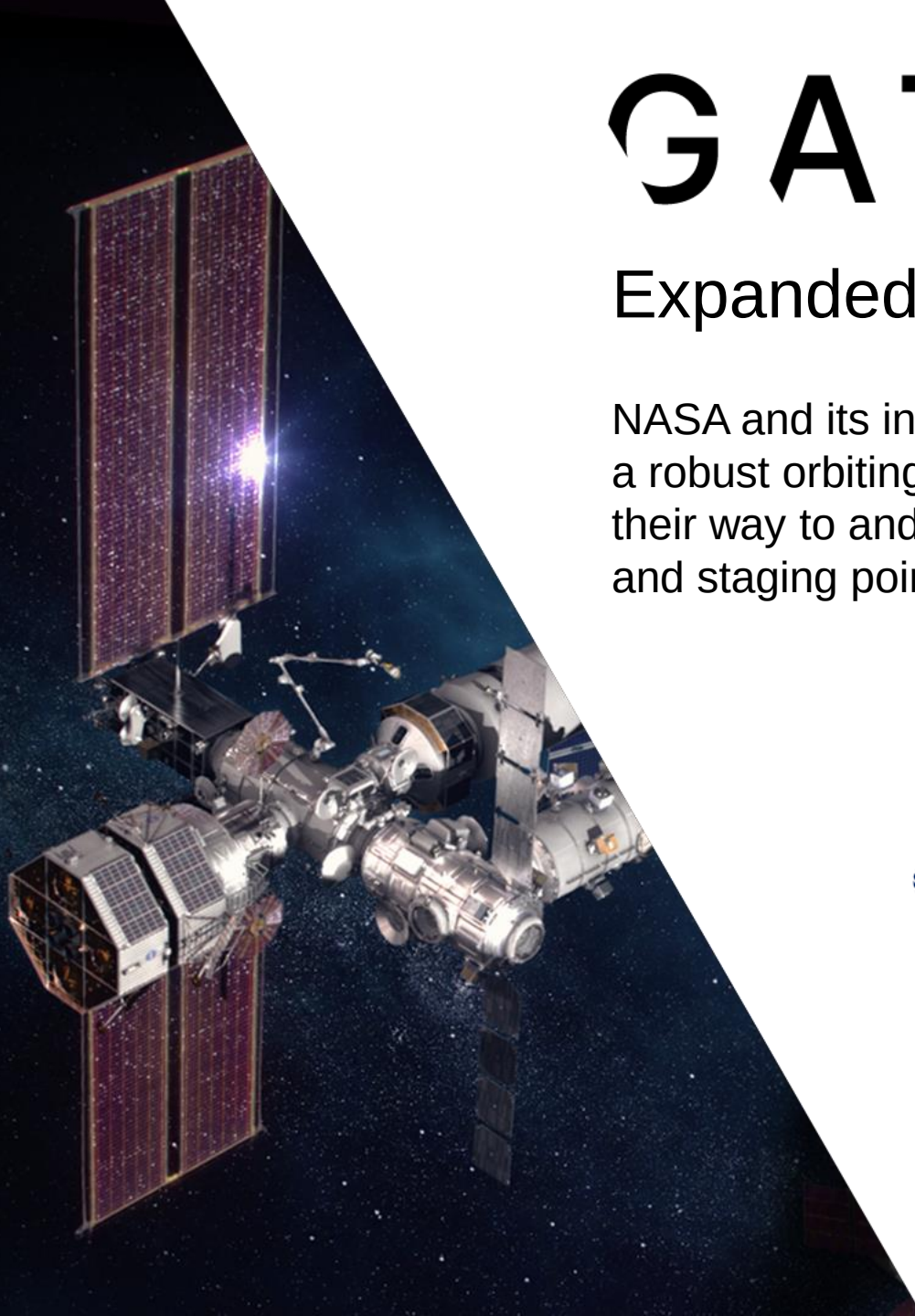
European Space Agency (ESA):

International Habitat (I-HAB) and refueling modules, along with enhanced lunar communications



The Japan Aerospace Exploration Agency (JAXA):

I-HAB's environmental control and life support system, batteries, thermal control, and imagery components



GATEWAY INTEGRATED SPACECRAFT CONFIGURATION



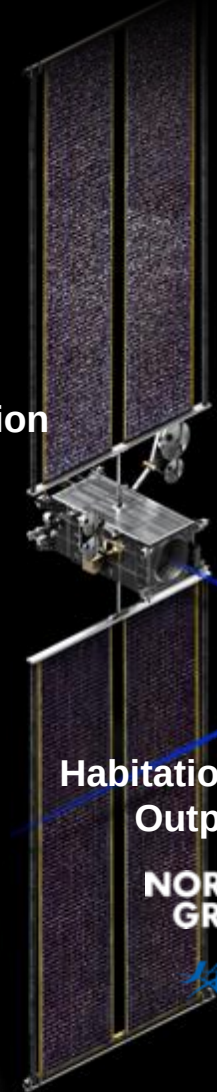
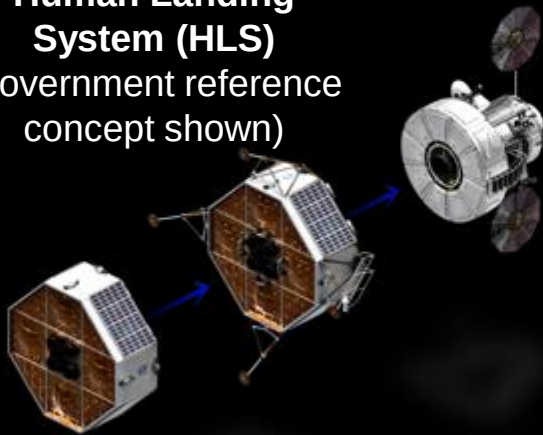
Co-manifested (PPE/HALO)
Launch Vehicle (not pictured)

SPACEX

Power and Propulsion
Element (PPE)

MAXAR

Human Landing
System (HLS)
(government reference
concept shown)



Gateway External
Robotic System (GERS)



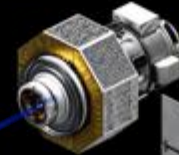
Habitation and Logistics
Outpost (HALO)

NORTHROP
GRUMMAN

JAXA ESA

ESPRIT-Refueler

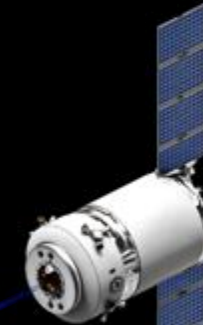
ESA



International Habitat
(I-HAB)

ESA

JAXA

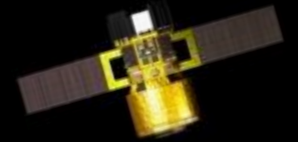


Logistics Module

SPACEX



Airlock
Provider TBD



HTV-XG

JAXA



Orion

NASA

ESA

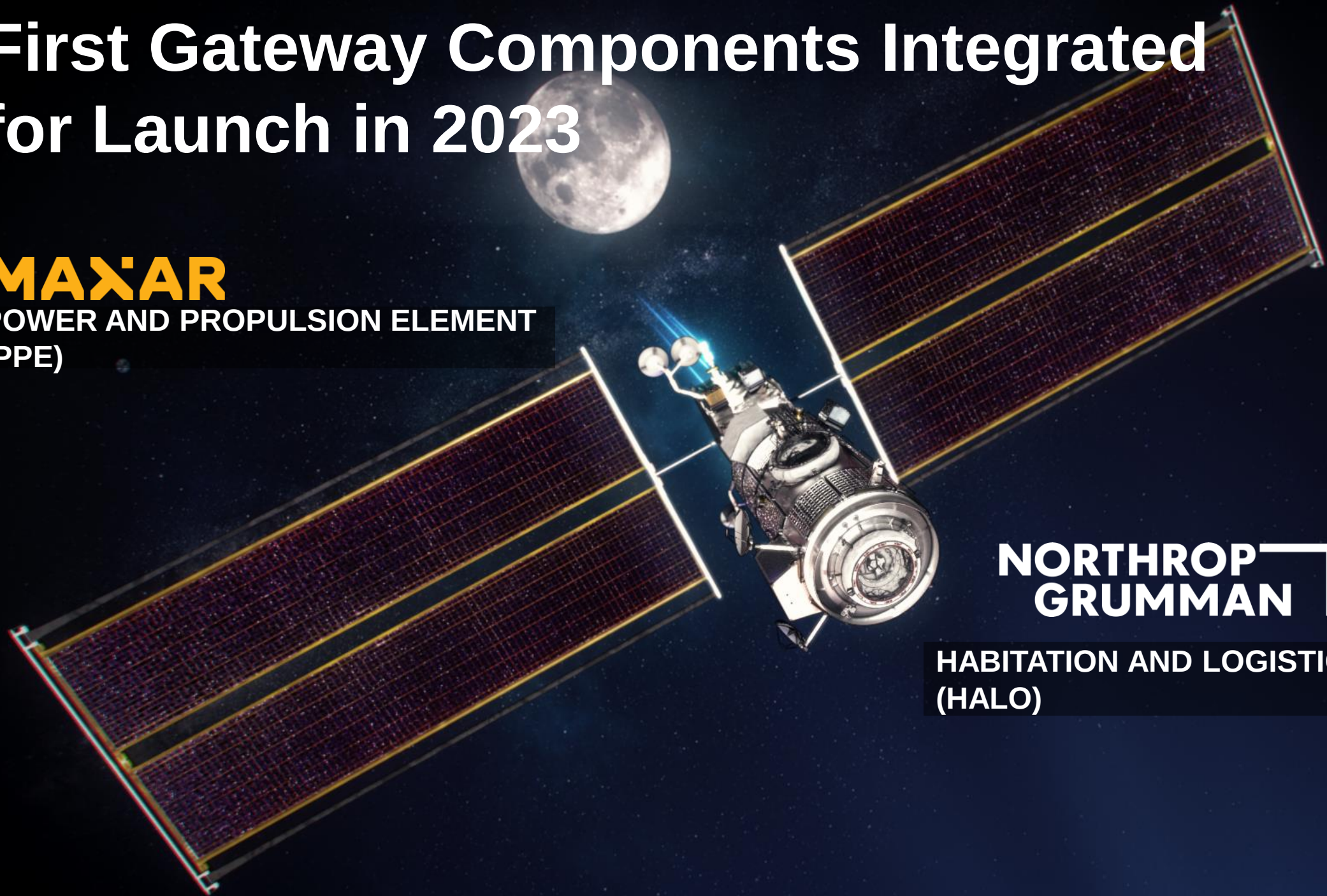
First Gateway Components Integrated for Launch in 2023

MAXAR

POWER AND PROPULSION ELEMENT
(PPE)

**NORTHROP
GRUMMAN**

HABITATION AND LOGISTICS OUTPOST
(HALO)



Gateway Logistics Services(GLS)

SPACEX

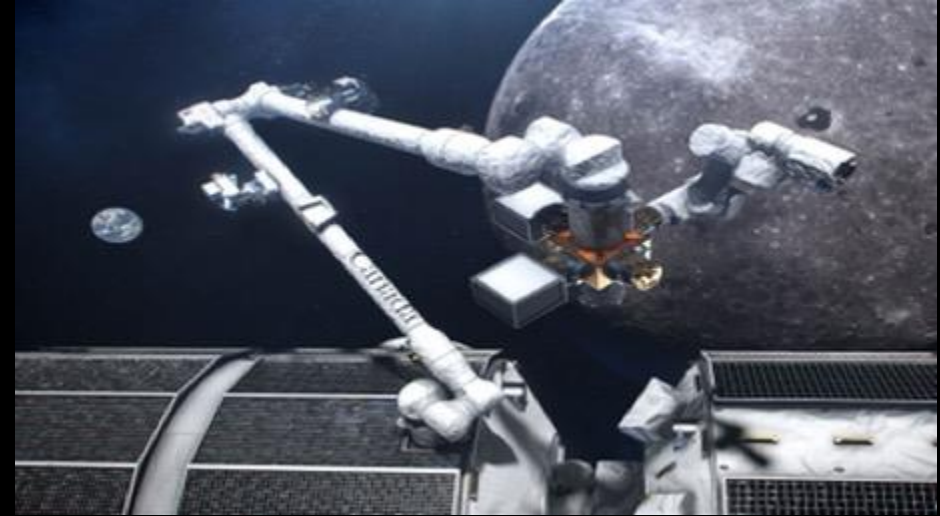
NASA selected SpaceX as the first U.S. commercial provider under the Gateway Logistics Services contract to deliver cargo, experiments and other supplies to the Gateway in lunar orbit.



GATEWAY COMPONENTS

CANADARM3

- Next-generation robotic arm capable of moving end-over-end to reach Gateway's exterior
- Robotic support for exterior maintenance and inspection
- Transfer and install external hardware and science payloads between Gateway modules, logistic vehicles and science airlock



Canadarm3 Illustration

AIRLOCK

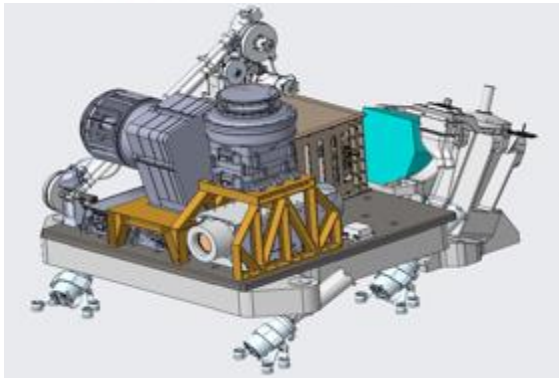
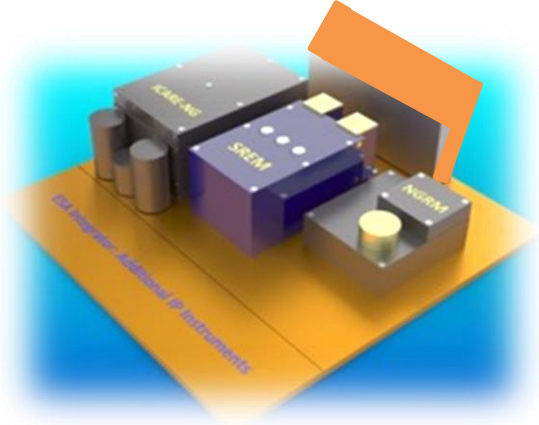
- Enables crewed space walks
- Transfers science experiments and hardware between the pressurized cabin and the exterior of Gateway

TBD partner agency

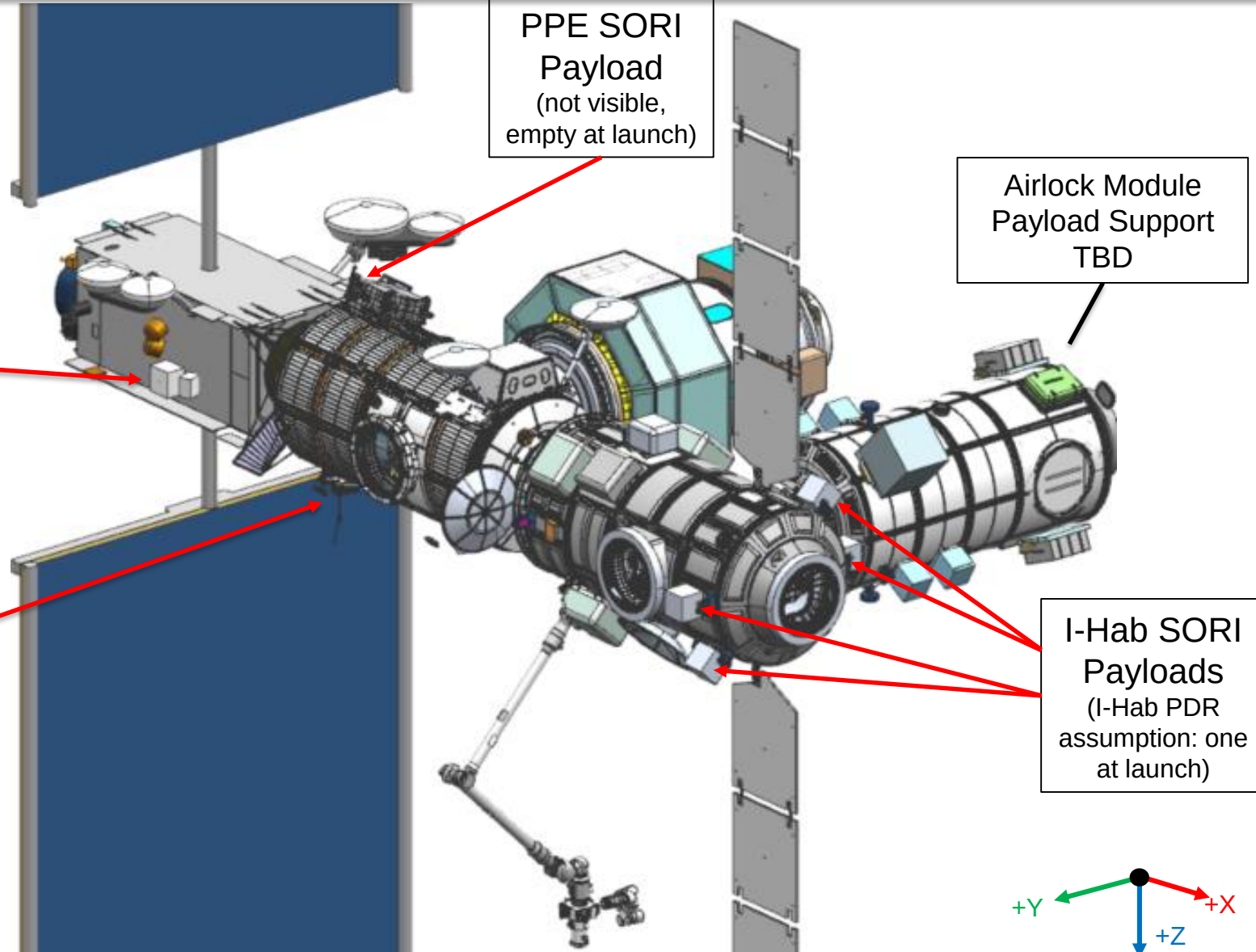


EXTERNAL UTILIZATION CAPABILITIES

European Radiation Sensors Array (ERSA)
ESA/ESTEC
Space Weather
(Includes JAXA Low-Velocity Dust Monitor)



Heliophysics Environmental & Radiation
Measurement Experiment Suite (HERMES)
NASA/GSFC
Heliophysics



ESA'S INTERNAL DOSIMETER ARRAY (IDA)

Instruments including those provided by Japan Aerospace Exploration Agency (JAXA) will inform for improvements in radiation physics models for cancer, cardiovascular, and central nervous system effects, helping assess crew risk on exploration missions



Internal Dosimeter Array, IDA

HERMES Science Grant Awards

- Led by SMD Heliophysics – Jim Spann, Ph.D
- ROSES Call with Gateway International Partner
- Six competitively-selected interdisciplinary science teams selected

ERSA/IDA Science Grants

- ESA led – Leonardo Surdo, Ph.D.
- Gateway International Partner involved in the call
- ESA is preparing to announce the grant awardees

All investigations have a data sharing agreement – the template is in final review and approval phase to the Gateway Program Control Board

CLPS Contractor Pool



Payload Accommodations

- Providers are required to “accommodate” the needs of NASA payloads, including:
 - Utilities: power, data, commanding, etc.
 - Mounting: fields of view, alignments, co-locations, etc.
 - Environments: thermal, vibe, emi/emc, etc.
 - Operations: conops, mission phases, etc.
- CLPS Task Orders are generally awarded competitively; payloads should therefore not be designed for a specific CLPS provider
- Firm Fixed Price (FFP) Task Orders necessitate stable definition of interfaces and requirements PRIOR to release of the Request for Task Plan (RFTP)
 - If it is not defined in the RFTP then it is defined de facto by the CLPS provider, or else is a “new” requirement at a cost
 - If requirements cannot be finalized, RFTP should specify achievable envelope for both sides to work toward
 - “Requirements” in an FFP procurement environment are what you are going to get, so RFTP requirements should align with what is needed for mission success
- ESSIO has capture lessons learned – Culture, Risk and Decision-Making, and Payload Interfaces
 - Working to incorporate these lessons in current and future CLPS activities

LUNAR SURFACE EXPLORATION | Updated with new changes

2022–2026

NASA AWARDED CLPS DELIVERY GOALS

PEREGRINE-1 / 2-AB / ASTROBOTIC

- Regolith volatiles composition
- Local radiation environment

1ST NOVA-C / 2-IM & 20C / INTUITIVE MACHINES

- Plume/surface interactions, charged particles near surface
- Lander prop tank gauge test

2ND NOVA-C / PRIME-1/ INTUITIVE MACHINES

- Drilling for volatiles

XL-1 / 19C / MASTEN

- Regolith volatiles composition
- Surface terrain and mineralogy

BLUE GHOST-1 / 19D / FIREFLY

- Characterize Earth's magnetosphere and the structure & thermal properties of the Moon's interior

GRIFFIN-1 / 20A / ASTROBOTIC

VIPER / NASA

- Search for volatiles, below surface and in permanently shadowed regions

3RD NOVA-C / CP-11 / INTUITIVE MACHINES

- Study lunar swirl to address the origin of magnetized crust, swirls, & space weathering on airless bodies

SERIES-2 / CP-12 / DRAPER

- Characterize Schrödinger basin structure; understand Moon's interior & evolution to its current state

KEY

- HUMAN EXPLORATION
- SCIENCE
- SPACE TECHNOLOGY
- ★ CLPS DELIVERY

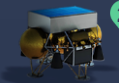
SOUTH POLE SURFACE MISSIONS



1 2ND NOVA-C
SHACKLETON
CONNECTING RIDGE
★★



3 GRIFFIN-1
& VIPER
NOBILE CRATER
★★



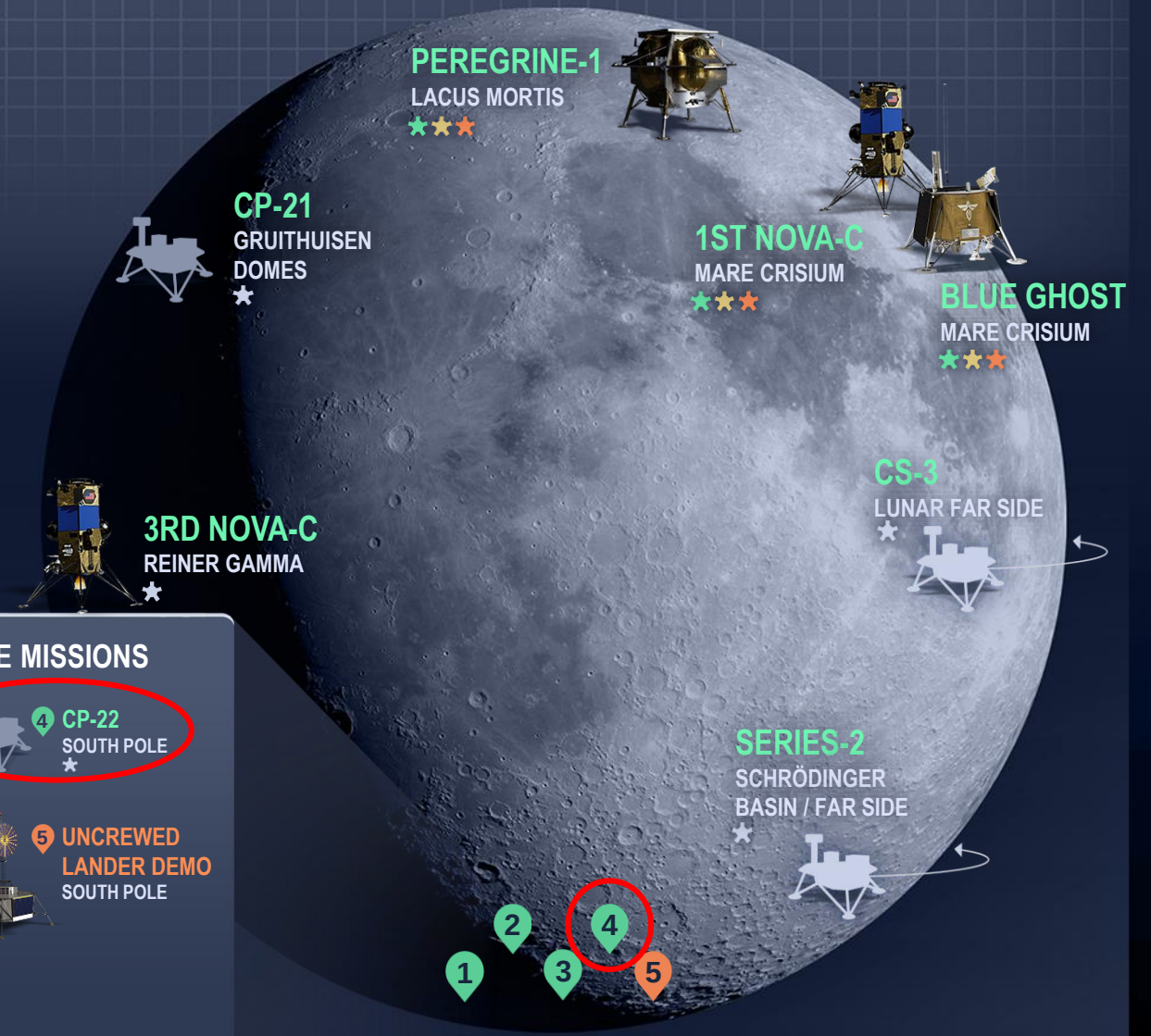
2 XL-1
HAWORTH CRATER
★★



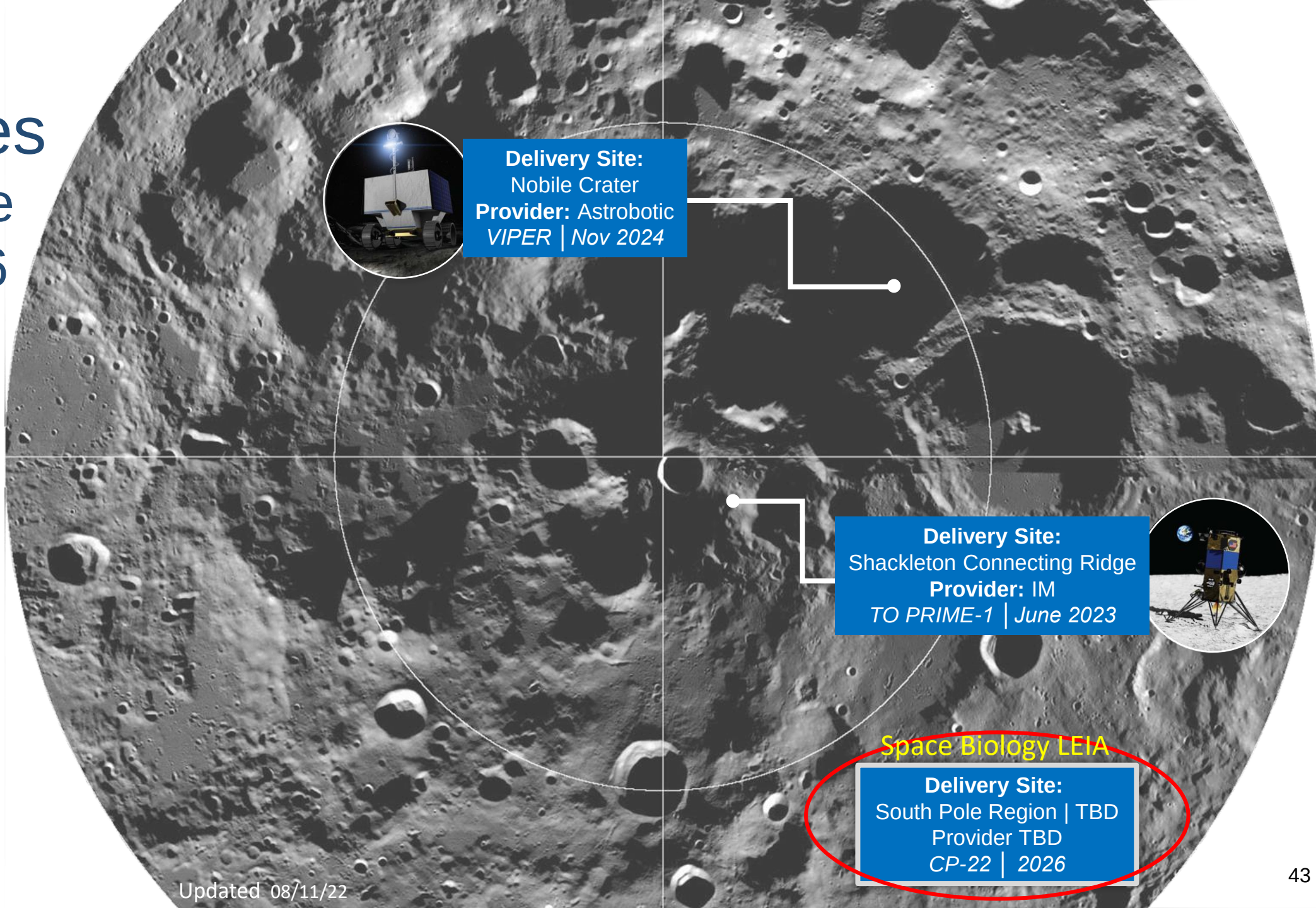
4 CP-22
SOUTH POLE
★



5 UNCREWED
LANDER DEMO
SOUTH POLE



CLPS Deliveries South Pole 2023-2026



Updated 08/11/22

LEIA: Lunar Explorer Instrument for space biology Applications (CLPS Mission CP-22)

A. Mark Settles

Bioengineering Branch

NASA Ames Research Center

andrew.m.settles@nasa.gov

Sergio R. Santa Maria

KBR/FILMSS

NASA Ames Research Center

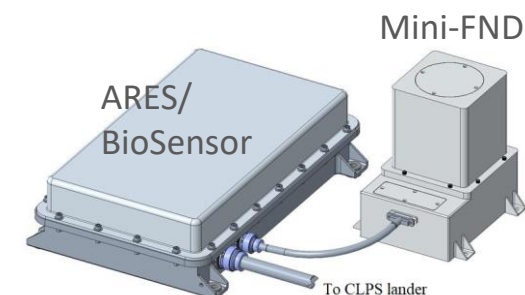
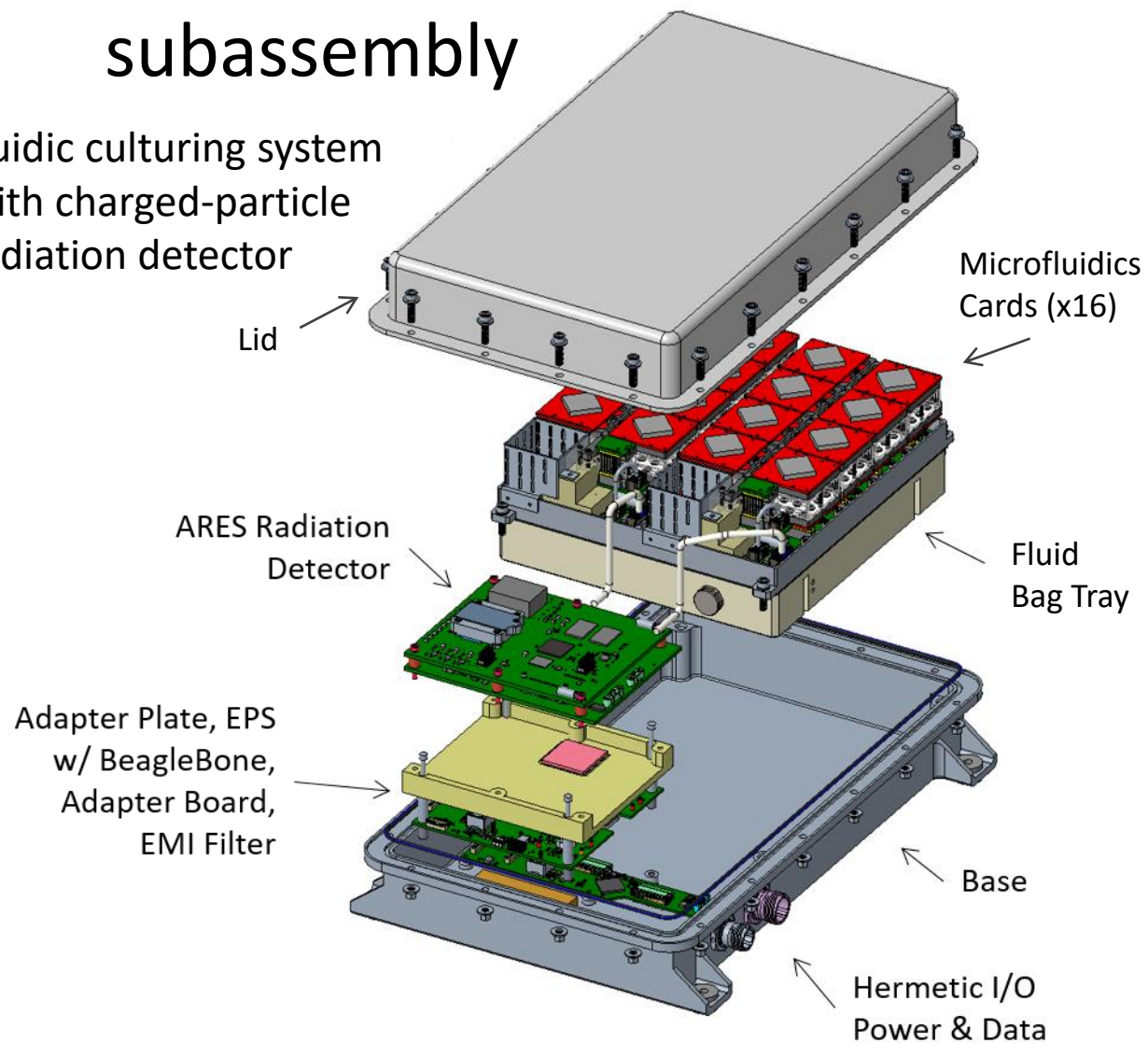
sergio.santamaria@nasa.gov

Sponsored and funded by ESSIO; Supported by Space Biology

LEIA payload

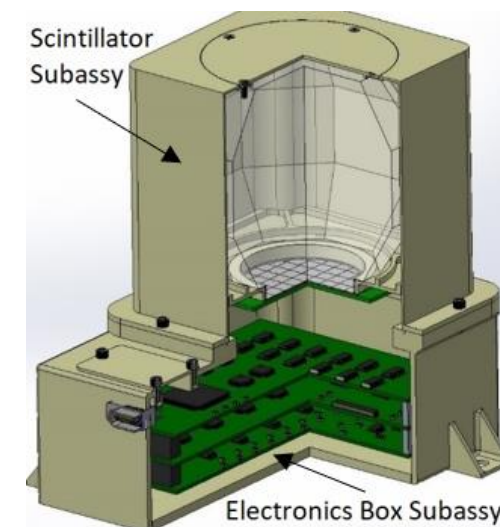
ARES/BioSensor subassembly

fluidic culturing system
with charged-particle
radiation detector



*MLI not shown

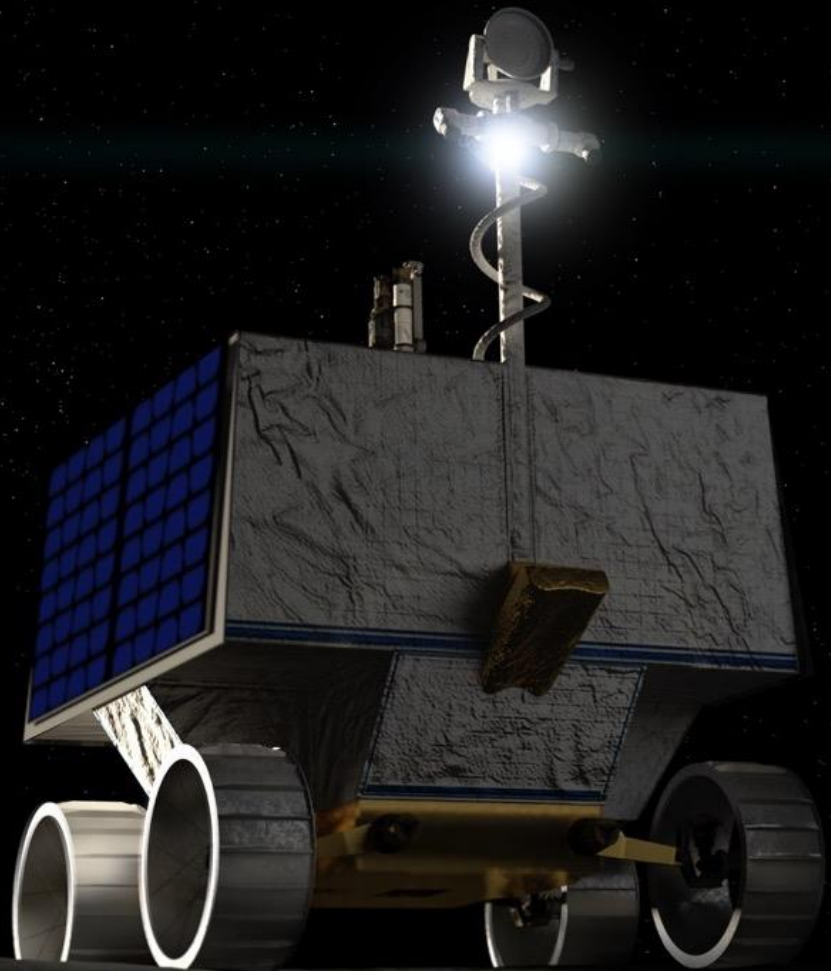
Mini-FND fast neutron detector





Volatiles Investigating Polar Exploration Rover (VIPER)

- VIPER is the first surface resource mapping mission on another celestial body
- At the South Pole of the Moon, this mobile robot will get a close-up view of the distribution and concentration of water ice that could eventually be harvested to sustain human exploration on the Moon, Mars — and beyond
- NASA awarded a task order to Astrobotic to deliver the agency's VIPER to the lunar South Pole in late 2023 as part of the Commercial Lunar Payloads Services program



Future Definition of CLPS

- Continue building the commercial market; CLPS service options are expected to expand as market and company capabilities evolve
 - Estimating periodic on-ramp opportunities into the CLPS Vendor Pool going forward depending upon need and service availability
 - Maintain flexibility of the CLPS IDIQ to award Task Orders for upcoming capabilities, data buys
 - SMD manifests will continue to be competitively-selected payloads
 - Expect to continue cadence of ~2 flights per year
 - Support of other mission directorates and international partners through delivery of priority science/technology investigations to the lunar surface
- Support of Artemis crewed activities through delivery of scientific equipment, supplies for longer duration missions, human-centric infrastructure (e.g., LTV, ISRU demos/equipment, etc.)
 - New capabilities that would enhance science return, ops, and open new avenues for scientific investigations
 - Mobility
 - Orbital Drop-off
 - Comm Relay
 - EMI Quiet Operation
 - Increased Delivery Mass
 - Surviving/operation throughout the lunar night
 - Articulation
 - PSR/Cold Operations
 - Sample Return



SSERVI Overview

SSERVI at a Glance:

Jointly funded by NASA SMD and ESDMD, SSERVI is focused on **science enabling human exploration and science enabled by human exploration**.

Currently **12 Overlapping U.S. Teams** funded in 2017 and 2019, each with 5-year cooperative agreements that provide continuity between collaborating teams.

1000+ publications since SSERVI started in 2013. Many additional conference publications and other scientific and exploration-related products.

11 Int'l partners with a focus on lunar science and missions:

Australia, Canada, France, Germany, Israel, Italy, Japan, Korea, the Netherlands, Saudi Arabia, United Kingdom



The Solar System Exploration Research Virtual Institute (SSERVI) sponsors human exploration and scientific discovery by integrating interdisciplinary research to prioritize and resolve key knowledge gaps.

SSERVI Manages the Solar System Treks Project (SSTP):

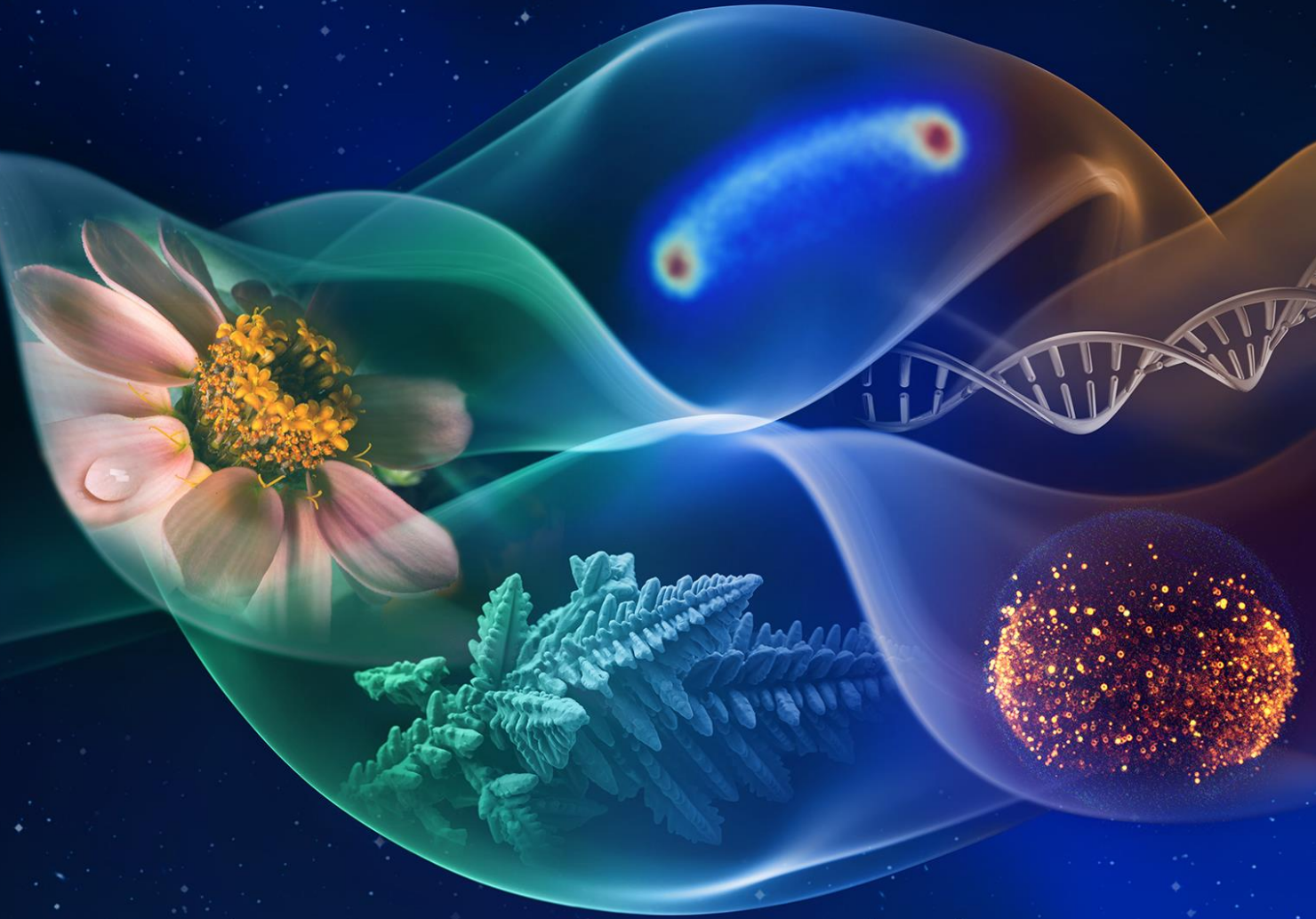
A free, web-based visualization tool originally created during Constellation program at the request of NASA HQ with high-resolution visualizations of planetary bodies using real spacecraft data. Provides mission planning data analyses to domestic and international lunar missions. New portals and updates released in support of upcoming missions. Access all Trek portals at <https://trek.nasa.gov>

SSERVI Cooperative Agreement Notice (CAN-4):

- New Lunar Focus, New IDEA Focus/requirements
- Step 1 due October 15, 2022
- Step 2 due December 18, 2022
- Target CAN-4 team selection: Mid CY 2023
- [For additional details see: https://tinyurl.com/jw3jrdbu](https://tinyurl.com/jw3jrdbu)



BPS and Artemis/CLPS



BIOLOGICAL AND PHYSICAL SCIENCES ADVANCING THE FRONTIERS OF SPACE EXPLORATION

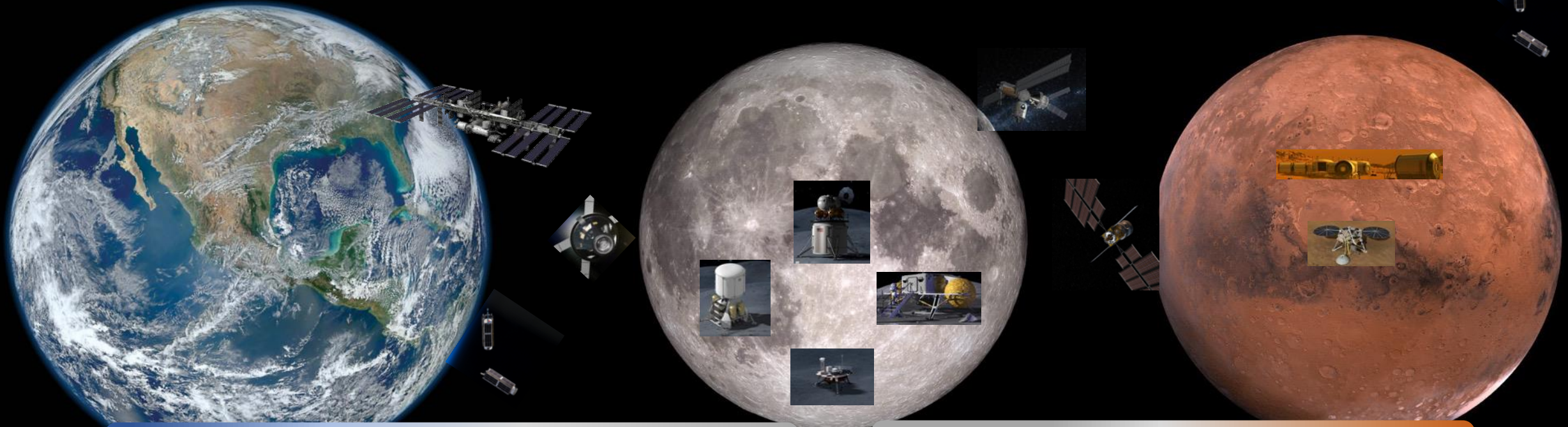
Advance fundamental
scientific knowledge:
Earth, LEO, and beyond

Transformative
science through
missions in space

Translation to R&D for
technology and health
care applications

Enable sustainable living from
transit to and inhabiting of
exploration destinations

Continuum of space environments for research to understand life in space



Earth-based and LEO research and technology to
advance lunar exploration and habitats development

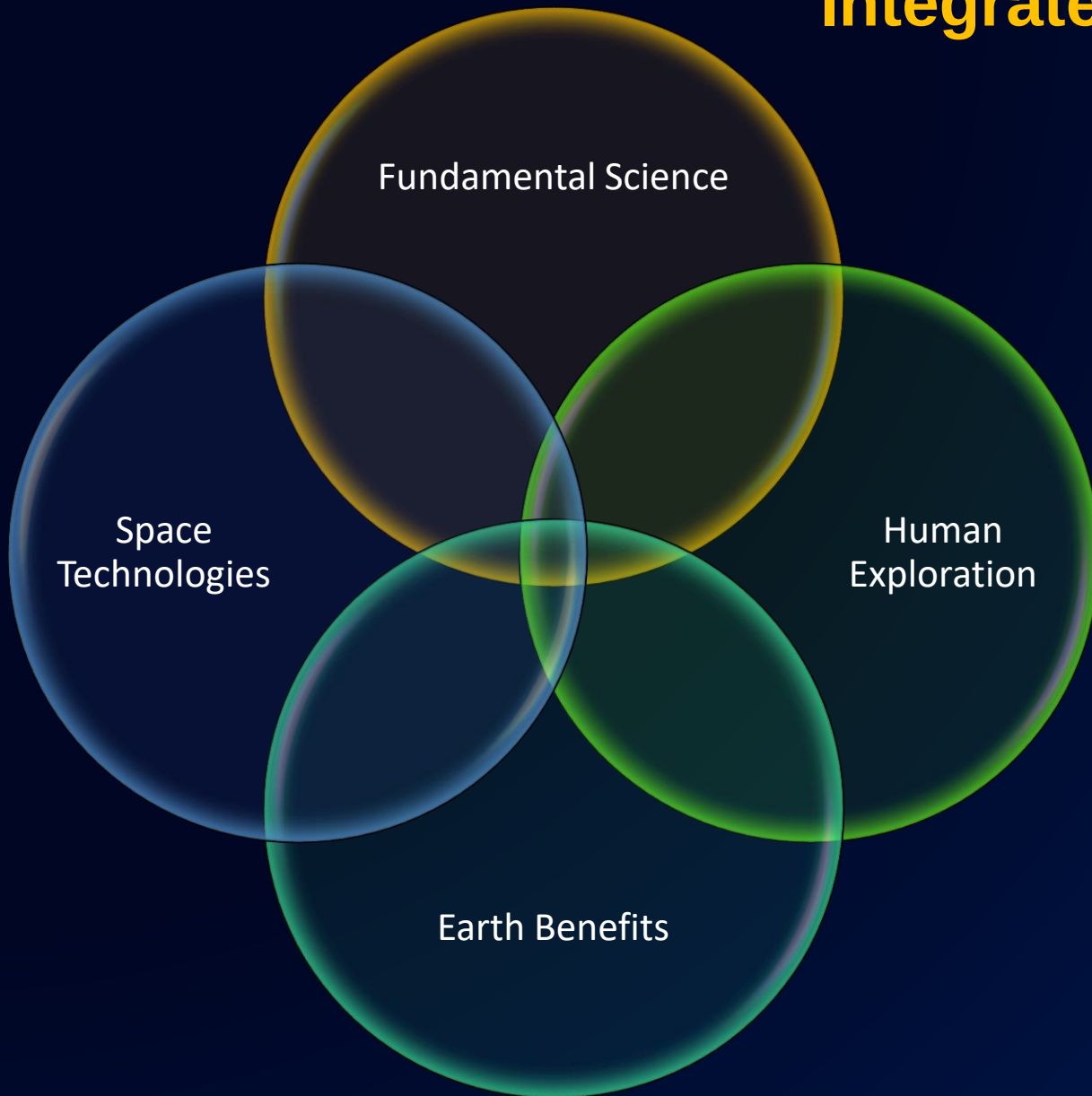
Lunar research and technology to advance
Mars exploration and habitat development

EXPLORE

DISCOVER

THRIVE

Integrated Lunar Science Research



- Studies contributing to fundamental science knowledge, lunar habitation sustainability, and Mars-forward transit and surface exploration
- Provide fundamental data and knowledge contributing to research and development of applications
 - Exploration-specific needs
 - Commercial utilization needs
 - Earth benefits
- Advance our community of scientists towards new research and continue to grow this community with new beyond LEO research goals and objectives
- Inspire, educate, and train the scientists and engineers, including the next generation, who will continue to advance NASA science and technology well into the future

Lunar Exploration and BPS

Orion Capsule



Gateway

- Multinational science payloads
- Data and specimen sharing



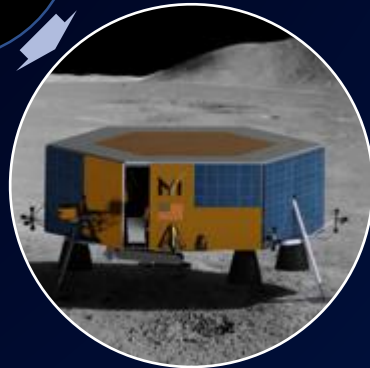
BPS

Human Landing Systems



Commercial Lunar Payload Services Lander

- Payload housed on lander
- Placed directly on the lunar surface by a lander capability
- Pre-positioning on the moon for astronaut access



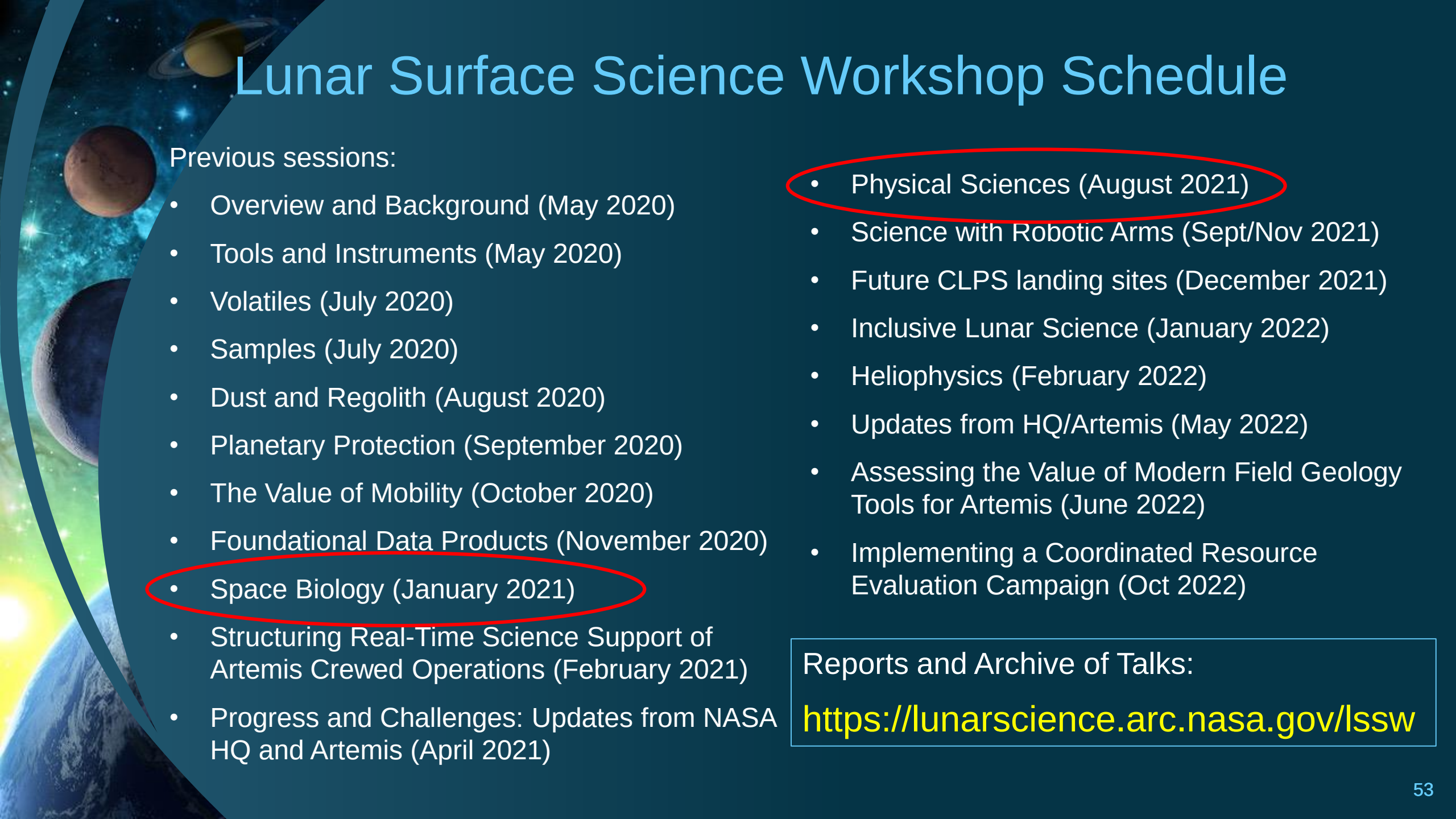
Low Earth Orbit Platforms

- ISS, Bion, Free-Flyers, etc



Ground-Based Research

Location-Specific and Continuum of Research Across All Platforms and Locations



Lunar Surface Science Workshop Schedule

Previous sessions:

- Overview and Background (May 2020)
- Tools and Instruments (May 2020)
- Volatiles (July 2020)
- Samples (July 2020)
- Dust and Regolith (August 2020)
- Planetary Protection (September 2020)
- The Value of Mobility (October 2020)
- Foundational Data Products (November 2020)
- Space Biology (January 2021)
- Structuring Real-Time Science Support of Artemis Crewed Operations (February 2021)
- Progress and Challenges: Updates from NASA HQ and Artemis (April 2021)
- Physical Sciences (August 2021)
- Science with Robotic Arms (Sept/Nov 2021)
- Future CLPS landing sites (December 2021)
- Inclusive Lunar Science (January 2022)
- Heliophysics (February 2022)
- Updates from HQ/Artemis (May 2022)
- Assessing the Value of Modern Field Geology Tools for Artemis (June 2022)
- Implementing a Coordinated Resource Evaluation Campaign (Oct 2022)

Reports and Archive of Talks:

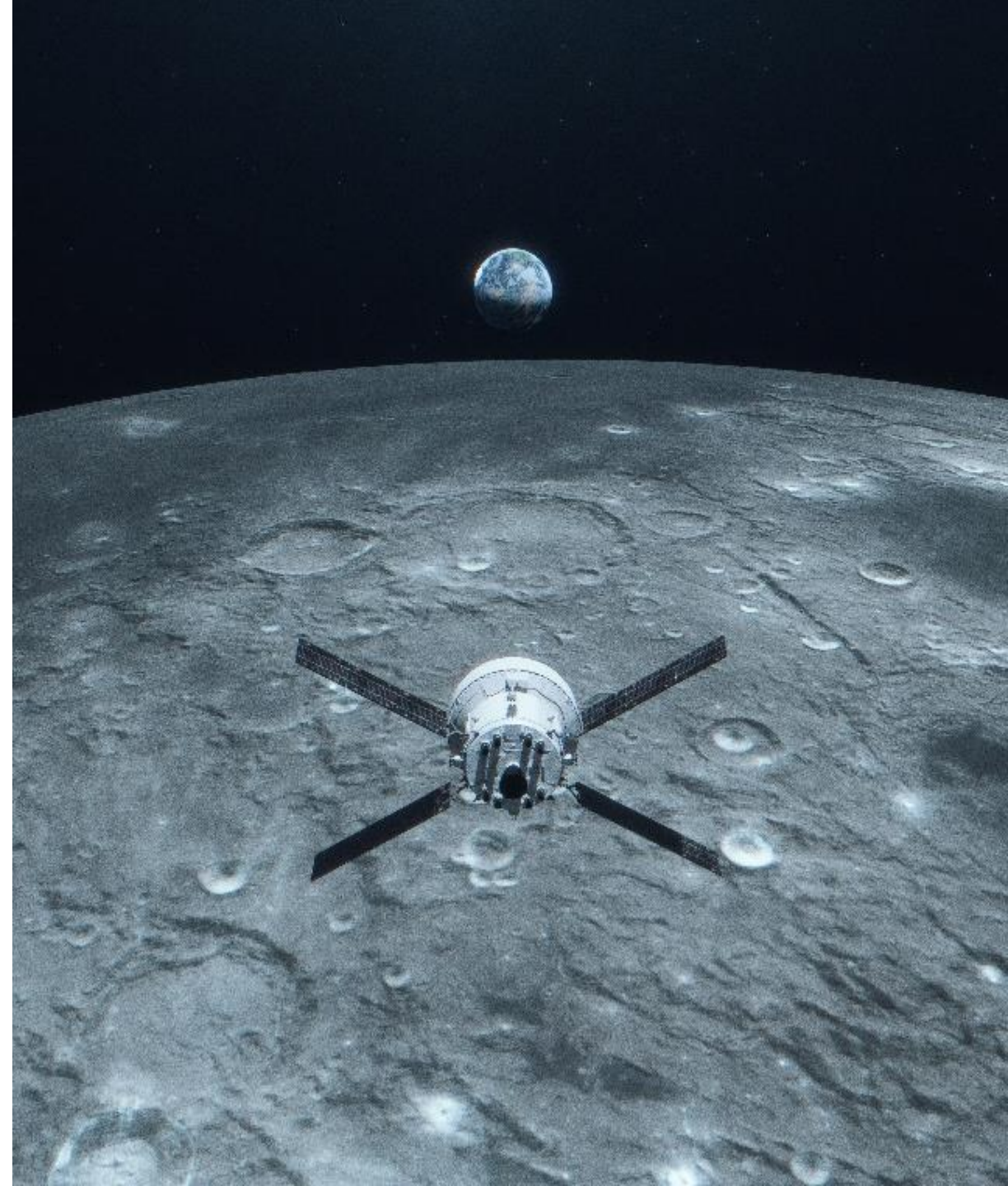
<https://lunarscience.arc.nasa.gov/lssw>

Continuous BPS Engagement in Artemis Strategic and Planning Activities

- Direct participating in all ACD Committees, Panels, and Groups working on science utilization
 - Development of over-arching objectives and Level-1 documents for Artemis
 - Development of mission specific utilization requirements documents
 - Investigations and evaluations of resources, capabilities, use-case scenarios, and fields of merit for Artemis, including Gateway, Human Landing System, Lunar Terrain Vehicle, Pressurized Rover, and Lunar Base Camps
 - Direct interfacing to the ACD Utilization Leadership
- Direct Participation in and support of ESSIO/LDEP Lunar and Mars Science Activities for NASA SMD
 - Invitation for full engagement with and within ESSIO/LDEP
 - Development of solicitations for Artemis III/beyond, PRISM, and SSERVI CAN
 - Artemis Internal NASA Science Team
 - NASA Administrator Office actions and tasks for Artemis
 - Mars Exploration Program activities associated with utilization and future architecture
 - Regular ESSIO staff meetings and Program Scientist tags
 - ESSIO-assigned Program Scientist and Program Executive to support BPS Division

Recent Active Pursuits of Science On and Around the Moon

- Opportunities for lunar science on all missions
 - Artemis I: BioExpt-1
 - Artemis II: Space Biology Experiment
 - Currently in final assessment by Artemis for approval
 - Investigating a science payload on the Uncrewed Demo and obtaining technical data collected by Starship
 - Candidate studies for Gateway (currently on hold)
- BPS science is being included in all applicable Artemis and PRISM solicitation through ESSION and SSERVI solicitations
- Involved in the Moon-2-Mars strategy objectives process and documentation
- Develop support from the JSC Astromaterials Acquisition and Curation Office
 - Ground research using Apollo and Artemis archived lunar samples and regolith simulants
- Physical Sciences presentation at the monthly Systems Technology Mission Director Technology Meeting (STMD)
 - Identify areas of common interest
 - Identify STMD data and analysis needs that require Physical Sciences Program fundamental research
- BPS Translational Science Program actively engaging other government agencies and HRP for collaborative investigations on the Moon
- BPS Space Biology Program continued dialog with HRP on collaborative science beyond LEO



Challenges to Scientific Research for the Moon and Mars

Scientific Research

Crew Autonomy ↑

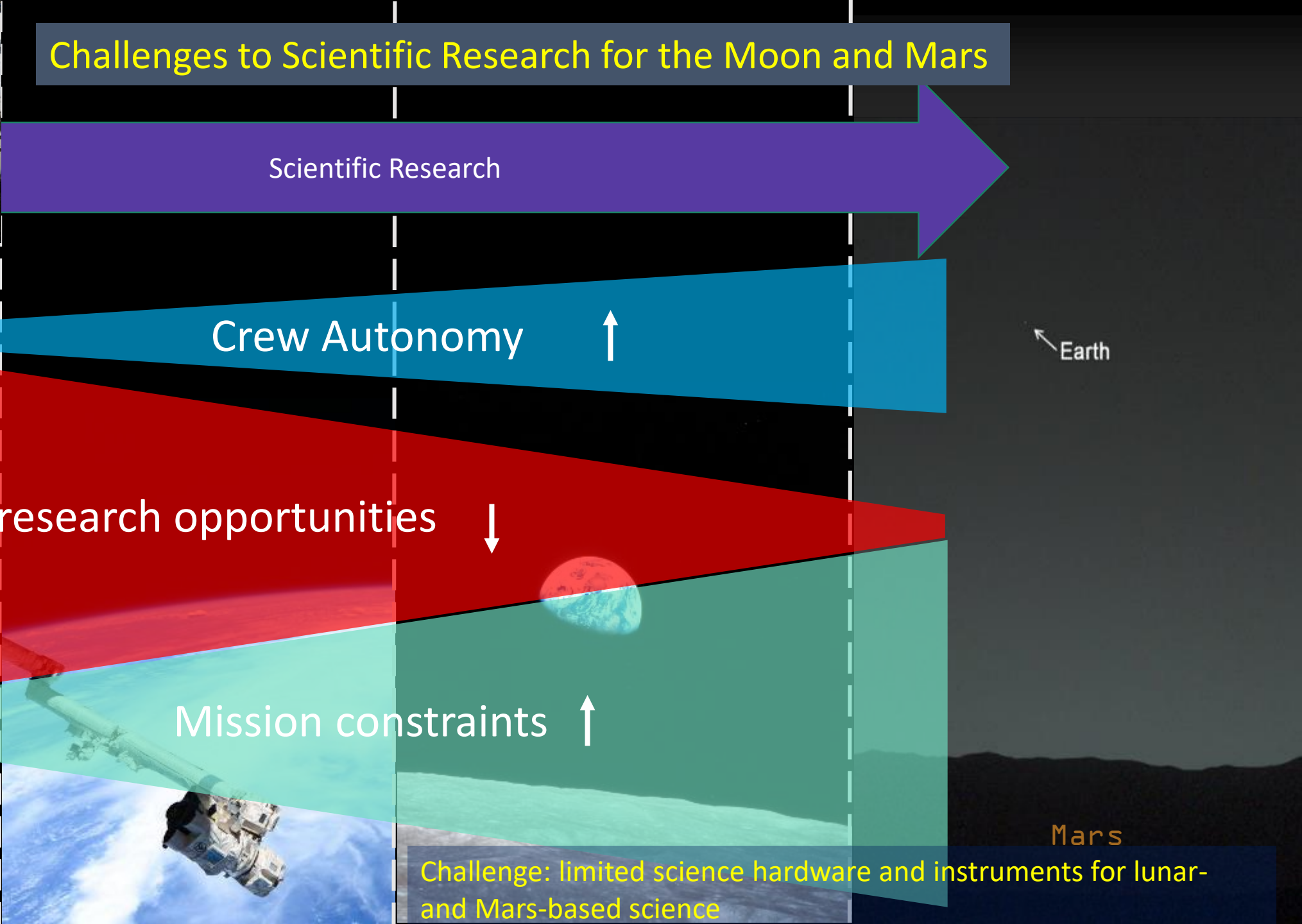
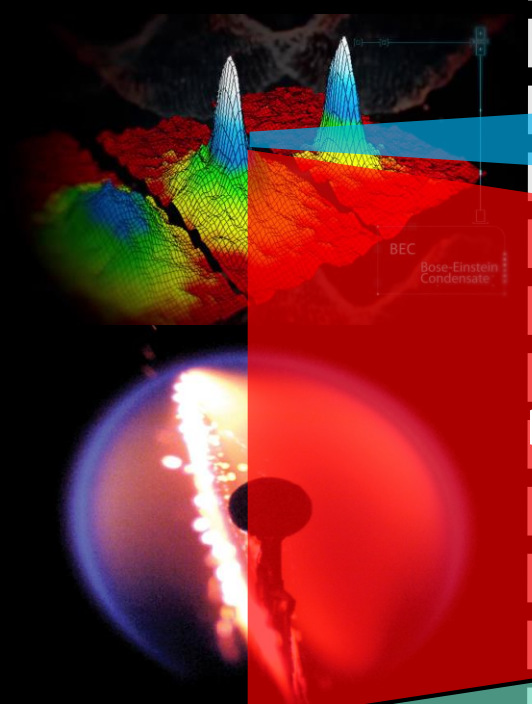
research opportunities ↓

Mission constraints ↑

Challenge: limited science hardware and instruments for lunar- and Mars-based science

Earth ↖

Mars



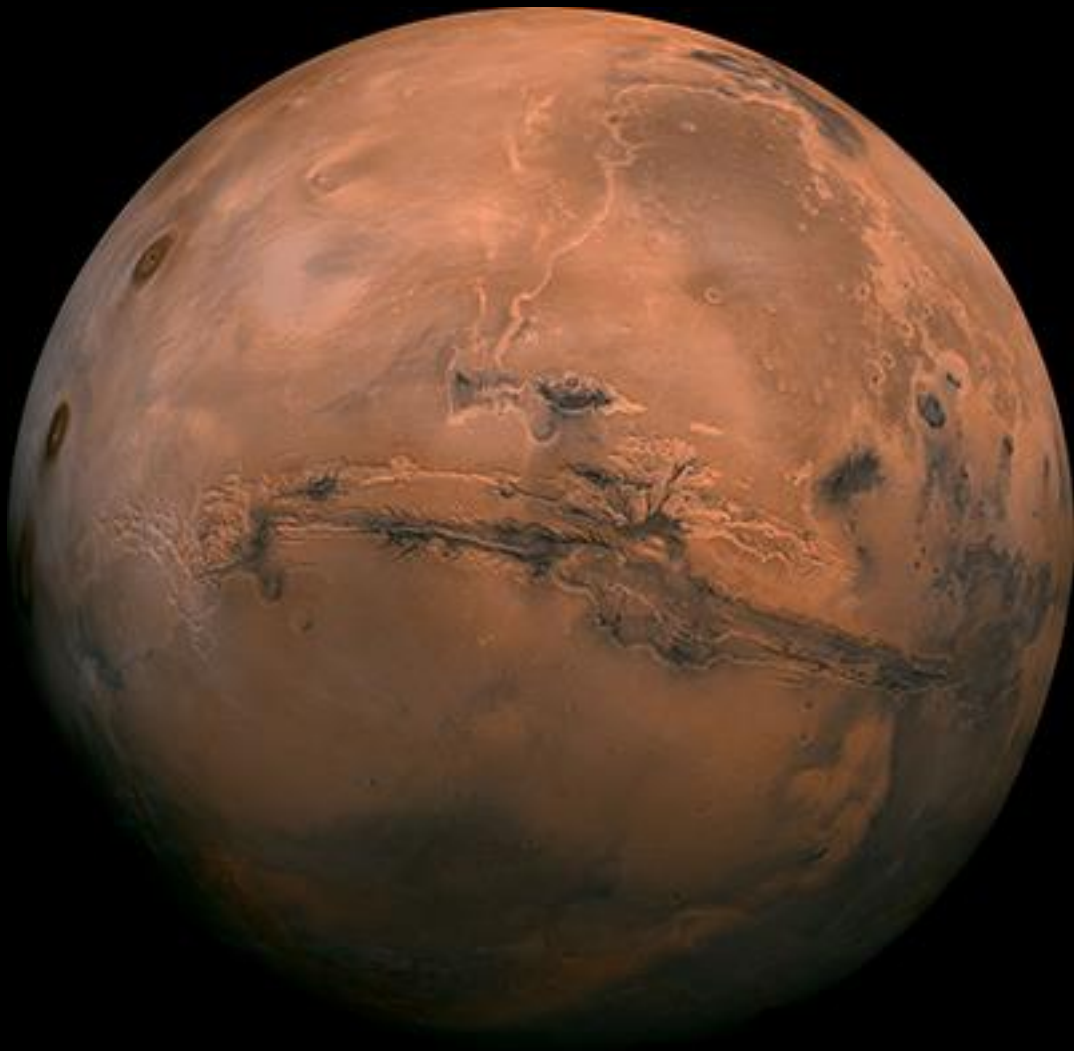
Building the BPS Lunar and Mars Science Communities

The pursuit of biological and physical sciences in these new frontiers will necessitate BPS science community involvement other science societies and their associated meetings

- Lunar Exploration Analysis Group (<https://www.lpi.usra.edu/leag/>)
- Mars Exploration Program Analysis Group (<https://mepag.jpl.nasa.gov/>)
- Lunar Surface Innovation Consortium (<https://lsic.jhuapl.edu/>)

NASA SMD places a high priority on community-driven definition of exploration objectives, priorities, and comments to drive their science strategies and planning

- All SMD Artemis and CLPS campaigns, strategies, objectives, and planning can trace back to key science community-developed roadmaps and documents from the Decadal Surveys, Analysis Group, and workshop and conferences
- The Moon to Mars Strategy was developed based on the above and RFI to the communities



The architecture designs and exploration planning is in progress

- BPS has been invited to participate in internal NASA and external community activities to capture its science
- A request has gone out from NASA for information on community-driven roadmaps, objectives, and priorities for human on Mars exploration
 - The information is needed for initial architecture design
 - BPS was approved to stand down on providing its objectives and priorities until after the BPS Decadal Survey is released in 2023
- BPS will hold a Humans On Mars workshop in November, 2023 prior to the ASGSR Annual Meeting to engage the community
 - A website forum with Mars reference materials and science discussion is in development to prepare the community for the workshop
 - Periodic seminars on Mars is in consideration



Acknowledgements

Exploration Science Strategy and Integration Office

Planetary Science Division, Lunar Discovery and Exploration Program and Mars Exploration Program

Exploration Systems Development Mission Directorate

Artemis Campaign Development

Gateway Program

Exploration Systems Development Division Payload Integration Tactical Team

Solar Systems Exploration Virtual Research Institute

Lunar and Planetary Institute, Universities Space Research Association

They have given BPS a strong voice in lunar and Mars exploration and integrated our science as part of the vocabulary of exploration beyond LEO



Thank you