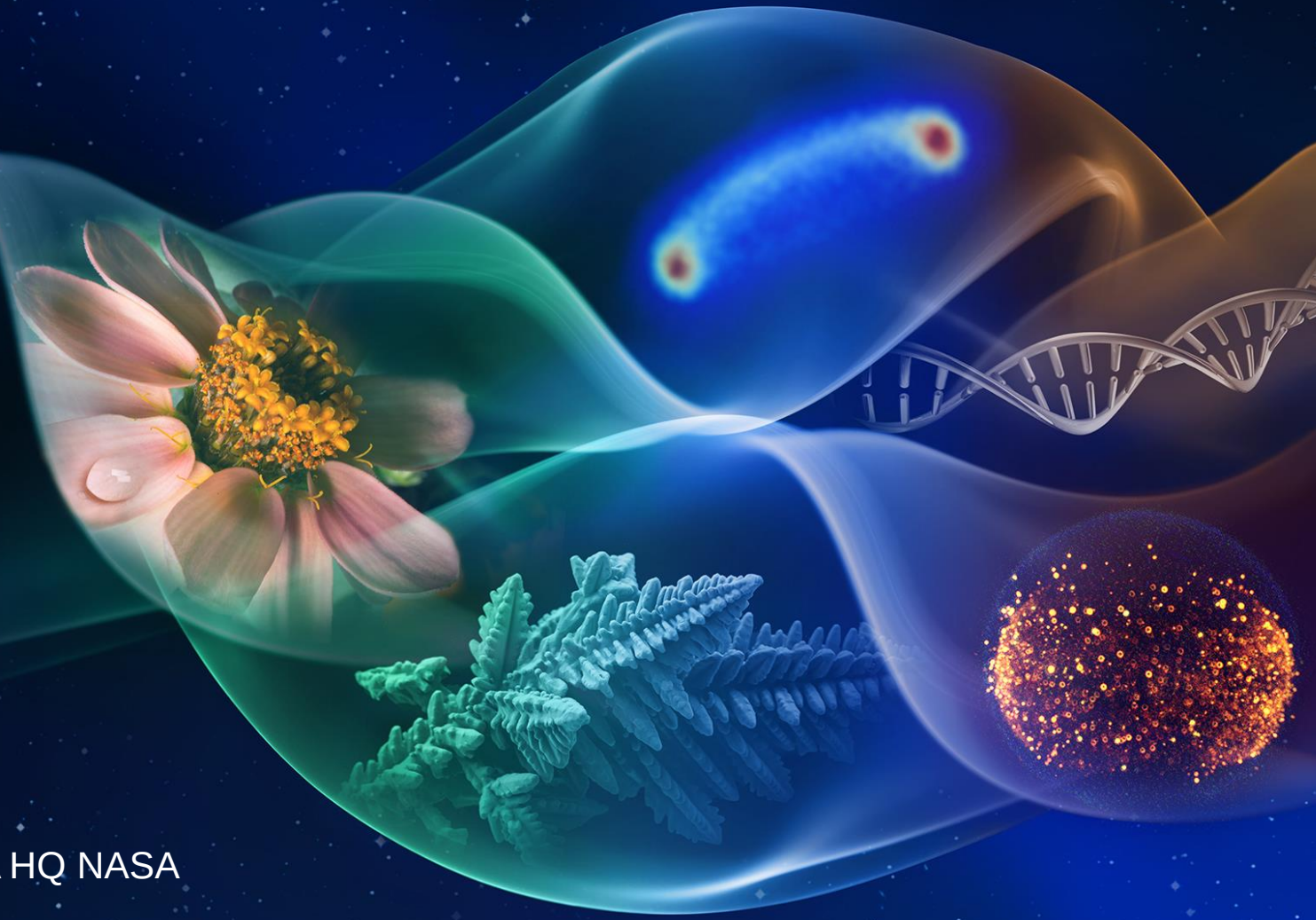
National Aeronautics and Space Administration

Biological and Physical Sciences Division



The Next Big Scientific Step for BPS: To the Moon and Beyond

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

Biological and Physical Sciences Advisory Committee, November, 2022

Summary

- NASA is actively pursuing and including science utilization as a priority for all Artemis and Gateway missions
- NASA BPS Division is directly included and fully engaged in Artemis and Gateway science utilization panels, committees, groups, and tasks
- NASA Artemis, Gateway Program, and SMD Exploration Science Strategy and Integration Office are actively advocating for and giving a voice to BPS science
- Challenges for resources, capabilities, accommodations, and budgets exist to enabling science investigations and operations for all science disciplines in NASA SMD
- NASA BPS Division is and will become more actively engaged with our academic and commercial communities and other government agencies concerning Moon and Mars science
- NASA SMD considers community input and comment as essential and required for achieving lunar and Mars science of the highest excellence for NASA

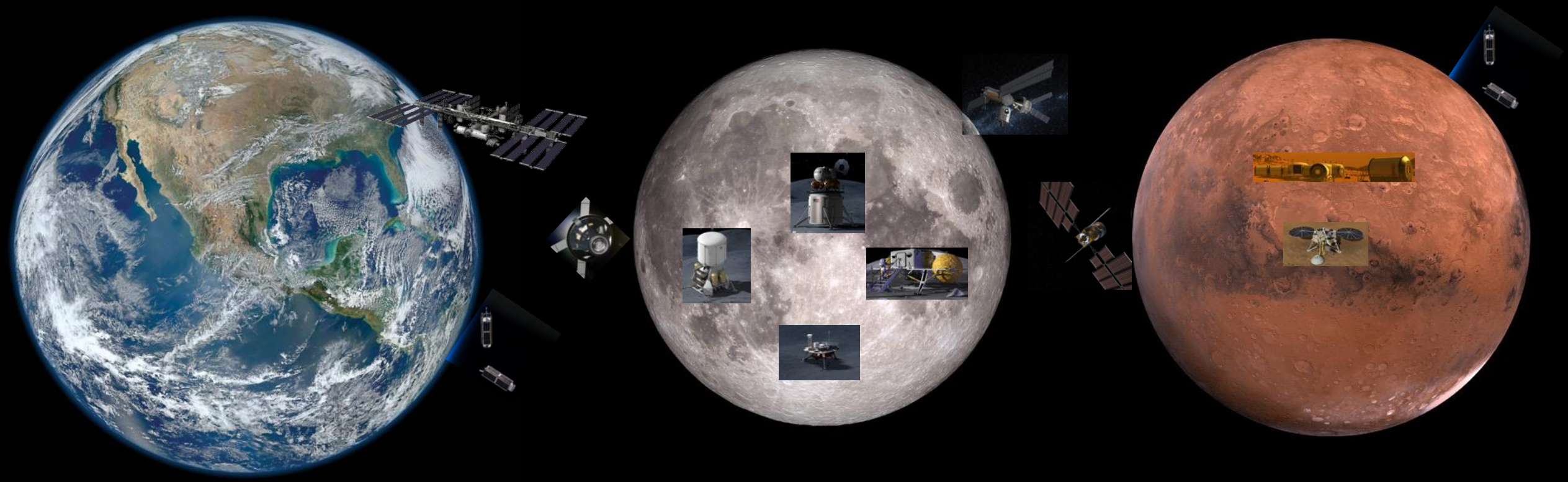
BIOLOGICAL AND PHYSICAL SCIENCES
ADVANCING THE FRONTIERS OF SPACE EXPLORATION

Advance fundamental scientific knowledge: Earth, LEO, and beyond

Transformative science through missions in space

Translation to R&D for technology and health care applications

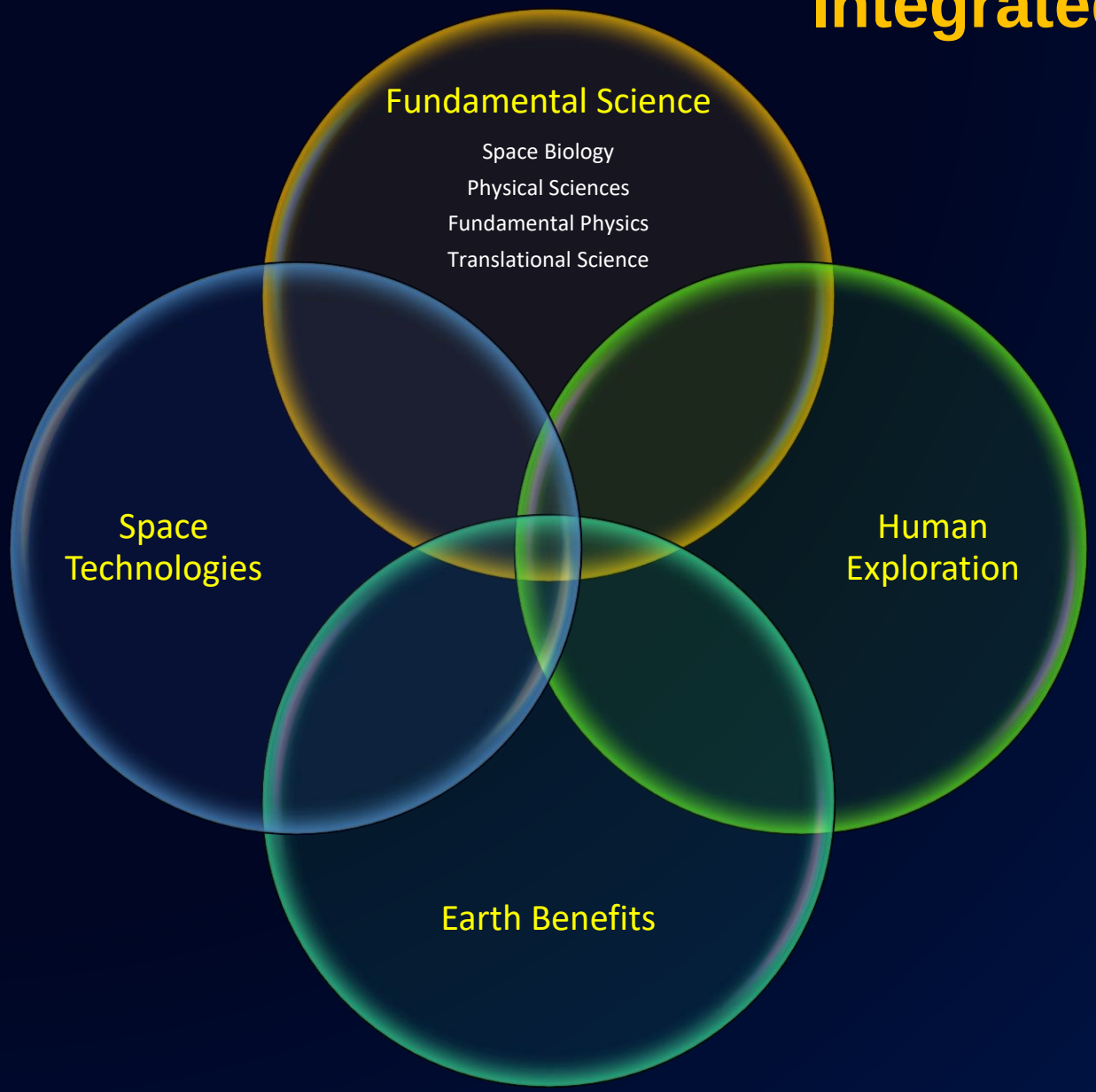
Enable sustainable living from transit to and inhabiting of exploration destinations



Continuum of space environments for research to understand biological and physical systems in space

EXPLORE | DISCOVER | THRIVE

Integrated Lunar Science Research



- Studies contributing to fundamental science knowledge advancement
- Provide fundamental data and knowledge contributing to research and development of applications and technologies
- Advance our community of scientists towards new research and continue to grow this community with new beyond LEO research
- Inspire, educate, and train the scientists and engineers 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

Low Earth Orbit Platforms
- ISS, CLD, Free-Flyers, etc.

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

Ground-Based Research

Lunar Exploration and BPS

Only Return Platform

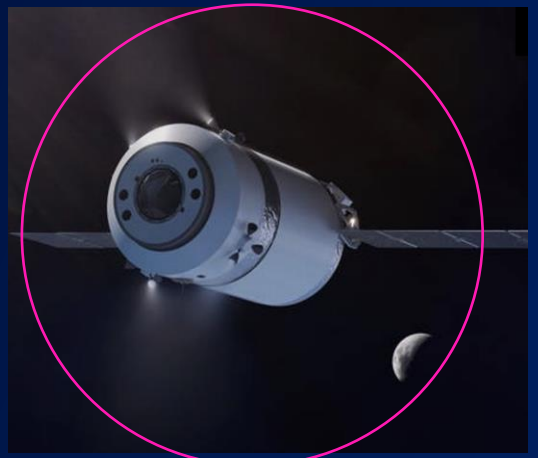
* **Orion Capsule**

100 kg of shared utilization mass for return

Gateway
- Multinational science payloads
- Data and specimen sharing

BPS

Gateway Logistics Module



Science Delivery

Human Landing Systems

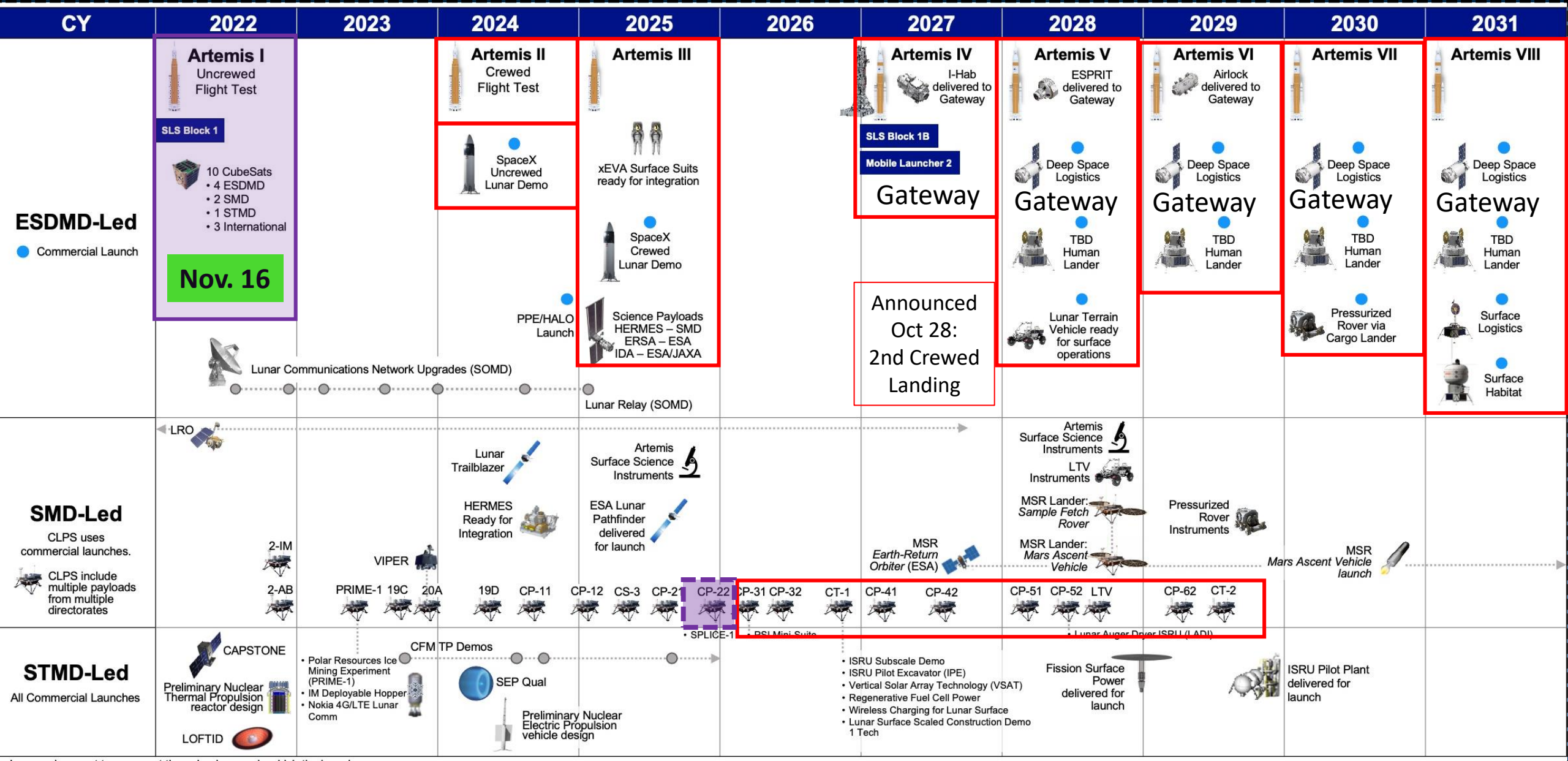
Science Delivery

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

Science Delivery

*Very small mass may be available for Orion but payload delivery accommodations are not likely

BPS Aspiration for Lunar Exploration Science
Moon to Mars Planning Manifest



Imagery is meant to represent the calendar year in which the launch occurs.
Does not include impact from FY22 appropriations.

UPDATED
20220323

Solicitations for Lunar Surface Science (Artemis and CLPS)

- Released by Exploration Science Strategy and Integration Office only
- Lunar surface-specific and –agnostic science
- Funding: Science and Instrument/Hardware
- All science proposals are considered for defined number of selection slots – no separate allocations for different science disciplines
- BPS has representation in the solicitation processes
- BPS may have opportunity to select proposals for award but will be required to fund the additional proposals not selected by ESSIO

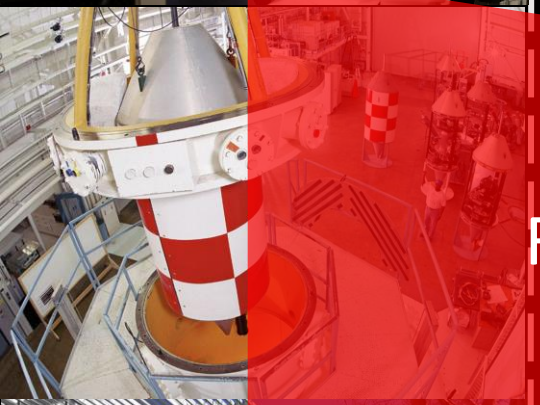
Solicitations for Gateway

- Released by BPS Division Programs or International Partner
- Funding for Science
  - Encouraging international collaborative proposals
- Hardware funded by payload sponsor (e.g. BPS Divsion)
- Selection slots defined for different disciplines associated with the call

Solicitation for Ground (Earth)-Based Only Lunar Science

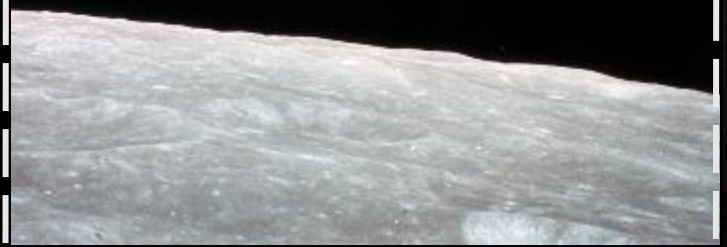
- Released by the BPS Division Programs
- Released by Solar Systems Exploration Research Virtual Institute

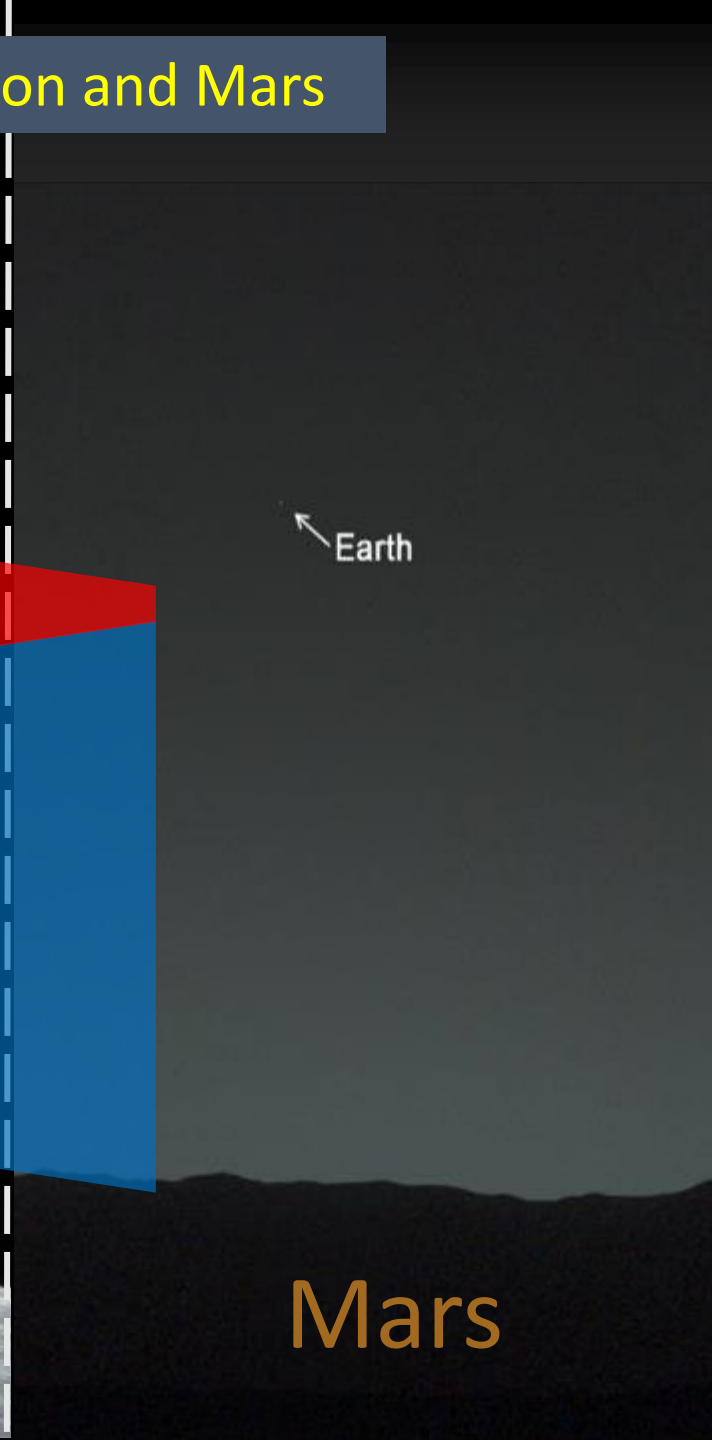
Challenge to BPSD Scientific Research for the Moon and Mars



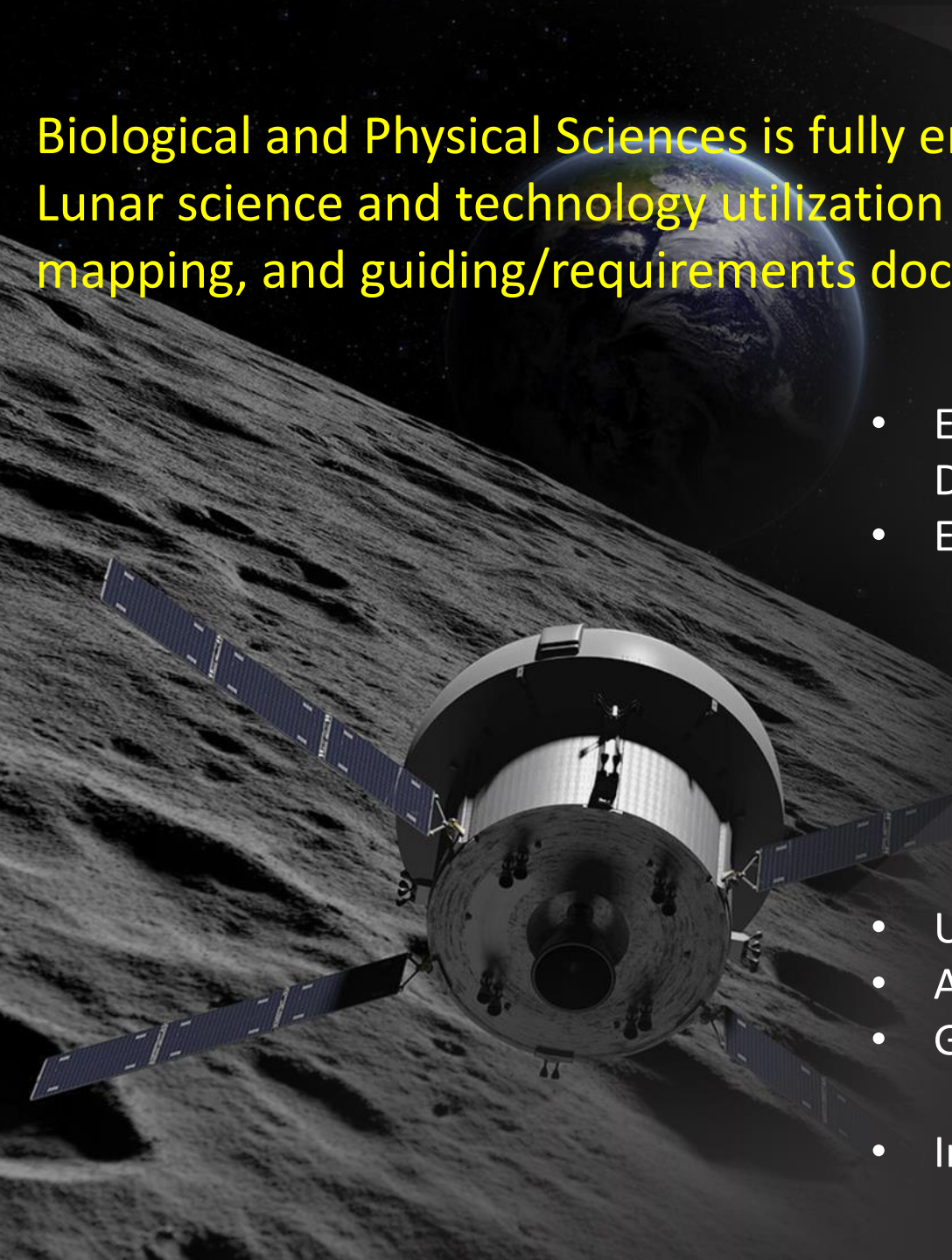
Research Complexity

Mission constraints

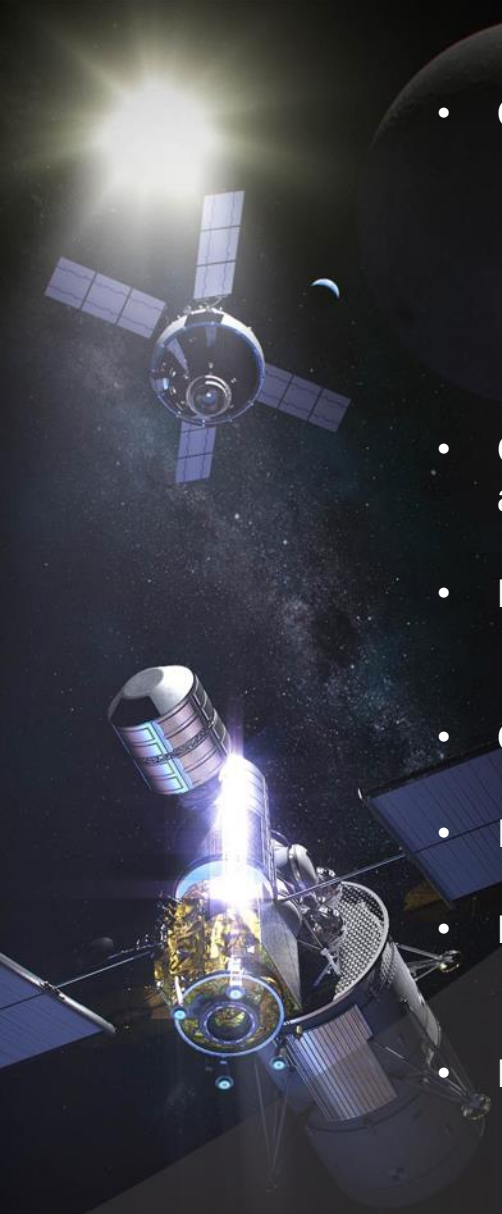




Biological and Physical Sciences is fully engaged in all key NASA cross-Divisional and -Directorate Lunar science and technology utilization teams and strategic and tactical planning, road mapping, and guiding/requirements documents development



- Exploration Science Strategy and Integration Office Office/Lunar Discovery and Exploration Program (ESSIO/LDEP; SMD, PSD)
- Exploration Systems Development Mission Directorate (ESDMD)
  - Technical Integration Office/Science and Technology Utilization (S&TU)
  - Artemis Campaign Development (ACD)
  - Gateway Program
  - Human Landing System Program
  - Common Exploration Systems Development Division
- Utilization Coordination and Integration Group (UCIG; S&TU)
- Artemis Utilization Coordination Panel (AUCP; ACD)
- Gateway Utilization Coordination Panel (International, GUCP)
  - Discipline Science Working Groups
- Internal Artemis Science Team (SMD; PSD)



BPSD 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)

- Communicated space biology and physical sciences unique capabilities and resource needs Artemis, Gateway, and CLPS teams

- BPS science is being included in all applicable lunar science, Artemis, and PRISM solicitation
  - All Artemis flight research solicitation will be released by ESSIO and not the SMD Divisions

- Conducted Lunar Surface Science Workshops with PSD/ESSIO/Lunar and Planetary Institute

- Involved in the NASA 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

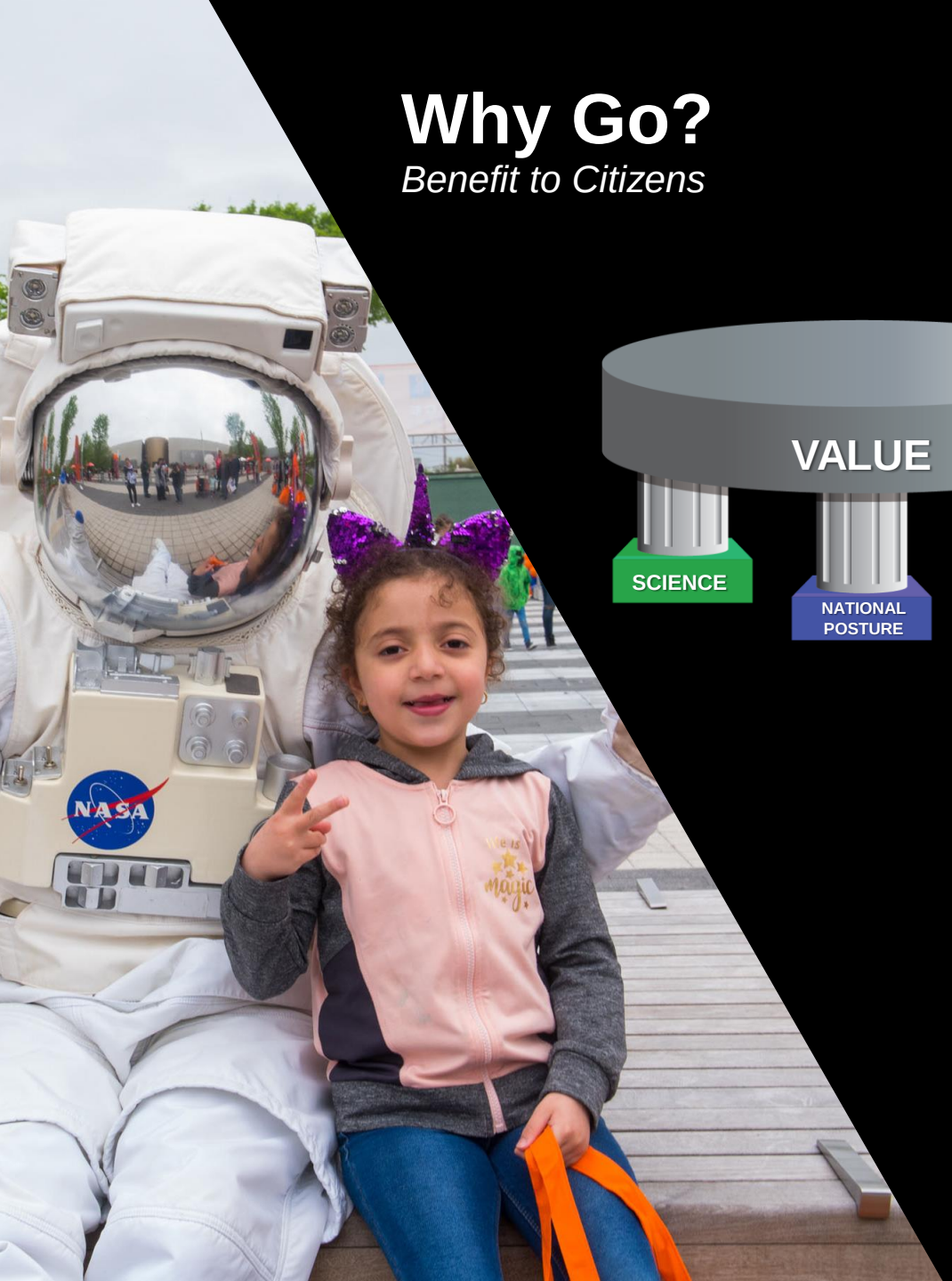
The purpose of NASA's Moon to Mars Objectives effort is to develop and document an objectives-based approach to its human deep space exploration efforts.

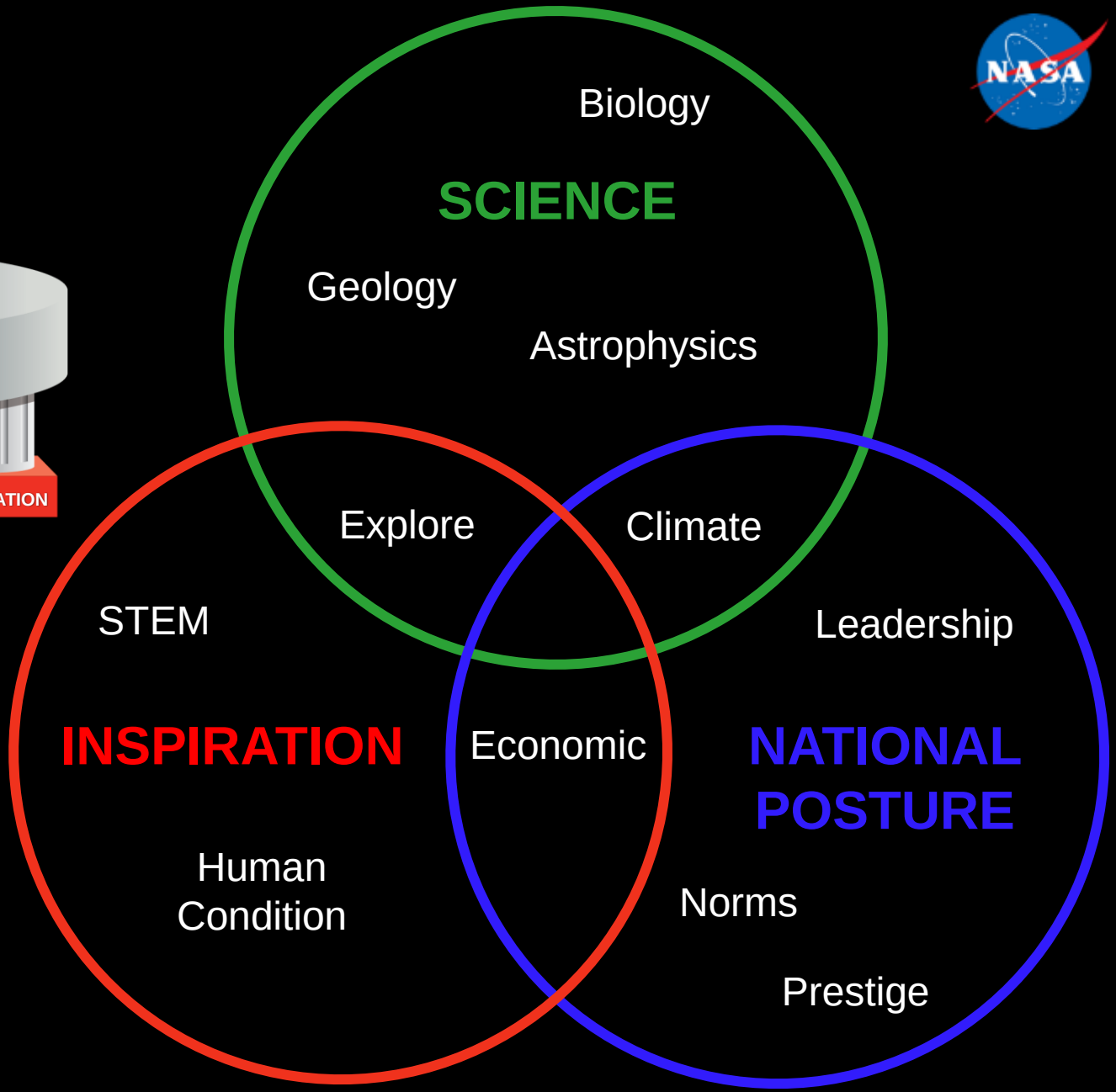
Executive Summary:
https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf

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

Why Go?

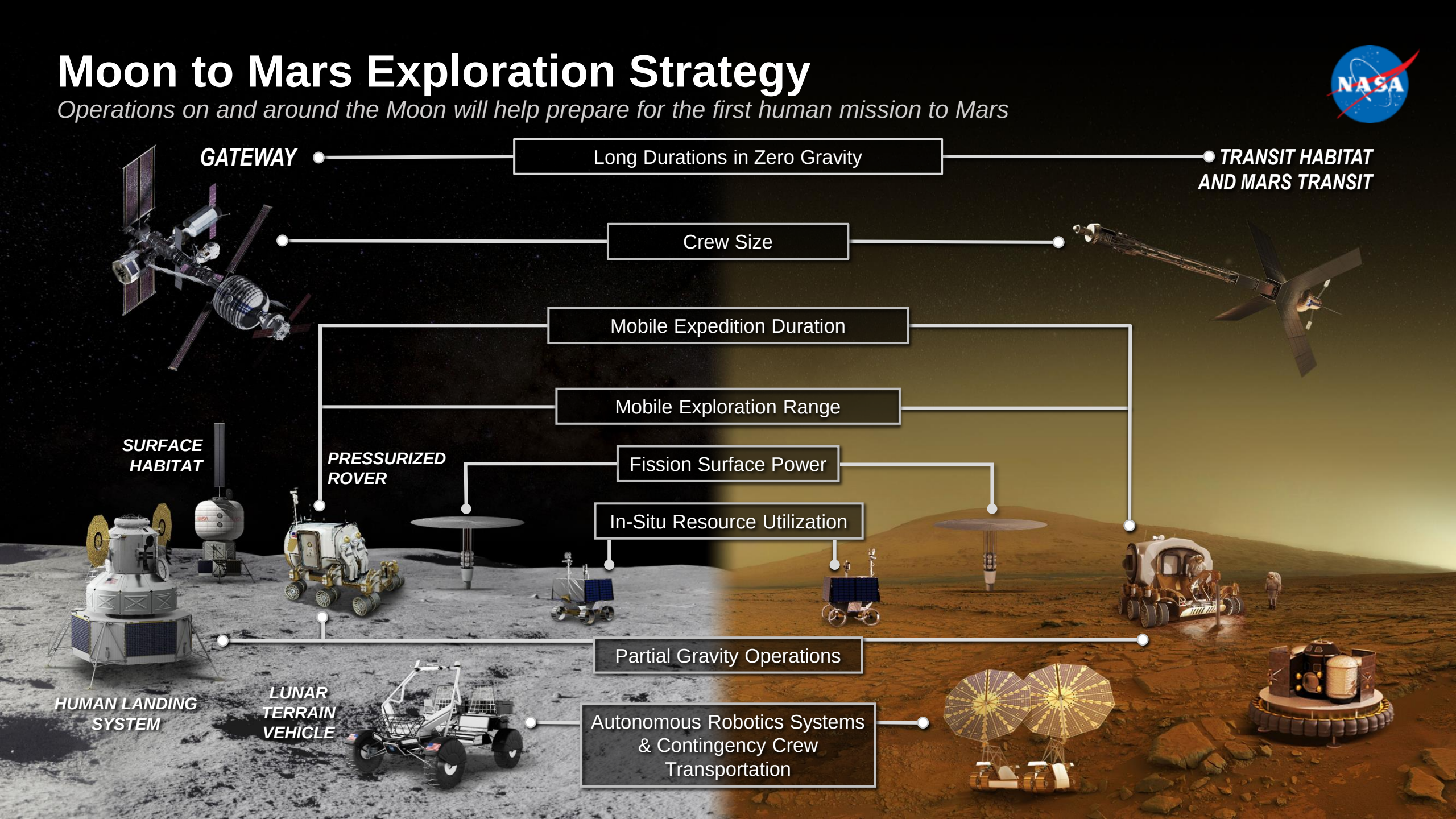
Benefit to Citizens





Moon to Mars Exploration Strategy

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



Architecting from the Right

ARMD

ESDMD

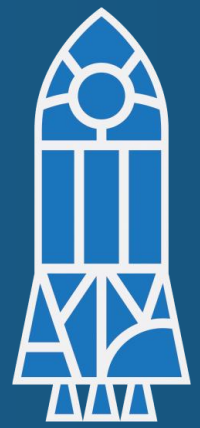
SMD

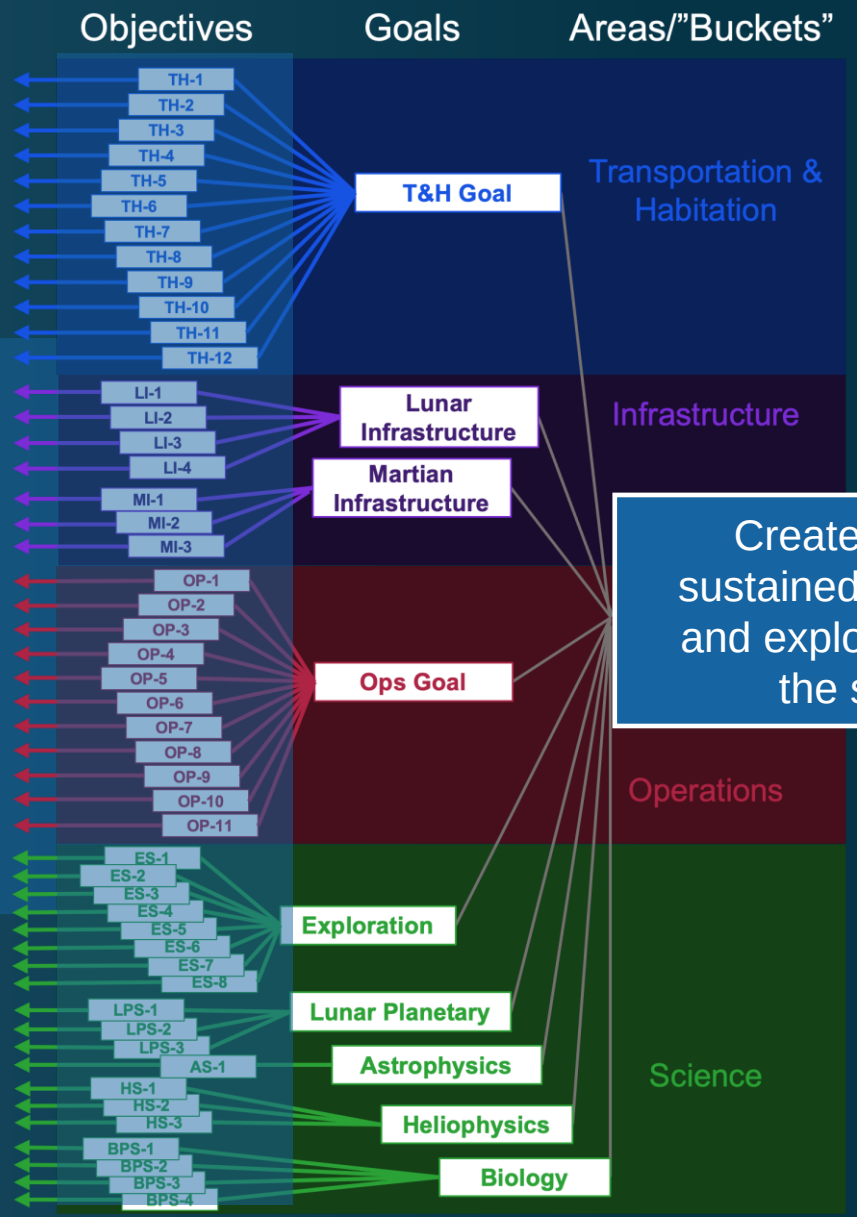
SOMD

STMD

Qualifiers and requirements

Objectives to ESDMD





Create a blueprint for sustained human presence and exploration throughout the solar system

Moon to Mars Strategy Industry Workshop 28 July 2022, J. Free and K. Vogel

Moon to Mars Strategy Objectives

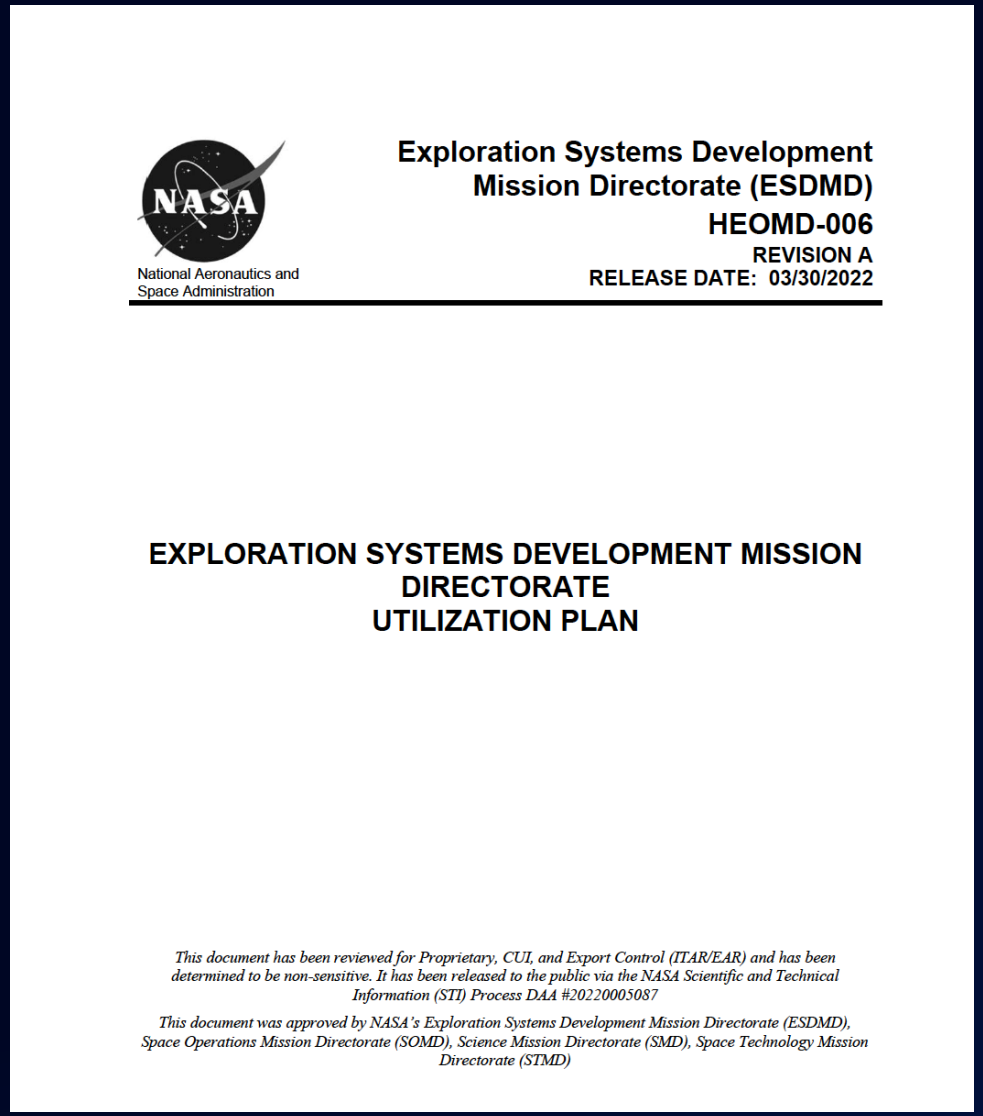
- Recurring Tenets (Common Themes Across the Objectives)
- Lunar and Planetary, Heliophysics Science Objectives
- Human and Biological, Physics and Physical Science Objectives
- Science-Enabling and Applied Science Objectives
- Lunar and Mars Infrastructure Objectives
- Transportation and Habitation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



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:

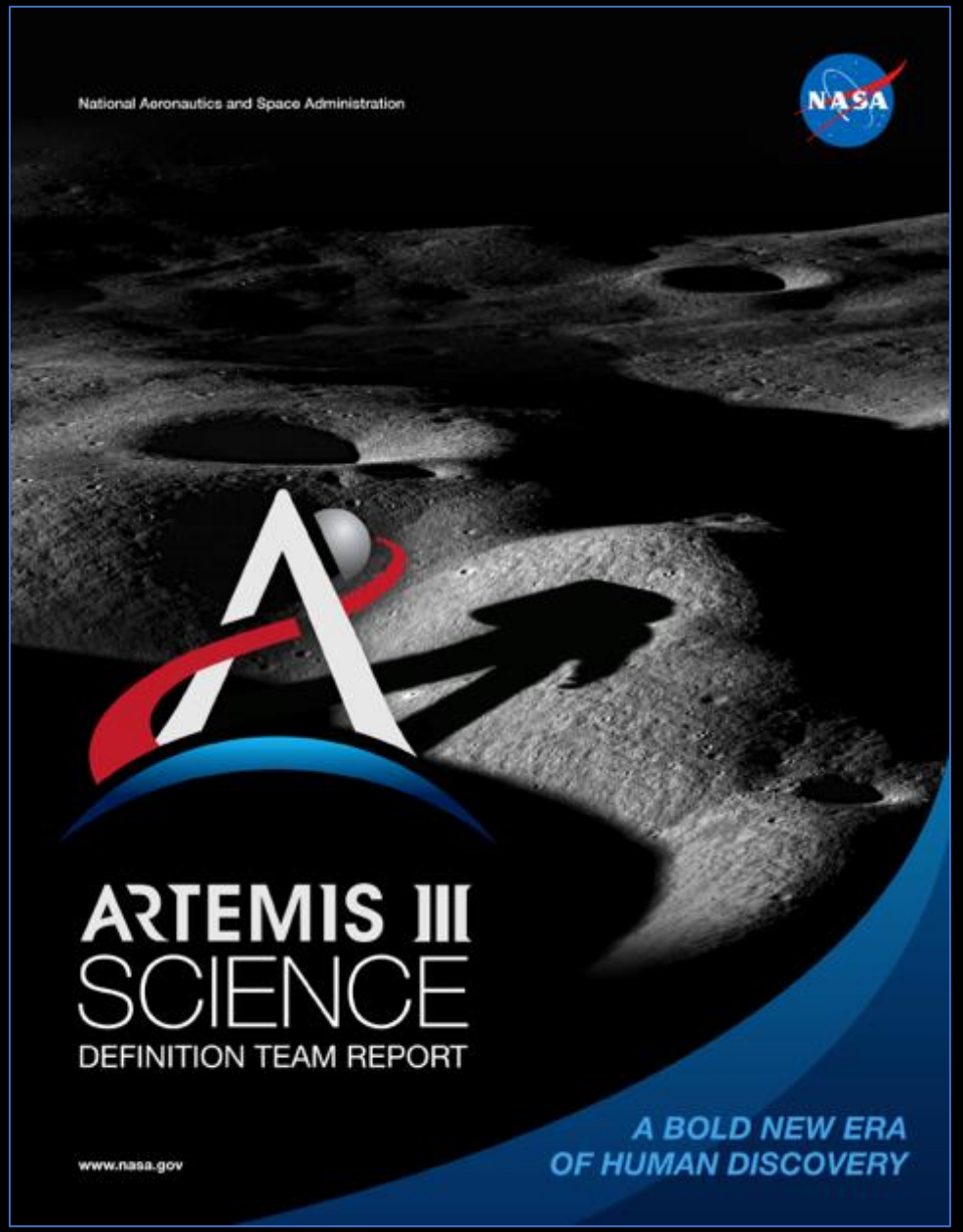
- Human Exploration Utilization Goals and Objectives
- Cornerstone Capabilities that Enable Multiple Objectives
- Phasing of Capabilities and Facility Requirements
- Integrated LEO Mission-Specific Utilization Requirements
- Integrated Artemis Mission Utilization Objectives (Annex 4)
  - Strategic requirements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

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

Artemis III Science Definition Team Report

(available at www.nasa.gov/reports)

Table of Contents



https://www.nasa.gov/sites/default/files/atoms/files/artemis-iii-science-definition-report-12042020c.pdf

Objectives Trace

- NASA Biological and Physical Sciences Decadal Report
  Release during summer, 2023
- Artemis III Science Definition Team Report
  https://www.nasa.gov/sites/default/files/atoms/files/artemis-iii-science-definition-report-12042020c.pdf
- Lunar Exploration Analysis Group (LEAG) Lunar Roadmap
  https://www.lpi.usra.edu/leag/roadmap/
- The Global Exploration Roadmap and 2020 Update
  https://www.nasa.gov/sites/default/files/atoms/files/ger_2018_small_mobile.pdf
- MEPAG Roadmap
  https://mepag.jpl.nasa.gov/reports.cfm?expand=science

Websites

- NASA Space Technology Mission Directorate
  https://www.nasa.gov/directorates/spacetech/about_us/index.html
- NASA Human Research Program and Human Systems Risk Board “5 Hazards of Human Spaceflight
  https://www.nasa.gov/hrp/hazards
- NASA Human Research Program Roadmap, Risks, Knowledge Gaps
  https://humanresearchroadmap.nasa.gov
- Lunar Exploration Analysis Group – Science Community Society
  https://www.lpi.usra.edu/leag/
- Mars Exploration Program Analysis Group (MEPAG) – Science Community Society
  https://mepag.jpl.nasa.gov
- Lunar Surface Innovation Consortium
  https://lsic.jhuapl.edu
- Solar System Exploration Research Virtual Institute (SSERVI)
  https://sservi.nasa.gov

U.S. Lunar Solicitations

- **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 – Proposers identify the landing site
- **SSERVI Cooperative Agreement Notice (CAN-4)**
- **Team ground-only research around lunar exploration and technology themes**
- **F.11 Stand Alone Location Agnostic Payloads and Research Investigations on the Surface of the Moon (SALA PRISM)**
  - ROSES - 2023
  - Science that can be conducted anywhere on the Moon

Evolving and Expanding the BPS Science communities

Building New Scientific Networks and Collaborations for the Artemis Generation

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

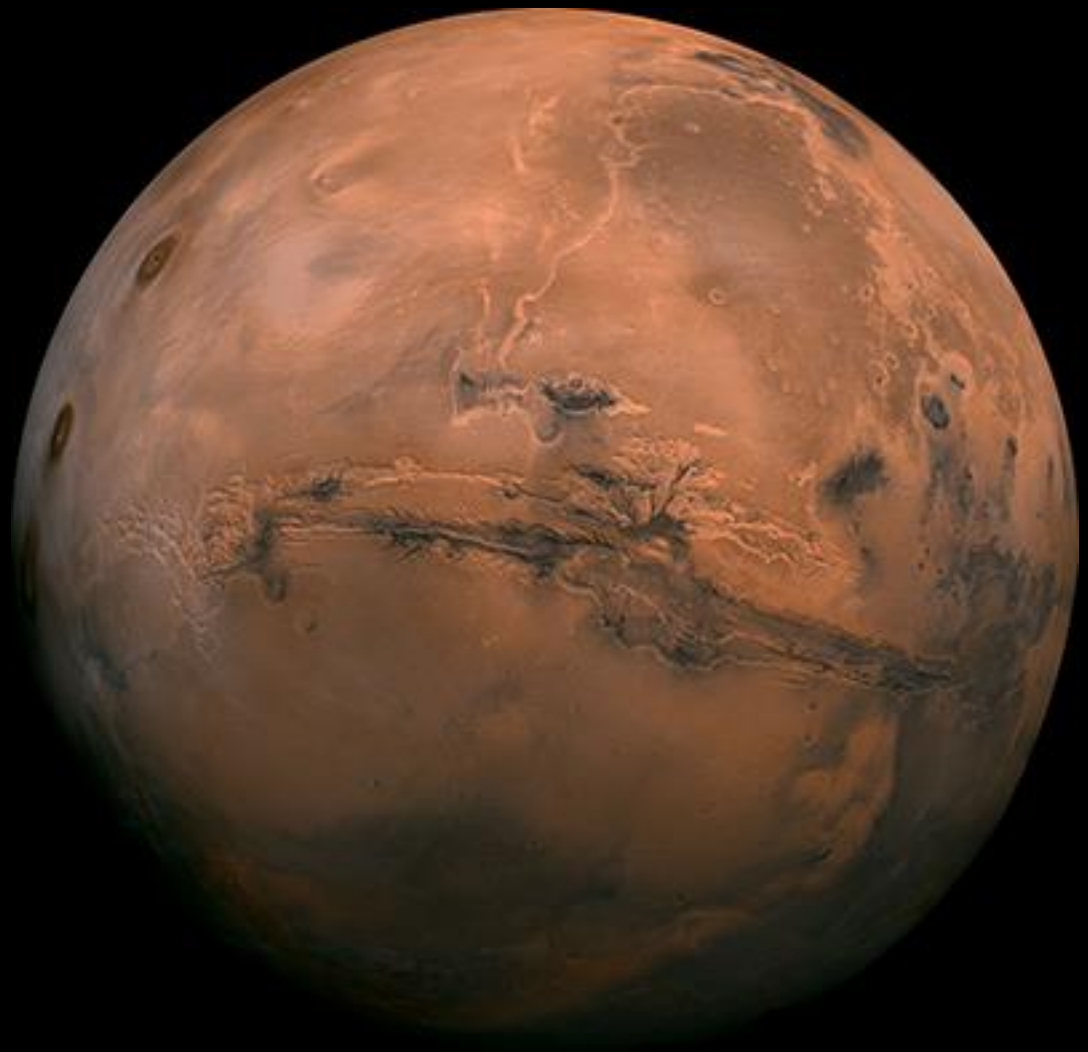
- Lunar Exploration Analysis Group (https://www.lpi.usra.edu/leag/)
- Mars Exploration Program Analysis Group (https://mepag.jpl.nasa.gov/)
- Lunar Surface Innovation Consortium (https://lsic.jhuapl.edu/)
- Solar System Exploration Virtual Research Institute (SSERVI; https://sservi.nasa.gov/)

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

This is a shared responsibility between BPS Division, its Portfolios at the Field Centers, our science communities
NASA SMD places a high priority on science community involvement and input as drivers for its research

The architecture designs and exploration planning is in progress



- Participated in internal NASA and external community activities to capture its science
- Involved in the international ISS4Mars strategic Development
  https://www.sciencedirect.com/science/article/pii/S2352309322000013?dgcid=author
- BPS will hold a Humans On Mars workshop in November, 2023 prior to the ASGSR Annual Meeting to engage the community
  * 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
    - 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
- BPS has been involved in developing the Planetary Protection Roadmap based on knowledge gaps

Acknowledgements

Exploration Science Strategy and Integration Office
Planetary Science Division, Lunar Discovery and Exploration Program and Mars Exploration Program
Exploration Systems Development Mission Directorate, S&TU, Utilization Coordination and Integration Group
Artemis Campaign Development, Artemis Utilization Coordination Group
Gateway Program, Gateway Utilization Coordination Group
Artemis Campaign Development, Human Landing Systems
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 front seat in lunar and Mars exploration and made our science part of the vocabulary of exploration beyond LEO


Thank You

Acronyms

ACD	Artemis Campaign Development
ARMD	Aeronautics Research Mission Directorate
AUCP	Artemis Utilization Coordination Panel
BPS	Biological and Physical Sciences
CAN	Cooperative Agreement Notice
CLD	Commercial Low Earth Orbit Development
ESDMD	Exploration Systems Development Mission Directorate
ESSIO	Exploration Science Strategy and Integration Office
GUCP	Gateway Utilization Coordination Panel
HBS	Human Biological Science
HEO	Human Exploration and Operations
ISS	International Space Station
LEAG	Lunar Exploration Analysis Group
LEO	Low Earth Orbit
LSCI	Lunar Surface Initiative Consortium
LTV	Lunar Traverse Vehicle
MEPAG	Mars Exploration Program Analysis Group
PPS	Physics and Physical Sciences
PRISM	Payloads and Research Investigations on the Surface of the Moon
PSD	Planetary Sciences Division
ROSES	Research Opportunities in Space and Earth Sciences
SMD	Science Mission Directorate
SOMD	Space Operations Mission Directorate
SSERVI	Solar System Exploration Research Virtual Institute
ST&U	Science and Technology Utilization
STMD	Science Technology Mission Directorate
UCIG	Utilization Coordination and Integration Group