

The background of the slide is a composite image of space. On the left, a large, detailed view of the Moon is shown, with its craters and surface texture clearly visible. To its upper left, the reddish-orange planet Mars is partially visible. A small rocket is shown in the distance, moving from left to right, with a bright blue and white trail of exhaust behind it. The sky is a deep, dark blue, filled with numerous small white stars. In the bottom right corner, the silhouette of a person's head and shoulders is visible, looking towards the left. The overall scene is set against a backdrop of a sunset or sunrise, with a gradient of orange and yellow light at the bottom.

**EXPLORESPACE TECH**  
TECHNOLOGY DRIVES EXPLORATION

# NASA's Space Technology Mission Directorate Overview And Moon-to-Mars Strategic Framework

Walt Engelund | Deputy Associate Administrator for Programs, Space Technology Mission Directorate

# Ensuring American global leadership in Space Technology

STMD is building upon the Strategic Technology Framework creating an integrated strategy that shows our investments across technical thrust areas leading to achieving strategic outcomes



**Advance US space technology innovation and competitiveness in a global context**



**Encourage technology driven economic growth with an emphasis on the expanding space economy**



**Inspire and develop a diverse and powerful US aerospace technology community**

# SPACE TECHNOLOGY PORTFOLIO

## EARLY STAGE INNOVATION AND PARTNERSHIPS

- Early Stage Innovation
  - Space Tech Research Grants
  - Center Innovation Fund
  - Early Career Initiative
  - Prizes, Challenges & Crowdsourcing
  - NASA Innovation Advanced Concepts
- Technology Transfer

## SBIR/STTR PROGRAMS

- Small Business Innovation Research
- Small Business Technology Transfer

## TECHNOLOGY MATURATION

- Game Changing Development
- Lunar Surface Innovation Initiative

## TECHNOLOGY DEMONSTRATION

- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities

Technology Drives Exploration

LOW

MID

Technology Readiness Level

HIGH

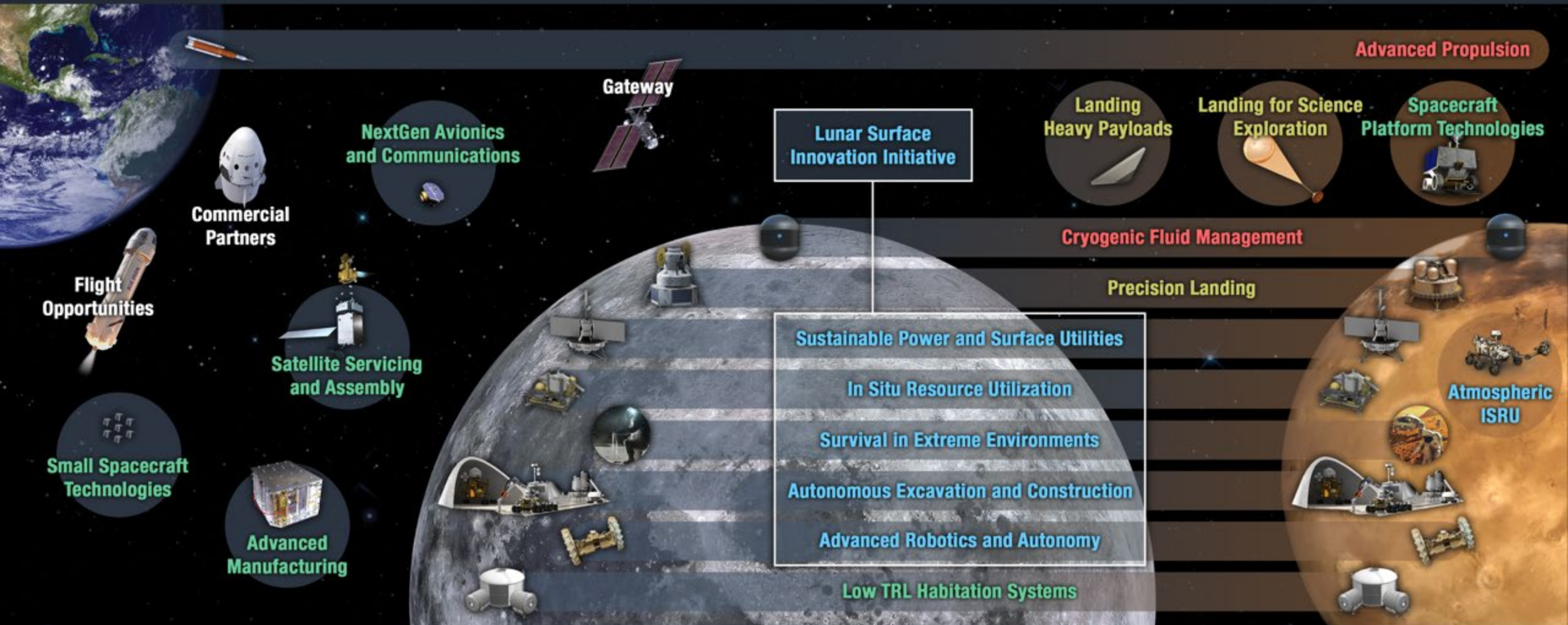
# Ensuring American Global Leadership in Space Technology

**Rapid, Safe, and Efficient  
Space Transportation**

**Expanded Access to Diverse  
Surface Destinations**

**Sustainable Living and Working  
Farther from Earth**

**Transformative Missions  
and Discoveries**



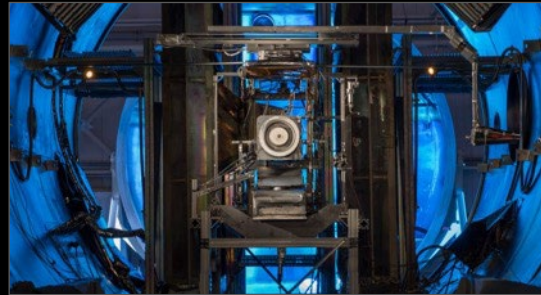
## Technology Drives the Space Economy

# STMD FY 2022-2023 Highlights



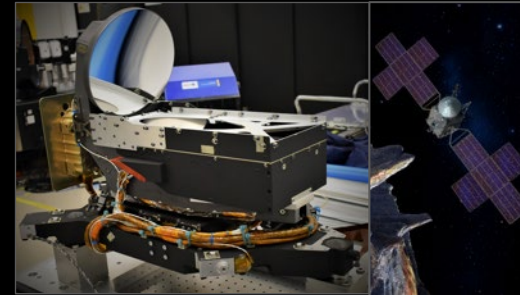
## Flight Opportunities and Small Spacecraft Technology

- 35+ suborbital and small spacecraft flights planned '22 - '23
- CAPSTONE lunar mission launch in May '22 in support of Artemis program



## Solar Electric Propulsion *April 2023*

Qualification thruster #1  
assembly complete



## Deep Space Optical Communications

- Delivered in June 2021
- Tech demo flying with Psyche mission to a metal asteroid (Oct 2023)



## LOFTID Mission *November 2022*

In partnership with ULA, tested an inflatable heat shield - the largest blunt body aeroshell ever demonstrated

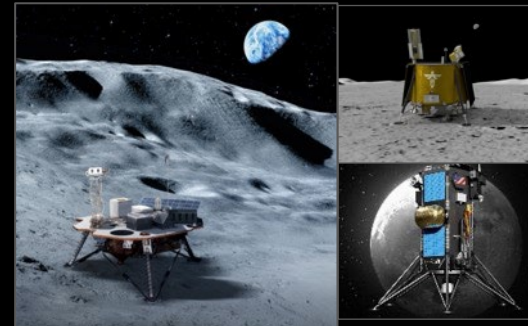


## DARPA/NASA Nuclear Thermal Propulsion Flight Demo Demonstration Rocket for Agile Cislunar Operations (DRACO)



## Cryogenic Fluid Management *FY 2023-2026*

Four (4) flight technology demonstrations



## CLPS Missions *2024-25*

Space tech has over 25 payloads manifested on commercial robotic landers with more opportunity in the future (Intuitive Machines, Firefly etc.)



## Navigation Doppler LiDAR (NDL) LaRC NDL CLPS Demos on Astrobotic and Intuitive Machines and commercialization through Psionic

# Near-term Lunar Technology Demos

*Early lunar surface demonstrations, via the Commercial Lunar Payload Services (CLPS) Program, are key opportunities to mature the key capabilities required for NASA and industry.*

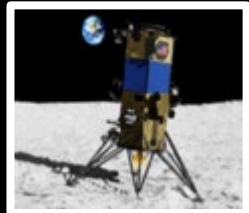
**Intuitive Machines (IM)-2 Mission**  
Late 2024



**Polar Resources Ice-Mining Experiment (PRIME-1)**



**LTE Proximity Comms**  
(Tipping Point w/Nokia)

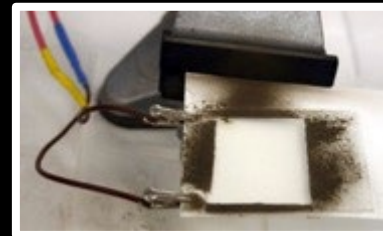


**Deployable Lunar Hopper**  
(Tipping Point w/IM)

**CLPS 19D Mission (Firefly)**  
Late 2024



**LaRC Stereo Camera for Lunar Plume Surface Studies (SCALPSS)**



**Electrodynamic Dust Shield (EDS)**

**CLPS CP11 Mission (IM)**  
Early 2025



**Cooperative Autonomous Distributed Robotic Explorers (CADRE)**

National Aeronautics and  
Space Administration



# NASA'S MOON TO MARS STRATEGY AND OBJECTIVES DEVELOPMENT

A blueprint for sustained  
human presence and  
exploration throughout  
the Solar System



# Cross-Directorate Federated Board



The Federated Board (FB) seeks to drive **consensus**, promote efficient **conflict resolution**, help interpret **strategic guidance** and expectations from Agency leadership, and provide **advice** to Mission Directorate/Agency leadership, including governance councils. It is not a decision-making body.

*\*Revised scope emphasized structured vetting and advisory functions. Architecture ownership resides in the MD's.*

## FEDERATED BOARD

Executive Secretariat

Chair

ARMD

SOMD

ESDMD

A-Suite  
DSA

SMD

STMD

Auxiliary Members:  
As Required

### CORE FUNCTIONS

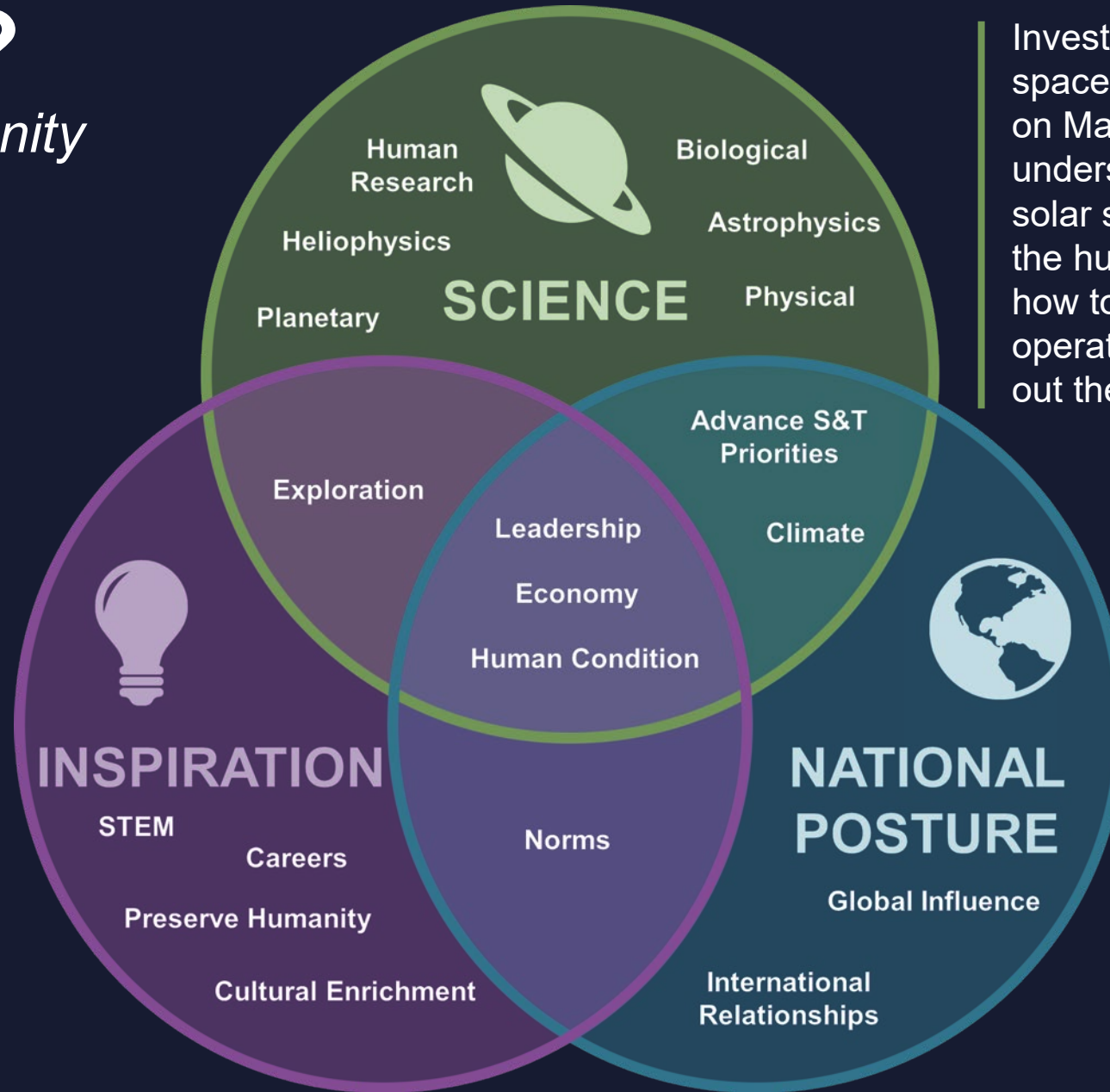
- Coordinate
- Review
- Advise
- Advocate

“Ensures Agency priorities and general architectural direction are tightly/efficiently integrated for Artemis/M2M and other activities that require coordination across the Mission Directorates (MDs)”



# Why Go?

*Benefits to Humanity*



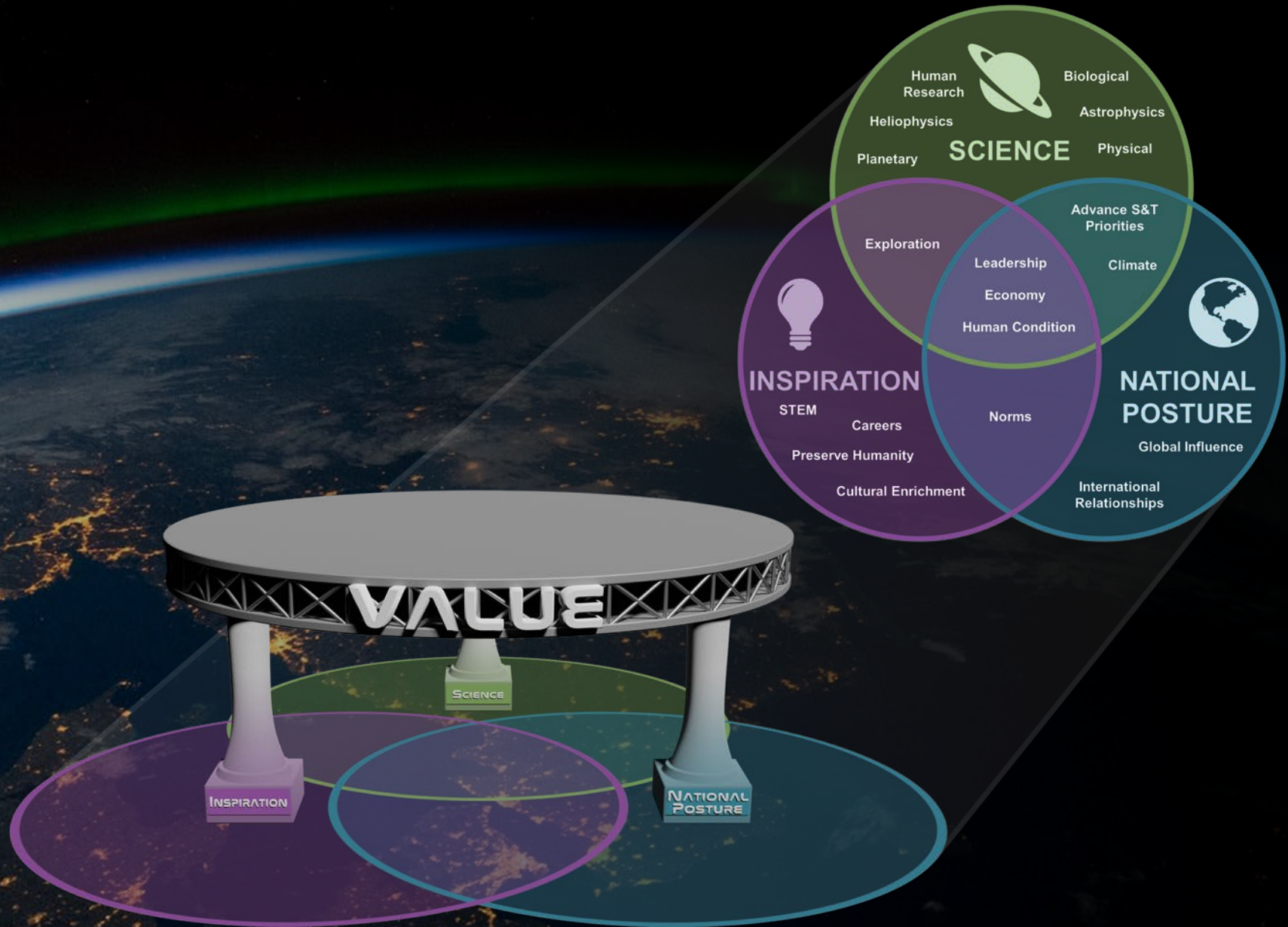
Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the solar system, the Earth, the human body, and how to perform new operations while we are out there exploring.

Accepting audacious challenges and succeeding through perseverance and tenacity in the face of adversity motivates current and future generations to dare mighty things.

What we choose to do, how we do those things, and who we do them with greatly impacts our place in the world today, our quality of life, and our possibilities for the future.

# Why Go?

*Benefit to Citizens*

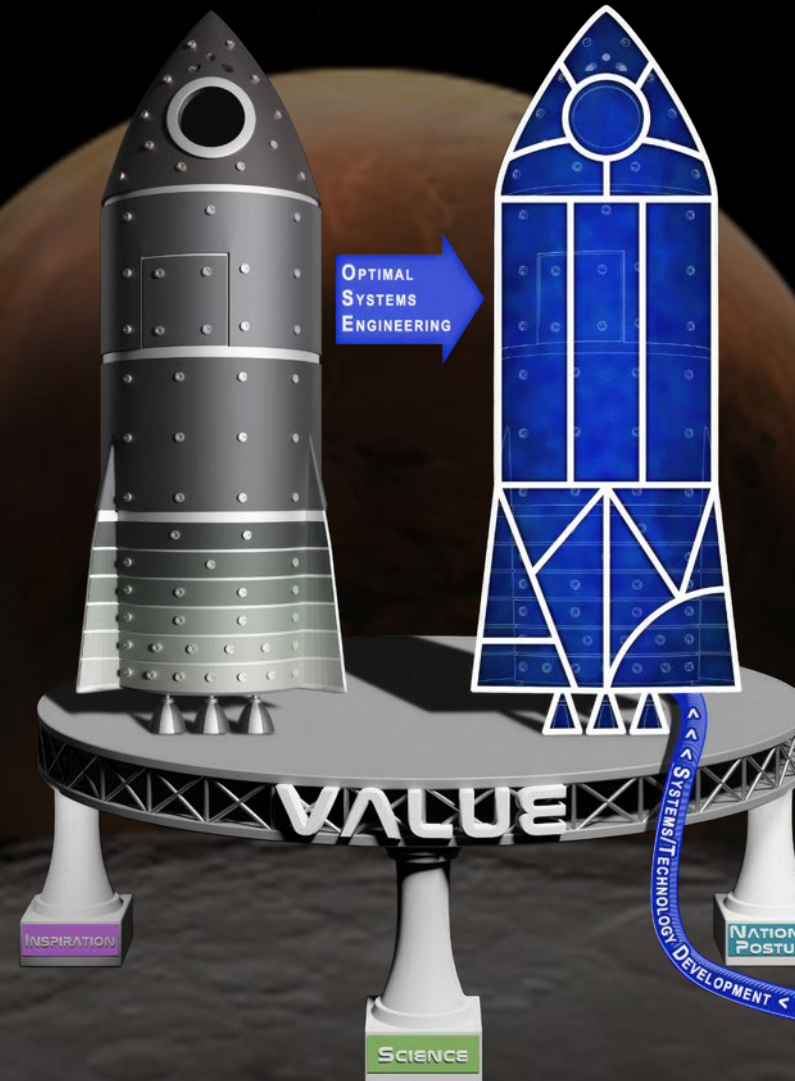


# WHAT

- Rigorously Developed
- Detailed
- Consistent

# HOW

- Elements required to create the "What"
- Defined and Managed by a Program Office
- Approved by Leadership
- Sufficient Funding Required



# WHY



# Historical Context

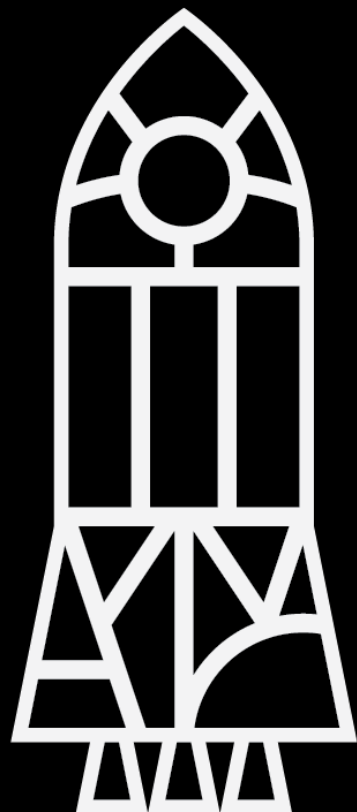


30+ year roller-coaster ride for Moon to Mars (M2M) development

Widespread stress/anxiety in the wake of Constellation cancellation

Capability-based approach does not fully support a long-term strategy to Mars.

## The M2M Plan



Limited funding received



Attempts to “stick with the plan” behind the scenes...



- Initially, prioritized and prepared for more fruitful days
- Led to decentralized efforts
- Over time lose clarity on overall plan

**Need objective-based approach**

Must think **strategically**... with **resilience/flexibility** in mind... to better achieve **unity of purpose**

# Hindrances to Effective Systems Engineering



Changing and/or broad goals

External Pressures

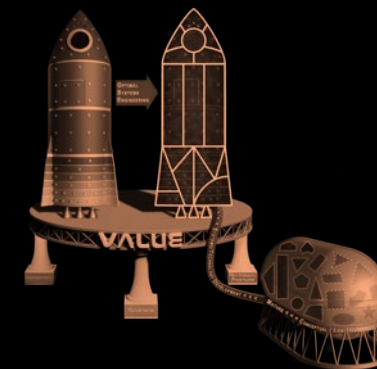
Insufficient Funding

Stovepipes

Fears of being cut

Poor/Restricted Communication

Distributed Motivations





**Science**



**Transportation & Habitation**



**Infrastructure**



**Operations**

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

# Methodology Principles of the M2M Strategy



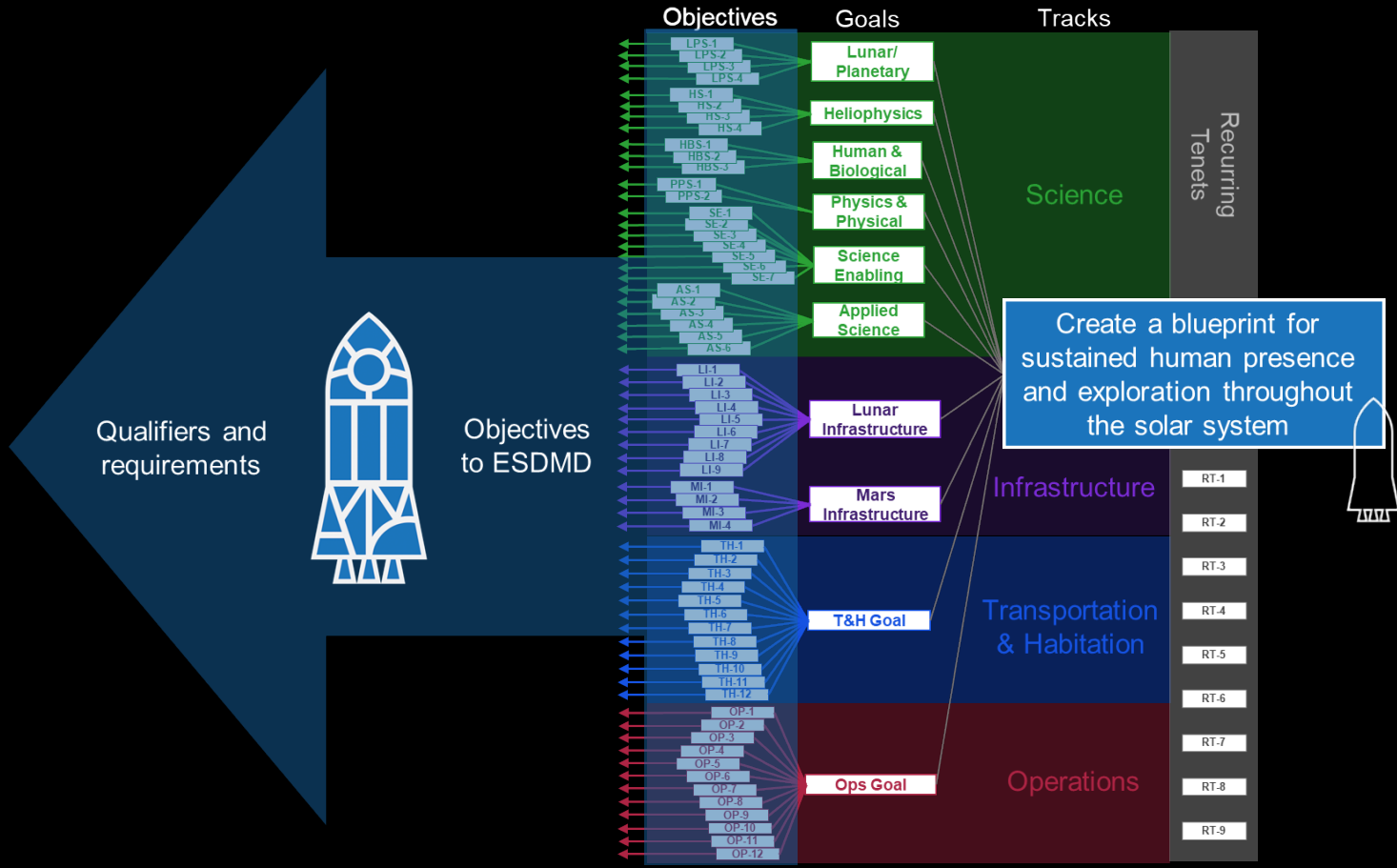
Objective-Based Approach

Architect from the Right

Constancy of Purpose

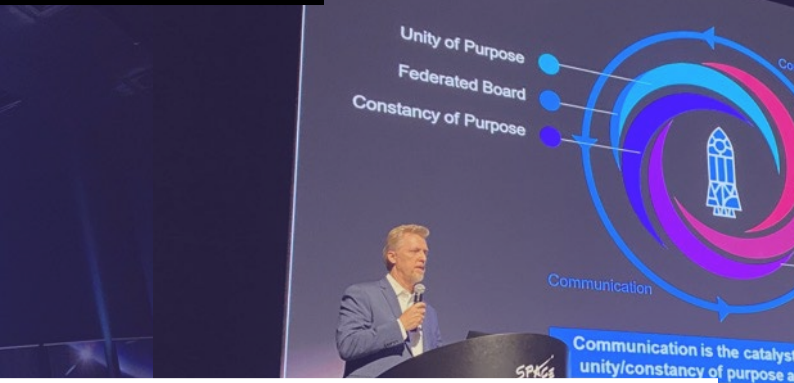
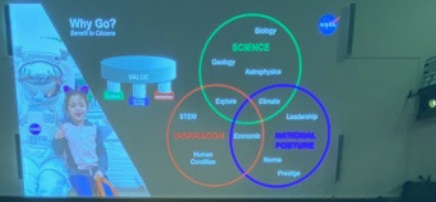
Unity of Purpose

Enhanced Communication & Engagement





# Stakeholder Outreach



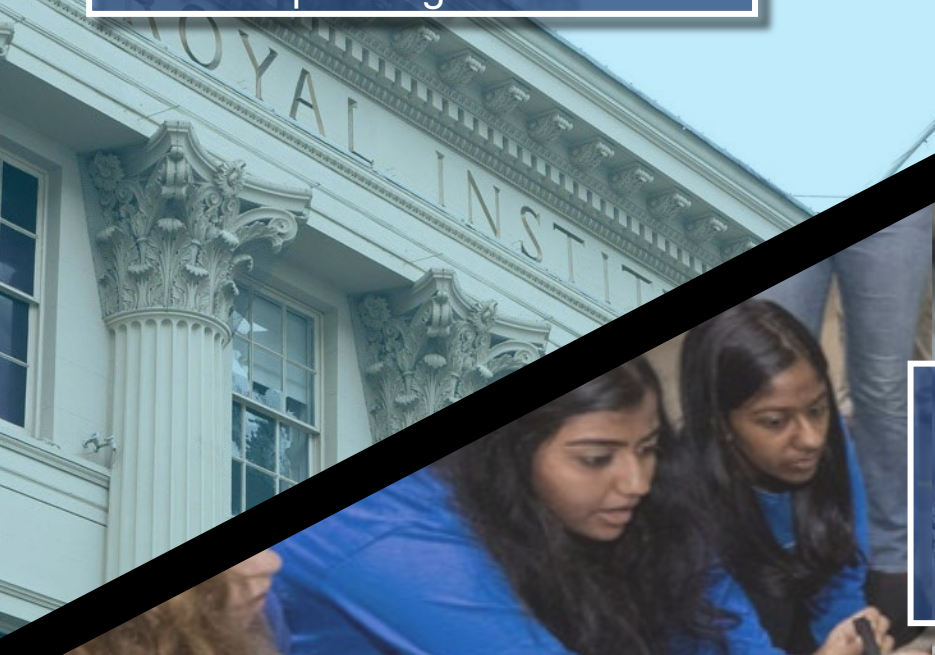
**International Workshops**

- London, U.K.
- July 2022, 2023
- Feb 2024, Washington DC
- 22 Space Agencies

**Over 5,000 inputs**

**US Workshops**

- June 2022, Houston, TX
- July 2023, National Harbor, MD
- Feb 2024, Washington, DC
- 900 responses
- 32 organizations



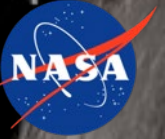
**NASA@Work**

- Virtual campaign
- May 16th – June 3rd , 2022
- 156 inputs, 391 votes





# Revised M2M Objectives Roll-up



- 63 Top-Level Objectives across 10 Top-Level Goals

- 26 Science
- 13 Infrastructure
- 12 Transportation & Habitation
- 12 Operations

- 9 Recurring Tenets (RT)

- Common themes across objectives

- Updated Glossary



- RT-1: International Collaboration
- RT-2: Industry Collaboration
- RT-3: Crew Return
- RT-4: Crew Time
- RT-5: Maintainability and Reuse
- RT-6: Responsible Use
- RT-7: Interoperability
- RT-8: Leverage Low Earth Orbit
- RT-9: Commerce and Space Development

**Science Objectives (1 of 4)**

**Lunar/Planetary Science (LPS) Goal:** Address high priority planetary science questions that are best accomplished by on-site human explorers on and around the Moon and Mars, aided by surface and orbiting robotic systems.

- LO-1-1: Uncover the extent of water on the Moon and Mars, including how and where it is stored, and whether it is available for use by humans and other robotic systems.
- LO-1-2: Assess the habitability of the Moon and Mars, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-1-3: Investigate the geology and mineralogy of the Moon and Mars, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-1-4: Investigate the history of the Moon and Mars, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-1-5: Investigate the geology and mineralogy of the Moon and Mars, including the extent of the habitable zone, the availability of resources, and the potential for life.

**Heliophysics Science (HS) Goal:** Address high priority heliophysics science and space weather questions that are best accomplished using a combination of human explorers and robotic systems at the Moon, at Mars, and in deep space.

- LO-2-1: Investigate the structure and dynamics of the solar wind, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-2-2: Investigate the structure and dynamics of the solar wind, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-2-3: Investigate the structure and dynamics of the solar wind, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-2-4: Investigate the structure and dynamics of the solar wind, including the extent of the habitable zone, the availability of resources, and the potential for life.
- LO-2-5: Investigate the structure and dynamics of the solar wind, including the extent of the habitable zone, the availability of resources, and the potential for life.

**Human Lunar Activity (HLA) Goal:** Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.

- LO-3-1: Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.
- LO-3-2: Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.
- LO-3-3: Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.
- LO-3-4: Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.
- LO-3-5: Demonstrate industrial scale (ISRU) capabilities in support of continuous human lunar presence and a robust lunar economy.

**Human Mars Activity (HMA) Goal:** Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.

- LO-4-1: Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.
- LO-4-2: Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.
- LO-4-3: Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.
- LO-4-4: Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.
- LO-4-5: Demonstrate industrial scale (ISRU) capabilities in support of continuous human Mars presence and a robust Mars economy.

**Recurring Tenets**

Common themes across objectives

- RT-1: International Collaboration: partner with international community to address common goals and objectives
- RT-2: Industry Collaboration: partner with U.S. industry to achieve common goals and objectives
- RT-3: Crew Return: return crew safely to Earth while mitigating external impacts to crew health
- RT-4: Crew Time: maximize crew time available for science and engineering activities while ensuring mission duration
- RT-5: Maintainability and Reuse: utilize practical design systems for maintainability, reuse, and/or recycling to support the long-term sustainability of operations and increase Earth sustainability
- RT-6: Responsible Use: conduct all activities for the exploration and use of outer space for peaceful purposes consistent with international obligations, and principles of responsible behavior in space
- RT-7: Interoperability: enable interoperability and compatibility between operations and provide standards among systems, elements, and crews throughout the mission
- RT-8: Leverage Low Earth Orbit: leverage infrastructure in Low Earth Orbit to support M2M activities
- RT-9: Commerce and Space Development: foster the expansion of the economic sphere beyond Earth orbit to support U.S. industry and innovation

# Infrastructure Objectives (1 of 2)



**Lunar Infrastructure (LI) Goal:** Create an interoperable global lunar utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing science objectives and testing for Mars.

LI-1<sup>L</sup>: Develop an incremental lunar power generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.

LI-2<sup>L</sup>: Develop a lunar surface, orbital, and Moon-to-Earth communications architecture capable of scaling to support long term science, exploration, and industrial needs.

LI-3<sup>L</sup>: Develop a lunar position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs.

LI-4<sup>L</sup>: Demonstrate advanced manufacturing and autonomous construction capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-5<sup>L</sup>: Demonstrate precision landing capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-6<sup>L</sup>: Demonstrate local, regional, and global surface transportation and mobility capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-7<sup>L</sup>: Demonstrate industrial scale ISRU capabilities in support of continuous human lunar presence and a robust lunar economy.

LI-8<sup>L</sup>: Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing maximizing the use of in-situ resources, and support systems needed for continuous human/robotic presence.

LI-9<sup>L</sup>: Develop environmental monitoring, situational awareness, and early warning capabilities to support a resilient, continuous human/robotic lunar presence.

# Infrastructure Objectives (2 of 2)

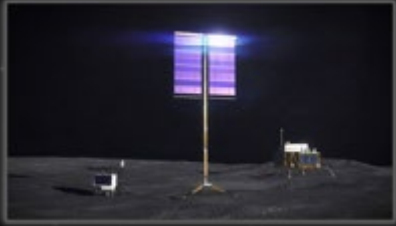


***Mars Infrastructure (MI) Goal:*** Create essential infrastructure to support initial human Mars exploration campaign.

- MI-1<sup>M</sup>: Develop Mars surface power sufficient for an initial human Mars exploration campaign.
- MI-2<sup>M</sup>: Develop Mars surface, orbital, and Mars-to-Earth communications to support an initial human Mars exploration campaign.
- MI-3<sup>M</sup>: Develop Mars position, navigation and timing capabilities to support an initial human Mars exploration campaign.
- MI-4<sup>M</sup>: Demonstrate Mars ISRU capabilities to support an initial human Mars exploration campaign.

# STMD Investment Areas Supporting Lunar Infrastructure Objectives

Creating an interoperable global lunar utilization infrastructure and essential infrastructure to support initial human Mars exploration campaign



LI-1<sup>L</sup>: Develop an incremental **lunar power** generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.



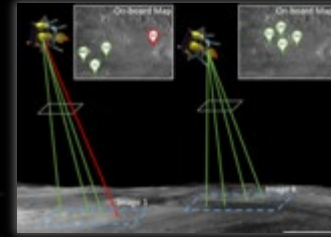
LI-2<sup>L</sup>: Develop a lunar surface, orbital, and Moon-to-Earth **communications** architecture capable of scaling to support long term science, exploration, and industrial needs.



LI-3<sup>L</sup>: Develop a lunar **position, navigation and timing** architecture capable of scaling to support long term science, exploration, and industrial needs.



LI-4<sup>L</sup>: Demonstrate **advanced manufacturing and autonomous construction** capabilities in support of continuous human lunar presence and a robust lunar economy.



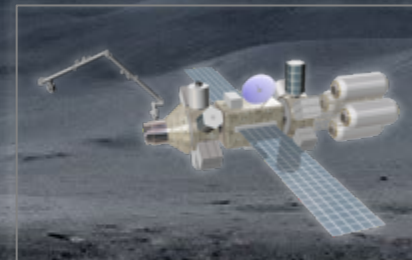
LI-5<sup>L</sup>: Demonstrate **precision landing** capabilities in support of continuous human lunar presence and a robust lunar economy.



LI-6<sup>L</sup>: Demonstrate local, regional, and global **surface transportation and mobility** capabilities in support of continuous human lunar presence and a robust lunar economy.



LI-7<sup>L</sup>: Demonstrate industrial scale **ISRU** capabilities in support of continuous human lunar presence and a robust lunar economy.



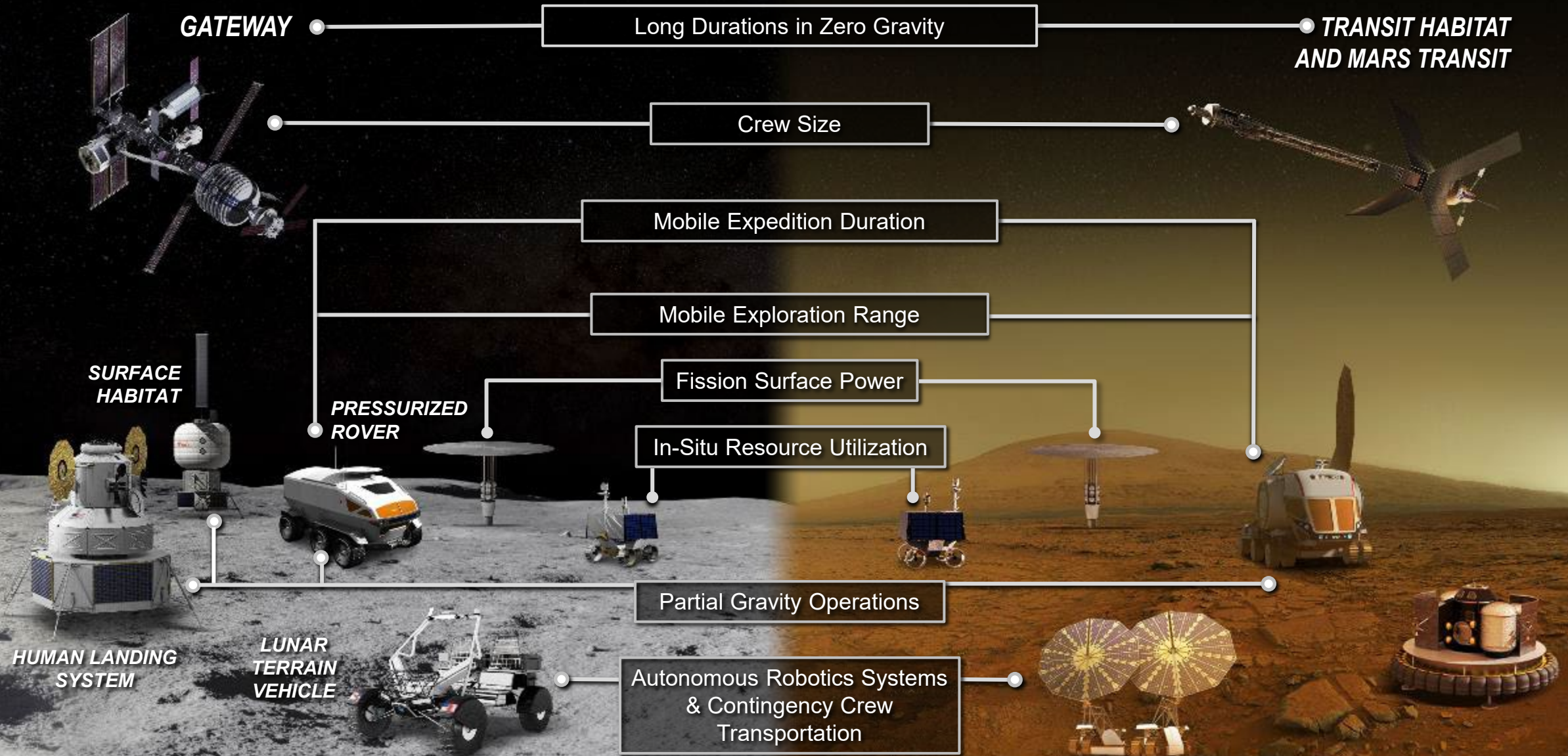
LI-8<sup>L</sup>: Demonstrate technologies supporting cislunar orbital/surface depots, **construction and manufacturing** maximizing the use of in-situ resources, and support systems needed for continuous human/robotic presence.



LI-9<sup>L</sup>: Develop **environmental monitoring, situational awareness**, and early warning capabilities to support a resilient, continuous human/robotic lunar presence.

# Moon to Mars Exploration Strategy

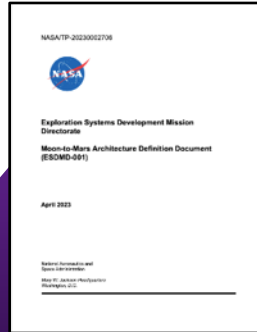
Scientific exploration and operations at the Moon will help prepare for the first human missions to Mars



# Downloadable Products

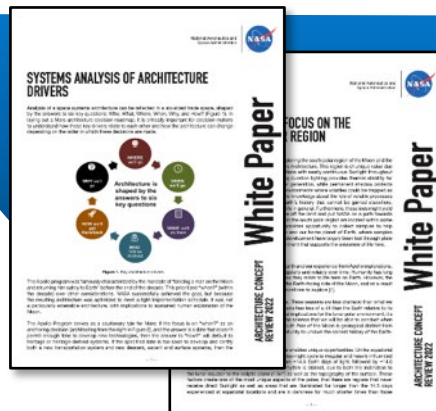


[www.nasa.gov/MoonToMarsArchitecture](http://www.nasa.gov/MoonToMarsArchitecture)



**Architecture Definition Document**  
Detailed documentation of a snapshot of NASA's human spaceflight architecture and exploration strategy

**Moon to Mars Architecture Summary**  
High-level overview of NASA's Moon to Mars architecture and exploration strategy



**White Papers**  
Six papers on architecture study details for frequently discussed topics



We came in peace.

**We return for all humanity.**

**@NASAArtemis**

