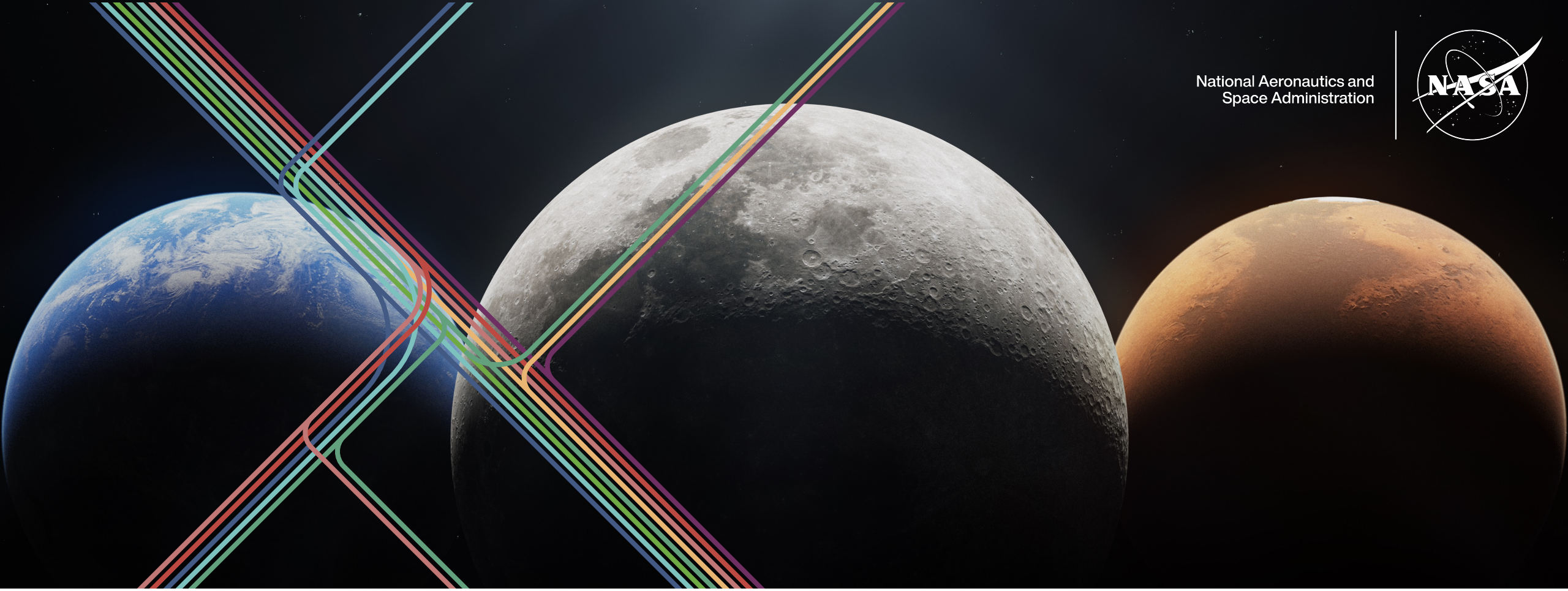


National Aeronautics and Space Administration

2025 Moon to Mars Architecture Workshops

Nujoud Merancy
Deputy Associate Administrator
Strategy and Architecture
NASA – ESDMD - SAO

Welcome!

National Aeronautics and Space Administration

- Welcome to the 2025 Moon to Mars Architecture workshops for International Partners
- Your input is critically important to the continued success of the architecture effort
- Feedback continues to inform the evolution of the architecture
- Participants include
  - …over 70 registrants
  - …representing over 20 space agencies
  - …emerging and established agencies
- **We look forward to your participation**

Moon to Mars Architecture

National Aeronautics and Space Administration

Beginning in 2022, NASA reset the strategic effort to enable human exploration of deep-space

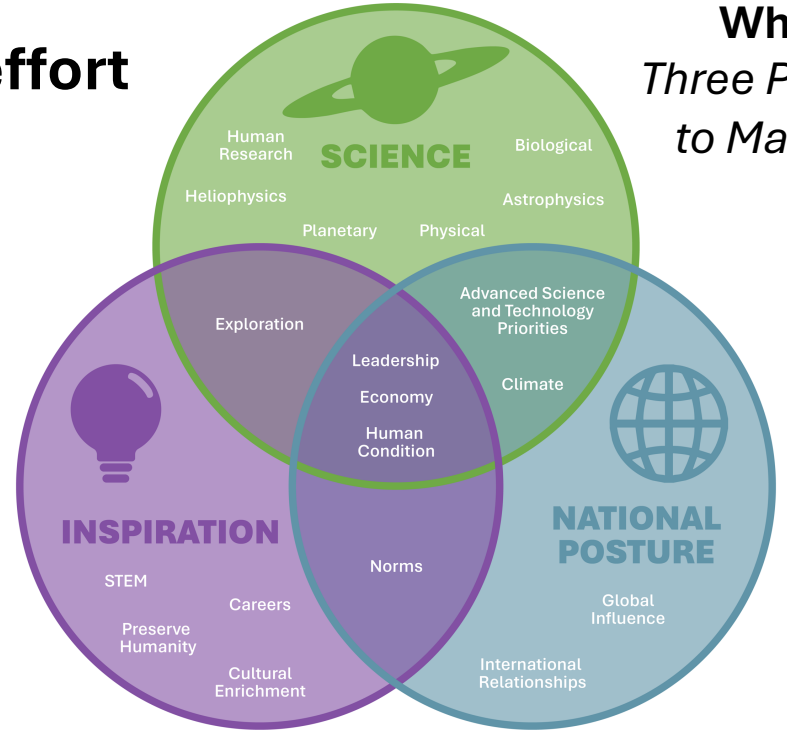
- Objectives based architecting
- Enable flexibility and resilience
- Rooted in systems engineering fundamentals

All of Agency, All of Stakeholders

- Coordinated and collaborative
- Enhanced communication
- Commitment to transparency

Why We Explore

Three Pillars of Moon to Mars Exploration



NASA's Moon to Mars Strategy and Objectives Development

https://go.nasa.gov/4fXVGeY

Architecting from the Right

National Aeronautics and Space Administration

Programs & Projects

etc …

Architecture

The high-level unifying structure that defines a system. It provides a set of rules, guidelines, and constraints that defines a cohesive and coherent structure consisting of constituent parts, relationships and connections that establish how those parts fit and work together.

Use Cases

Operations executed to produce desired objective needs

Functions

Actions performed to effect desired uses cases

Moon to Mars Objectives

Science | Enhance our understanding of planetary and solar, human biology, and physical sciences in unique environments of the Moon, Mars, and deep space.

Infrastructure | Develop the power, communications, navigation, resource utilization, and other capabilities necessary to support human exploration.

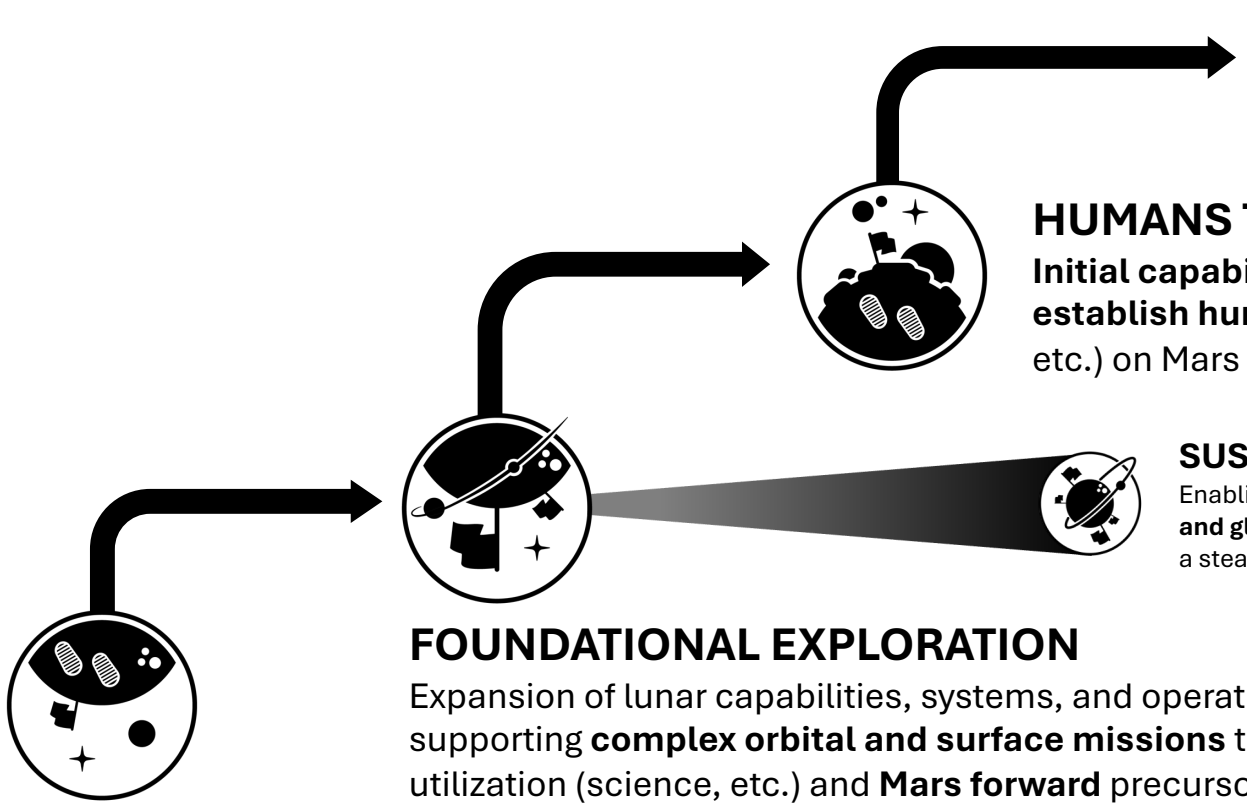
Transportation and Habitation | Create the systems necessary for humans to travel to the Moon and Mars, live and work there, and return to Earth safely.

Operations | Conduct crewed missions to gradually build technologies and capabilities to live and work on planetary surfaces other than Earth.

Rigorous systems engineering applied to identify the needs, understand relationships and identify gaps between systems to identify most effective and efficient solutions toward achieving long-term vision.

Architecture Segments

National Aeronautics and Space Administration



FUTURE SEGMENTS
Continued development and exploration at Mars and beyond for sustained exploration of the cosmos.

HUMANS TO MARS
Initial capabilities, systems, and operations necessary to **establish human presence** and initial utilization (science, etc.) on Mars and continued exploration.

SUSTAINED LUNAR EVOLUTION
Enabling capabilities, systems, and operations to support **regional and global utilization** (science, etc.), **economic opportunity**, and a steady cadence of human presence at the Moon.

FOUNDATIONAL EXPLORATION
Expansion of lunar capabilities, systems, and operations supporting **complex orbital and surface missions** to conduct utilization (science, etc.) and **Mars forward** precursor missions.

HUMAN LUNAR RETURN
Initial capabilities, systems, and operations necessary to **re-establish human presence** and initial utilization (science, etc.) on and around the Moon.

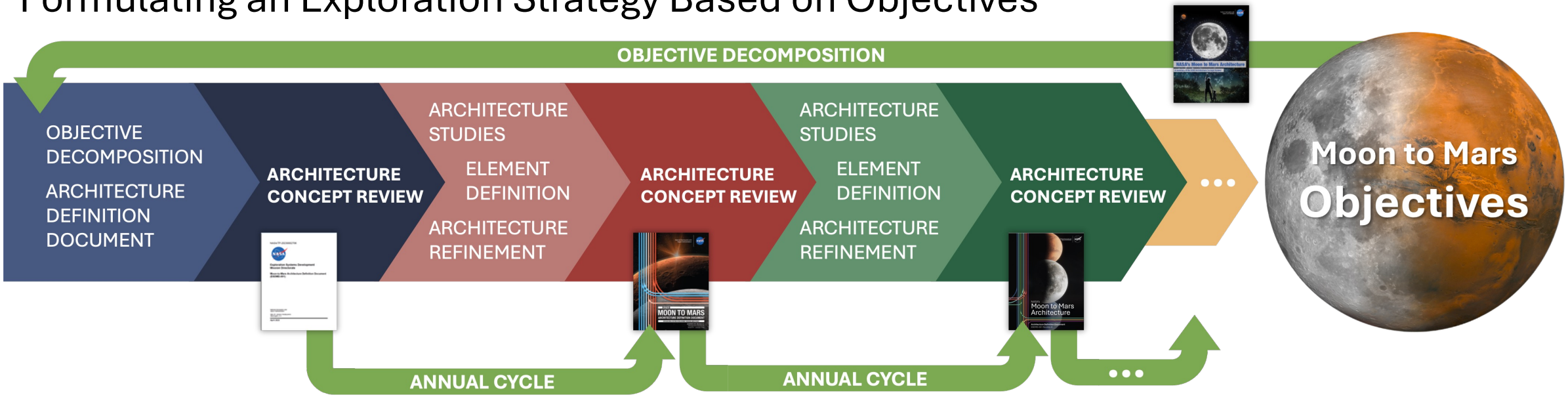
Segment | A portion of the architecture that integrates sub-architectures and progressively increases in complexity and objective satisfaction.

NASA's Moon to Mars Architecture

National Aeronautics and Space Administration

An Evolutionary Architecture Process:

Formulating an Exploration Strategy Based on Objectives



TRACEABILITY

Decomposition of Blueprint Objectives to executing Architecture elements

ARCHITECTURE FRAMEWORK

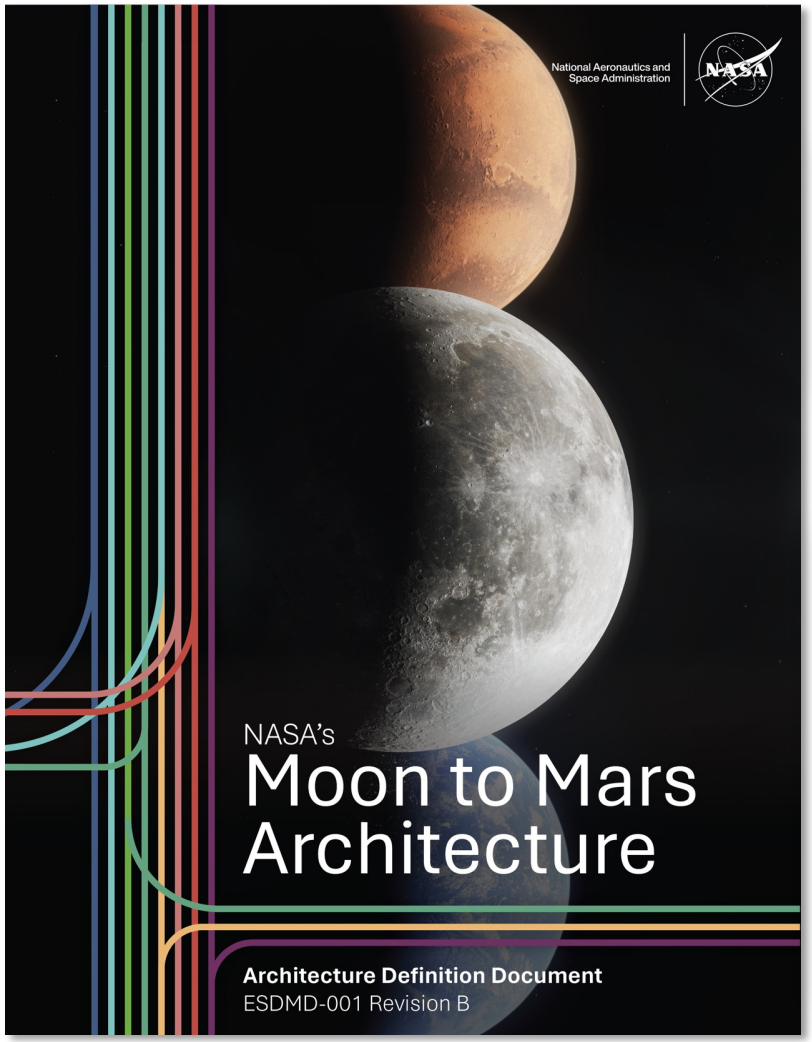
Organizational construct to ensure system/element relationships are understood and gaps can be identified

PROCESS & PRODUCTS

Clear communication and review integration paths for stakeholders

Architecture Products

National Aeronautics and Space Administration



NASA's Architecture Definition Document

Executive Overview

Architecture White Papers

NASA documents its roadmap for deep space exploration in the Architecture Definition Document.

The agency updates the document yearly and publishes it alongside other public-facing products including white papers on relevant topics and an executive overview of the architecture.

13

Revision B Published **December 13**

NASA's Moon to Mars Architecture Website

nasa.gov/architecture

2024 Feedback Key Takeaways

National Aeronautics and Space Administration

Industry and Academia Workshop

- Communication has improved.
- Stakeholders appreciated transparency regarding decisions and decision-making.
- Industry desires more clarity on the agency's investment priorities.
- Industry and academia would appreciate being involved earlier in the gap definition process.
- Enable more discussion opportunities at workshop.

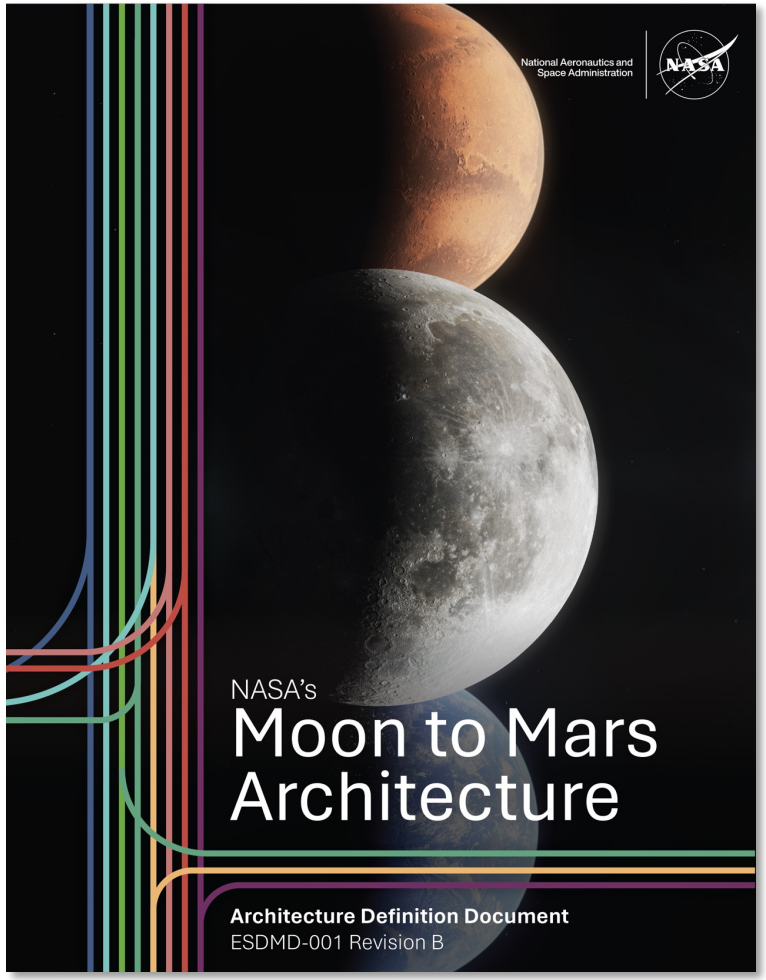
International Partner Workshop

- Building community is integral to success.
- Partners want to engage their own domestic stakeholders and build support for space.
- Emerging space agencies desire more clarity on where they can engage in the architecture.
- Partners desire clear paths through pre-formulation to element initiation.

We've tailored our architecture products to meet desires expressed at last year's workshops. Your feedback and engagement is critically important to the continued success of the Moon to Mars Architecture.

Architecture Concept Review 2024 (ACR24)

National Aeronautics and Space Administration



At ACR24, agency leaders representing each of NASA's mission directorates, centers, and technical authorities provided concurrence on architecture updates:

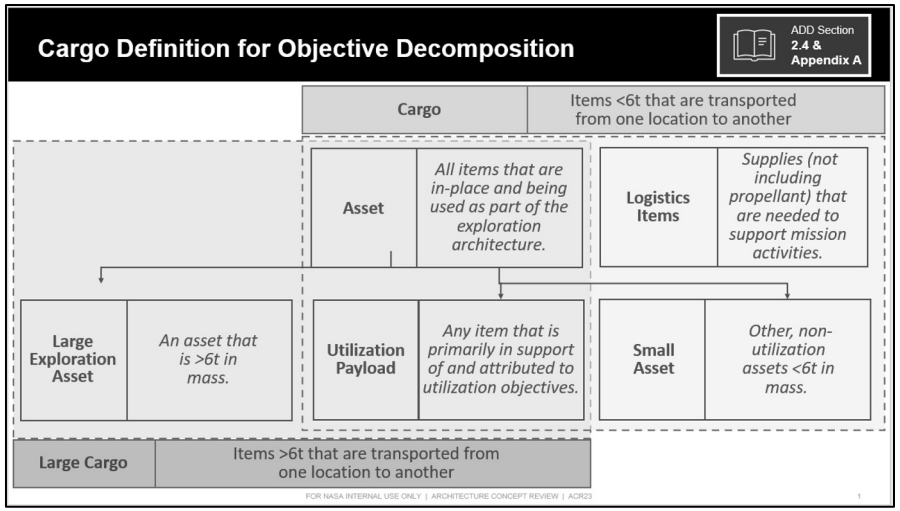
- Revision B of NASA's Architecture Definition Document (ADD)
- Two new Moon to Mars Architecture elements
- Architecture-driven technology gaps definition and prioritization
- Initial Mars surface power technology decision
- Prioritization of 5 additional Mars architecture decisions
- 12 white papers

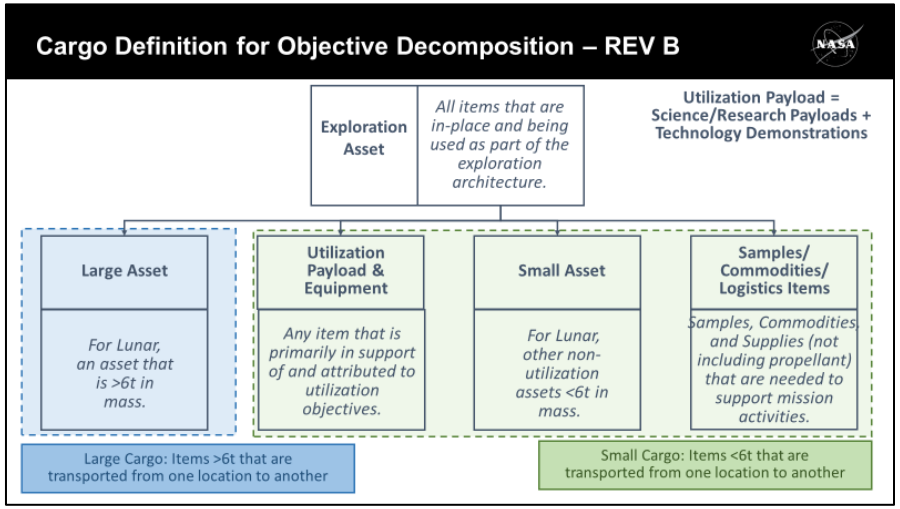
NASA published ACR24 products on December 13. This includes revision B of the ADD, the 12 white papers, and an executive overview of the architecture.

ADD Rev B Updates

National Aeronautics and Space Administration

- ADD Revision B updates add 50+ pages of new content including the two new appendices and the two new exploration elements
- The revision also reflects a refined and updated objective decomposition that seeks to improve clarity and embrace lessons learned
- **Updated Definitions (Appendix D) reflected in the Objective Decomposition:**
  - Refined definition of utilization payload to include equipment
  - Included an all-encompassing term of “Exploration Asset”
  - Better defined the delineation between large and small cargo
  - Included call out to samples in addition to commodities and logistics items





Decomposition Updates

National Aeronautics and Space Administration

- **Characteristics and Needs**
  - Updated for better accuracy, clarity, and consistency
  - Implemented new numbering schema for better organization
  - Rewrote for science objectives to improve clarity and consistency
  - Utilized model-based systems engineering (MBSE) environment
- **Lunar Use Cases and Functions**
  - Refined to better align syntax and remove overlapping or redundant functions
  - Added “bucketing” or classes of capabilities to better align assets with functions
  - Updates reflect two years of lessons learned and stakeholder feedback
- **Mars Use Cases and Functions**
  - Added for the Transportation & Habitation, Mars Infrastructure, and Operations Objectives
  - Followed similar syntax and nomenclature of lunar objective decomposition
- **Asset Mapping Tables**
  - Split utilization payloads into equipment, science/research payloads, and technology demonstrations
  - Clarified interpretation of asset mappings as a contribution to the architecture by an asset

New Element: **Initial Surface Habitat**

National Aeronautics and Space Administration

Architecture **Elements** Approved at **ACR24**

Initial Surface Habitat

Enables expanded exploration capabilities up to 4 surface crew, establishes opportunities for Mars-forward precursor missions, and increased exploration capabilities and science during missions

FN#	Primary Functions Met by Element
FN-H-101 L	Enable a pressurized, habitable environment on the lunar surface for short durations (days to weeks)
FN-H-201 L	Operate habitation system(s) in uncrewed mode between crewed missions on the lunar surface
FN-P-402 L	Provide power for deployed external surface utilization payload(s) and/or equipment for long durations (months to years+)
FN-U-201 L	Provide intravehicular activity facilities, utilization accommodation, and resources, operable during crewed and uncrewed increments on the lunar surface

+15 additional functions.

New Element: **Lunar Surface Cargo Lander**

National Aeronautics and Space Administration

Architecture **Elements** Approved at **ACR24**

Lunar Surface Cargo Lander

Dedicated cargo lander to deliver logistics, utilization, small exploration assets, and other cargo to the Moon; payload capacity on the order of 2 tons

FN#	Primary Functions Met by Element
FN-T-202 L	Transport a moderate amount of cargo (1000s of kg) from Earth to south pole region sites on the lunar surface
FN-T-204 L	Transport a moderate amount of cargo (1000s of kg) from Earth to distributed sites outside of the south pole region on the lunar surface
FN-T-402 L	Provide precision landing for cargo transport to the lunar surface
FN-T-403 L	Enable landing on the lunar surface under all lighting conditions

NEW ADD APPENDIX

Architecture-Driven **Technology Gaps**

National Aeronautics and Space Administration

Architecture Definition Document

APPENDIX C

- With a broad array of needs competing for technology development resources, the agency must judiciously target priority technologies that enable NASA to achieve its exploration goals
- To this end, NASA has applied rigorous systems engineering processes to develop and prioritize architecture-driven technology gaps to inform technology development investments
- The resulting list is included in Appendix C of Revision B of the Architecture Definition Document and will be updated annually

Architecture gaps are…

…***capability areas*** to enable the architecture (i.e., technologies that need to be matured or invented)

…***solution-agnostic***

…published as one-pagers in ***ADD rev-B*** (56 total gaps currently)

…***prioritized*** based on four criteria

…***updated*** as existing gaps are closed and new gaps are identified

To learn more, read the associated white paper and participate in the workshop white paper poster session and/or briefing.
www.nasa.gov/architecture

NEW ADD APPENDIX

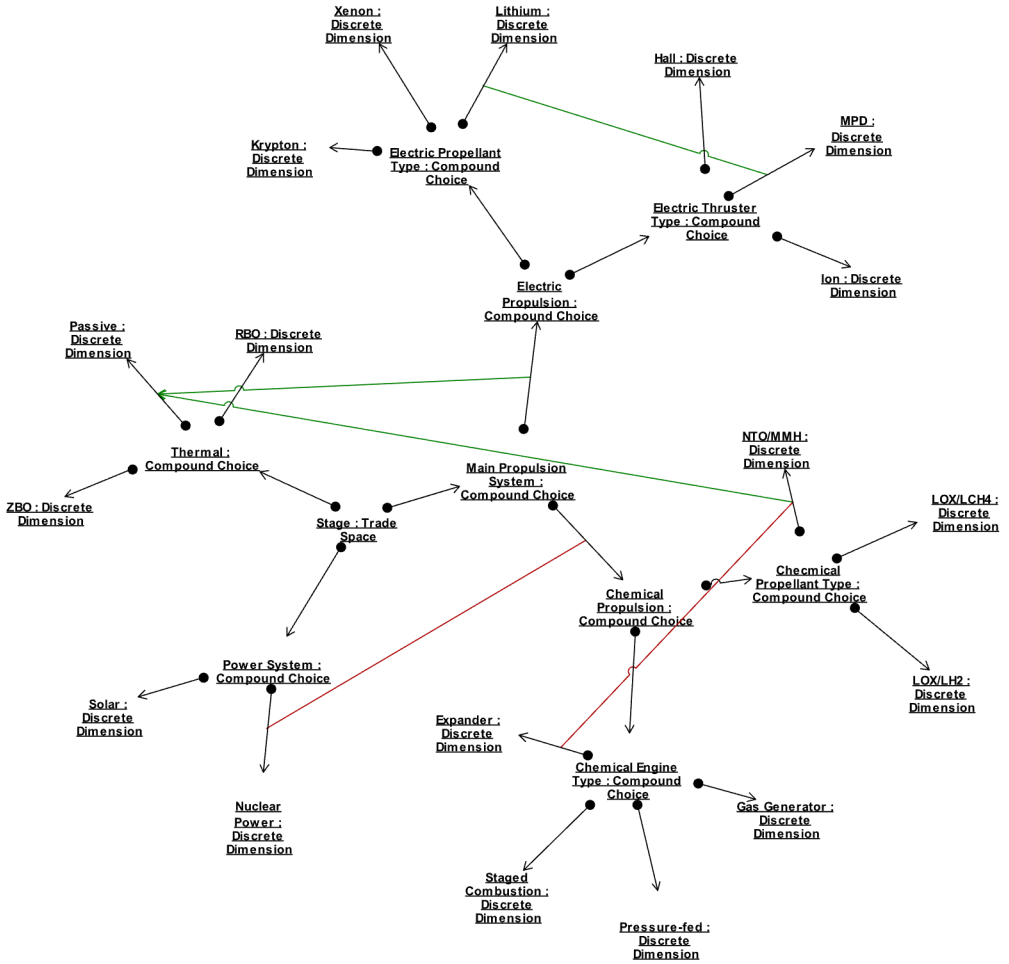
Key Moon to Mars Architecture **Decisions**

National Aeronautics and Space Administration

Architecture Definition Document

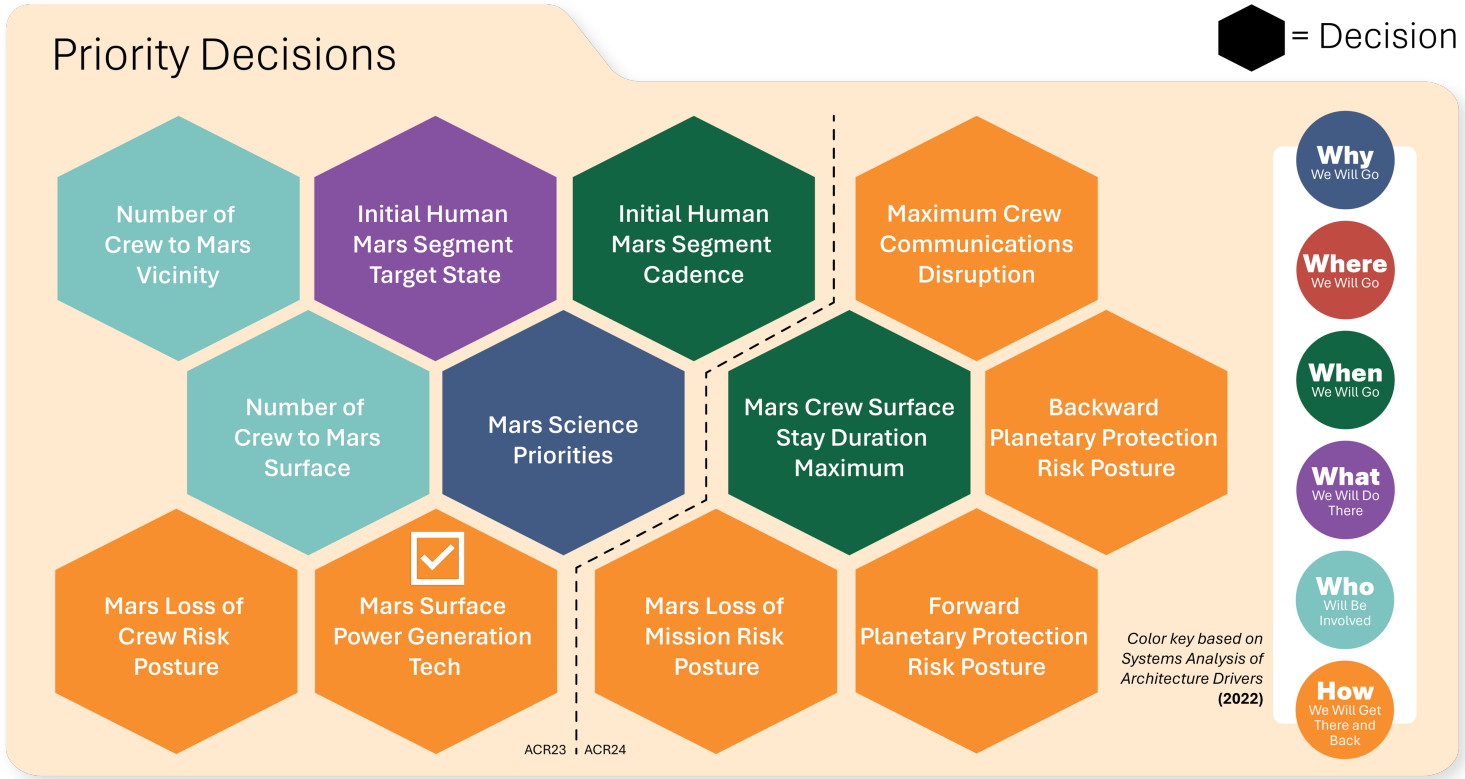
APPENDIX B

- In laying out an architecture decision roadmap, it is critically important for decision-makers to understand how key drivers relate to each other and how an architecture can change depending on the order in which decisions are made
- NASA has applied rigorous systems engineering principles in laying out an architecture decision roadmap that clearly identifies a logical order in which decisions may be made based on their precedence relationships
- NASA documents these decisions in Appendix B of the Architecture Definition Document and will update yearly as new decisions are identified or made



Mars Decisions: **New Priority Decisions**

National Aeronautics and Space Administration



- As part of the 2024 Architecture Concept Review, NASA added five additional decisions to its initial list of seven priority Mars decisions
- Additionally, NASA made it's first Mars decision, selecting nuclear fission and the primary surface power generation technology for initial crewed missions to Mars.
- To learn more about the rationale for that decision, read the associated white paper and participate in the poster session and/or briefing later in the workshop.

2024 White Papers

National Aeronautics and Space Administration

1. Mars Entry, Descent, and Landing Challenges
2. Humans in Space to Accomplish Certain Objectives
3. Artemis Accomplishing Decadal Recommendations
4. International Partnerships: Policies, Opportunities, & Engagement
5. Responsible Exploration
6. Mars Surface Power Tech Decision
7. Mars Crew Complement Considerations
8. Mars Ascent Propellant Considerations
9. Lunar Mobility Drivers and Needs
10. Lunar Surface Cargo
11. Lunar Reference Frame
12. Architecture-Driven Technology Gaps

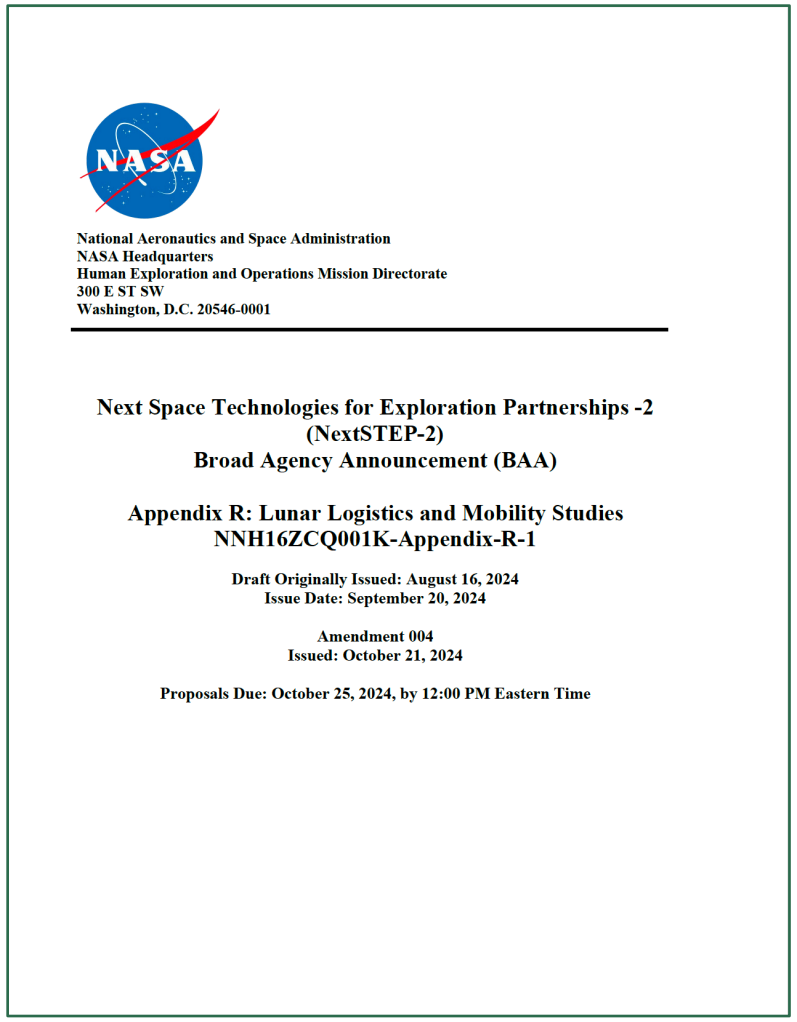
NASA's Moon to Mars Architecture Website

nasa.gov/architecture

All products are hosted on the architecture website.

Logistics and Mobility: Request for Proposals

National Aeronautics and Space Administration



National Aeronautics and Space Administration
NASA Headquarters
Human Exploration and Operations Mission Directorate
300 E ST SW
Washington, D.C. 20546-0001

Next Space Technologies for Exploration Partnerships -2
(NextSTEP-2)
Broad Agency Announcement (BAA)

Appendix R: Lunar Logistics and Mobility Studies
NNH16ZCQ001K-Appendix-R-1

Draft Originally Issued: August 16, 2024
Issue Date: September 20, 2024

Amendment 004
Issued: October 21, 2024

Proposals Due: October 25, 2024, by 12:00 PM Eastern Time

- To advance its lunar logistics strategy, NASA released a Broad Agency Announcement through the Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) Omnibus
- The request sought **proposals from industry** that might advance lunar cargo and mobility capabilities. Proposed areas of study included:
  - **Logistics Carriers**
  - **Logistics Handling and Offloading**
  - **Logistics Transfer**
  - **Staging, Storage and Tracking**
  - **Trash Management**
  - **Surface Cargo Transportation and Mobility Systems**
  - **Integrated Strategy**

Pre-Solicitation Released
August 16, 2024

Pre-Solicitation Released
August 27, 2024

Solicitation Released
September 20, 2024

Source Selection Statement
January 22, 2025

What's Different this Year?

National Aeronautics and Space Administration

We want to hear from YOU!

- We've retooled the workshops to promote more engagement and interaction between all present
- We've added non-NASA panelists to broaden the perspectives highlighted in discussions
- We're focused on finding avenues to collaborate that close architecture and technology gaps