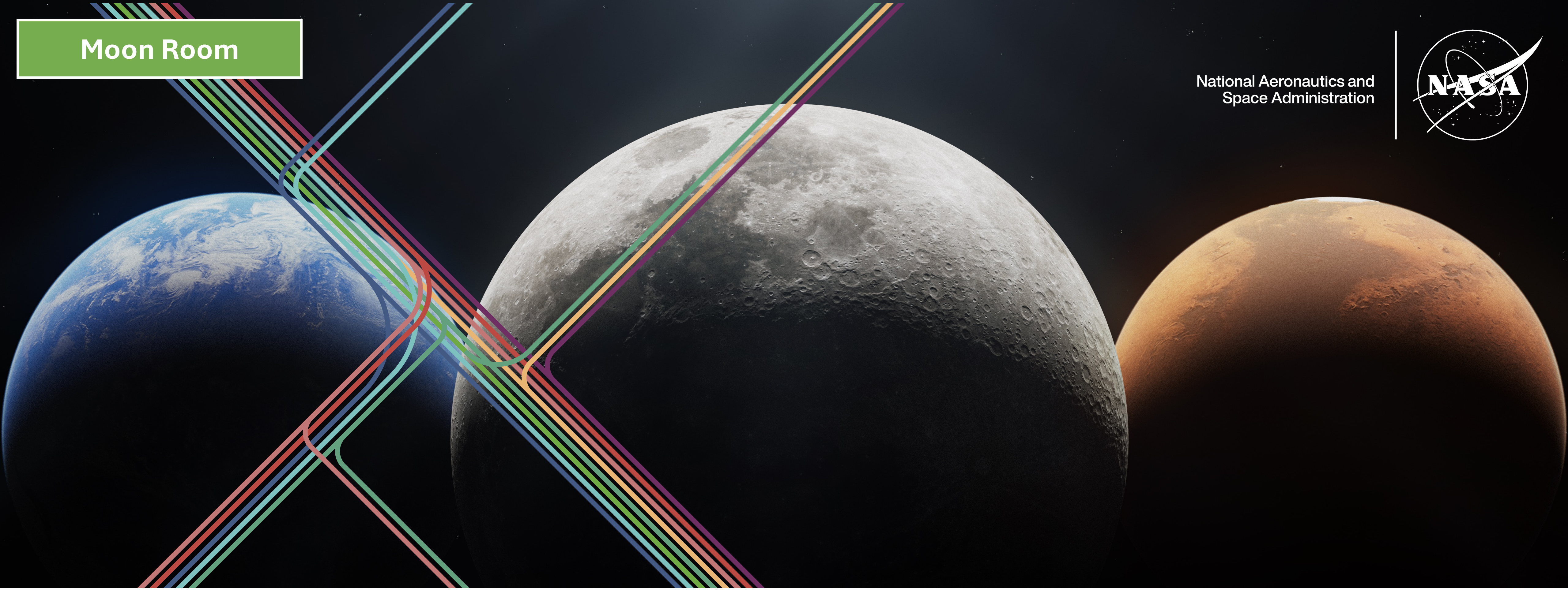
Moon Room

National Aeronautics and Space Administration



Architecture 101

Julie Grantier
Deputy Manager for Integration
Strategy and Architecture Office
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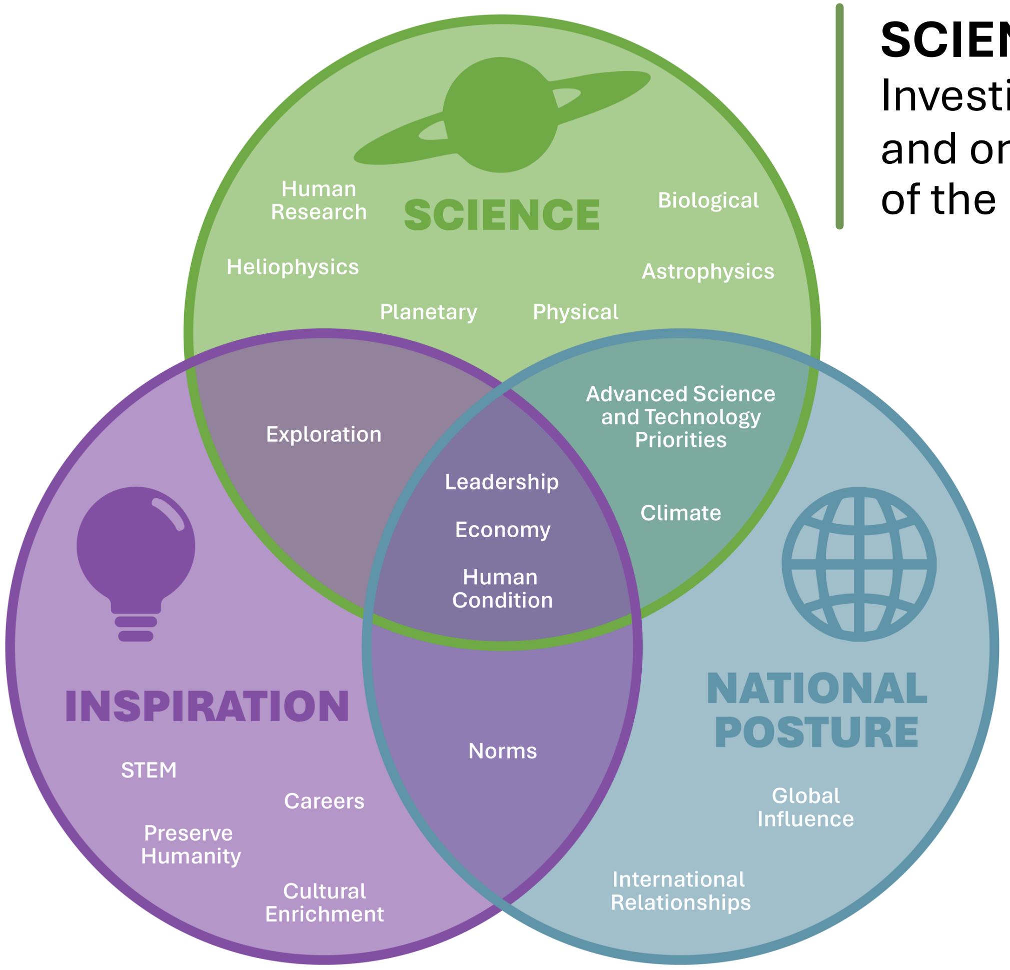
Why We Explore...

National Aeronautics and Space Administration



SCIENCE

Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the universe and our place in it.

INSPIRATION

Accepting audacious challenges motivates current and future generations to contribute to our voyage deeper into space.

NATIONAL POSTURE

What is done, how it's accomplished, and who participates affect our world, quality of life, and humanity's future.

NASA's Moon to Mars Strategy and Objectives Development

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

NASA's Moon to Mars Objectives

National Aeronautics and Space Administration

NASA's Moon to Mars Objectives document a long-term vision to crewed deep space exploration.

In contrast to a capabilities-based approach, an objectives-based approach focuses on the big picture, the "what" and "why," before prescribing the "how."

The methodology for the Moon to Mars Objectives is guided by five inter-related principles:

- Objectives-based Approach
- Enhanced Communication and Engagement
- Constancy of Purpose
- Unity of Purpose
- Architect from the Right Execute from the Left

NASA's Moon to Mars Objectives Document
https://go.nasa.gov/4eDTsk6

Exploration Objectives Categories and Goals

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Lunar and Planetary Science | Answer questions about the formation of our solar system, the geology and chemistry of planetary bodies, and the origins of life.

Heliophysics | Advance our study of the Sun and our ability to observe, model, and predict space weather.

Human and Biological Science | Grow our understanding of how the lunar, Martian, and deep space environments affect living things.

Physics and Physical Sciences | Investigate space, time, and matter in the unique environments of the Moon, Mars, and deep space.

Science Enabling | Realize integrated human and robotic techniques that address high-priority scientific questions around and on the Moon and Mars.

Applied Science | Carry out science utilizing integrated human and robotic techniques to inform the design of exploration systems.

Lunar Infrastructure | Enable government, industry, academia, and international partners to participate in a robust lunar economy and facilitate science.

Mars Infrastructure | Develop the power, communications, navigation, and resource utilization capabilities to support initial human Mars 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.

Architecting from the Right

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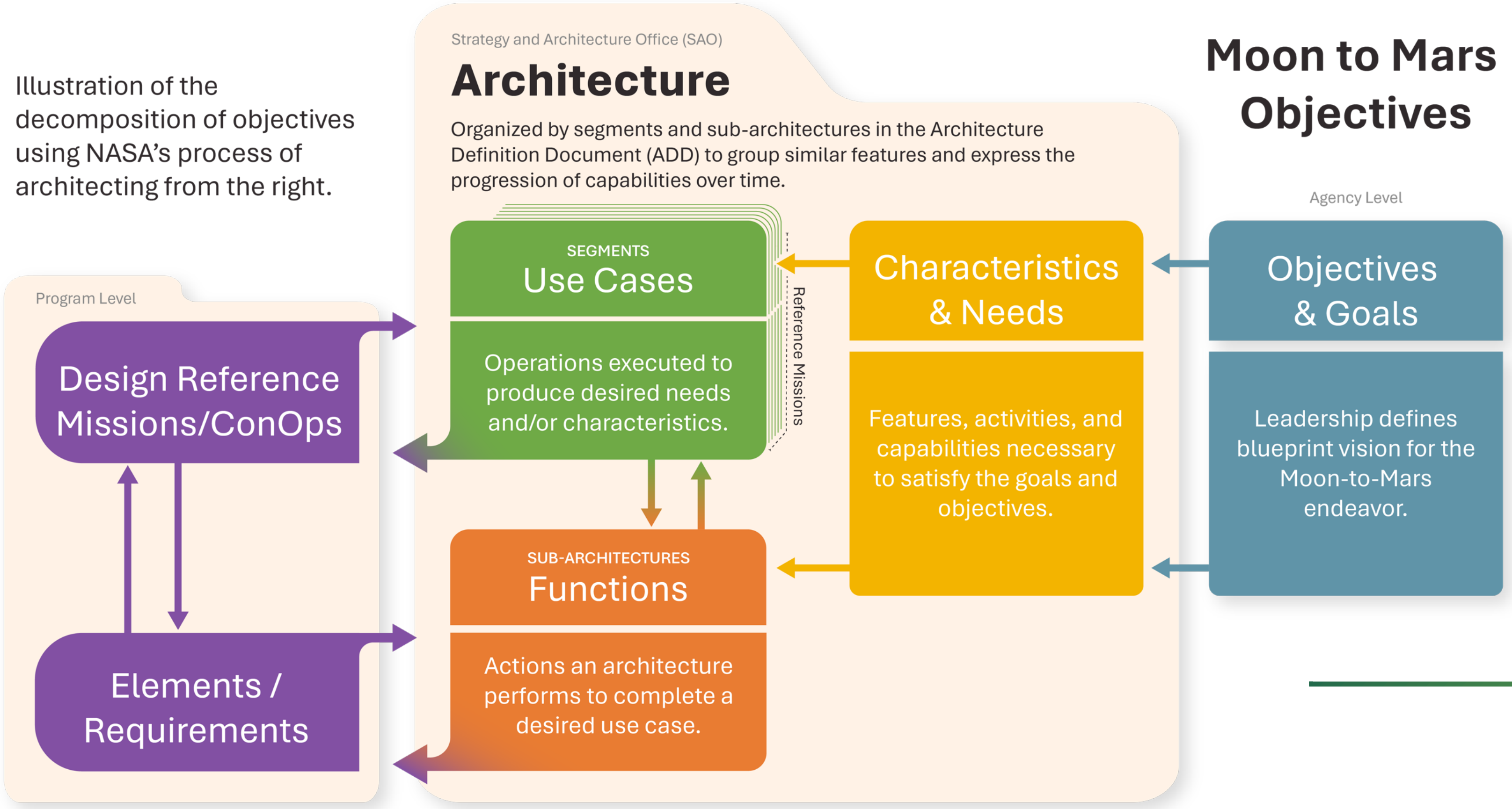
Illustration of the decomposition of objectives using NASA's process of architecting from the right.



Applies rigorous systems engineering approaches to identify the architecture needs, understand relationships and gaps between systems, and underpin analysis to identify the most effective and efficient solutions.

Architecture process provides a transparency in development not previously available

NASA's Moon to Mars Architecture Website

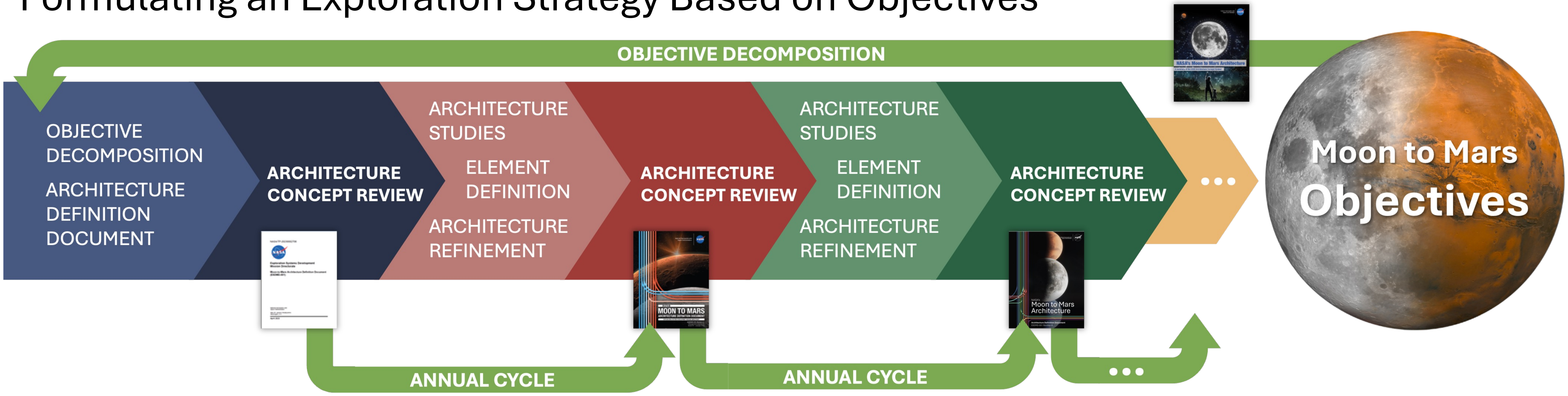
www.nasa.gov/architecture

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 Segments

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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.

Sub-Architectures

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Communications and Positioning, Navigation, and Timing Systems (C&PNT) enable transmission and reception of data, determination of location and orientation, and acquisition of precise time.

Autonomous Systems & Robotics employ software and hardware to assist the crew and operate during uncrewed periods.

Data Systems and Management transfer, distribute, receive, validate, secure, decode, format, compile, and process data and commands.

Habitation Systems ensure the health and performance of astronauts in controlled environments.

Infrastructure Support includes facilities, systems, operations planning and control, equipment, and services needed on Earth, in space, and on planetary surfaces.

In-situ Resource Utilization (ISRU) Systems extract resources in space or on the Moon or Mars to generate products.

Human Systems execute human and robotic missions; this includes crew, ground personnel, and supporting systems.

Logistics Systems package, handle, transport, stage, store, track, and transfer items and cargo.

Mobility Systems move crew and cargo around the lunar and Martian surfaces.

Power Systems generate, store, condition, and distribute electricity for architectural elements.

Transportation Systems convey crew and cargo to and from Earth to the Moon and Mars.

Utilization Systems enable science and technology demonstrations.

Sub-Architecture | A group of tightly coupled elements, functions, and capabilities that work together to accomplish one or more objectives.

Architecture Elements

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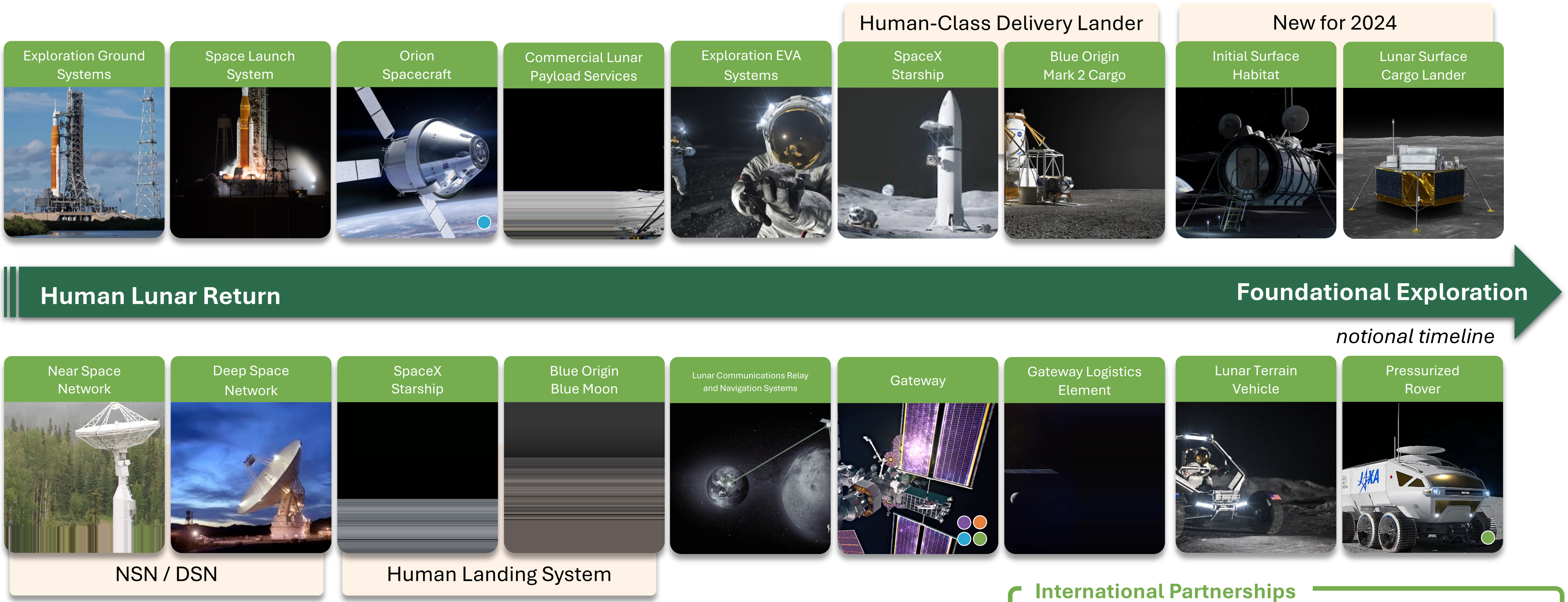


Element | A notional exploration system that enables a set of functions.

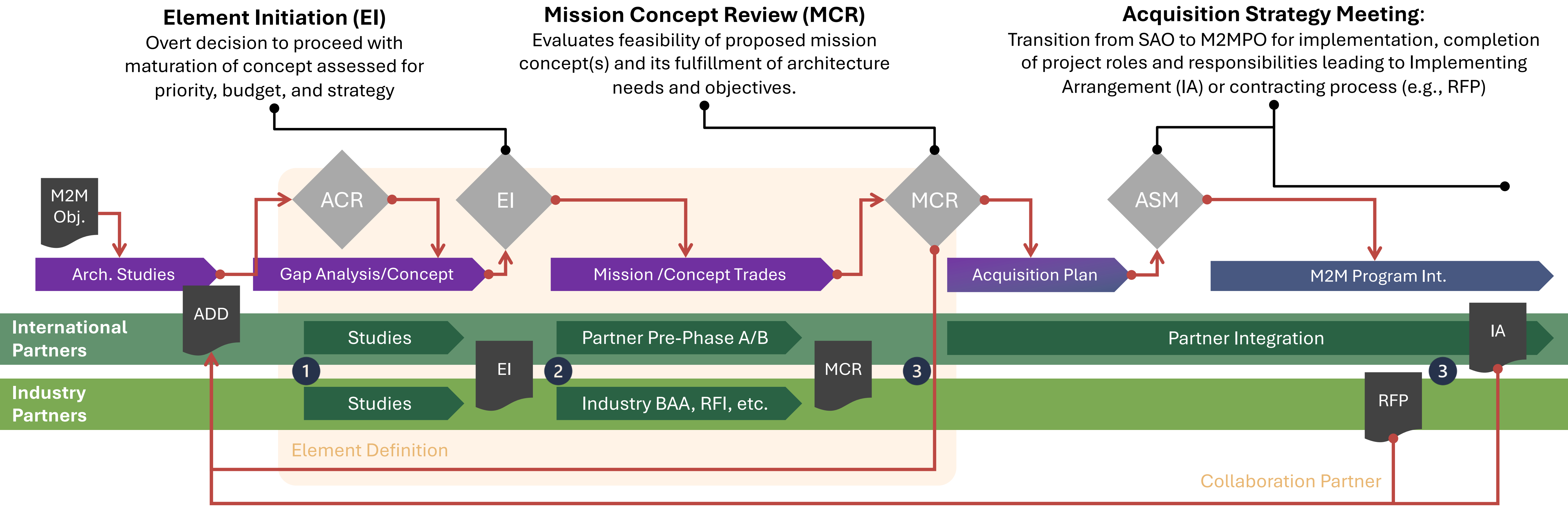
International Partnerships

- Canadian Space Agency
- European Space Agency
- Mohammed Bin Rashid Space Centre
- Japan Aerospace Exploration Agency

Partner Pre-formulation Process

Exploration Systems Development Mission Directorate

National Aeronautics and Space Administration



Document(s)

NASA Milestone

1. Feasibility studies and collaboration identify potential concept.
2. Mission refinement to optimize for strategic value and functional achievement, using study mechanisms to better inform planning.
3. Feedback incorporated into architecture products as milestones occur.

Collaboration Partner

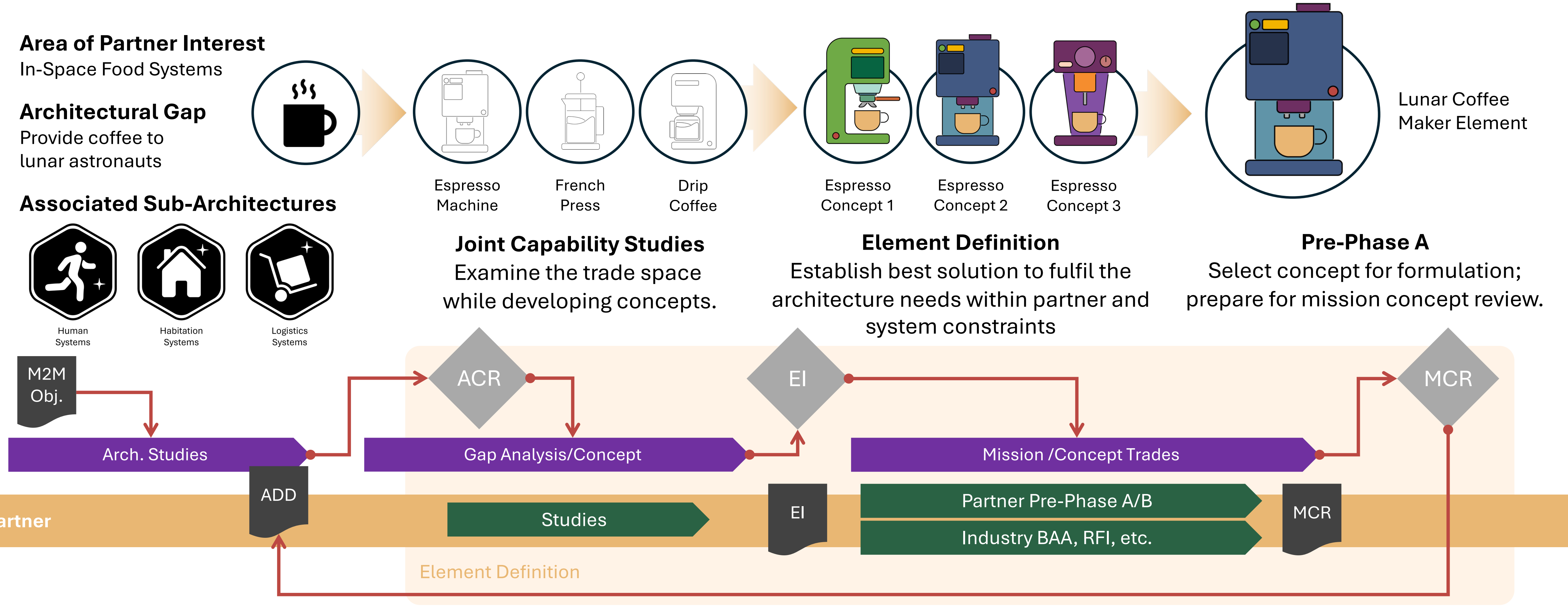
Strategy and Architecture Office (SAO)

Moon to Mars Program Office (M2MPO)

Concept Maturity Mapped to Process

Fictional Example: Lunar Coffee Maker

National Aeronautics and Space Administration



Architecture Products

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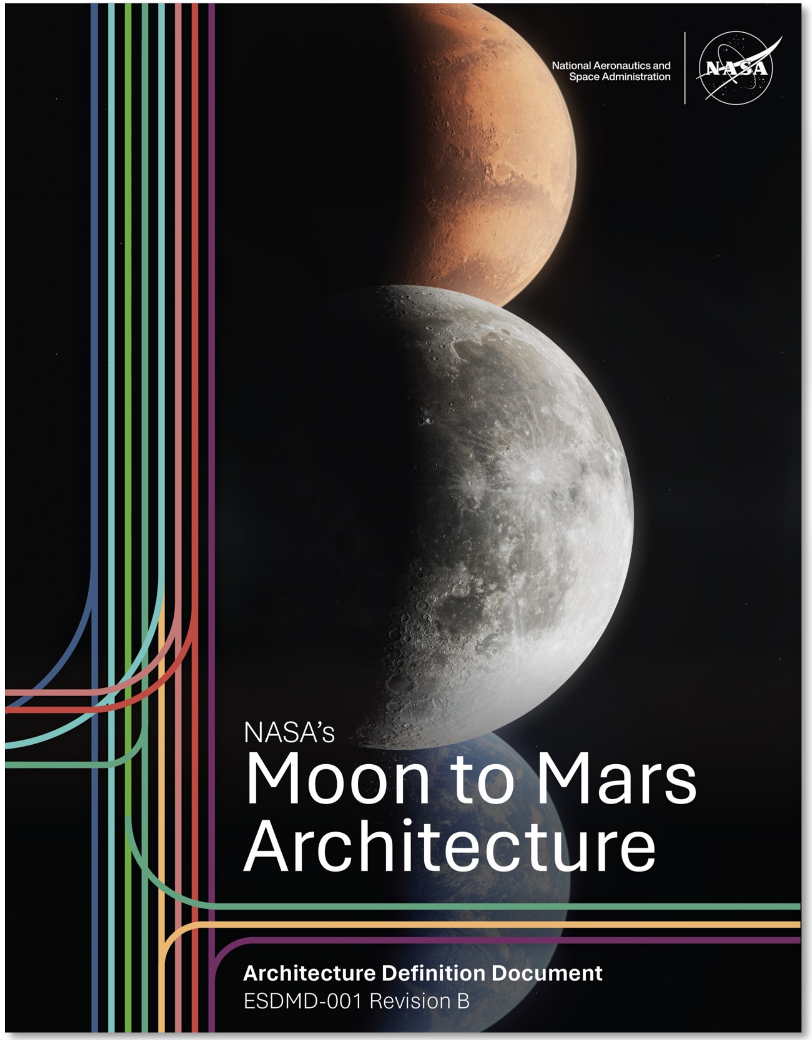

NASA's Architecture Definition Document

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.

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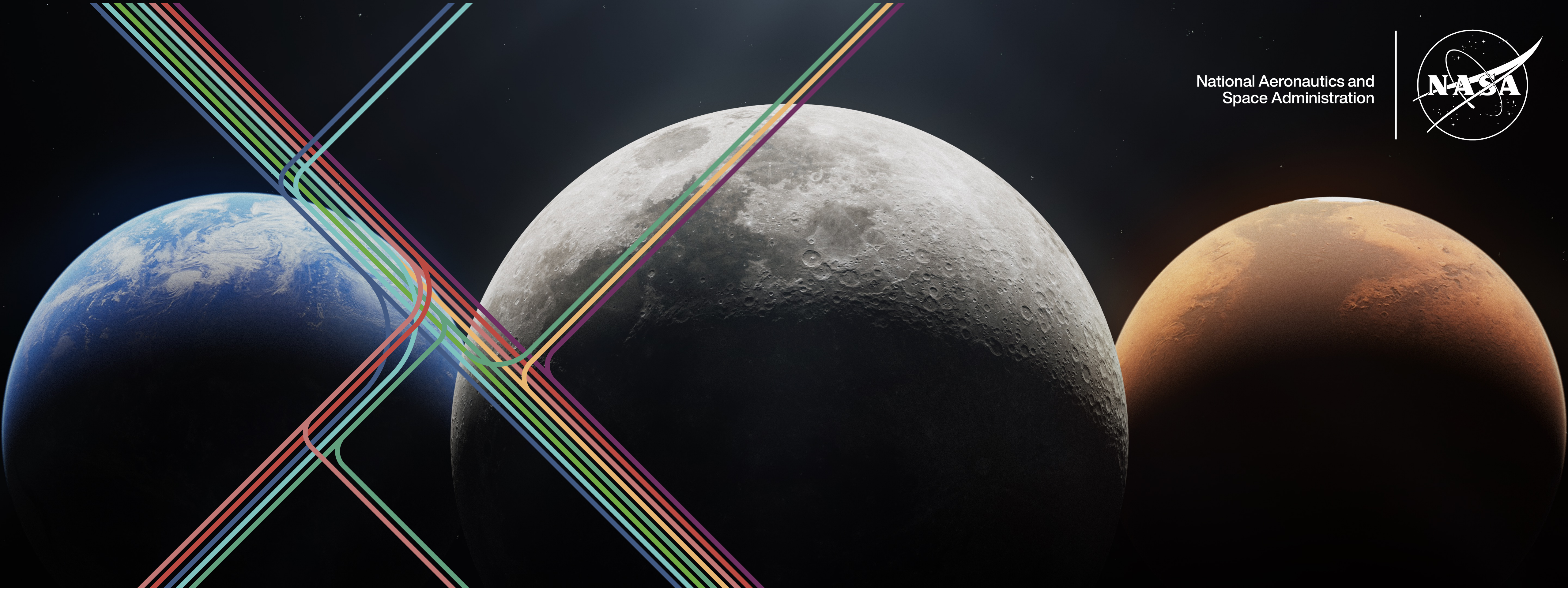
Revision B Published **December 13**

NASA's Moon to Mars Architecture Website

nasa.gov/architecture



National Aeronautics and
Space Administration

Architecture and Science

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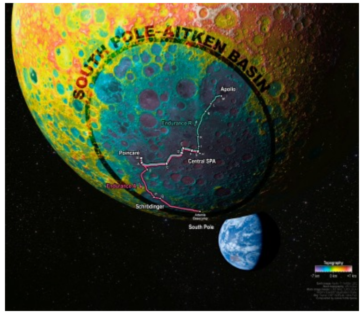
M2M Objectives – 26 Science Objectives

Science Enabled by Architecture

National Aeronautics and Space Administration

Image credit: *Keane et al*



LPS-1



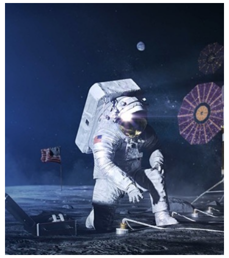
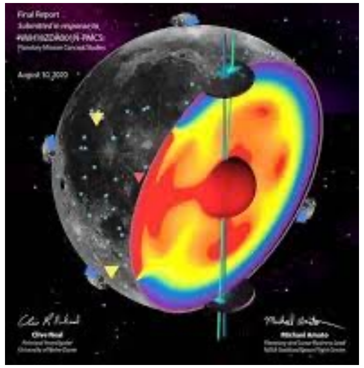




Image credit: *LGN*



LPS-2



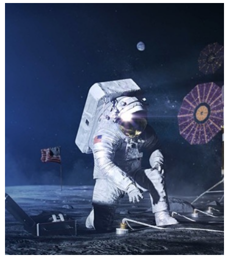
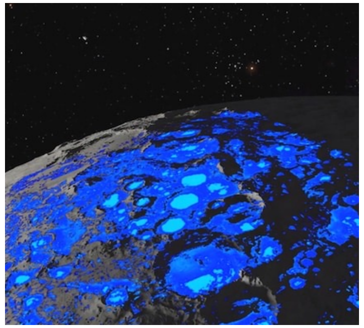




Image credit: *ESA*



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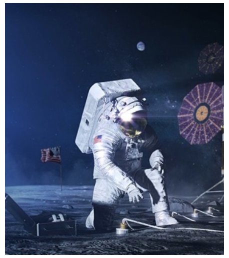




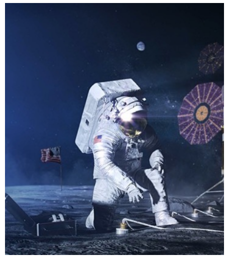
Science Enabled by Architecture

National Aeronautics and Space Administration


Image credit: *Pexels*

HBS-1





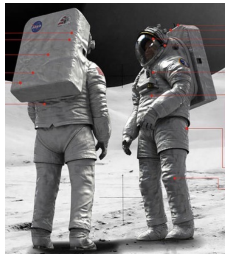
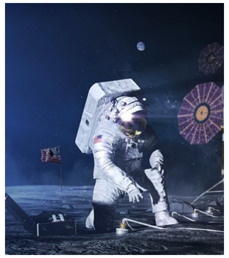



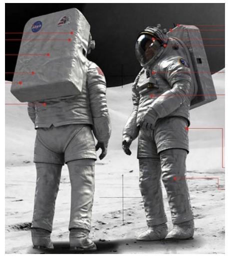


Image credit: *NASA*

HBS-2





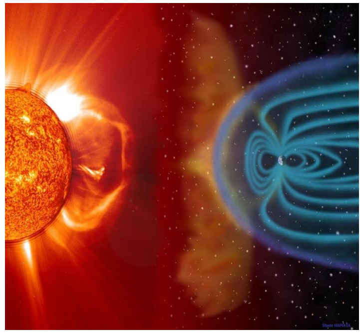
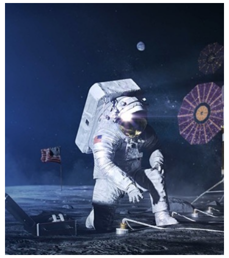
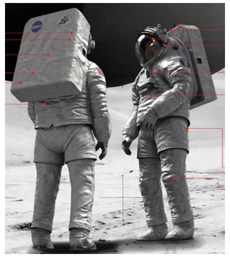



Image credit: *ESA*

HS






ROUNDTABLE

Moon Room

National Aeronautics and Space Administration

Architecture 101

Moon to Mars Architecture Workshop

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Questions and Discussion

National Aeronautics and Space Administration

Discussion Prompts

- Have you read the Architecture Definition Document? How is your organization using it to inform your investments and strategies? Are there changes in the documentation or process that would be useful to industry or academia?
- What future white paper topics would be helpful to your organization?
- Do you see opportunities for your organization to integrate with the architecture? Do you have questions about where your organization fits in the pre-formulation process? Do you know how to engage with NASA?
- What additional products or information would best help your organization to understand and engage with the architecture?
- How can NASA help industry forecast where gaps exist and when they need to come on-line?

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NASA's Moon to Mars Architecture Website
www.nasa.gov/architecture

Architecture White Papers

2022 White Papers	2023 White Papers	2024 White Papers
Why NRHO: The Artemis Orbit	Lunar Communications and Navigation Architecture	Lunar Mobility Drivers and Needs
Why Artemis will Focus on the Lunar South Pole Region	Lunar Site Selection	Lunar Surface Cargo
Mars Transportation	Analytical Capabilities In-situ vs. Returned	Priority Science Enabled through Architecture
Gateway: The Cislunar Springboard	Safe and Precise Landing at Lunar Sites	Lunar Reference Frame
Systems Analysis of Architecture Drivers	Mars Communications Disruption and Delay	Mars Crew Complement Considerations
Mars-Forward Capabilities to be Tested at the Moon	Mars Mission Abort Considerations	Mars Surface Power Tech Decision
	Mars Surface Power Generation	Mars Entry, Descent, and Landing Challenges
	Key Mars Architecture Decisions	Mars Ascent Propellant Considerations
	Round-Trip Mars Mission Mass Challenges	Humans in Space to Accomplish Science Objectives
	Human Health and Performance for Mars Missions	Responsible Exploration
	Lunar Logistics Drivers and Needs	International Partnerships
	Surface Extravehicular Activity Architectural Drivers	Architecture-Driven Technology Gaps
	Exploration Lessons Learned from the Space Station	

NASA's Moon to Mars Architecture Website
nasa.gov/architecture

White Papers | Answer questions, communicate NASA's latest thinking, and characterize architecture challenges.

Moon-Focused
Mars-Focused
Cross-Cutting