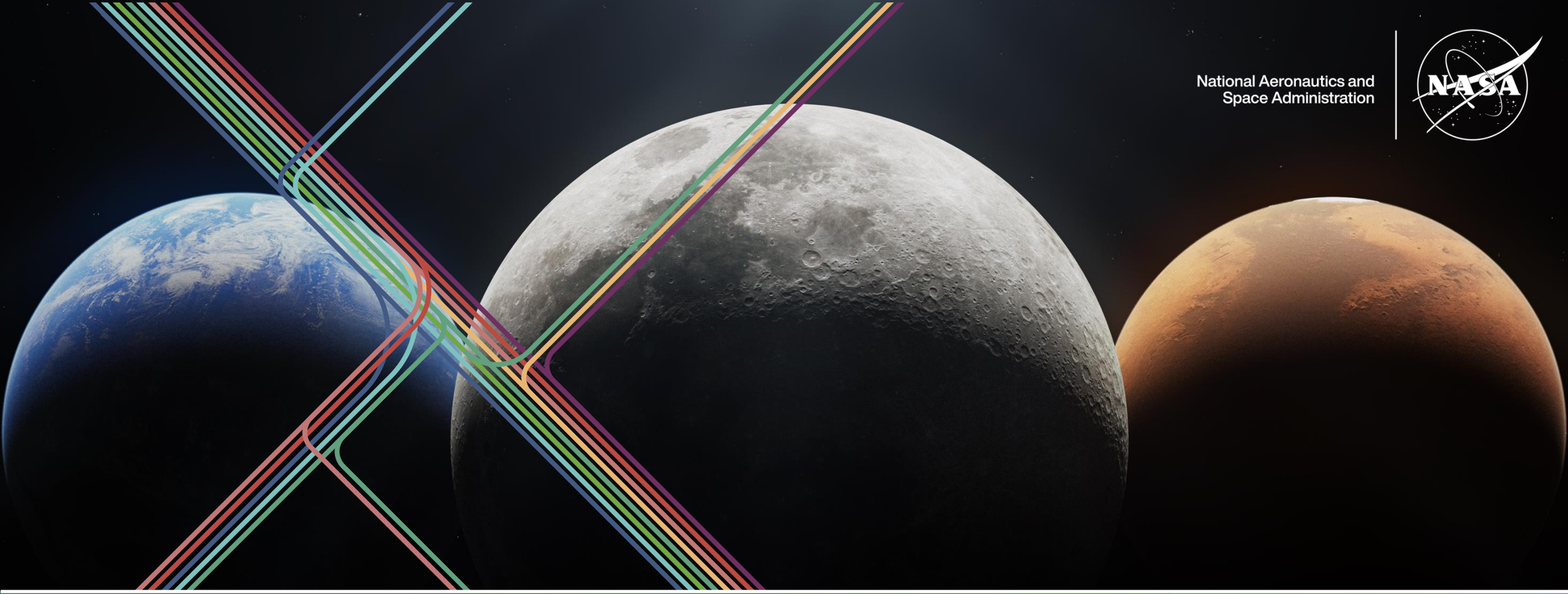

Architecture 101

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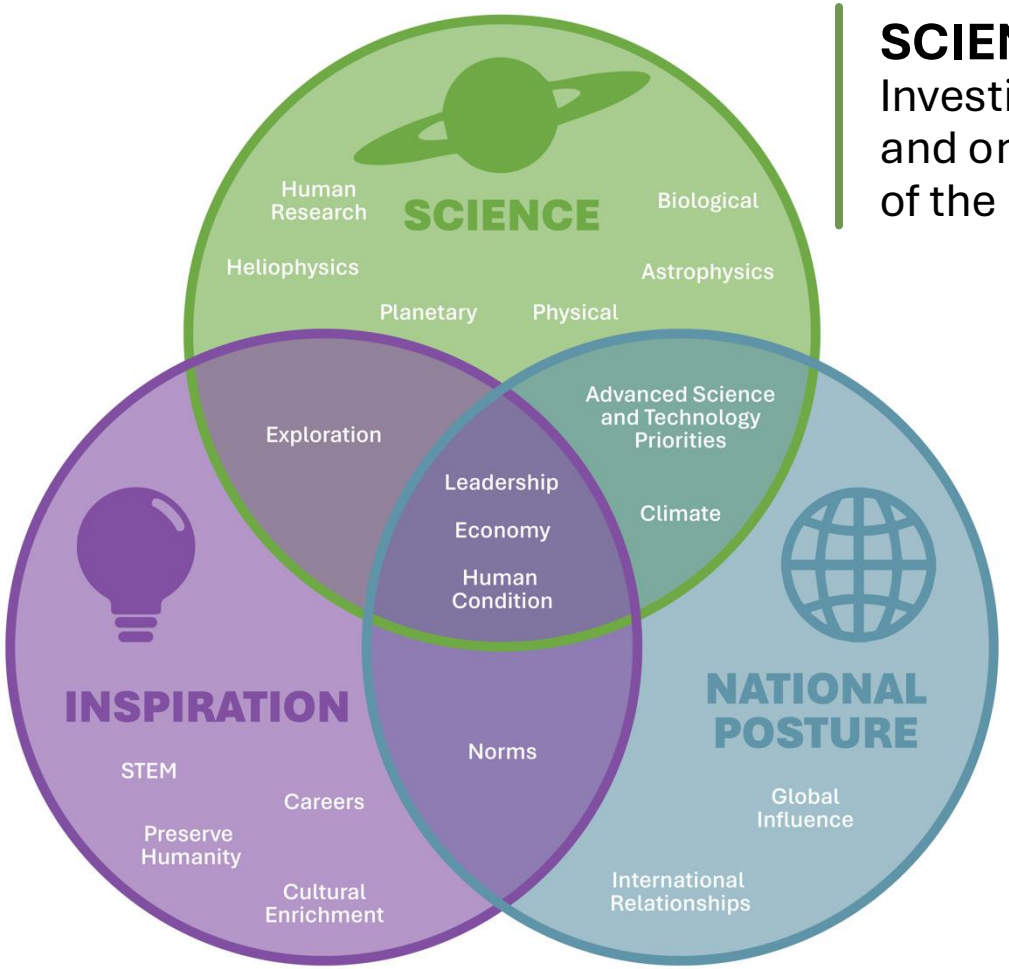
Why We Explore...

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

National Aeronautics and Space Administration

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.

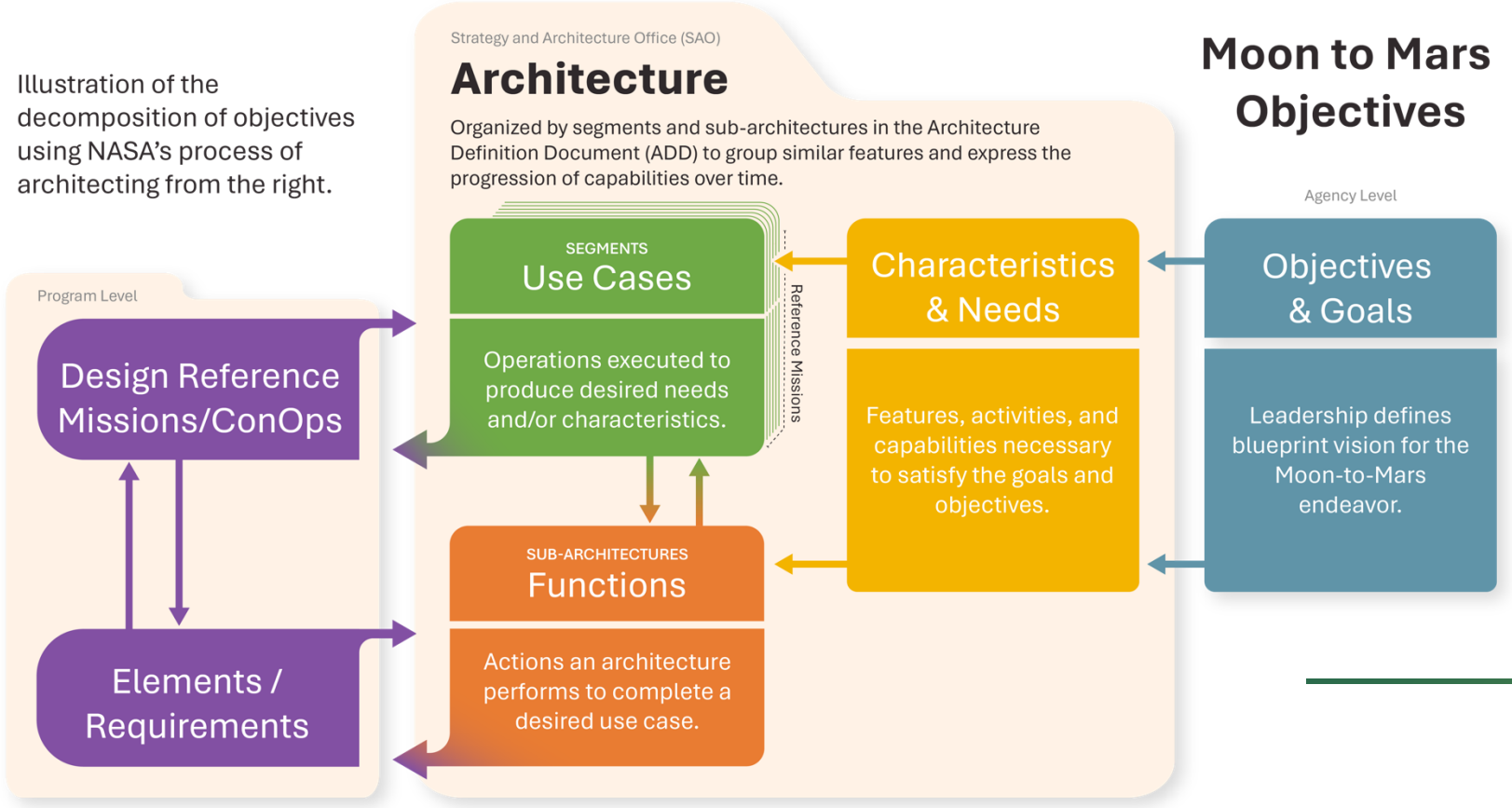
Transportation and Habitation | Create the systems necessary for humans to travel to the Moon and Mars, live and work there, and return to Earth safely.

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

Architecting from the Right

National Aeronautics and Space Administration

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

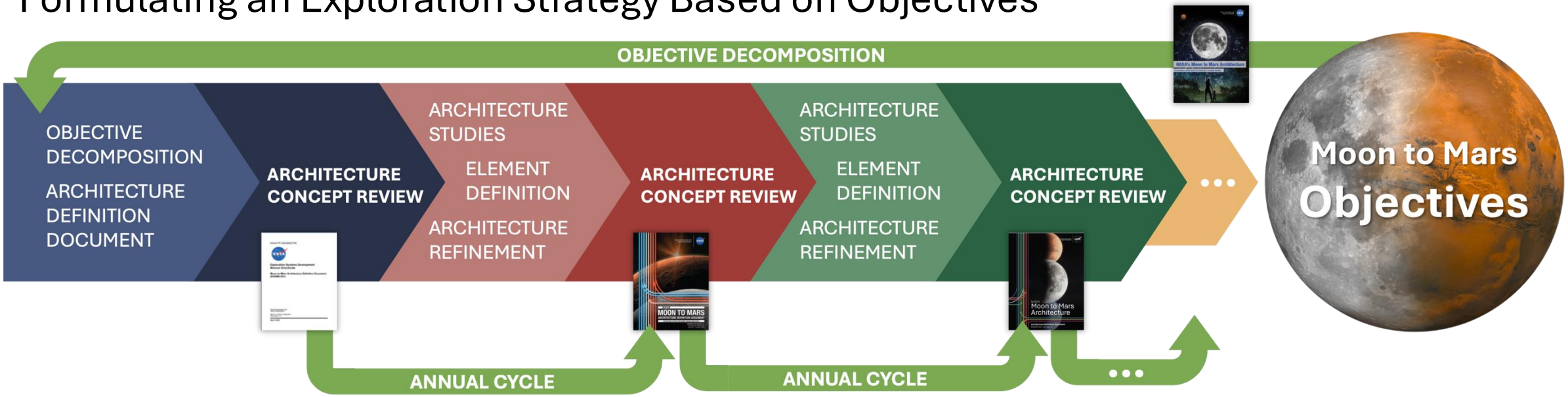
www.nasa.gov/architecture

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

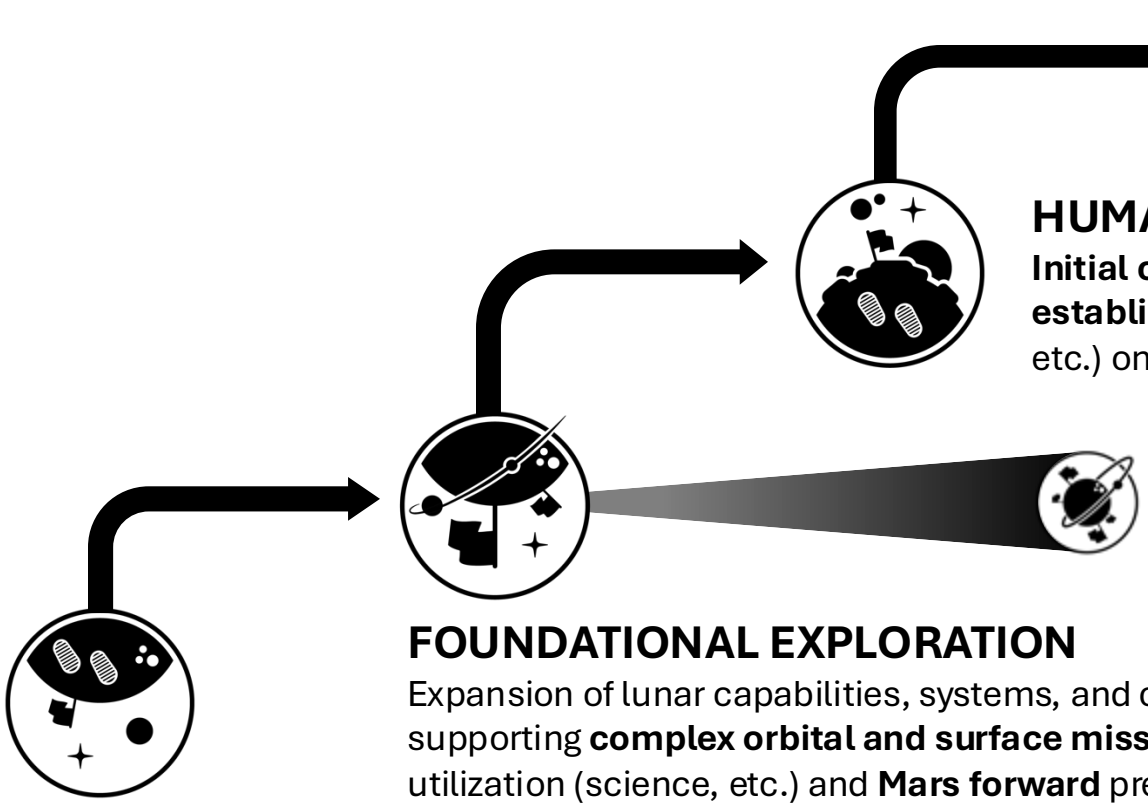
Organizational construct to ensure system/element relationships are understood and gaps can be identified

PROCESS & PRODUCTS

Clear communication and review integration paths for stakeholders

Architecture Segments

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.

Sub-Architectures

National Aeronautics and Space Administration

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

National Aeronautics and Space Administration

Human-Class Delivery Lander

New for 2024

Exploration Ground Systems

Space Launch System

Orion Spacecraft

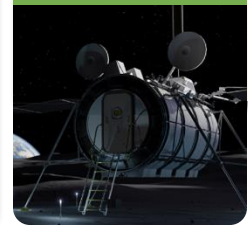
Commercial Lunar Payload Services

Exploration EVA Systems

SpaceX Starship

Blue Origin Mark 2 Cargo

Initial Surface Habitat

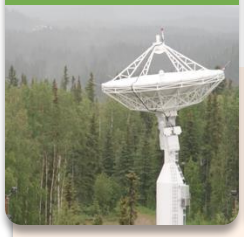


Lunar Surface Cargo Lander

Human Lunar Return → **Foundational Exploration**

notional timeline

Near Space Network



Deep Space Network

NSN / DSN

SpaceX Starship

Blue Origin Blue Moon

Human Landing System

Lunar Communications Relay and Navigation Systems

Gateway

Gateway Logistics Element

Lunar Terrain Vehicle

Pressurized Rover

International Partnerships

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

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

Partner Pre-formulation Process

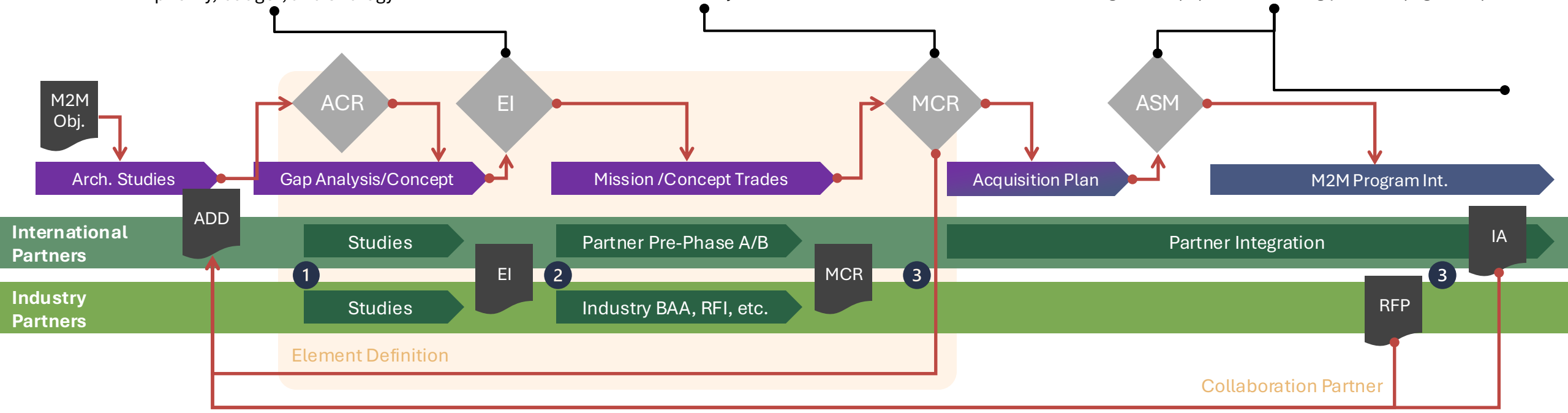
Exploration Systems Development Mission Directorate

National Aeronautics and Space Administration

Element Initiation (EI)
Overt decision to proceed with maturation of concept assessed for priority, budget, and strategy

Mission Concept Review (MCR)
Evaluates feasibility of proposed mission concept(s) and its fulfillment of architecture needs and objectives.

Acquisition Strategy Meeting:
Transition from SAO to M2MPO for implementation, completion of project roles and responsibilities leading to Implementing Arrangement (IA) or contracting process (e.g., RFP)



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

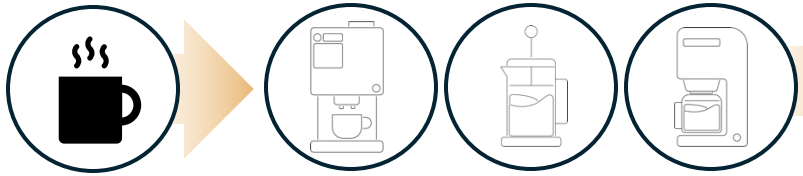
Fictional Example: Lunar Coffee Maker

National Aeronautics and Space Administration

Area of Partner Interest
In-Space Food Systems

Architectural Gap
Provide coffee to lunar astronauts

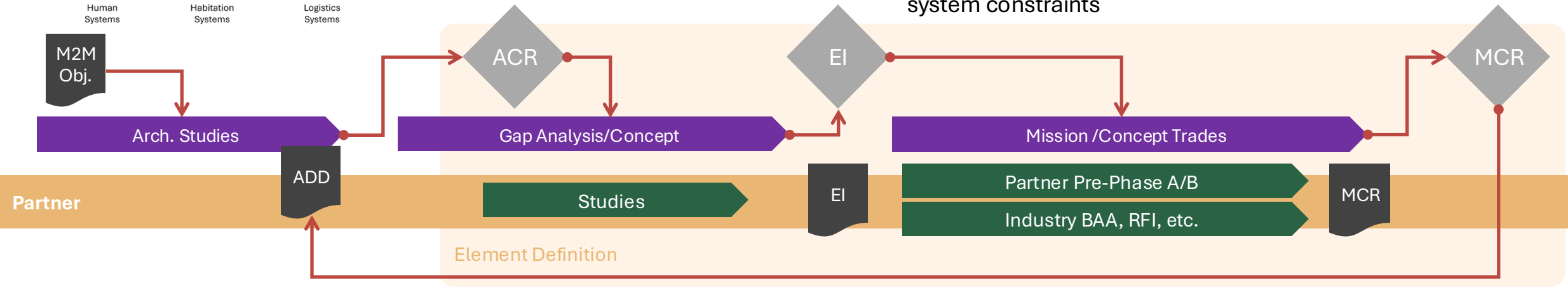
Associated Sub-Architectures



Joint Capability Studies
Examine the trade space while developing concepts.

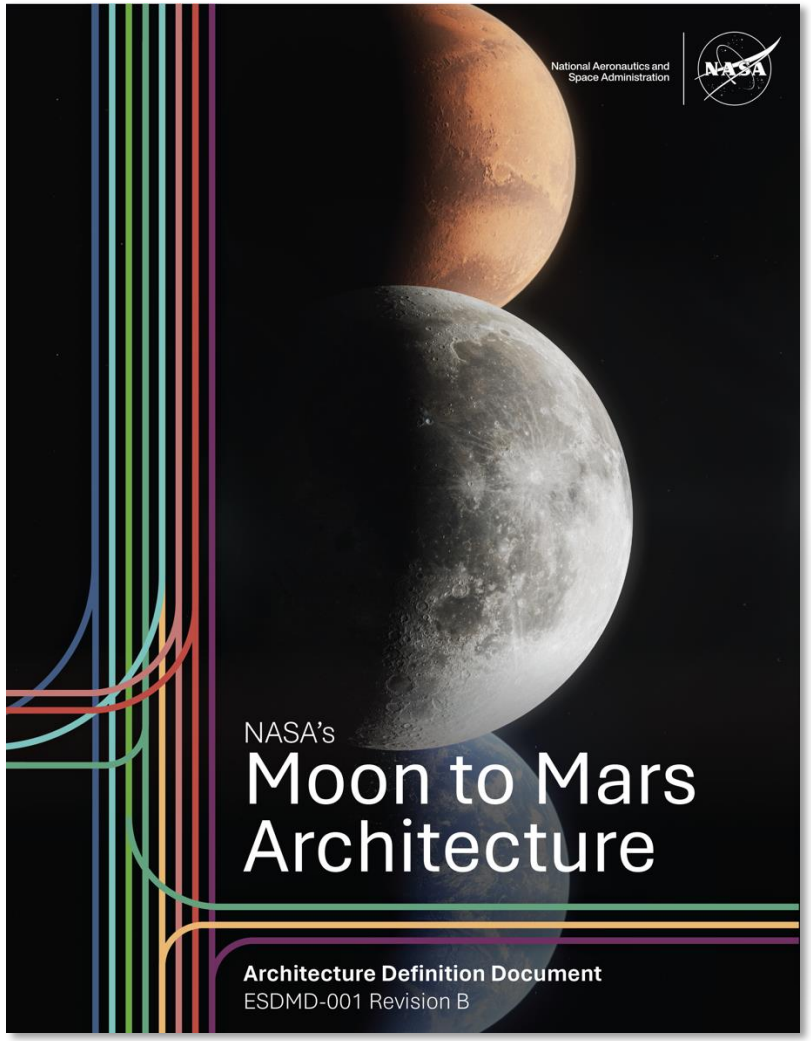
Element Definition
Establish best solution to fulfil the architecture needs within partner and system constraints

Pre-Phase A
Select concept for formulation; prepare for mission concept review.



Architecture Products

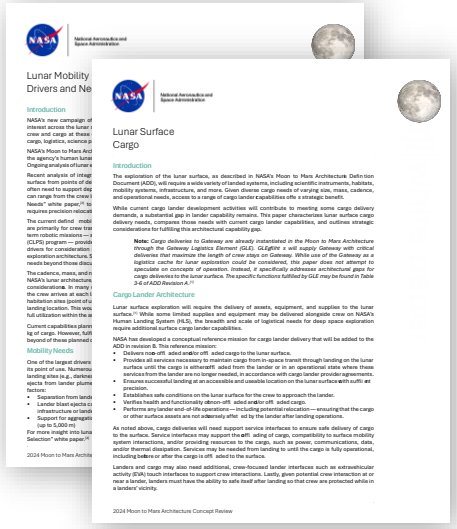
National Aeronautics and Space Administration



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.

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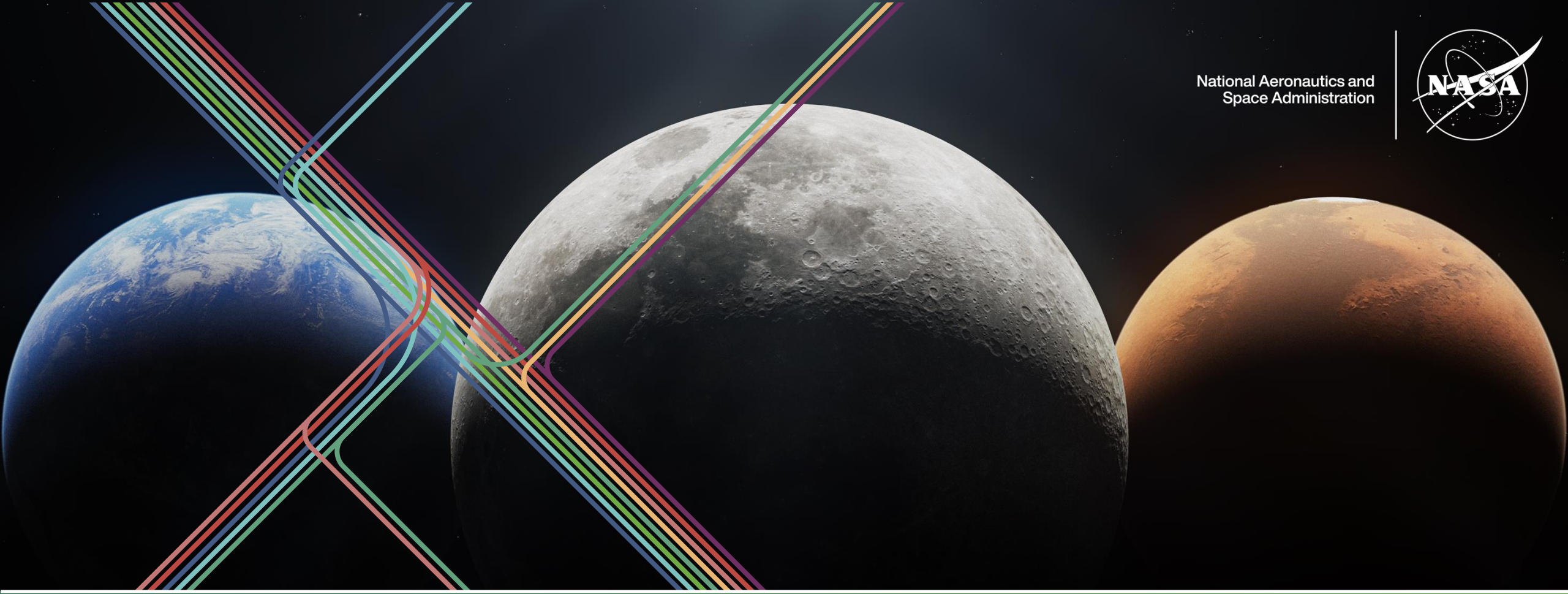
Revision B Published **December 13**

NASA's Moon to Mars Architecture Website

nasa.gov/architecture

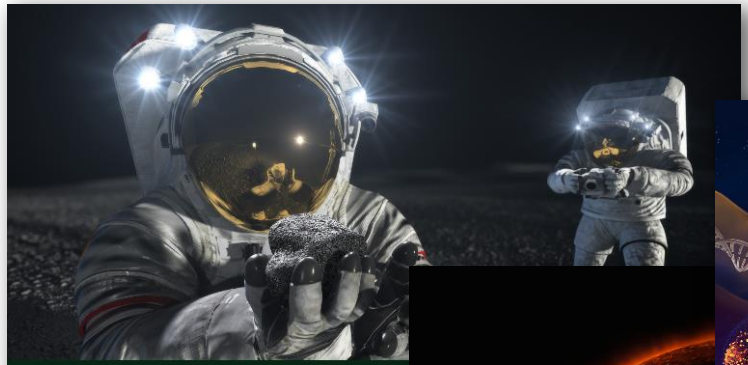


Architecture and Science

Brad Bailey
Deputy Associate
Administrator for Exploration
Science Mission Directorate
NASA – SMD

M2M Objectives – 26 Science Objectives

National Aeronautics and Space Administration



Lunar/Planetary Science (LPS)

Goal: Address high priority planetary science questions that ar and around the Moon and Mars, aided by surface and orbiting r

LPS-1^{LM}:	Uncover the record of solar system origin and early his formed and differentiated, characterizing the impact ch Moon and Mars, and characterize how impact rates in recorded on the Moon and Mars.
LPS-2^{LM}:	Advance understanding of the geologic processes affe structures, characterizing magmatic histories, characte exospheres, and investigating how active processes m
LPS-3^{LM}:	Reveal inner solar system volatile origin and delivery p abundance, composition, transport, and sequestration
LPS-4^{M}:	Advance understanding of the origin of life in the solar habitable environments exist(ed), what processes led habitable conditions have co-evolved over time, and w solar system beyond Earth.

Heliophysics Science (HS)

Goal: Address high-priority heliophysics science combination of human explorers and robotic syst

HS-1^{LM}:	Improve understanding of space weather phenomena to enable enhanced observation and prediction of the environment from space to the surface at the Moon and Mars.
HS-2^{LM}:	Determine the history of the Sun and solar system as recorded in the lunar and Martian regolith.
HS-3^{LM}:	Investigate and characterize fundamental plasma processes, including dust-plasma interactions, using the cislu near-Mars, and surface environments as laboratories.
HS-4^{LM}:	Improve understanding of magnetotail and pristine solar wind dynamics in the vicinity of the Moon and around M

Human and Biological Science (HBS)

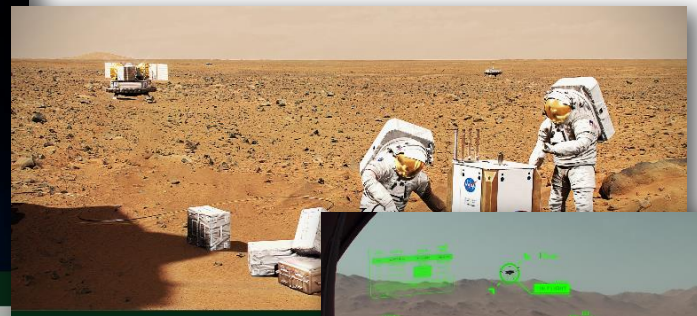
Goal: Advance understanding of how biology responds to the environments of the Moon, Mars, and deep space to advance fundamental knowledge, to support s future exploration.

HBS-1^{LM}:	Understand the effects of short- and l space on biological systems and he and plants.
HBS-2^{LM}:	Evaluate and validate progressively t with mission durations representativ
HBS-3^{LM}:	Characterize and evaluate how the in human health, performance, and spa

Physics and Physical Science (PPS)

Goal: Address high-priority physics and physical science ques attributes of the lunar environment.

PPS-1^{L}:	Conduct astrophysics and fundamental physics investigations of space and time from the radio quiet environment of the lunar far side.
PPS-2^{LM}:	Advance understanding of physical systems and fundamental physics by utilizing the unique environments of the Moon, Mars, and deep space.



Science-Enabling (SE)

Goal: Develop integrated human and robotic metho questions to be addressed around and on the Moon

SE-1^{LM}:	Provide in-depth, mission-specific scie transformational science on the surfac
SE-2^{LM}:	Enable Earth-based scientists to re advanced techniques and tools.
SE-3^{LM}:	Develop the capability to retrieve co on the Moon and volatile-bearing site facilities on Earth.
SE-4^{LM}:	Return representative samples from sample mass commensurate with mis
SE-5^{LM}:	Use robotic techniques to survey si in advance of and concurrent with as surface and maximize science return.
SE-6^{LM}:	Enable long-term, planet-wide researc and surface locations at the Moon and
SE-7^{LM}:	Preserve and protect representative regions and the radio quiet far side as science investigations.

Applied Science (AS)

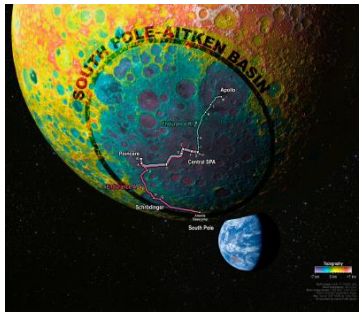
Goal: Conduct science on the Moon, in cislunar space, and around and on Mars using integrated human and robotic methods and advanced techniques, to inform design and development of exploration systems and enable safe operations.

AS-1^{LM}:	Characterize and monitor the contemporary environments of the lunar and Martian surfaces and orbits, including investigations of micrometeorite flux, atmospheric weather, space weather, space weathering, and dust, to plan, support, and monitor safety of crewed operations in these locations.
AS-2^{LM}:	Coordinate on-going and future science measurements from orbital and surface platforms to optimize human-led science campaigns on the Moon and Mars.
AS-3^{LM}:	Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions.
AS-4^{LM}:	Conduct applied scientific investigations essential for the development of bioregenerative-based, ecological life support systems.
AS-5^{LM}:	Define crop plant species, including methods for their productive growth, capable of providing sustainable and nutritious food sources for lunar, Deep Space transit, and Mars habitation.
AS-6^{LM}:	Advance understanding of how physical systems and fundamental physical phenomena are affected by partial gravity, microgravity, and general environment of the Moon, Mars, and deep space transit.

Science Enabled by Architecture

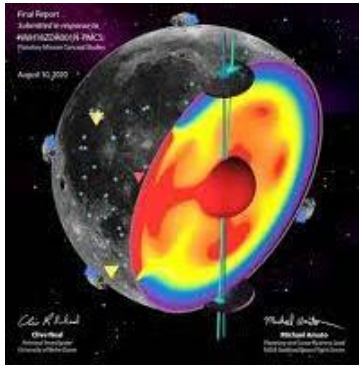
National Aeronautics and Space Administration

Image credit: *Keane et al*



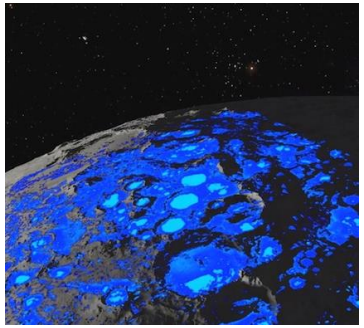
LPS-1

Image credit: *LGN*



LPS-2

Image credit: *ESA*



LPS-3

Science Enabled by Architecture

National Aeronautics and Space Administration

Image credit: *Pexels*

HBS-1

Image credit: *NASA*

HBS-2

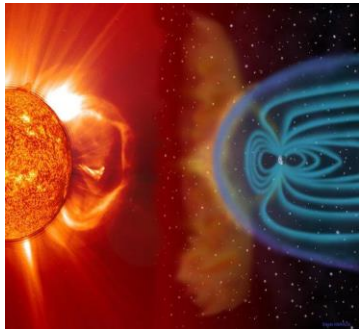
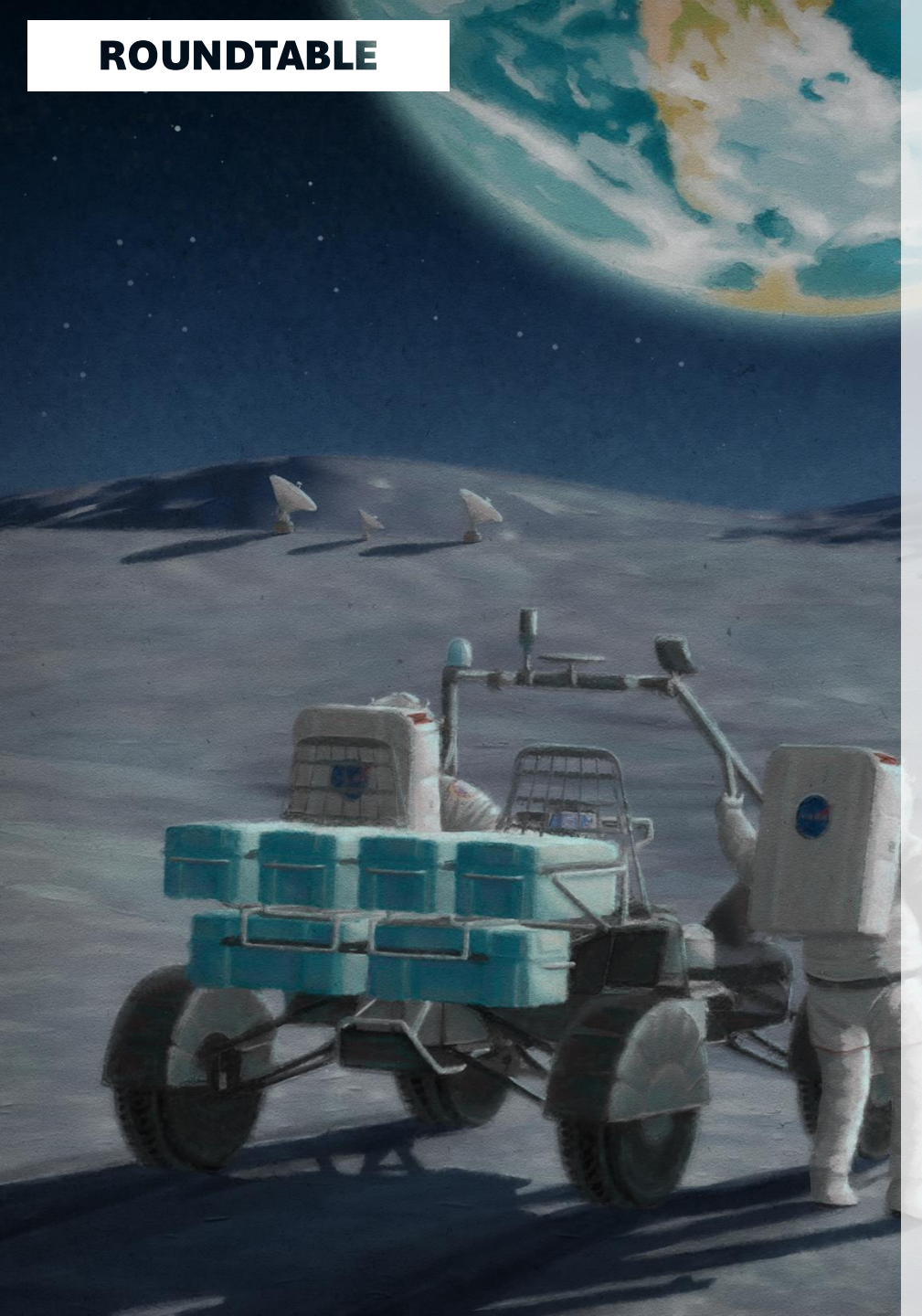


Image credit: *ESA*

HS

ROUNDTABLE



National Aeronautics and Space Administration

Architecture 101

Moon to Mars Architecture Workshop

Room 125

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SMD

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 - ESDMD - SAO

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

Architecture White Papers

National Aeronautics and Space Administration

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