

Architecture 101

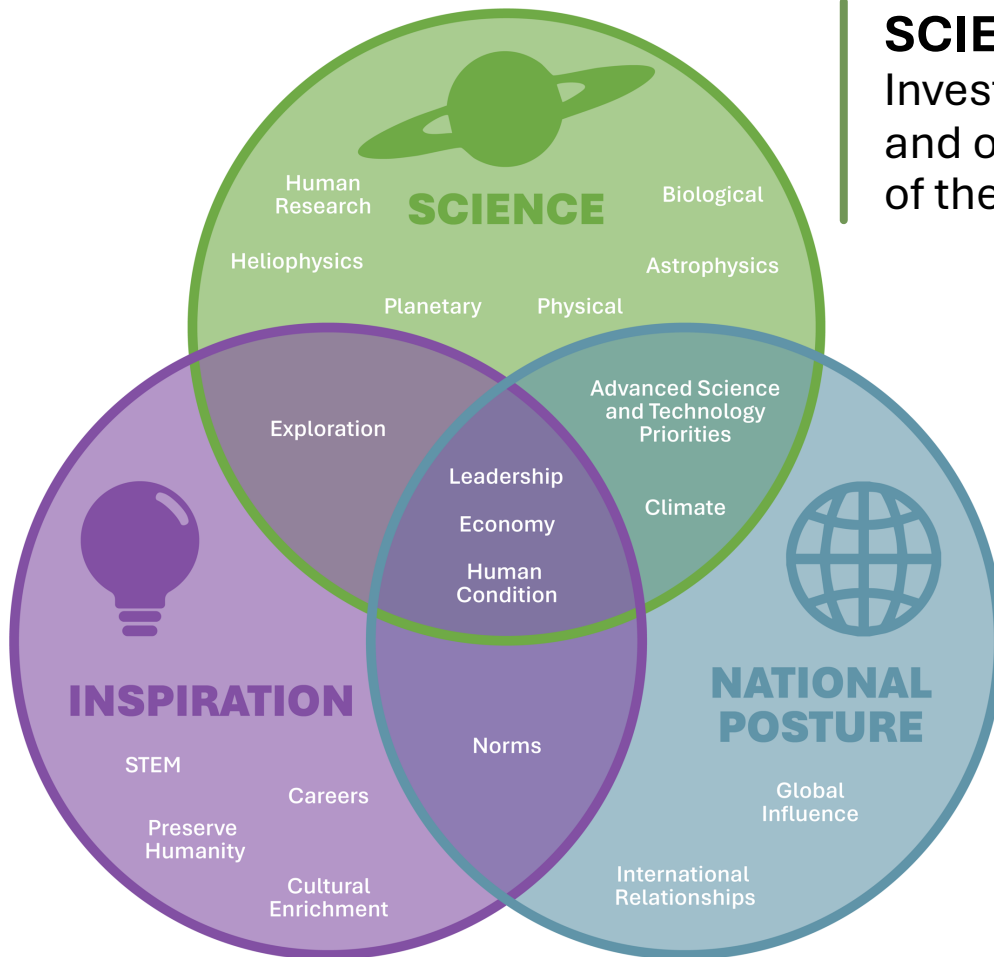
Julie Grantier

Deputy Manager for Integration
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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

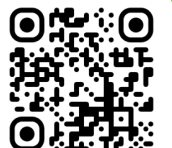
Unity of Purpose

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.

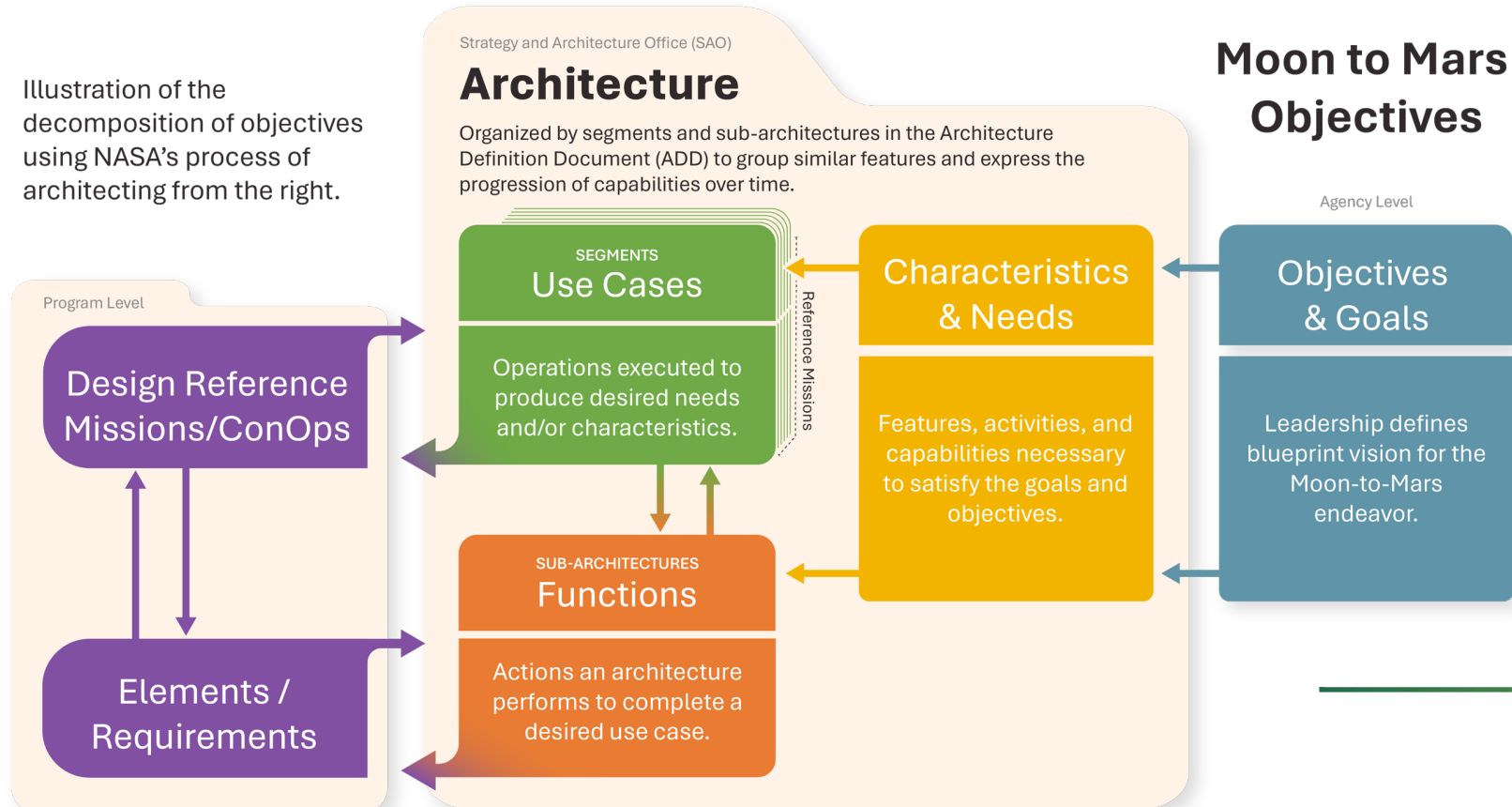


Operations | Conduct crewed missions to gradually build technologies and capabilities to live and work on planetary surfaces other than Earth.

Architecting from the Right



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

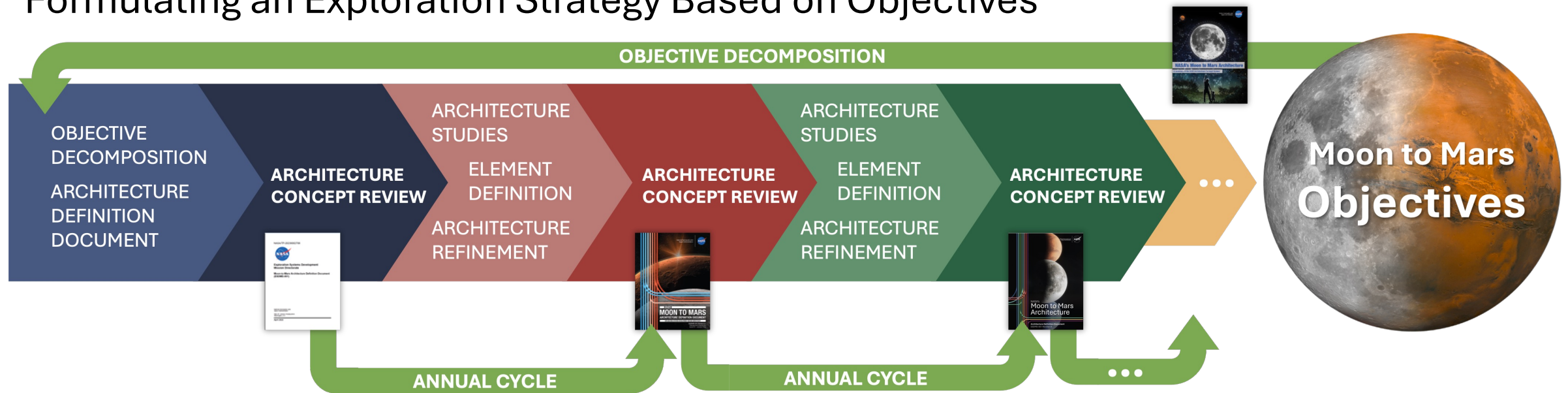


NASA's Moon to Mars Architecture

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An Evolutionary Architecture Process: Formulating an Exploration Strategy Based on Objectives



TRACEABILITY

- → ◇ Decomposition of Blueprint
- → □ Executing Architecture elements

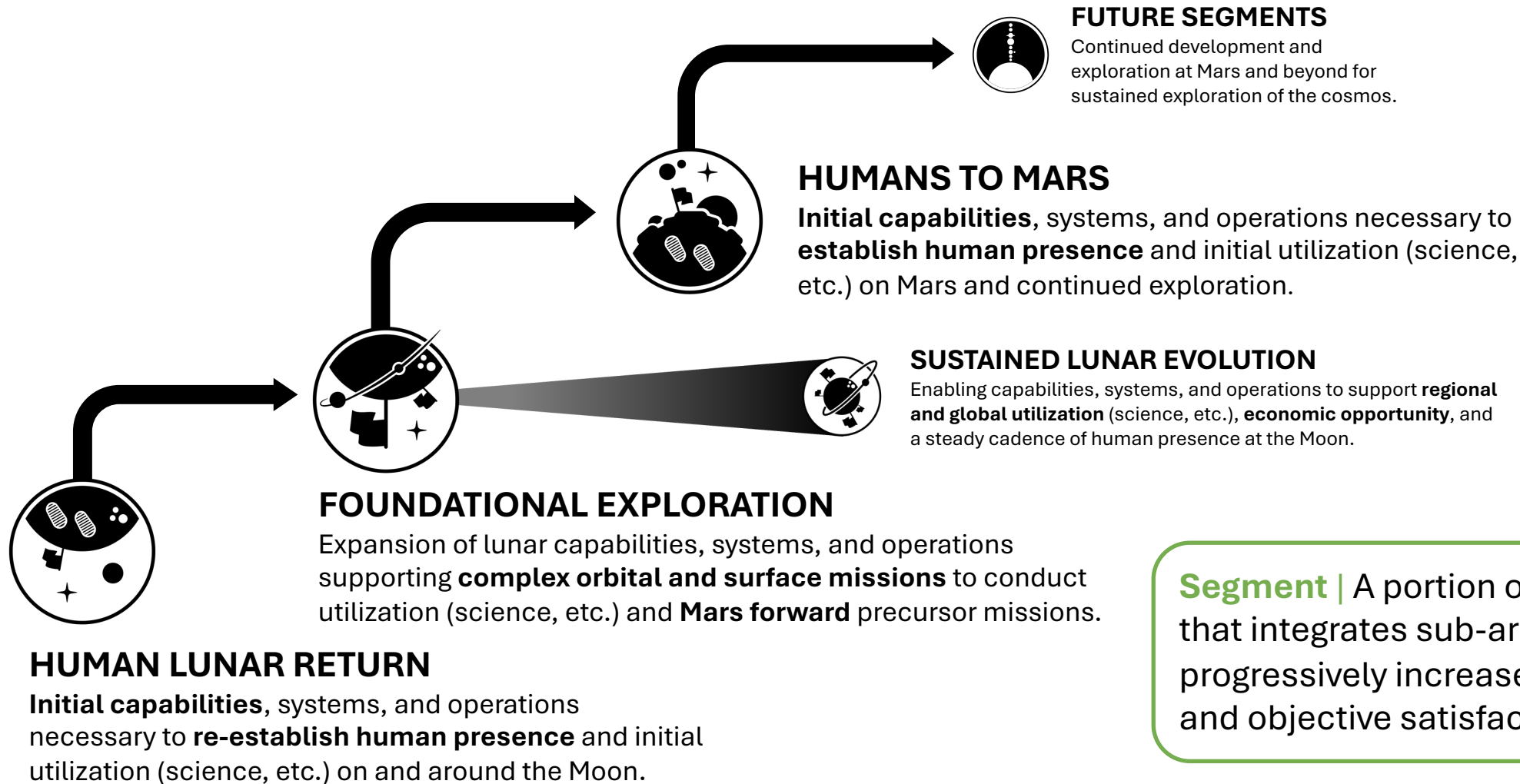
ARCHITECTURE FRAMEWORK

- 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



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

Sub-Architectures



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.



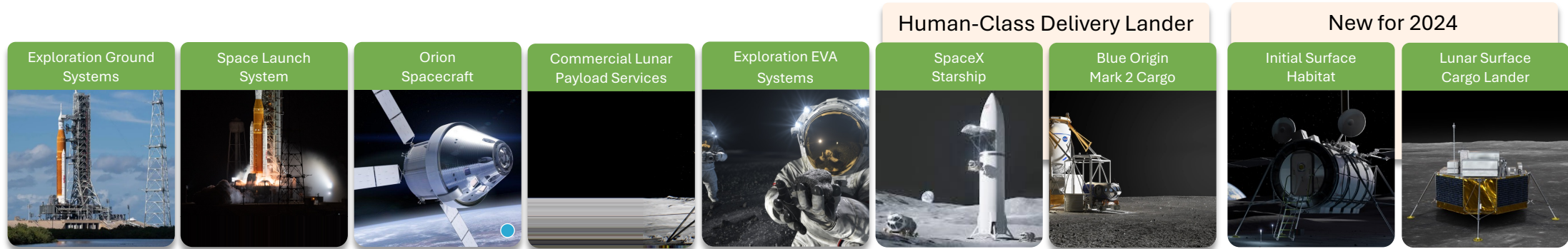
Utilization Systems enable science and technology demonstrations.



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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Human Lunar Return

Foundational Exploration



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

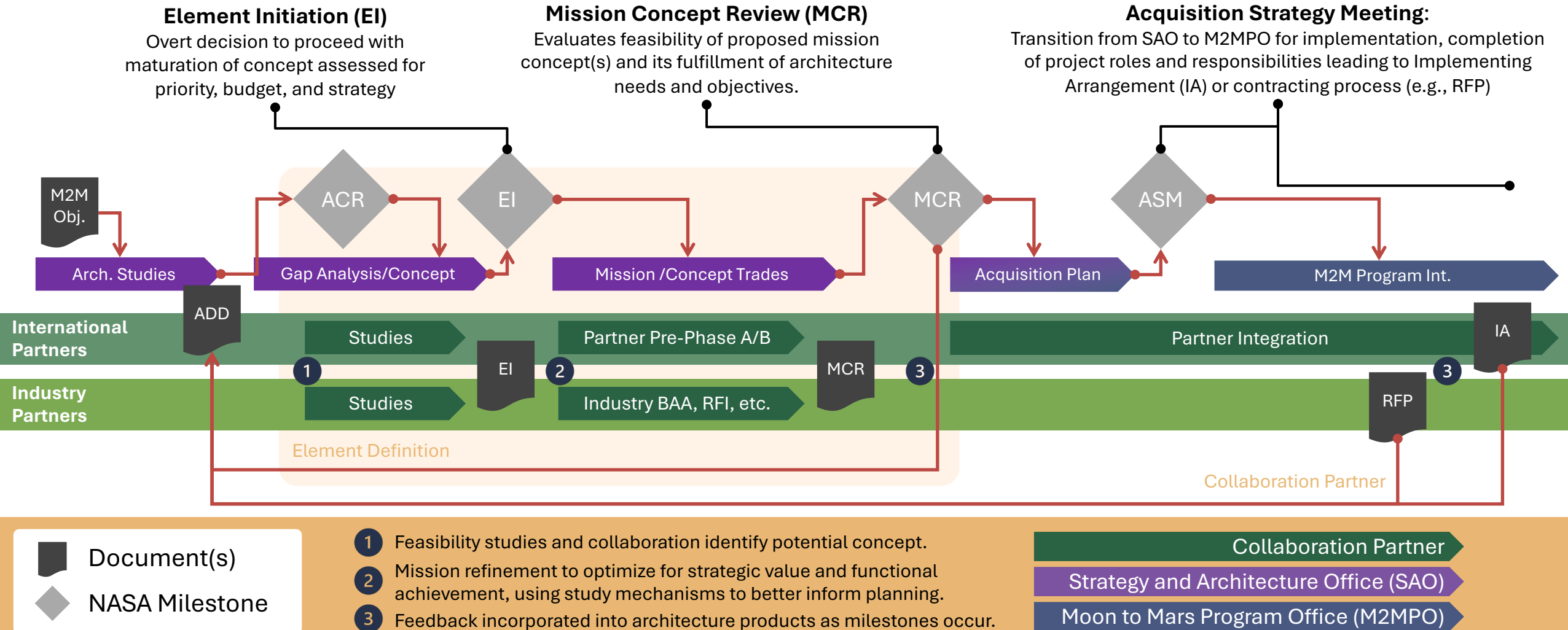
International Partnerships

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

Partner Pre-formulation Process

Exploration Systems Development Mission Directorate

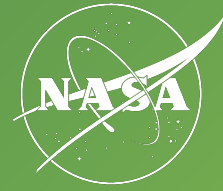
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Concept Maturity Mapped to Process

Fictional Example: Lunar Coffee Maker

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Area of Partner Interest

In-Space Food Systems

Architectural Gap

Provide coffee to
lunar astronauts

Associated Sub-Architectures



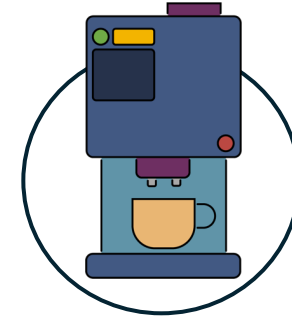
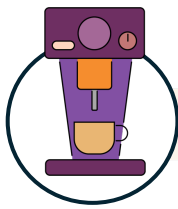
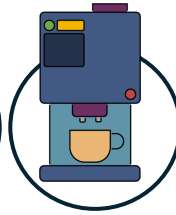
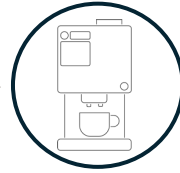
Human
Systems



Habitation
Systems



Logistics
Systems



Lunar Coffee
Maker Element

Espresso
Machine

French
Press

Drip
Coffee

Espresso
Concept 1

Espresso
Concept 2

Espresso
Concept 3

Joint Capability Studies

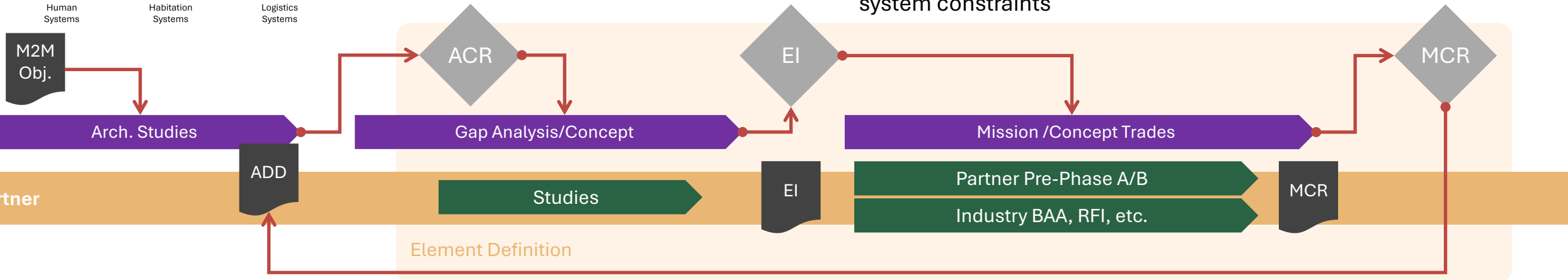
Examine the trade space
while developing concepts.

Element Definition

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

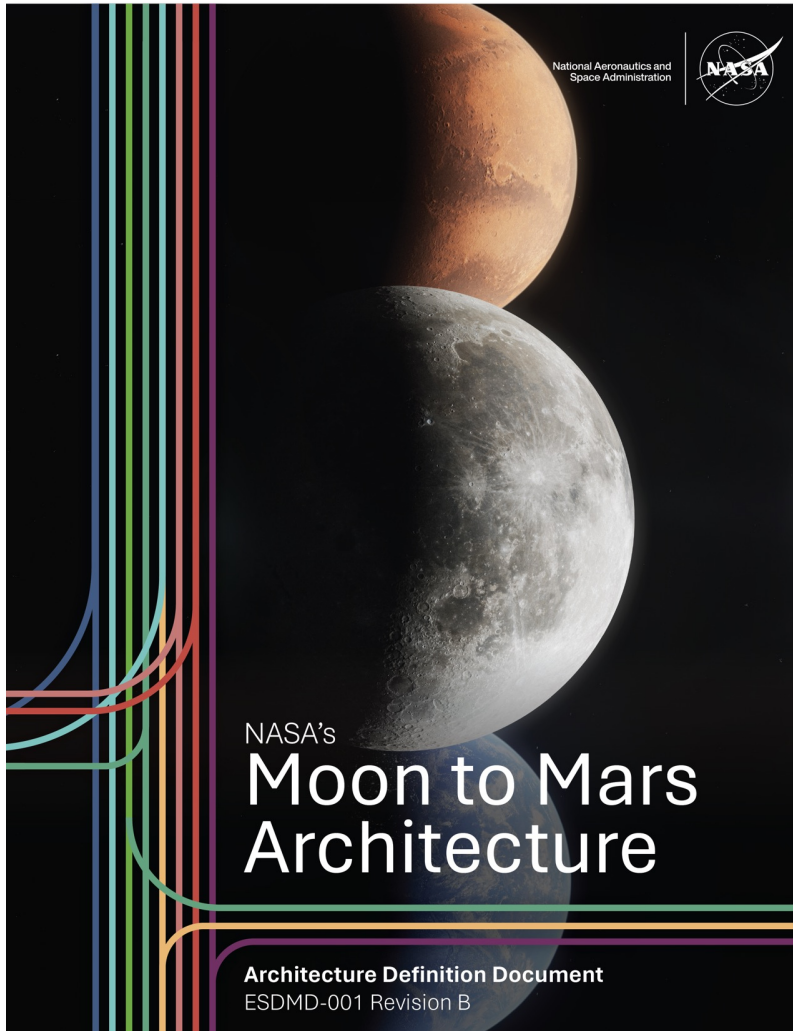
Pre-Phase A

Select concept for formulation;
prepare for mission concept review.

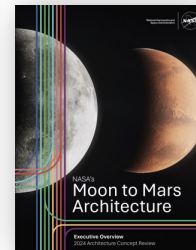


Architecture Products

National Aeronautics and
Space Administration



NASA's Architecture Definition Document



Executive Overview

Architecture White Papers

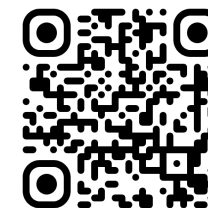


NASA documents its roadmap for deep space exploration in the Architecture Definition Document.

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.



Revision B
Published
December 13



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

Architecture and Science

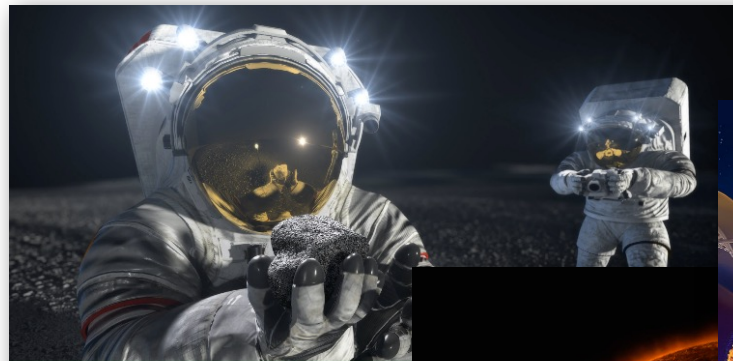
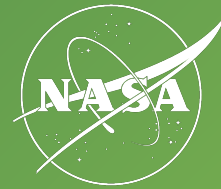
Zachary Pirtle

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Strategy and Integration Office (ESSIO)
Science Mission Directorate
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M2M Objectives – 26 Science Objectives

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LUNAR/PLANETARY SCIENCE (LPS)

Goal: Address high priority planetary science questions that are addressed around the Moon and Mars, aided by surface and orbiting resources.

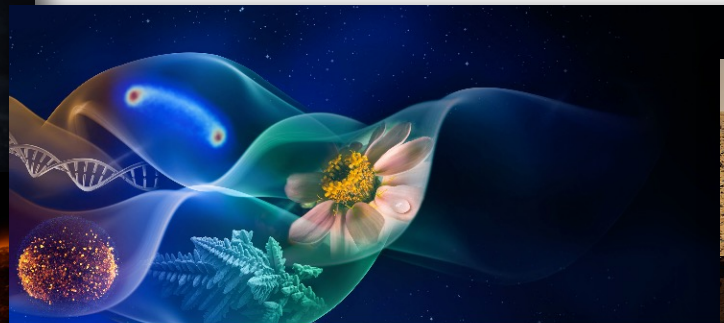
- LPS-1^{UM}: Uncover the record of solar system origin and early history, including how the Moon and Mars formed and differentiated, characterizing the impact cratering record on the Moon and Mars, and characterize how impact rates in the solar system have changed over time.
- LPS-2^{UM}: Advance understanding of the geologic processes affecting the Moon and Mars, characterizing magmatic histories, characterizing the evolution of the exospheres, and investigating how active processes may be occurring on the Moon and Mars.
- LPS-3^{UM}: Reveal inner solar system volatile origin and delivery pathways, abundance, composition, transport, and sequestration on the Moon and Mars.
- LPS-4^{UM}: Advance understanding of the origin of life in the solar system, including whether habitable environments exist(ed), what processes led to the emergence of life, and how habitable conditions have co-evolved over time, and what processes may be occurring in the solar system beyond Earth.



HELIOPHYSICS SCIENCE (HS)

Goal: Address high-priority heliophysics science questions that are addressed around the Moon and Mars, aided by surface and orbiting resources.

- HS-1^{UM}: 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^{UM}: Determine the history of the Sun and solar system as recorded in the lunar and Martian regolith.
- HS-3^{UM}: Investigate and characterize fundamental plasma processes, including dust-plasma interactions, using the cislunar and near-Mars, and surface environments as laboratories.
- HS-4^{UM}: Improve understanding of magnetotail and pristine solar wind dynamics in the vicinity of the Moon and around Mars.



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 safe exploration, and to inform design and development of exploration systems and enable safe operations.

- HBS-1^{UM}: Understand the effects of short- and long-term space on biological systems and human health and plants.
- HBS-2^{UM}: Evaluate and validate progressively more complex mission durations representative of human exploration.
- HBS-3^{UM}: Characterize and evaluate how the human health, performance, and safety are affected by the lunar and Martian environments.



PHYSICS AND PHYSICAL SCIENCE (PPS)

Goal: Address high-priority physics and physical science questions that are addressed around the Moon and Mars, aided by surface and orbiting resources.

- PPS-1^{UM}: Conduct astrophysics and fundamental physics investigations of space and time from the radio quiet environment of the lunar far side.
- PPS-2^{UM}: 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 methods and advanced techniques, to inform design and development of exploration systems and enable safe operations.

- SE-1^{UM}: Provide in-depth, mission-specific science and technology on the surface of the Moon and Mars.
- SE-2^{UM}: Enable Earth-based scientists to use advanced techniques and tools.
- SE-3^{UM}: Develop the capability to retrieve core samples from the Moon and volatile-bearing sites on Earth.
- SE-4^{UM}: Return representative samples from the Moon and Mars commensurate with mission goals.
- SE-5^{UM}: Use robotic techniques to survey sites in advance of and concurrent with human exploration and maximize science return.
- SE-6^{UM}: Enable long-term, planet-wide research and surface locations at the Moon and Mars.
- SE-7^{UM}: 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^{UM}: 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^{UM}: 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^{UM}: 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^{UM}: Conduct applied scientific investigations essential for the development of bioregenerative-based, ecological life support systems.
- AS-5^{UM}: 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^{UM}: 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

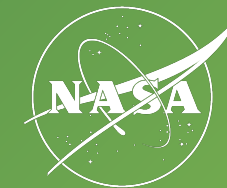
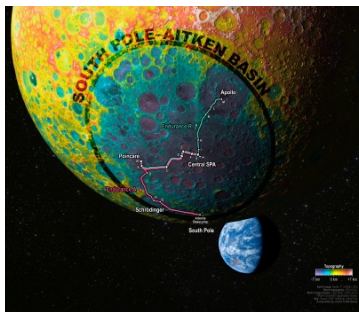


Image credit: Keane et al



LPS-1

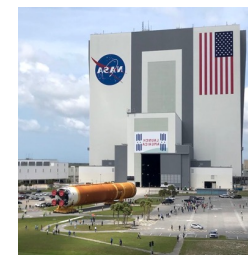
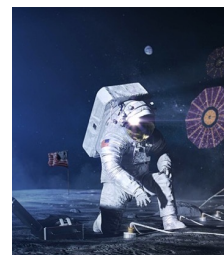
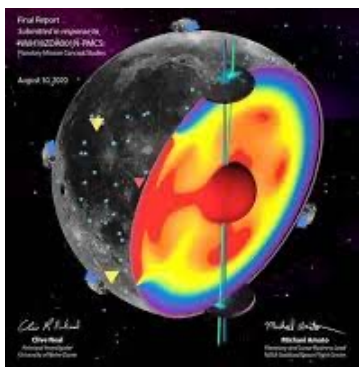


Image credit: LGN



LPS-2

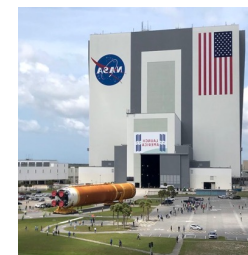
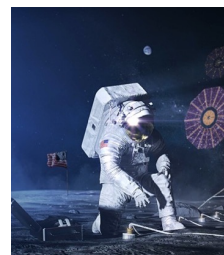
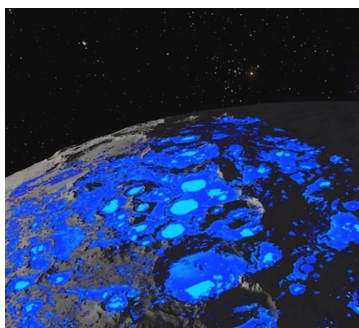
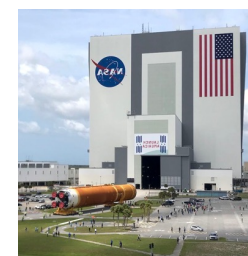
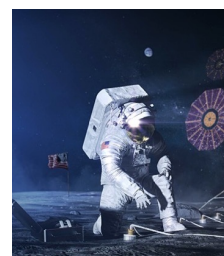
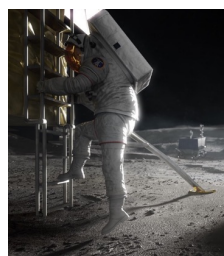


Image credit: ESA



LPS-3



Science Enabled by Architecture

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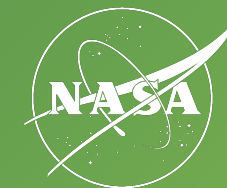


Image credit: Pexels



HBS-1

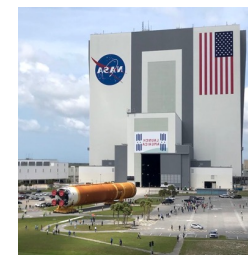
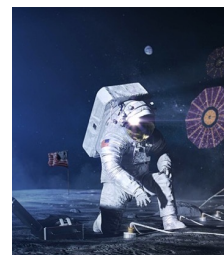


Image credit: NASA



HBS-2

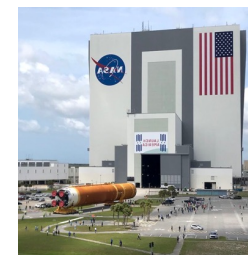
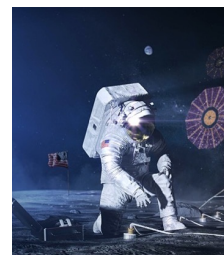
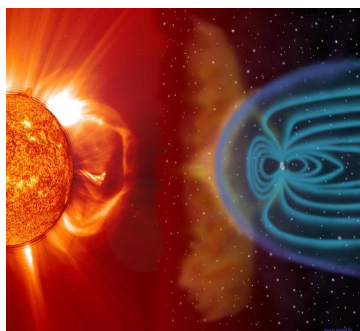
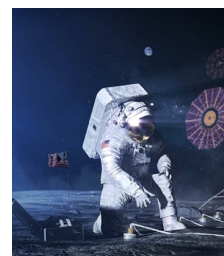
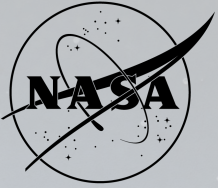


Image credit: ESA



HS





Architecture 101

Moon to Mars Architecture Workshop



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Questions and Discussion

National Aeronautics and
Space Administration



Discussion Prompts



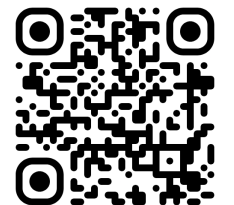
- Have you read the Architecture Definition Document? How is your organization using it to inform your investments and strategies? Are there changes in the documentation or process that would be useful to industry or academia?
- What future white paper topics would be helpful to your organization?
- 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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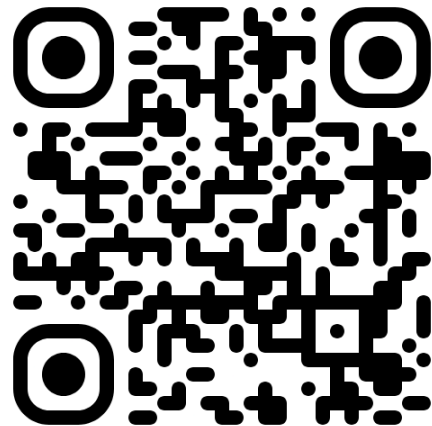


Architecture White Papers

National Aeronautics and
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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	



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

■ Moon-Focused
■ Mars-Focused
■ Cross-Cutting