



NASA's Moon to Mars Architecture

A Roadmap for Exploration Architected from the Right

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Protection Fall Meeting
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STRATEGY AND ARCHITECTURE OFFICE
EXPLORATION SYSTEMS DEVELOPMENT MISSION DIRECTORATE

Deep Space Exploration Priorities



“...Human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021



Space Policy Directive-1
December 2017



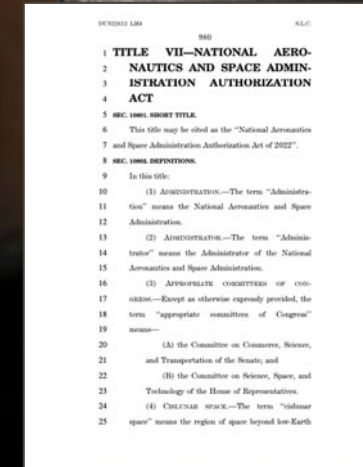
National Space Council
March 2019



Space Priorities Framework
December 2021



NASA Strategic Plan
March 2022



NASA Authorization Act
July 2022

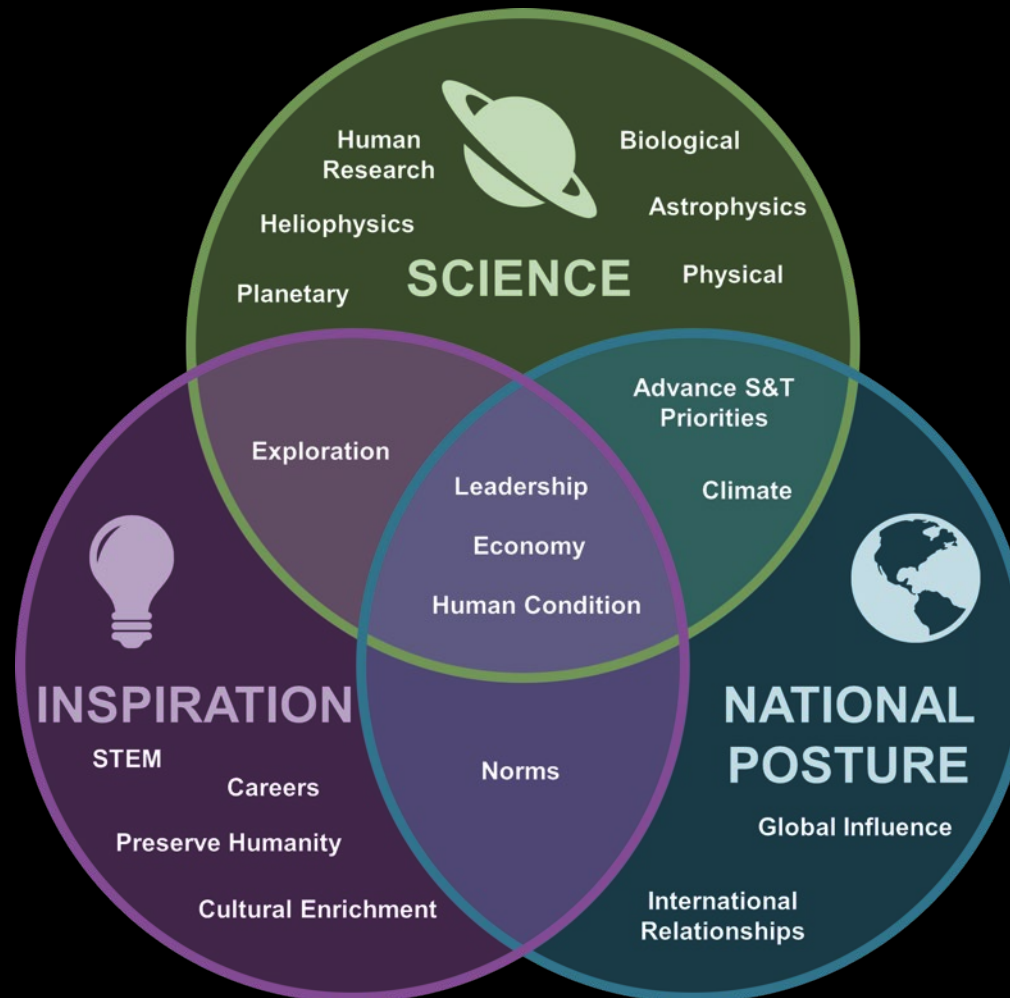


President's Budget Request
March 2023

Why Go? The Benefit to Humanity



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



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.

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.

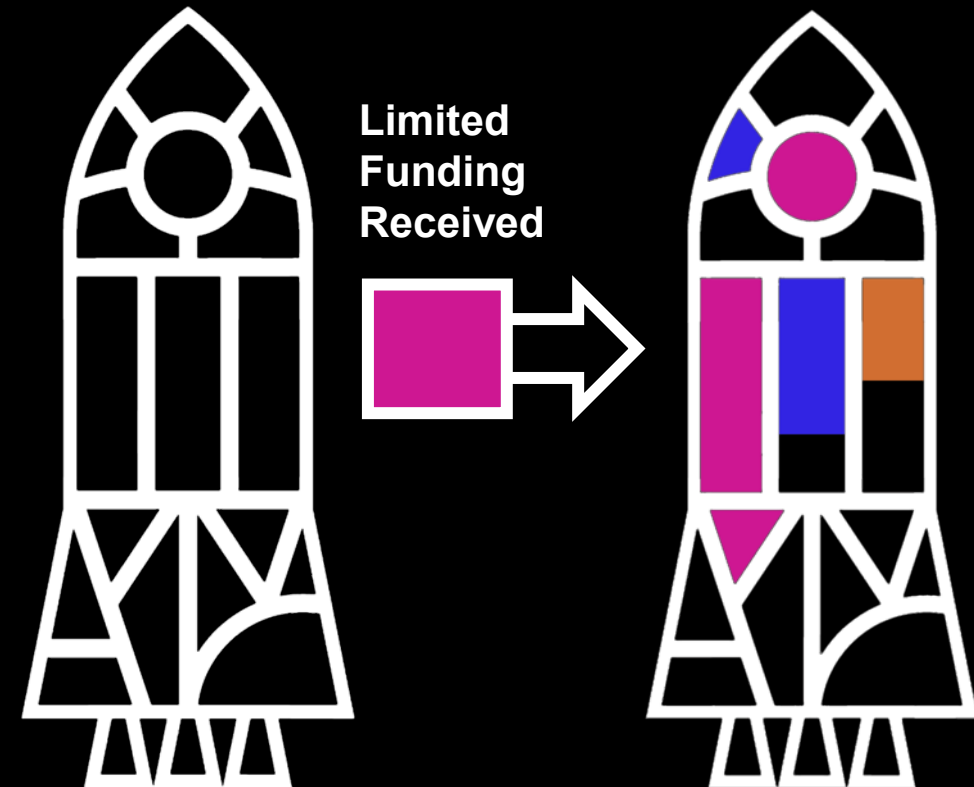
Historical Context: Moon to Mars Plan



We need an objective-based approach

We must think **strategically** with **resilience and flexibility** in mind and **enhance our communications** to better achieve **unity of purpose**

- We've been on a 30+ year roller-coaster ride for Moon to Mars development
- We've experienced widespread stress and anxiety in the wake of Constellation cancellation
- A capability-based approach does not fully support a long-term strategy to Mars



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

Recurring Tenets



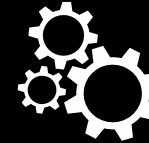
RT-1: INTERNATIONAL COLLABORATION

Partner with the international community to achieve common goals and objectives.



RT-4: CREW TIME

Maximize crew time available for science and engineering activities within planned mission durations.



RT-7: INTEROPERABILITY

Enable interoperability and commonality (technical, operations and process standards) among systems, elements, and crews throughout the campaign.



RT-2: INDUSTRY COLLABORATION

Partner with U.S. industry to achieve common goals and objectives.



RT-5: MAINTAINABILITY AND REUSE

When practical, design systems for maintainability, reuse, and/or recycling to support the long-term sustainability of operations and increase Earth independence.



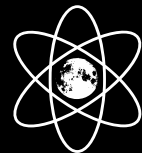
RT-8: LEVERAGE LOW-EARTH ORBIT

Leverage infrastructure in low Earth orbit to support Moon to Mars activities.



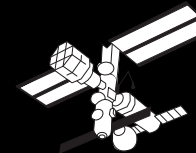
RT-3: CREW RETURN

Return crews safely to Earth while mitigating adverse impacts to crew health.



RT-6: RESPONSIBLE USE

Conduct all activities for the exploration and use of outer space for peaceful purposes consistent with international obligations, and principles for responsible behavior in space.



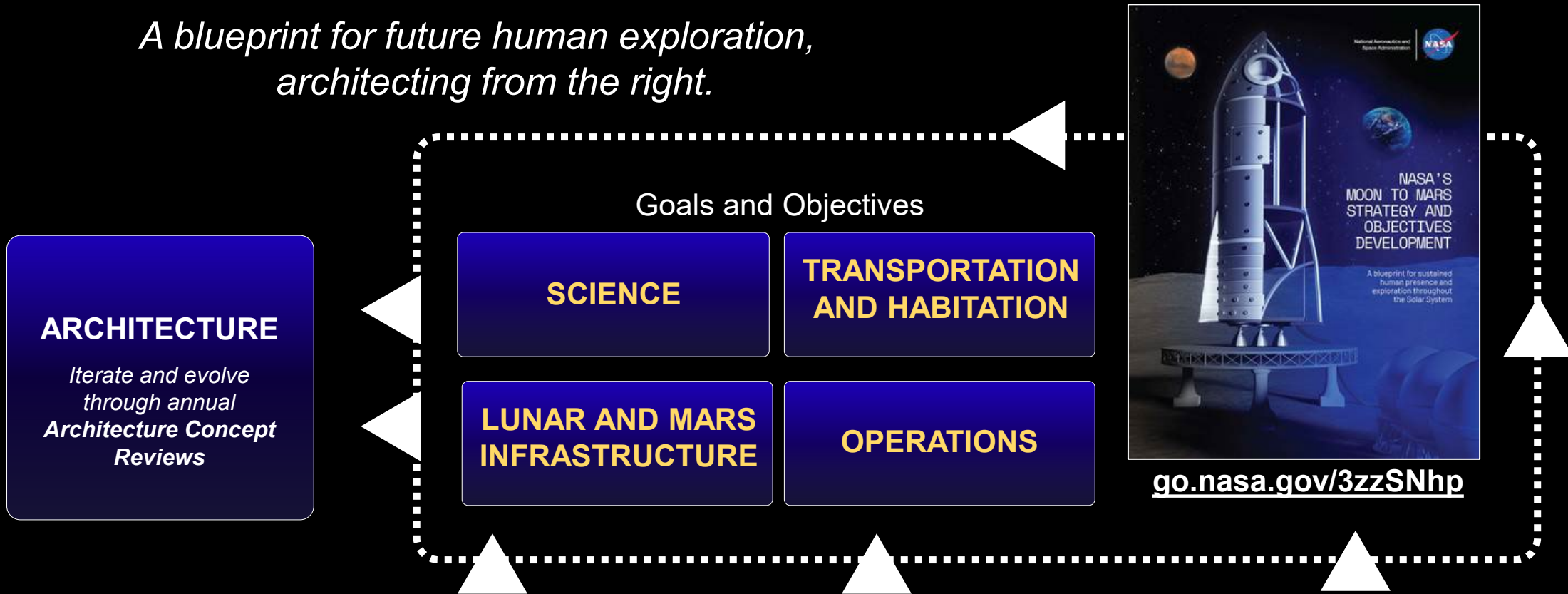
RT-9: COMMERCE AND SPACE DEVELOPMENT

Foster the expansion of the economic sphere beyond Earth orbit to support U.S. industry and innovation.

NASA's Moon to Mars Strategy and Objectives



*A blueprint for future human exploration,
architecting from the right.*



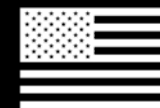
Requested feedback on these objectives in summer 2022 from the following key stakeholders:



NASA workforce:
our greatest asset



International partners: our key
current and future, anticipated
collaborators



U.S. industry, academia, DOE, NIH,
NSF, etc.: our national leaders in
space research and capabilities

Moon to Mars Objectives



Evolutionary Architecture Process

Formulating architecture and exploration strategy based on objectives



Key Components of the Approach

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 AND PRODUCTS

Clear communication and review integration paths for stakeholders

Architecture Concept Reviews



The purpose of the yearly Architecture Concept Review (ACR) is to help unify the agency, promote advocacy for the architecture, and generate inputs from across NASA.



Goal of Architecture Concept Review 22

ACR22 reached concurrence on...

- Newly established ACR process
- Disposition of key issues for Moon to Mars Architecture Definition Document
- Priority tasks for ACR23

ACR 23 Future Architecture Concept Reviews

Further refinements will align with budget cycle to accommodate for evolving...

- Detail and definition of objective needs and efforts to enable Mars missions
- Partner Contributions
- Technology and innovations
- Humans to Mars

2022 Architecture Concept Review



ARCHITECTURE CONCEPT REVIEW (ACR22)

Participation included representation from Mission Directorates, Agency Leadership, NASA Centers, Tech Authorities, ESDMD Leadership, Program Managers, and the Architecture Team

Executing from the Left: Segments and Sub-architectures



Segment: A portion of the architecture, identified by one or more notional missions or integrated use cases, illustrating the interaction, relationships, and connections of the sub-architectures through progressively increasing operational complexity and objective satisfaction.



Human Lunar Return

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

Focus for ACR 22



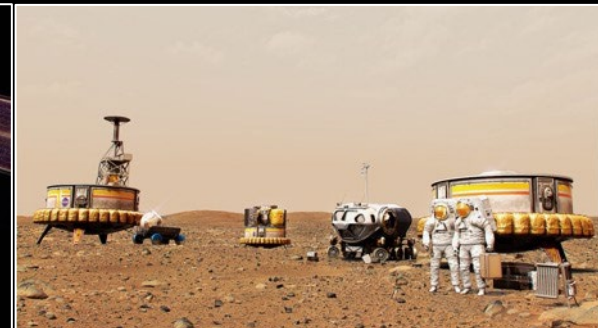
Foundational Exploration

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



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 on and around the Moon.



Humans to Mars

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

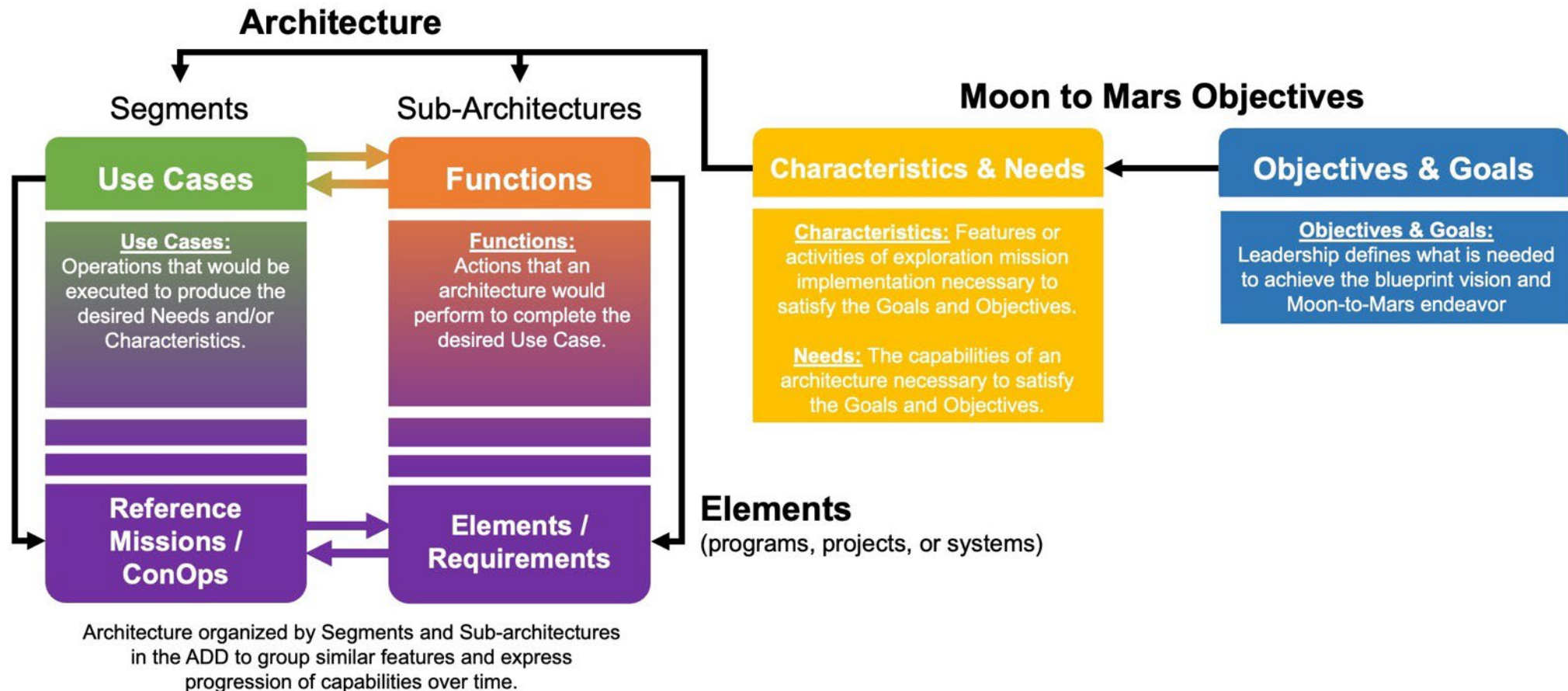
Focus for ACR 23

Sub-architecture: A group of tightly-coupled systems, functions, and capabilities that perform together to accomplish architecture objectives.

Communication, Positioning, Navigation, and Timing •
Habitation • Human Systems • Logistics • Mobility Systems
• Power • Transportation • Utilization Systems



Architecting from the Right



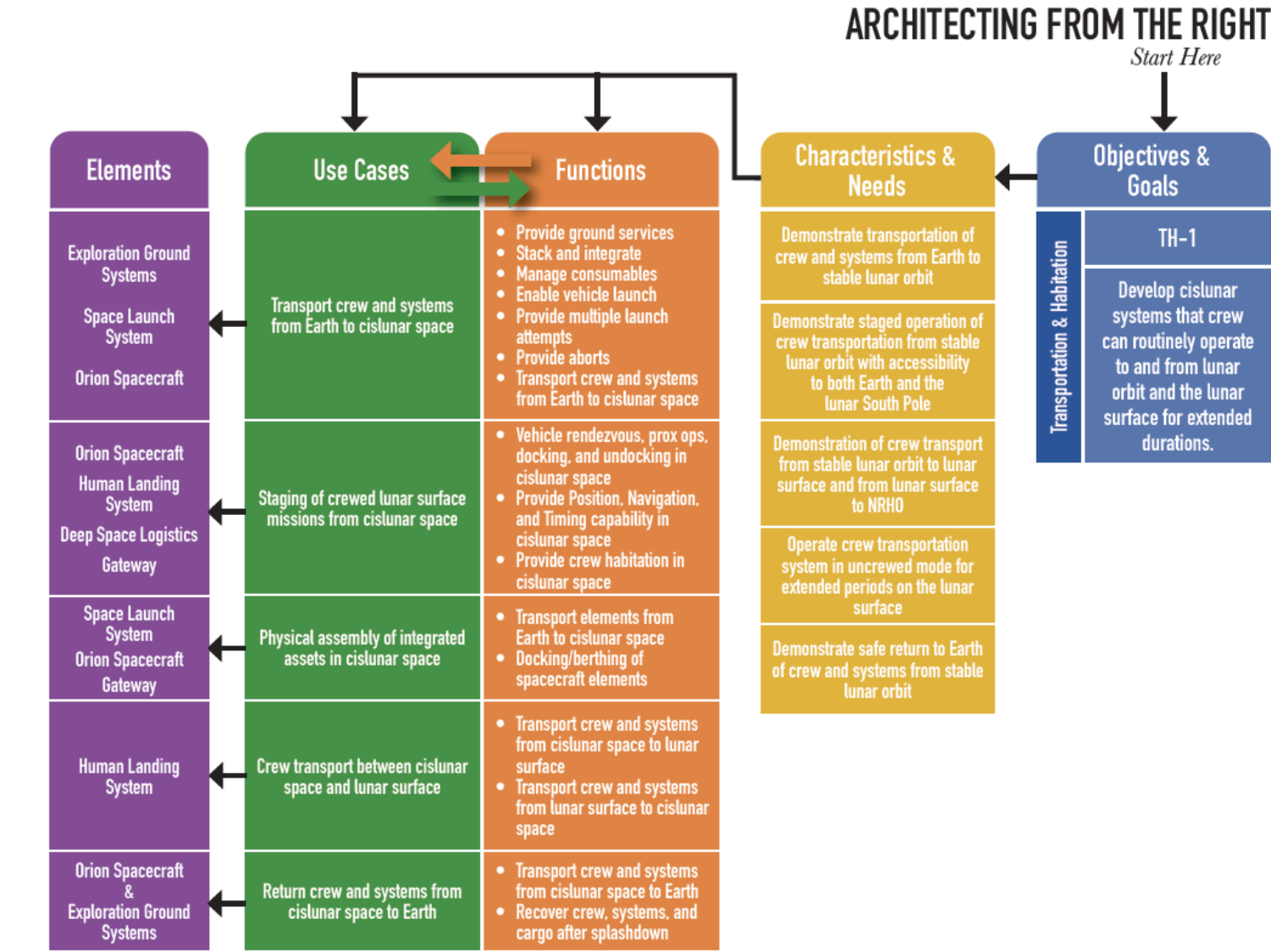
The Architecture process requires a decomposition of Moon to Mars Objectives to element functions and mission use cases to complete the process of “architecting from the right.” This establishes the relationship of executing programs and projects to the driving goals and objectives.

Decomposing to Elements



Example Objective Decomposition

Example of the full distillation of the objectives into lunar-specific Use Cases, Functions, and Elements for the *Human Lunar Return* segment using one of 12 Transportation and Habitation Objectives.

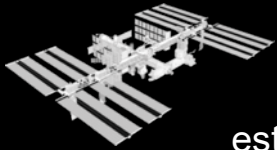


Capabilities Integration



CAPABILITY

The ability to complete a task or meet an exploration objective through Architecture, Engineering, Development, Technology, or Operations for a given set of constraints and level of risk



Current Capabilities

Capabilities we have today, established and flight validated on the International Space Station, robotic missions....

THE
DIFFERENCE
IS THE
← **GAP** →

Future Needed Capabilities

Anticipated future capabilities based on national space policy, planned mission architectures, agency strategic planning, and standards.



**GAP CLOSURE
APPROACH**



**TEST
LOCATION**



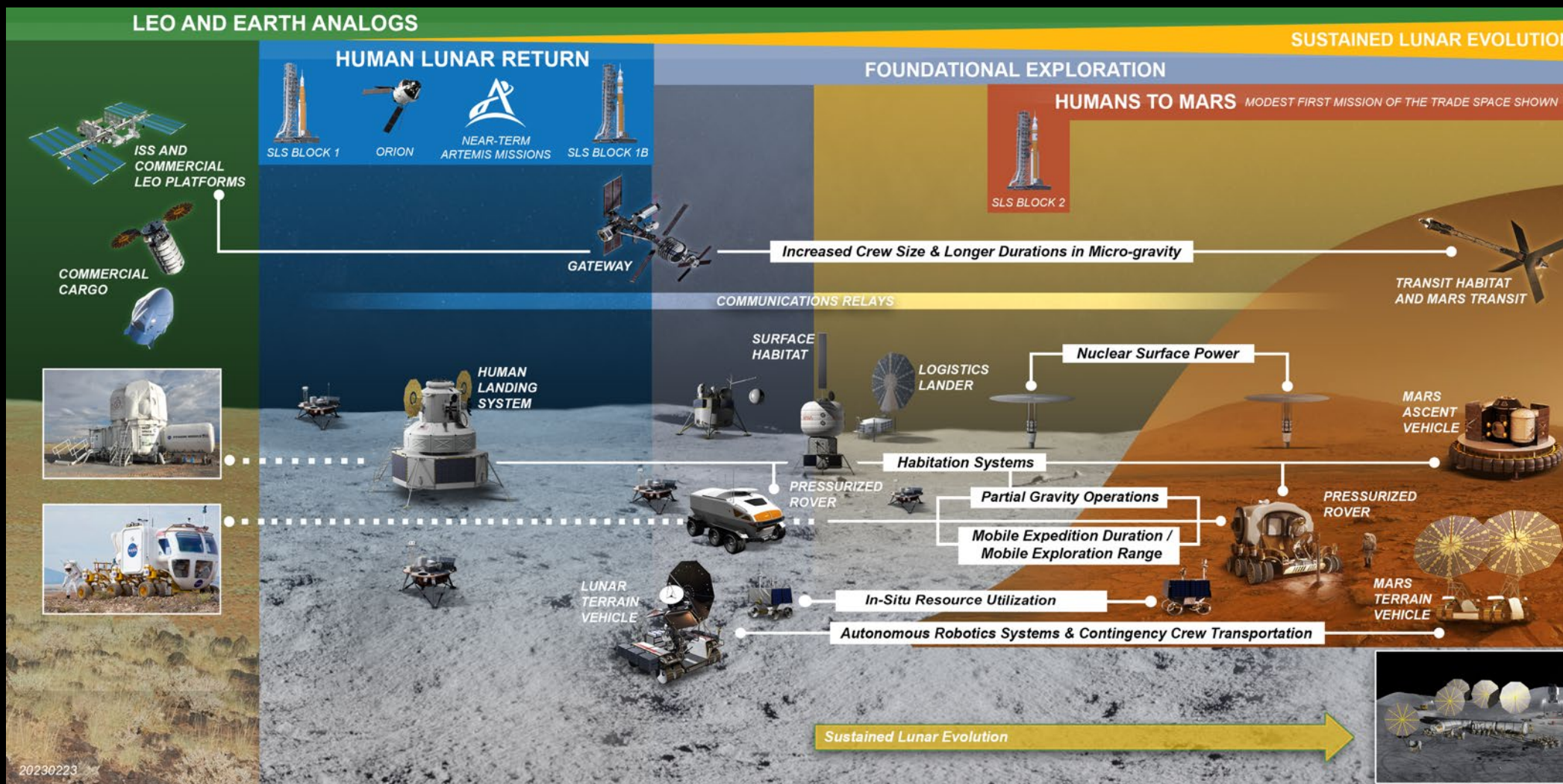
**MELESTONE
CLOSURE**



OUTCOMES



Moon to Mars Campaign Elements



Elements shown beyond "Human Lunar Return" are notional.

Looking Ahead



Continual Documentation

Documentation of refined objectives for distribution including rationale

Updated Architecture Definition Document available early 2024 with expanded Mars content and Foundational Exploration elements.

Enhanced Communication and Engagement

Continued discussions with International, Industry, Academia, Workforce, and Stakeholders

Architecture Concept Review

Closeout of the objectives integration effort and gap analysis will be approved at the 2023 NASA Internal Architecture Concept Review with results shared externally

White Papers

Strategy & Architecture Office will deliver a series of short white papers on various aspects of the architecture.

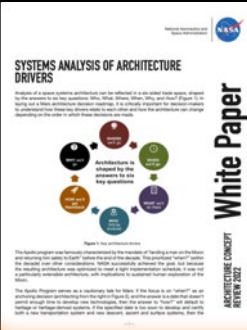
Those will begin in early 2024 after the completion of the 2023 Architecture Concept Review process.



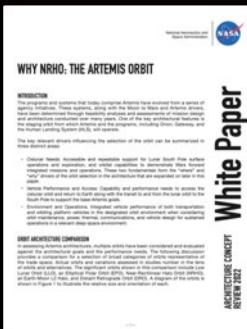


nasa.gov/architecture

Moon to Mars Architecture, Objectives, White Papers and More



Systems Analysis of Architecture Drivers



Why NRHO: The Artemis Orbit



Mars Transportation



Gateway: The Cislunar Springboard



Mars Forward Capabilities to Be Tested at the Moon

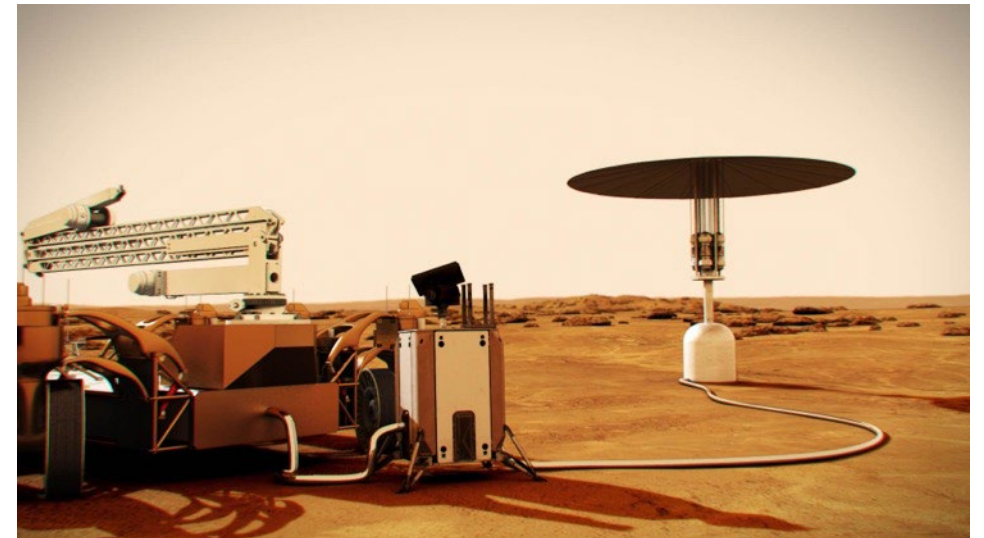


Why Artemis Will Focus on the Lunar South Polar Region

ACR23 Initial Humans to Mars Segment Focus



- **Objective decomposition for Mars objectives**
 - Deferred from ACR22 for schedule
 - Additional content as is traces to lunar supporting needs
- **Initial list of major Mars decisions that are needed**
- **Expanded content in the Mars trades and studies**
- **Mars White Papers:**
 - Mars Communication Challenges
 - Mars Mission Abort Challenges
 - Mars Round-Trip Mission Mass Challenges
 - Mars Surface Power Considerations
 - Human Health Countermeasures: Keeping Astronauts Safe & Productive on a Mission to Mars





Questions?

