



## NASA's Moon to Mars Architecture Workshop

# M2M Architecture Process Overview

### **JIM FREE**

Associate Administrator  
Exploration Systems Development  
Mission Directorate

### **CATHERINE KOERNER**

Deputy Associate Administrator  
Exploration Systems Development  
Mission Directorate

### **NUJOUD MERANCY**

Architecture Lead  
Exploration Systems Development  
Mission Directorate



# Deep Space Exploration Priorities

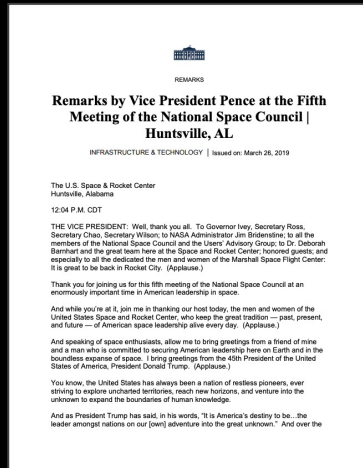


“...Human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

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



Space Policy Directive-1  
December 2017



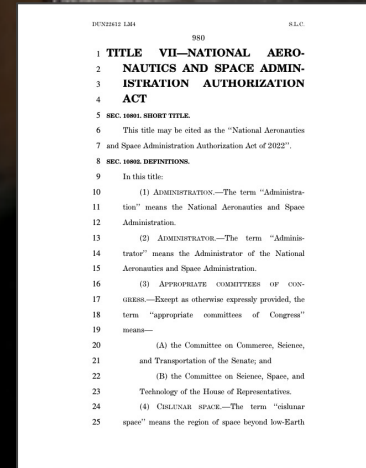
National Space Council  
March 2019



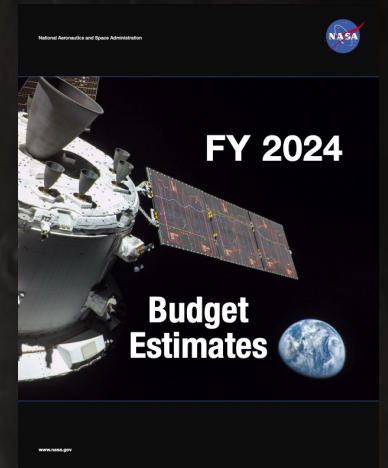
Space Priorities Framework  
December 2021



NASA Strategic Plan  
March 2022



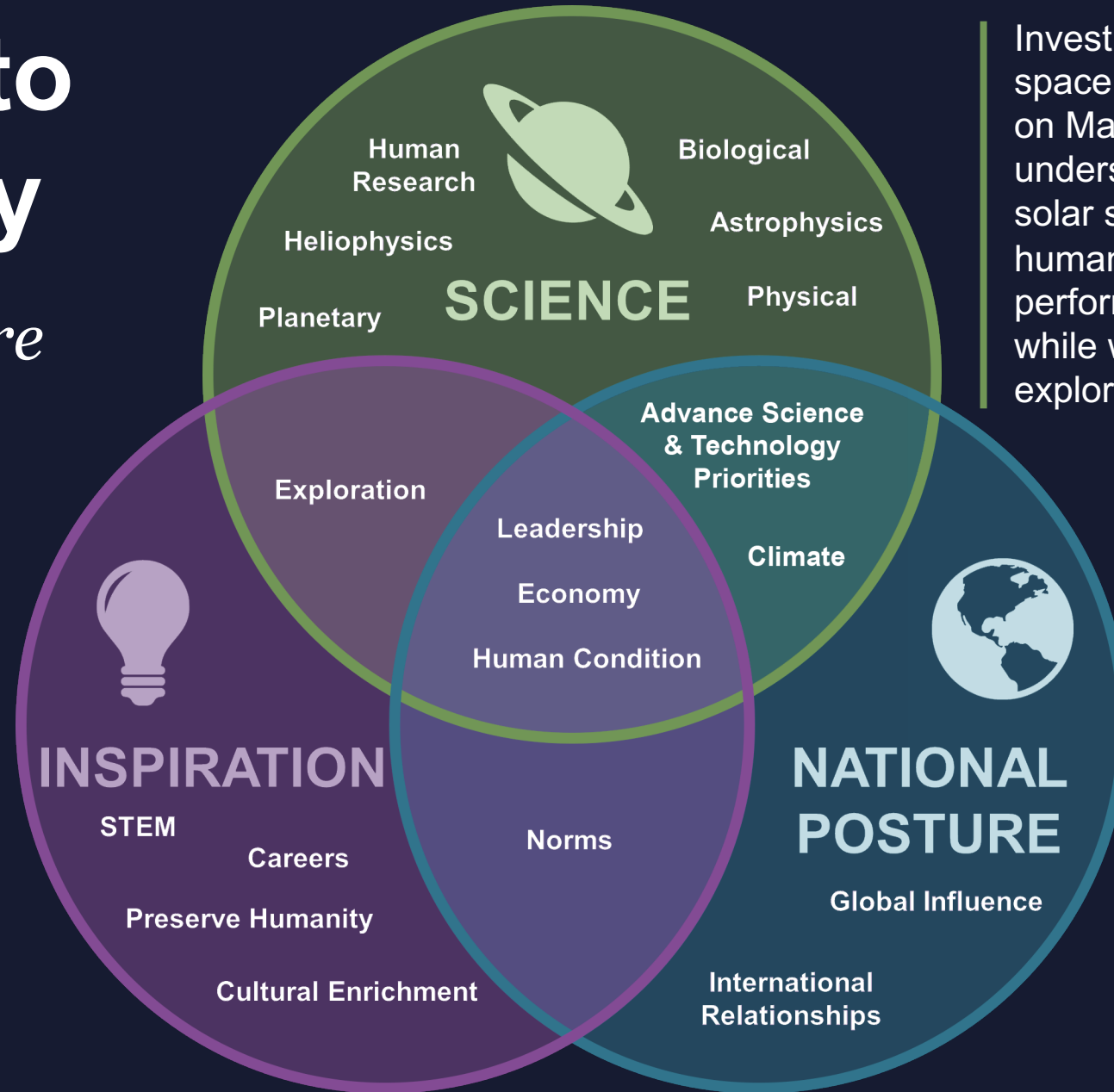
NASA Authorization Act  
July 2022



President's Budget Request  
March 2023

# Benefits to Humanity

## *Why We Explore*



Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the solar system, Earth, the human body, and how to perform new operations while we are out there exploring.

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

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.

# Who, What, When, Where, Why, and How?



## WHEN WILL WE ACHIEVE LUNAR OBJECTIVES?

- Multi-decadal campaign
- Support annual cadence of crewed missions
- Development of permanent infrastructure
- Expansion of economic sphere to the Moon

## WHO DOES THIS APPROACH INCLUDE?

- NASA
- U.S. Government
- Industry
- International Partners
- Academia
- Public

## WHAT FOUNDATIONAL CAPABILITIES ARE NEEDED?

- Long-duration microgravity systems
- Partial gravity destination platforms
- Low Earth Orbit assets and infrastructure

## WHERE SHOULD SYSTEMS BE?

- Ensure access to the lunar South Pole
- Capability for non-polar expeditions

## HOW WILL WE GET THERE AND RETURN?

- Lunar Microgravity staging in NRHO
- Earth ↔ NRHO ↔ Lunar surface
- Surface mobility

## WHY EXPLORE?

### —SCIENCE—

- Understand the universe
- Direct observations

### —INSPIRATION—

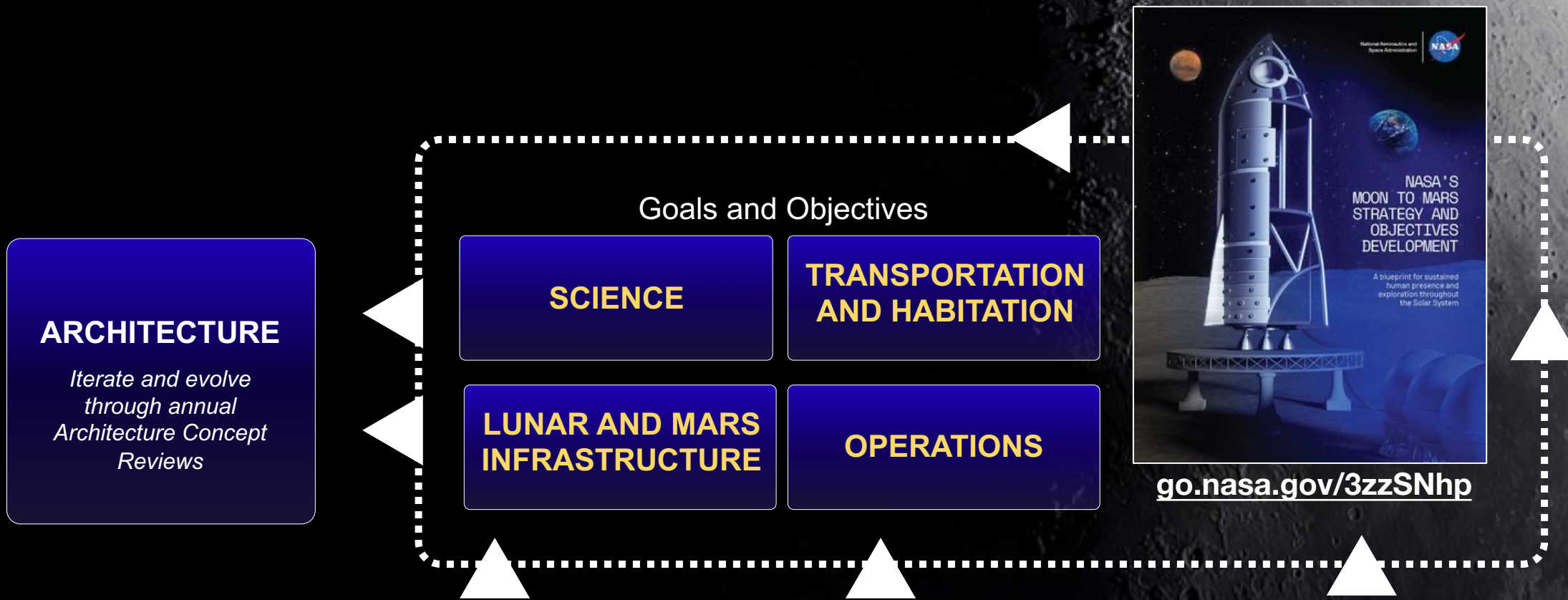
- “Artemis Generation”
- Overcome challenges
- Succeed with hard work

### —NATIONAL POSTURE—

- Enrich lives on Earth
- Technology development
- International partnerships

# NASA's Moon to Mars Strategy and Objectives

A blueprint for future human exploration (Architecting from the Right)



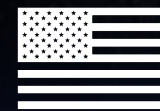
Requested feedback on these objectives in summer 2022 from the following key stakeholders:



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

# Architecture Concept Review



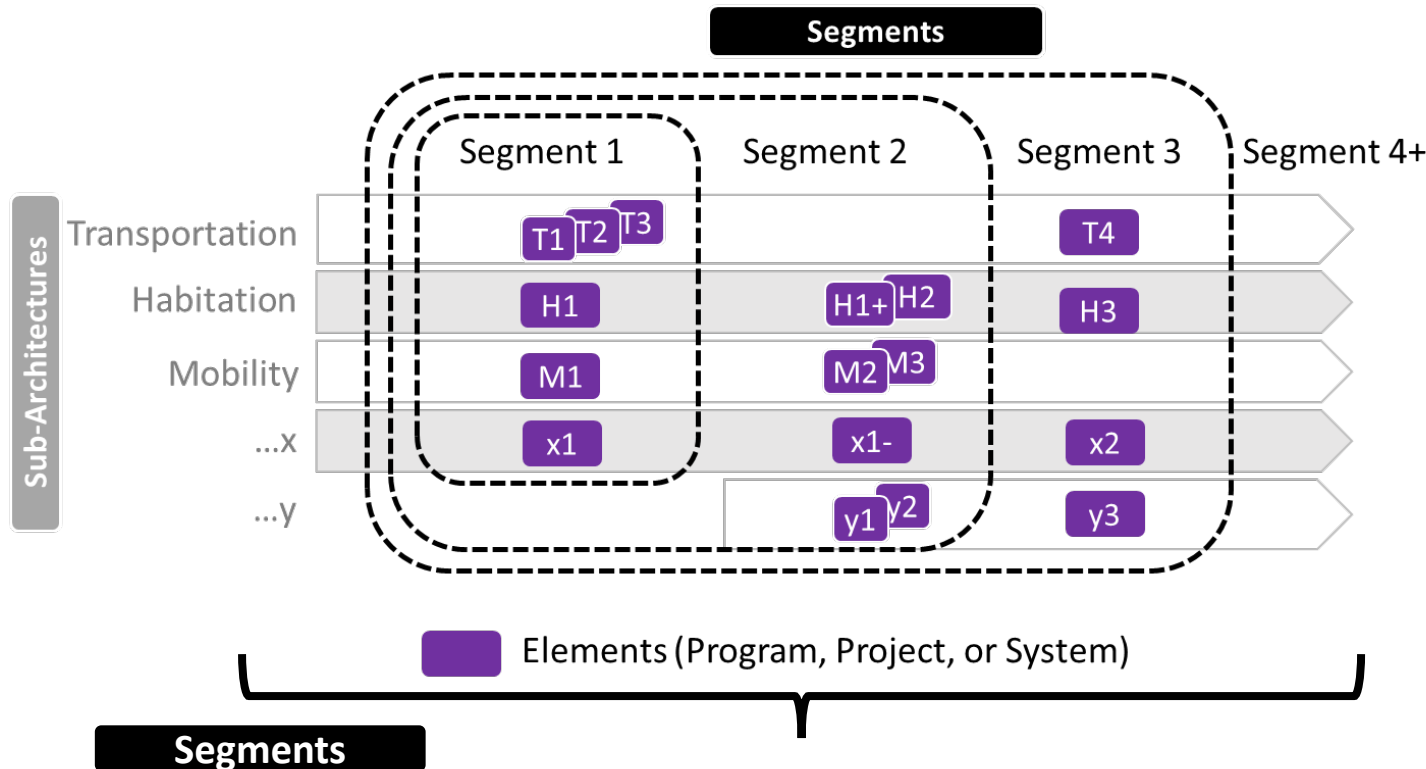
**The purpose of an Architecture Concept Review (ACR) is to help unify the agency, promote advocacy for the architecture, and generate inputs from across NASA.**

- The specific purpose of the Architecture Concept Review 22 (ACR22) was to:
  - Concur on the newly established yearly ACR process
  - Concur on disposition of key issues from ESDMD-001 Moon to Mars (M2M) Architecture Definition Document (ADD) Change Request
    - Human Lunar Return segment focus
  - Concur on priority tasks for the next ACR



**Future ACRs will be conducted annually in November to continue refining the architecture based on evolving policy, budget, partner contributions, and development schedules. Annual ACRs shifted to align with the NASA budget cycle.**

# Architecture Framework



## Sub-Architectures

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

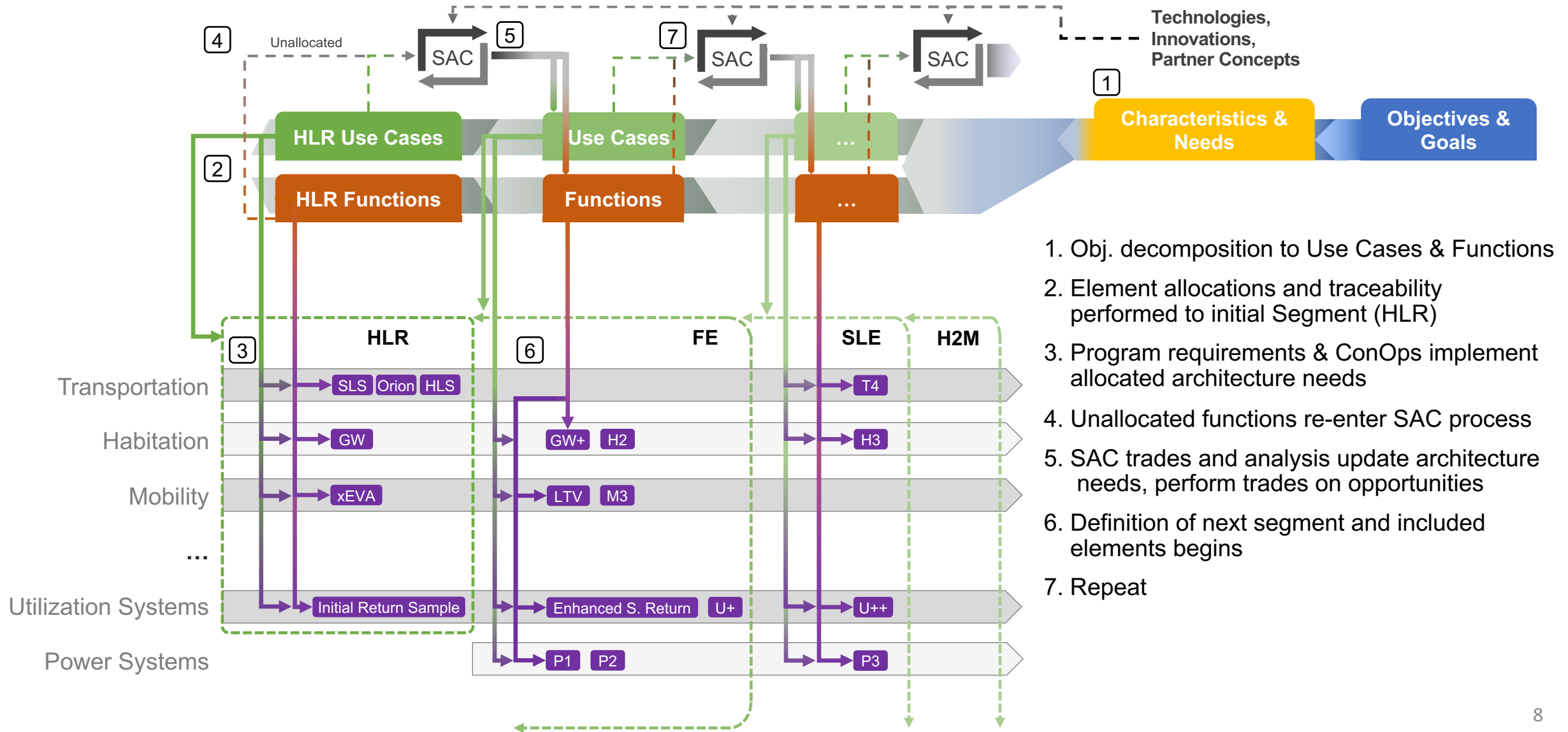
Ex: Transportation Systems: Contain common functions (e.g. RPOD) & need to ensure end-to-end allocation for crew transport from Earth to destinations to safe return

## Segments

**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.**

Ex: Human Lunar Return integrated use case similar to current Artemis IV operations

# Architecture Iteration Process



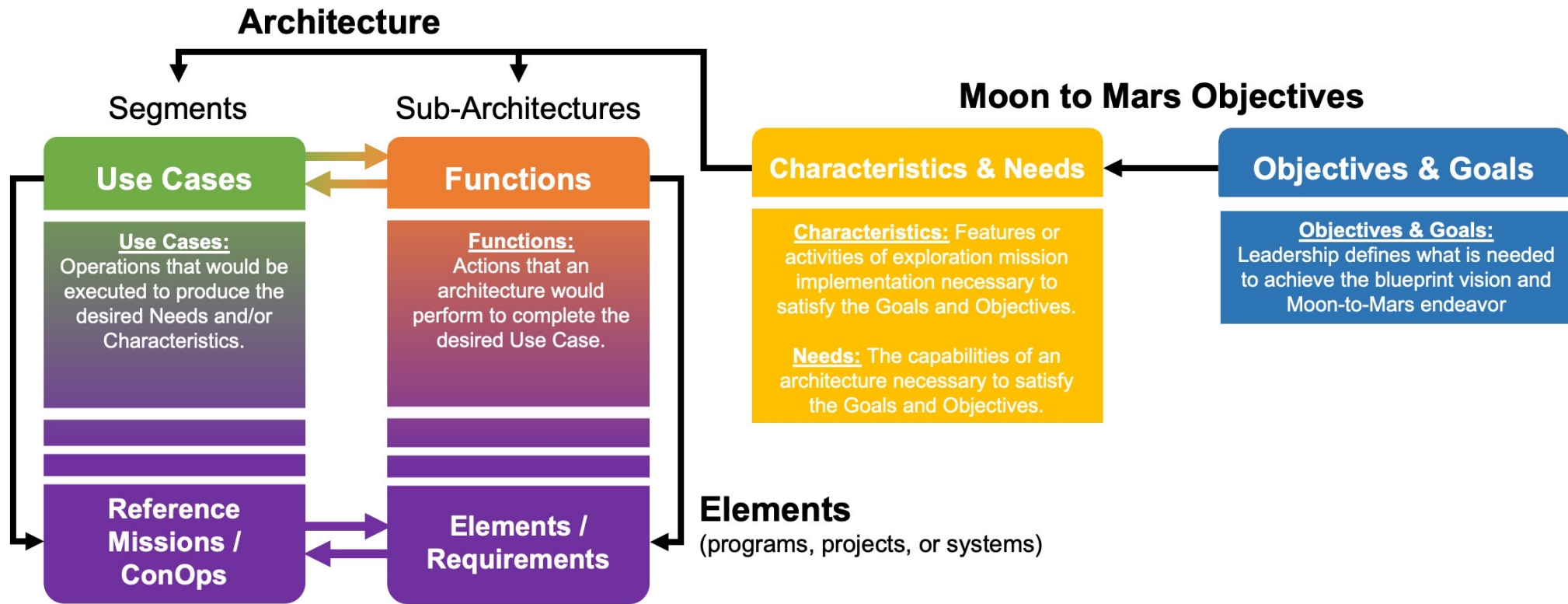


# Key Components of the Approach



Component	Rationale	Implementation
Traceability	Decomposition of Blueprint Objectives to executing Architecture elements	Characteristics & Needs Use Cases/ Functions
Architecture Framework	Organizational construct to ensure system/element relationships are understood and gaps can be identified	Sub-Architectures Campaign Segments
Process & Products	Clear communication and review integration paths for stakeholders	ADD Strategic Analysis Cycle Arch. Concept Reviews

# Architecting from the Right



Architecture organized by Segments and Sub-architectures in the ADD to group similar features and express progression of capabilities over time.

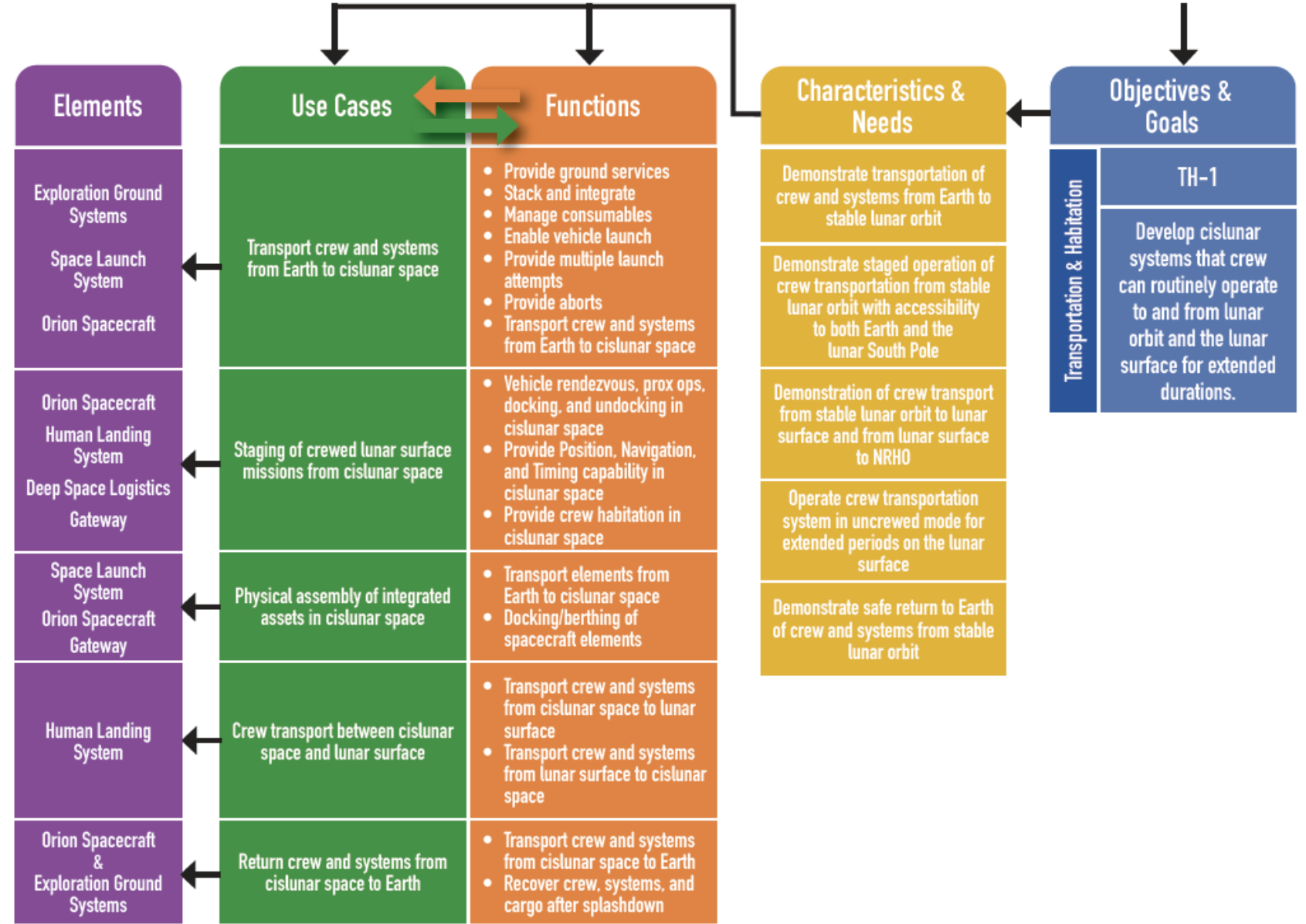
The Architecture process requires a decomposition of Moon to Mars Objectives to element functions and mission use cases to complete the process of “architecting from the right.” This establishes the relationship of executing programs and projects to the driving goals and objectives.

# 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.

## ARCHITECTING FROM THE RIGHT

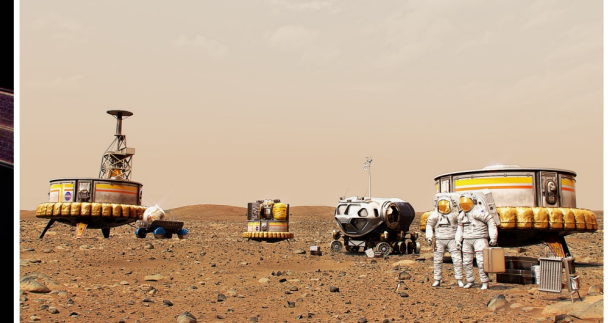
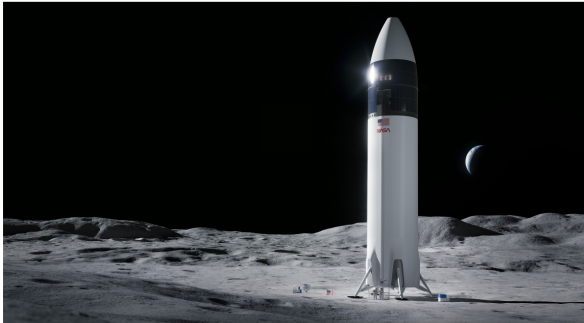
*Start Here*



# 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

## Foundational Exploration

## Sustained Lunar Evolution

## Humans to Mars

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

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

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.

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

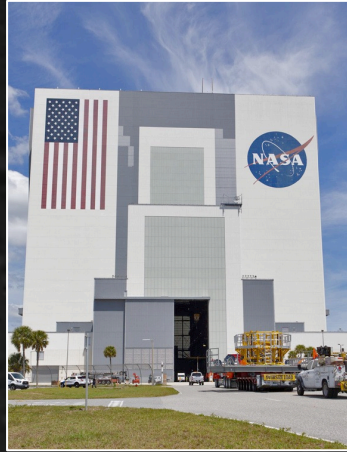
## Focus for ACR 22

## Focus for ACR 23

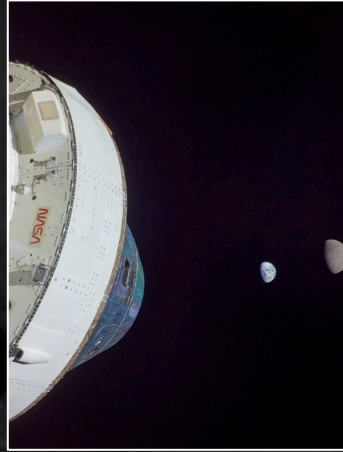
**Sub-architecture:** A group of tightly-coupled systems, functions, and capabilities that perform together to accomplish architecture objectives.

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

# Human Lunar Return Segment



EXPLORATION GROUND  
SYSTEMS



ORION SPACECRAFT



SPACE LAUNCH SYSTEM



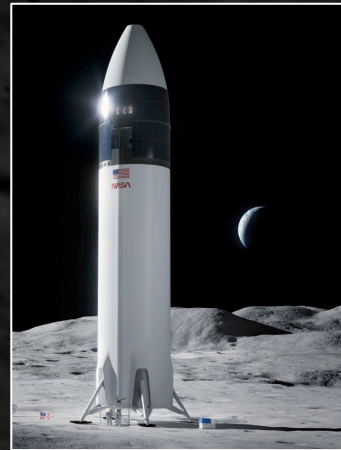
GATEWAY



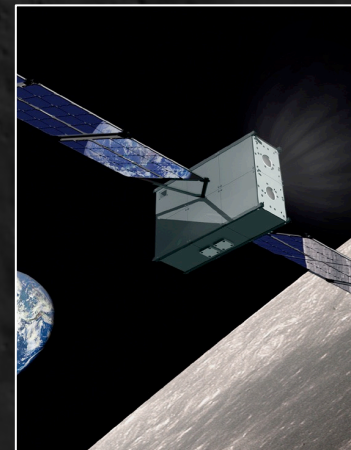
DEEP SPACE LOGISTICS



xEVA Systems



HUMAN LANDING SYSTEM



COMM, POSITIONING,  
NAV, TIMING (CPNT)

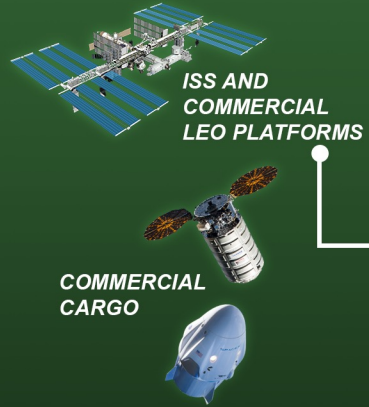


COMMERCIAL LUNAR  
PAYLOAD SERVICES

# MOON TO MARS CAMPAIGN SEGMENTS

ELEMENTS SHOWN BEYOND HUMAN LUNAR RETURN ARE NOTIONAL

## LEO AND EARTH ANALOGS



## HUMAN LUNAR RETURN



## FOUNDATIONAL EXPLORATION

## HUMANS TO MARS MODEST FIRST MISSION OF THE TRADE SPACE SHOWN



Increased Crew Size & Longer Durations in Micro-gravity



## COMMUNICATIONS RELAYS

SURFACE HABITAT

LOGISTICS LANDER

Nuclear Surface Power

MARS ASCENT VEHICLE

Habitation Systems

Partial Gravity Operations

Mobile Expedition Duration / Mobile Exploration Range

In-Situ Resource Utilization

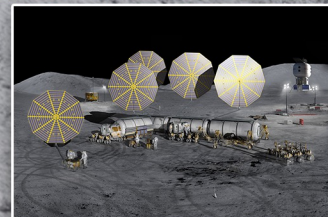
Autonomous Robotics Systems & Contingency Crew Transportation

PRESSURIZED ROVER

PRESSURIZED ROVER

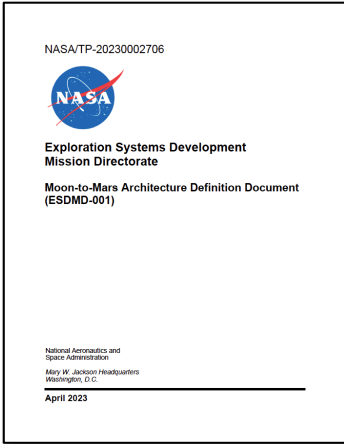
MARS TERRAIN VEHICLE

Sustained Lunar Evolution



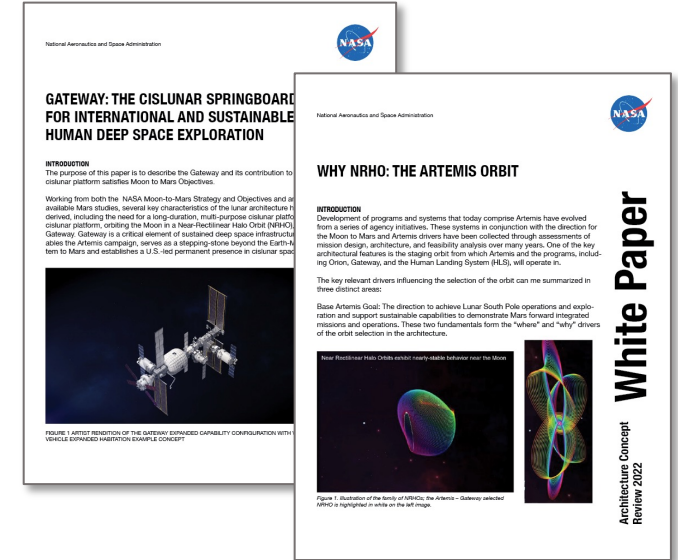
# ACR Public Products

Available at [www.nasa.gov/MoonToMarsArchitecture](http://www.nasa.gov/MoonToMarsArchitecture)



## Architecture Definition Document

- **Length:** 150 pages
- **Purpose:** detailed documentation of a snapshot of the human spaceflight architecture and exploration strategy
- **Audience:** highly technical – NASA, industry, international partners, committee staffers
- **Publication:** NASA Technical Reports Server
- **Update cadence:** Annual ACRs



## White Papers

- **Length:** 4-6 pages each
- **Purpose:** document architecture study details on frequently discussed topics
- **Audience:** technically informed – industry, international partners, staffers
- **Publication:** nasa.gov
- **Update cadence:** ACRs and as needed

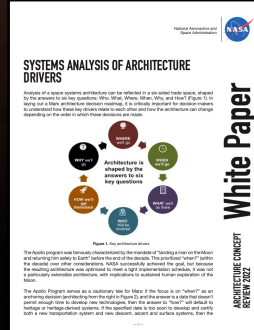


## Moon to Mars Architecture Summary

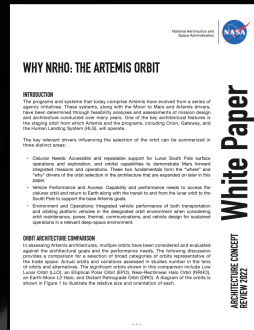
- **Length:** 18 pages
- **Audience:** technically informed – Advisory, legislative, investigative, auditing organizations
- **Purpose:** high-level documentation of M2M architecture and exploration strategy
- **Publication:** nasa.gov
- **Update cadence:** as needed

# ACR 22 White Papers

## Systems Analysis of Architecture Drivers



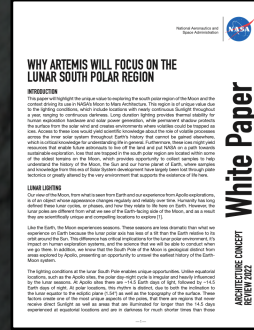
## Why NRHO: The Artemis Orbit



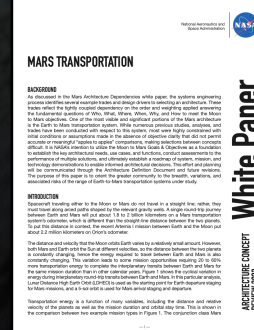
## Gateway: The Cislunar Springboard



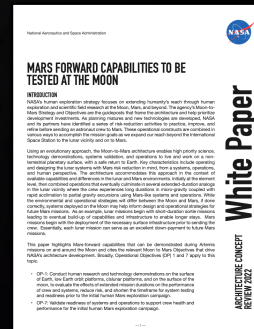
## Why Artemis Will Focus on the Lunar South Polar Region



## Mars Transportation

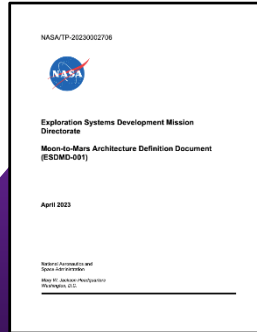


## Mars Forward Capabilities to Be Tested at the Moon





# Architecture Concept Review Products

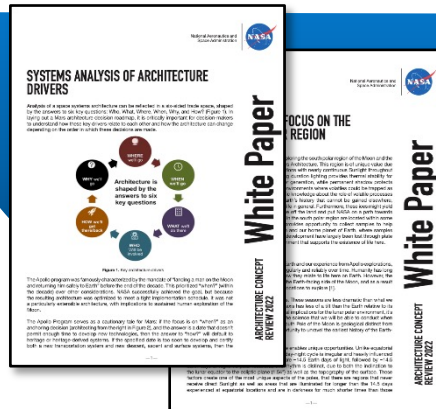


**Architecture Definition Document**  
Detailed documentation of a snapshot of NASA's human spaceflight architecture and exploration strategy

Jim briefs charts 12-17  
**Moon to Mars Architecture Summary**  
High-level overview of NASA's Moon to Mars architecture and exploration strategy



[www.nasa.gov/MoonToMarsArchitecture](http://www.nasa.gov/MoonToMarsArchitecture)



**White Papers**  
Six papers on architecture study details for frequently discussed topics