



NASA's Moon to Mars Architecture Workshop

Breakout Session: Human Lunar Return (HLR)

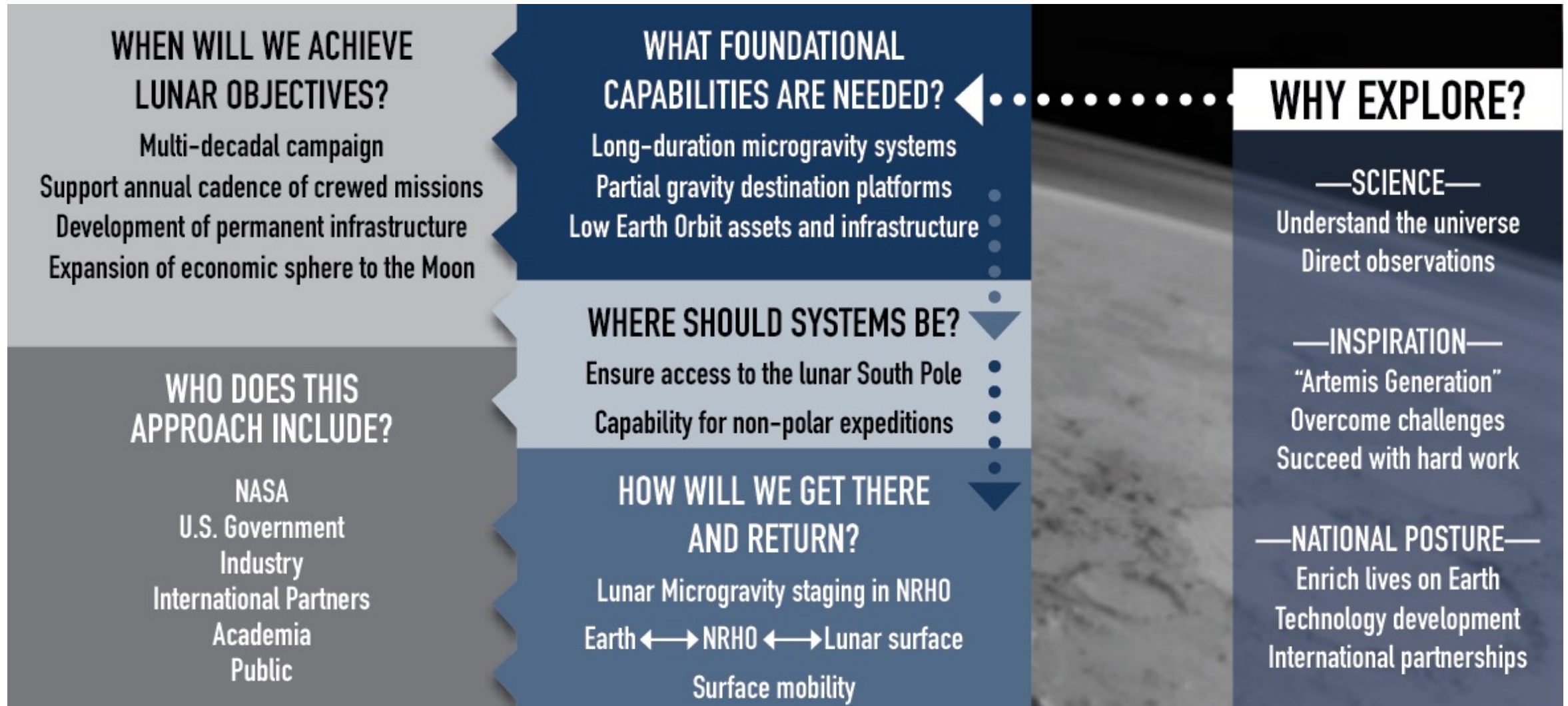
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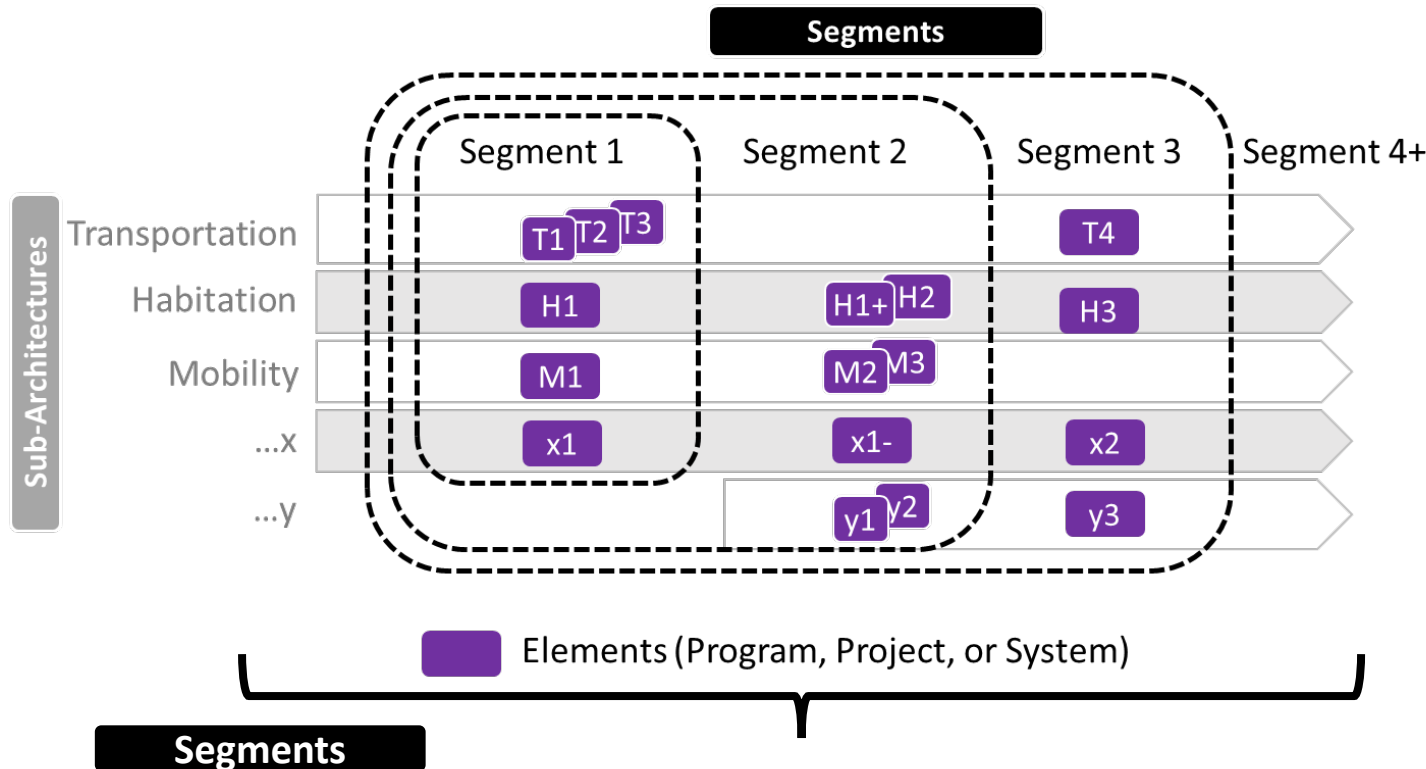
NASA Langley Research Center



Why Explore – the Starting Point of HLR



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

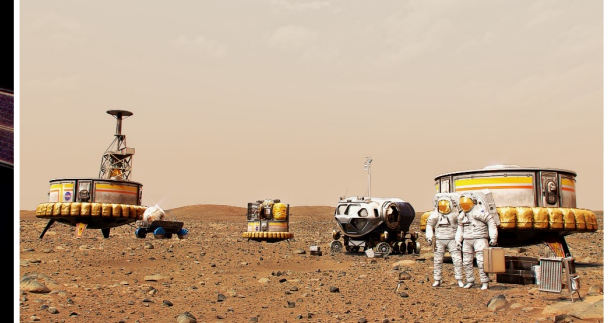
A portion of the architecture, identified by one or more notional missions or integrated use cases, illustrating the interaction, relationships, and connections of the sub-architectures through progressively increasing operational complexity and objective satisfaction.

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

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

Key Objectives for HLR



Objectives that drive the HLR segment include achieving science, inspiration, and national posture goals around and on the surface of the Moon

Science

Examples:

- Exploring the lunar south polar region to understand chronology, composition, and structure of this region LPS-1
LPS-2
- Understanding volatile composition and the environment of shallow permanently shadowed regions near the lunar south pole LPS-3
- Assessing the history of the Sun as preserved in lunar regolith HS-2
- Characterizing space weather dynamics to enable future forecasting capabilities HS-1
- Characterizing plant, model organism/systems, and human physiological responses in partial-gravity environments HBS-1

Transportation & Habitation

Examples:

- Systematically and progressively test areas such as crewed transportation to cislunar space TH-1, TH-2
- Rendezvous and docking, uncrewed Human Landing System demonstration, initial human landing TH-2

Operations

Examples:

- Supporting ground infrastructure OP-4
- Deep-space communications and tracking systems OP-2
- Crewed transportation to and from cislunar space, initial Gateway deployment OP-6

Human Lunar Return (HLR)



- Includes inaugural Artemis missions to enable returning humans to the Moon
- Demonstrates both crewed and uncrewed lunar systems, including the support to initial utilization (science, etc.) capabilities
- Demonstrates initial systems to validate system performance and to establish a core capability for follow-on campaign segments
- Comprises a variety of other efforts in work to support data-gathering and risk-reduction activities to help inform future decisions
 - E.g., the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE), Commercial Lunar Payload Services (CLPS), and Volatiles Investigating Polar Exploration Rover (VIPER)

HLR: Use Cases & Functions



- HLR Use Cases and Functions were driven by what is needed to re-establish human presence and initial utilization (science, etc.) on and around the Moon
- ~40 Use Cases and ~50 Functions have been mapped to HLR
- Mapping of the elements may not fully satisfy the use case, function, or associated objective or that completion is achieved

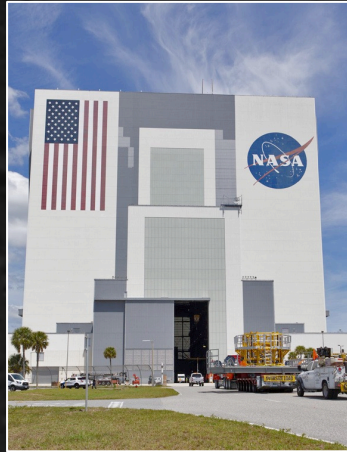
Table 3-2. Mapping of Use Cases to Element for Human Lunar Return Segment

Use Cases		Note: "X" indicates mapping of use cases to elements; It does not indicate that an element fully satisfies the use case, function, or blueprint objective, or that completion is achieved. Element descriptions can be referenced in section 3.1.4.											
		SLS	EGS	Orion	Gateway	HLS	LCRNS	xEVA System	CLPS	DSL	DSN / LEGS	Payloads	Unallocated
UC-01	Transport crew and systems from Earth to cislunar space	X	X	X									
UC-02	Staging of crewed lunar surface missions from cislunar space			X	X	X				X			
UC-03	Aggregation and physical assembly of spacecraft elements in cislunar space	X		X	X								
UC-04	Crew transport between cislunar space and lunar surface					X							
UC-06	Return crew and systems from cislunar space to Earth			X									
UC-09	Crew operations on lunar surface					X	X	X		X			
UC-11	Frequent crew EVA on surface												
UC-12	Crew conduct utilization activities												
UC-13	Crew conduct utilization activities												
UC-14	Crew emplacement and site selection												
UC-16	Crew emergency health care												
UC-20	Return of collected samples												
UC-21	Crewed missions to distribute samples												
UC-25	Crew EVA exploration and site selection												
UC-26	Crew collection of samples												

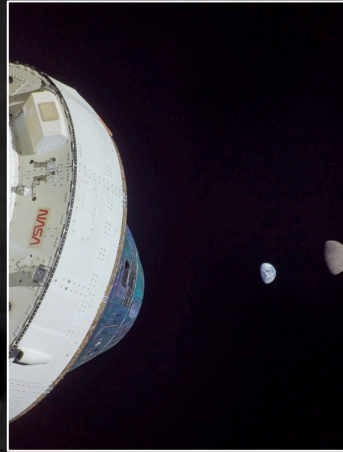
Table 3-3. Mapping of Functions to Elements for Human Lunar Return Segment

Functions		Note: "X" indicates mapping of functions to elements; It does not indicate that an element fully satisfies the use case, function, or blueprint objective, or that completion is achieved. Element descriptions can be referenced in section 3.1.4.											
		SLS	EGS	Orion	Gateway	HLS	LCRNS	xEVA System	CLPS	DSL	DSN / LEGS	Payloads	Unallocated
F-01	Provide ground services		X										
F-02	Stack and integrate	X	X										
F-03	Manage consumables and propellant		X										
F-04	Enable vehicle launch	X	X										
F-05	Provide multiple launch attempts	X	X										
F-06	Provide aborts	X		X		X							
F-07	Transport crew and systems from Earth to cislunar space	X	X	X									
F-08	Vehicle rendezvous, proximity ops, docking, and undocking in cislunar space			X	X	X				X			
F-09	Provide PNT capability in cislunar space						X						
F-10	Provide crew habitation in cislunar space			X	X								
F-11	Transport elements from Earth to cislunar space	X											
F-12	Docking/berthing of spacecraft elements			X	X	X				X			
F-13	Transport crew and systems from cislunar space to lunar surface South Pole sites					X							
F-14	Transport crew and systems from lunar surface to cislunar space					X							

Human Lunar Return Segment



EXPLORATION GROUND SYSTEMS



ORION SPACECRAFT



SPACE LAUNCH SYSTEM



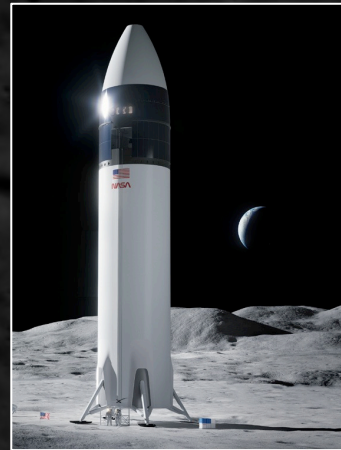
GATEWAY



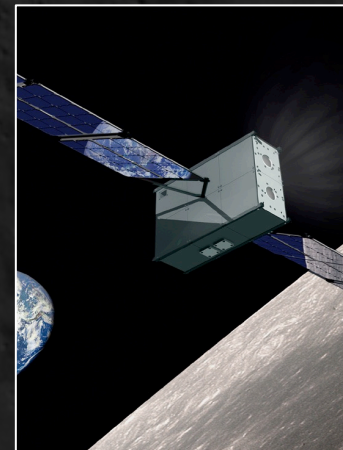
DEEP SPACE LOGISTICS



xEVA Systems



HUMAN LANDING SYSTEM



COMM, POSITIONING, NAV, TIMING (CPNT)



COMMERCIAL LUNAR PAYLOAD SERVICES

Reference Missions - HLR

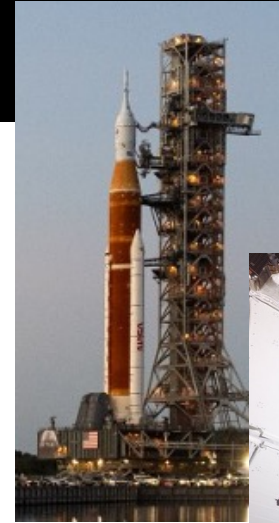


3.1.3.1 Crewed Initial Lunar Surface Reference Mission

- Transporting crew and systems from Earth to cislunar space
- Staging crewed lunar surface missions from cislunar space
- Assembling integrated assets in cislunar space
- Transporting crew and systems between cislunar space and the lunar surface
- Returning crew and systems from cislunar space to Earth
- Crew operations on the lunar surface
- Frequent crew EVA on the surface
- Crew conducting utilization activities on the surface.
- Additional science, utilization, crew health and performance, and operations are also envisioned

3.1.3.2 Crewed Gateway and Lunar Surface Reference Mission

- Crew conducts utilization activities in cislunar space
- Enable ground personnel and science teams to directly engage with crew on the surface and in lunar orbit - augmenting the crew's effectiveness at conducting science activities
- Enables crew and/or robotic emplacement and set-up of science instrumentation in lunar orbit with long-term remote operation
- Autonomous/semi-autonomous mission operations in cislunar space



Discussion Questions (1/2)



- Is the depth of detail for HLR sufficient?
- As more Artemis missions are flown as part of HLR, what level of detail do you expect to see in the ADD for flown vs. upcoming missions?
- Is there information that might be beneficial to include in future segment chapters or updates to HLR content?
- What questions did you have about HLR that were not answered in the ADD?

Discussion Questions (2/2)



- Do Use Cases and Functions have enough context?
- Are there any Functions and/or Use Cases that should be included in HLR segment that were not?

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Table 3-3. Mapping of Functions to Elements for Human Lunar Return Segment

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