

Three stylized silhouettes of astronauts in space suits, each filled with a different space-themed illustration. The left silhouette is blue and shows a rocket launch. The middle silhouette is black and shows a lunar surface with a rover. The right silhouette is red and shows a Martian landscape with a rover. A dark blue horizontal bar is overlaid across the center of the silhouettes.

Mission Directorate Panel: Exploration Systems Development



Highlights of ACR22 Feedback

- **ADD:**

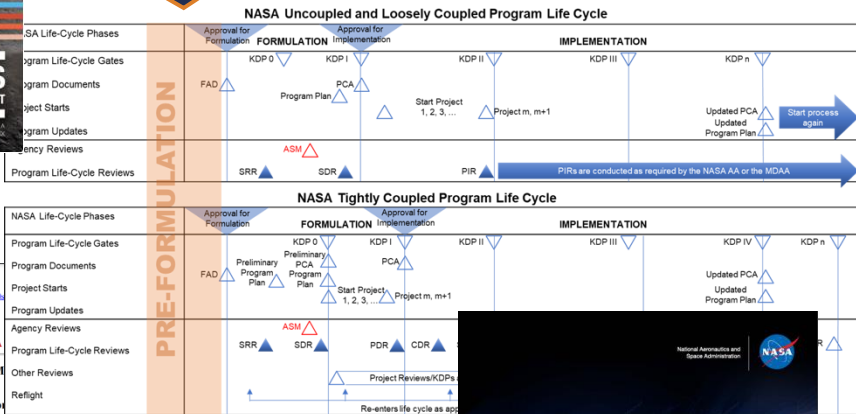
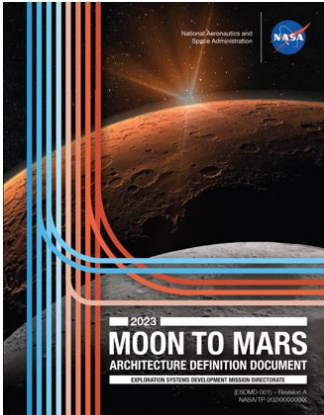
- Overall positive to continue systems engineering rigor & communication
- Need to standardize and level decomposition content
 - ✓ *Established syntax structure, revised commonality C&Ns + UC/F, leveled across objective areas*
- Some verbs and nouns don't translate from English easily
 - ✓ *Modified to use more common words and/or added to glossary where necessary*
- Identified needs for additional content and sub-architectures
 - ✓ *Four additional sub-architectures added to address cross-cutting integration*
- Need to continue integration and adaptation to evolutionary approach

- **White Papers:** Extremely helpful for key information and plain language discussion

- ✓ *Increased from 6 White Papers in ACR22 to an additional 13 White Papers for ACR23*

- **NASA team highly values your engagement and bi-directional communication across IP, industry, academia, inter-governmental stakeholders**

Architecture Products to Action



- Historically, human spaceflight pre-formulation transient independent efforts

- Moon to Mars is multi-decadal; consistent and repeatable pre-formulation needed

- Moon to Mars Architecture used to derive new elements and address gaps to ensure coherency and value

NASA 7120.5 - NPR

NASA Procedural Requirements COMPLIANCE IS MANDATORY FOR NASA

NASA Space Flight Program and Project Management Handbook

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Change History

Preface

F.1 Purpose

F.2 Applicability

F.3 Authority

F.4 Applicable Documents and Forms

F.5 Measurement/Verification

F.6 Cancellation

Chapter 1. Introduction

1.1 Key Policy Changes to NPR 7120.5 Revision F Since Revision E

1.2 Background

1.3 Overview of Management Process

1.4 Acquisition

1.5 Document Structure

Chapter 2. NASA Life Cycles for Space Flight Programs and Projects

2.1 Programs and Projects

NASA 7120.5 NPR



Key ESDMD Process Milestones

Element Initiation (EI):

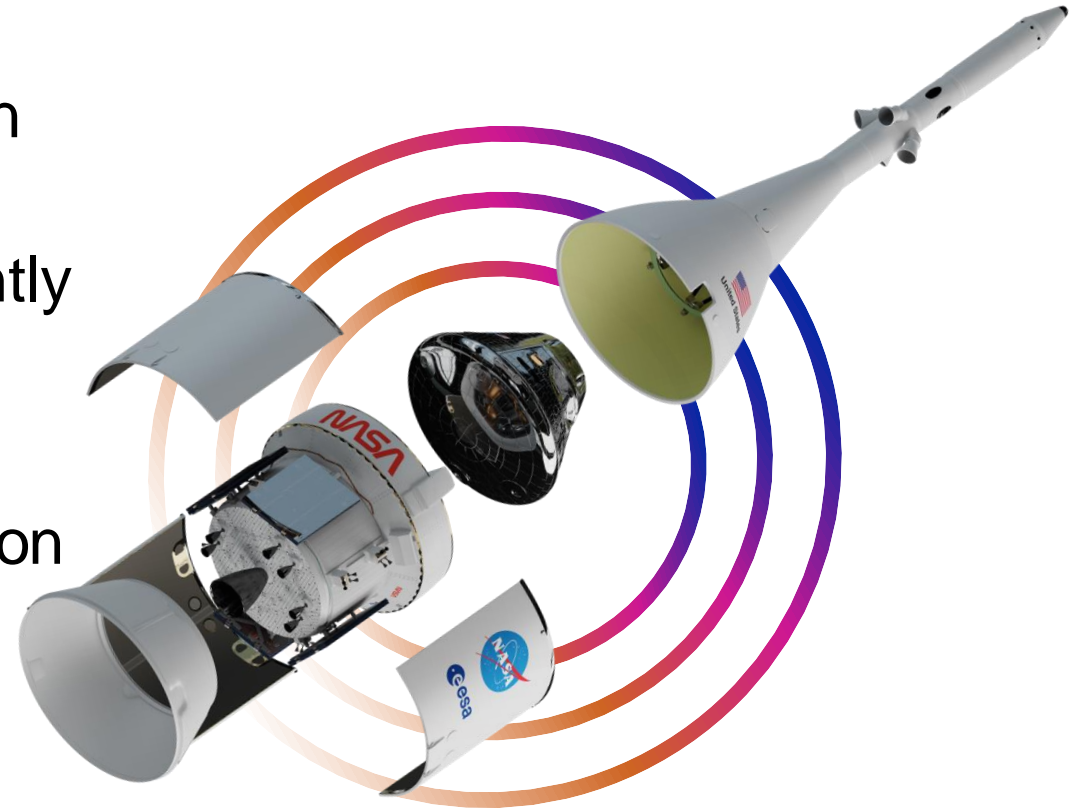
ESDMD reviews whether a potential concept provides a solution to needs or gaps identified in the Moon to Mars Architecture

Ensures that NASA invests in effective, sufficiently mature technologies and capabilities

Mission Concept Review (MCR):

To evaluate the feasibility of the proposed mission concept(s) and its fulfillment of the Architecture needs and objectives.

Ensures NASA program/project readiness and feasibility to acquire systems



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Mission Directorate Panel: Architecture Enables Science

Architecture Enables M2M Science Objectives



Image Credit Keane et al	 LPS-1							
Image Credit LGN	 LPS-2							
Image Credit ESA	 LPS-3							
Image Credit Pexels	 HBS							
Image Credit NASA	 HBS							
Image Credit ESA	 HS							

Strategic Research and Priorities from NASEM Decadal Surveys



NASA and Community Reports



Upcoming Academy/ SDT Studies That Will Inform Architecture

- High Priority Science Campaigns for Human Explorers on the Surface of Mars
- Key Destinations Across the Moon to Address Decadal-level Science Objectives with Human Explorers
- SPA Sample Return Science Definition Team Report
- Science Accomplished during Human Mars Transit (planned)
- Science Addressed from a Sustained Lunar Basecamp (planned)

1:1 Trace of Lunar Themes from Planetary Decadal to M2M Objectives (M2M LPS Objectives in BLUE)



BOX 22.2 Science Themes for Lunar Exploration [Planetary Decadal]

Science Theme 1: Uncover the lunar record of solar system origin and early history. The Moon's composition, structure, and ancient surface preserve a record of early events: from the giant impact that produced the Earth–Moon system to ongoing bombardment as life on Earth emerged and evolved.

[LPS-1: Uncover the record of solar system origin and early history, by determining how and when planetary bodies formed and differentiated, characterizing the impact chronology of the inner solar system as recorded on the Moon and Mars, and characterize how impact rates in the inner solar system have changed over time as recorded on the Moon and Mars.]

Science Theme 2: Understand the geologic processes that shaped the early Earth that are best preserved on the Moon. The Moon retains a record of processes that set the evolutionary paths of rocky worlds, including volcanism, magnetism, tectonism, and impacts.

[LPS-2: Advance understanding of the geologic processes that affect planetary bodies by determining the interior structures, characterizing the magmatic histories, characterizing ancient, modern, and evolution of atmospheres/exospheres, and investigating how active processes modify the surfaces of the Moon and Mars.]

Science Theme 3: Reveal inner solar system volatile origin and delivery processes. The Moon hosts water and other volatiles in its interior, across its surface, and in ice deposits at its poles, providing a record that may help constrain the origins of Earth's oceans and the building blocks for life, as well as ongoing volatile delivery processes.

[LPS-3: Reveal inner solar system volatile origin and delivery processes by determining the age, origin, distribution, abundance, composition, transport, and sequestration of lunar and Martian volatiles.]

Suggested Questions to be Addressed with a focus on FE and SLE Segments



Image Credit
[Gene and Cell Magazine](#)

1. Are the functions, needs, characteristics, and use cases appropriate to accomplish the defined Science Objectives or are there some required to support the objectives that are not yet in the ADD?



Image Credit
[NASA](#)

2. What science is necessary to be conducted on the Moon to be ready for humans to perform science on Mars?

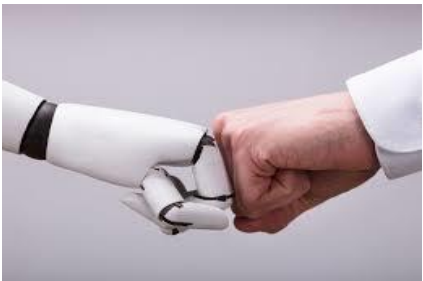


Image Credit
[Journal of Petroleum Technology](#)

3. Which science is best achieved through human exploration vs. robotic missions? Or a combination?

4. Are there any science-focused white papers that would help the community understand why certain decisions have been made?

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Mission Directorate Panel: Space Technology

STMD's Investments Support Later Segments



Human Lunar Return

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



Foundational Exploration

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



Sustained Lunar Evolution

Enabling capabilities, systems, and operations to support regional and global utilization, 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 on Mars and continued exploration.

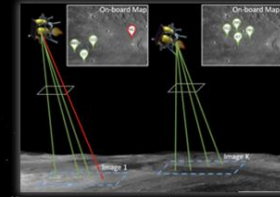
Future Segments

Lunar Infrastructure Technology Investments



LI-1^L: Develop an incremental **lunar power** generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.

MI-1^M

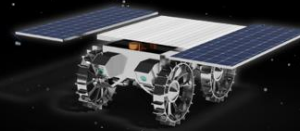


LI-5^L: Demonstrate **precision landing** capabilities in support of continuous human lunar presence and a robust lunar economy.



LI-2^L: Develop a lunar surface, orbital, and Moon-to-Earth **communications** architecture capable of scaling to support long term science, exploration, and industrial needs.

MI-2^M



LI-6^L: Demonstrate local, regional, and global **surface transportation and mobility** capabilities in support of continuous human lunar presence and a robust lunar economy.



LI-3^L: Develop a lunar **position, navigation and timing** architecture capable of scaling to support long term science, exploration, and industrial needs.

MI-3^M



LI-7^L: Demonstrate industrial scale **ISRU** capabilities in support of continuous human lunar presence and a robust lunar economy.

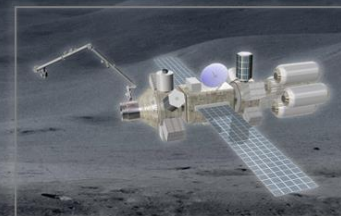
MI-4^M



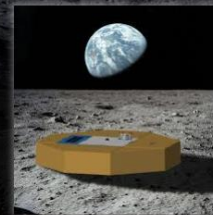
LI-4^L: Demonstrate **advanced manufacturing and autonomous construction** capabilities in support of continuous human lunar presence and a robust lunar economy.



LI-8^L: Demonstrate technologies supporting cislunar orbital/surface depots, **construction and manufacturing** maximizing the use of in-situ resources, and support systems needed for continuous human/robotic presence.



LI-9^L: Develop **environmental monitoring, situational awareness**, and early warning capabilities to support a resilient, continuous human/robotic lunar presence.



Current STMD Investment Areas

STMD 2024 Role in Architecture Development



- Supporting Objectives Decomposition
- Participating in virtually all SAC24 tasks: coordination, SME analysis
- Significant role in Mars Surface Power Technology Decision activity
- Working gap prioritization processes across the architecture
- Leading task to define and document technology on-ramp strategies

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Mission Directorate Panel: Space Operations



Human Research Program

STEPS TO MARS



EARTH:

Simulated spaceflight hazards
in Ground Analogs | :envihab |
Antarctic Stations | NEK | HERA |
Space Radiation Lab

LOW EARTH ORBIT:

International Space Station –
A unique testbed to study micro-
gravity and environment hazards,
with varying mission durations

LUNAR MISSIONS:

Decreasing Earth-dependence
around and on the lunar surface.
Provides insight into deep space
radiation; behavioral health, and
gravity transitions



HRP Integration Across Platforms

Human Research Program (HRP)



Astronauts will work through this obstacle course immediately after returning to Earth so that researchers can learn more about how mission-ready crew can be after landing on a planet's surface.

Studies like this will affect priority decisions for Mars (e.g. mission length, mission cadence, etc.)

A volunteer from NASA's Artemis Extravehicular Activity training group moves a 30-pound object through a boulder field while in a spacesuit connected to NASA's Active Response Gravity Offload System, or ARGOS. Credit: NASA

SCaN Human Lunar Return Contributions

Space Communications and Navigation (SCaN)



SCaN leading lunar loading analyses for the Human Lunar Return segment utilizing baselined ground rules and assumptions. Results will either validate architecture or highlight where changes are needed.

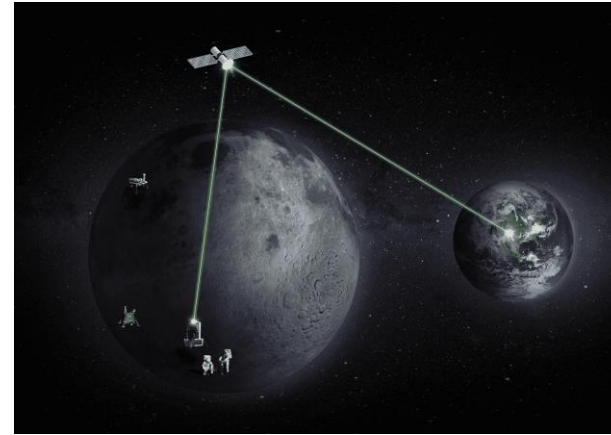


Human Lunar Return

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



Deep Space Network Lunar Exploration Upgrades (DLEU)



Lunar Communications and Navigation Relay Services (LCRNS)



Lunar Exploration Ground Segment (LEGS)
(18-Meter Class Antenna Subnet)

International Partnerships and Contributions

NASA is seeking international partnerships in space communications and navigation areas to support Artemis mission activities

SCaN Architecture Concepts and Studies

Space Communications and Navigation (SCaN)



Lunar Surface Wireless

3GPP/5G cellular technology for a robust lunar surface C&N infrastructure that is scalable to meet long-term needs

Essential to address surface and orbital link proliferation

Enables direct surface/local communication and aggregates data for transition to backhaul



Lunar Navigation System

Like GPS, but at and for the Moon
Supports the need for 10-m surface positioning and 25-m HLS landing knowledge requirements

Long-term support of complex surface ops, situational awareness, prediction and avoidance



Optical Communications

Optical communications supports high bandwidth needs, data aggregation, and relieves spectrum pressure.

It also supports precision navigation observables

Long-term operations in deep space will require data volumes and rates that exceed radio capabilities

O2O optical demonstration is on track for Artemis II



Deep Space Network Futures

Identify future mission drivers and space exploration requirements shaping the network from 2030 – 2050

Identify user capabilities required to ensure that the needed end-to-end capabilities can be realized

Develop roadmap for critical and key network capabilities of the future with linkages to drivers and requirements