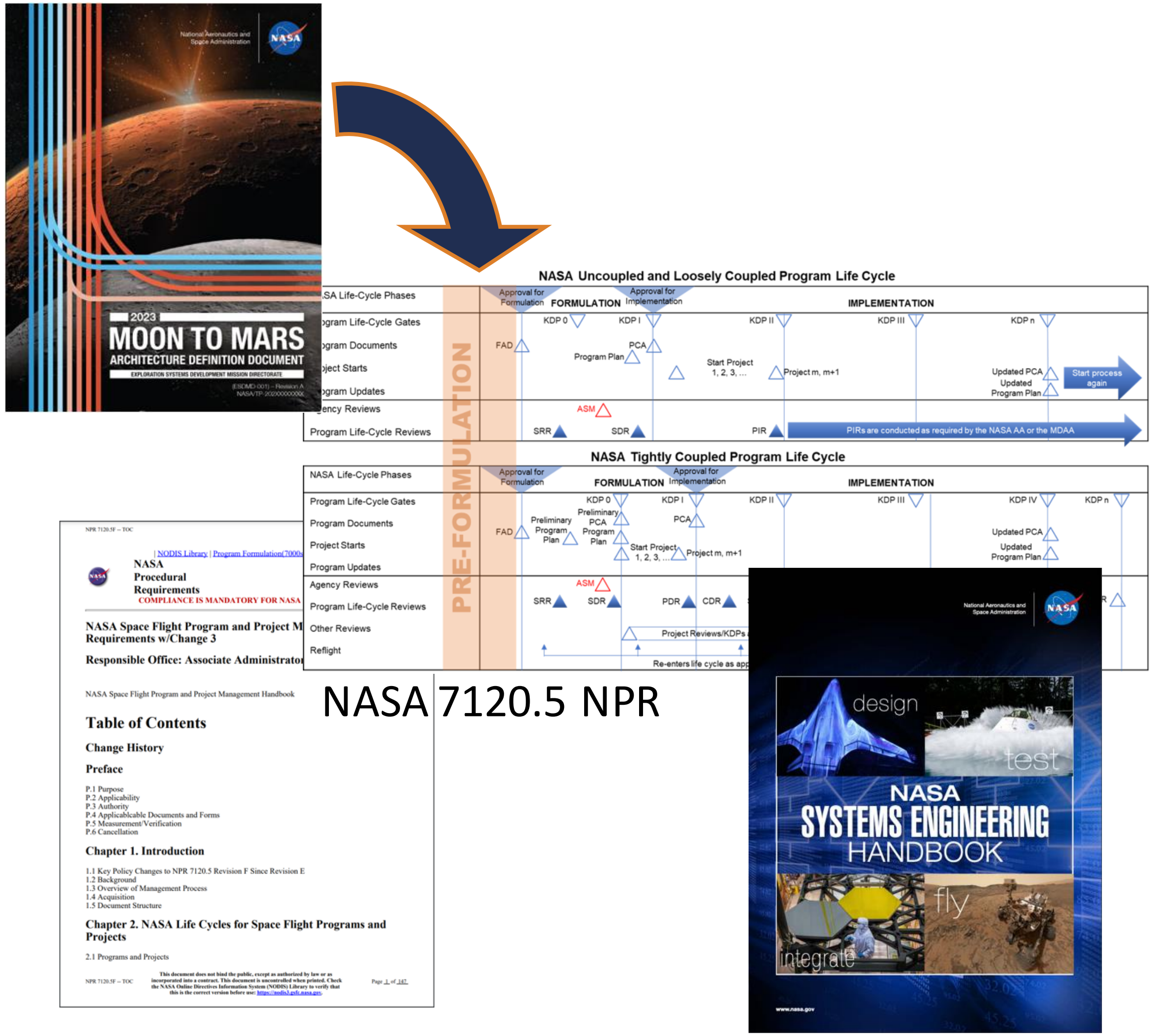
Mission Directorate Panel: Exploration Systems Development

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

Key ESDMD Process Milestones

Element Initiation (EI):

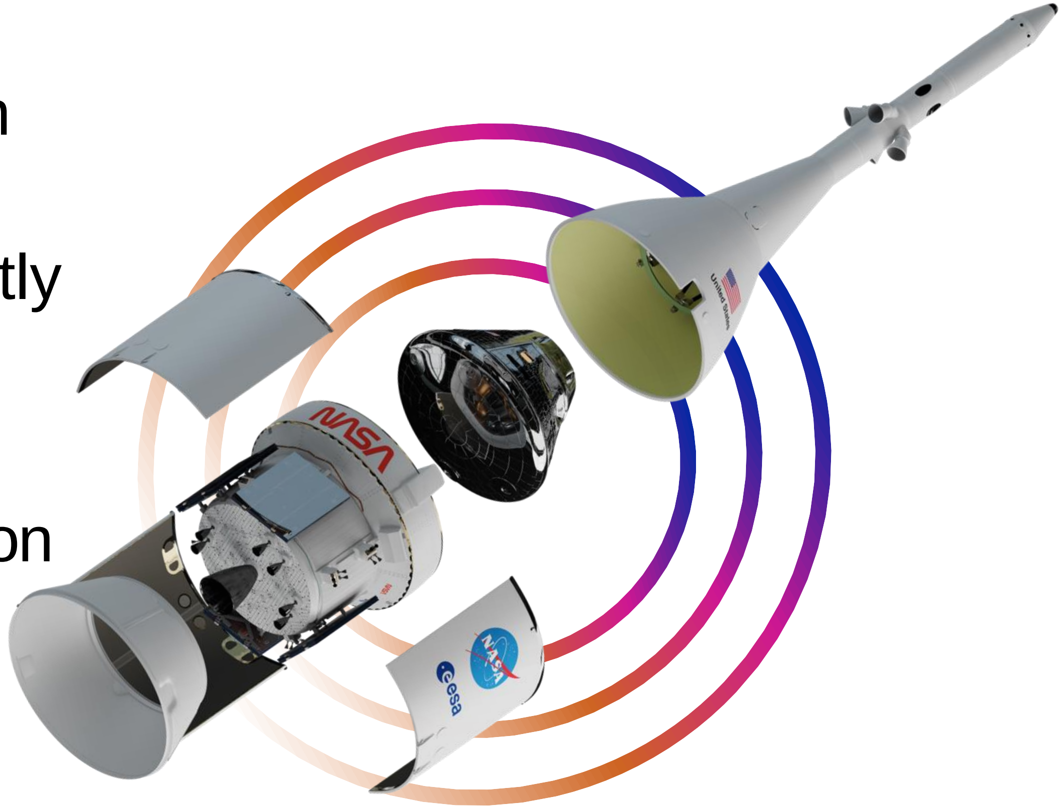
ESDMD reviews whether a potential concept provides a solution to needs or gaps identified in the Moon to Mars Architecture

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



Mission Directorate Panel: Architecture Enables Science

Architecture Enables M2M Science Objectives

Image Credit
Keane et al

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LGN

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ESA

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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?

National Aeronautics and
Space Administration

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

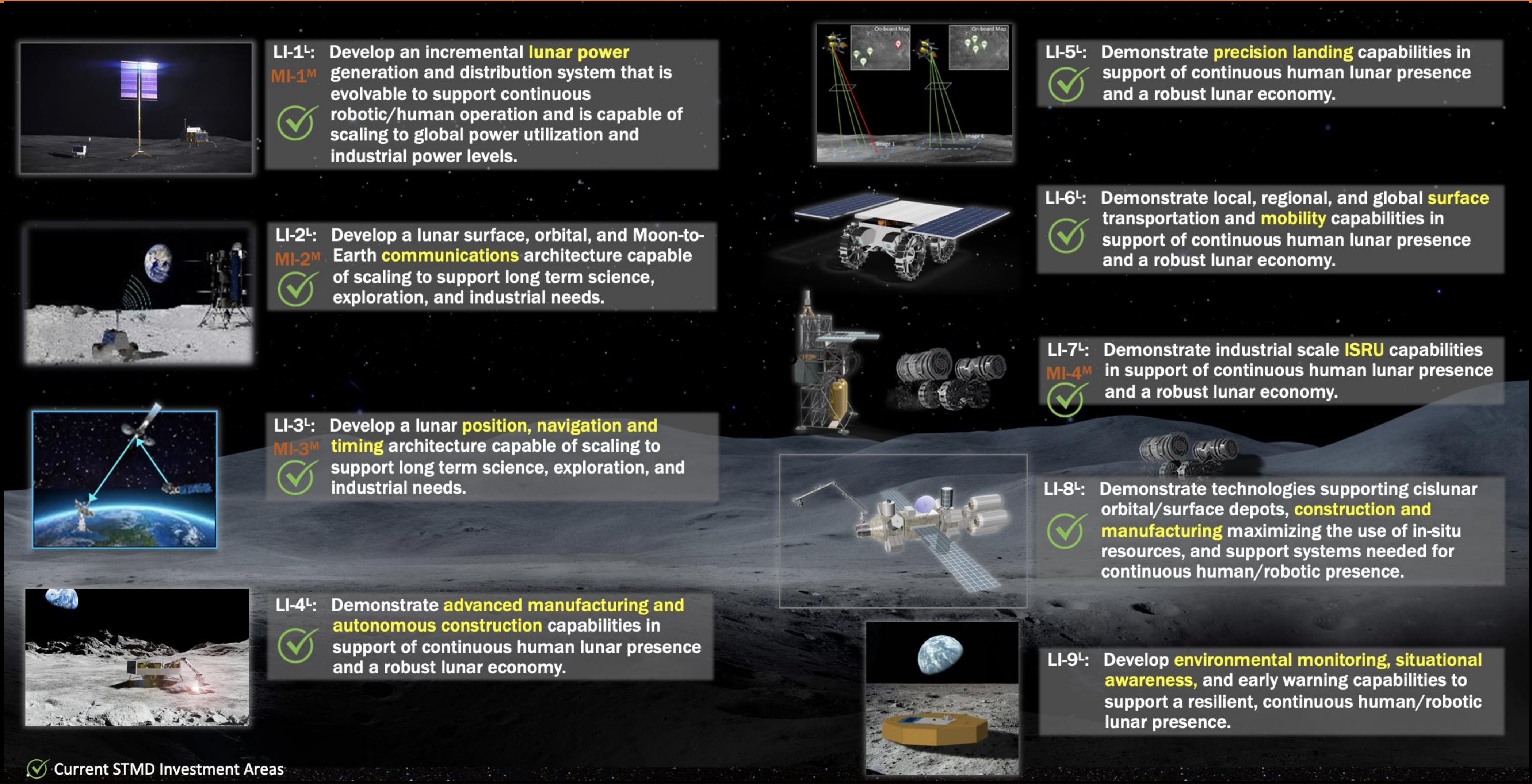
Enabling capabilities, systems, and operations to support regional and global utilization, economic opportunity, and a steady cadence of human presence on and around the Moon.

Future Segments

Humans to Mars

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

Lunar Infrastructure Technology Investments



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

Mission Directorate Panel: Space Operations

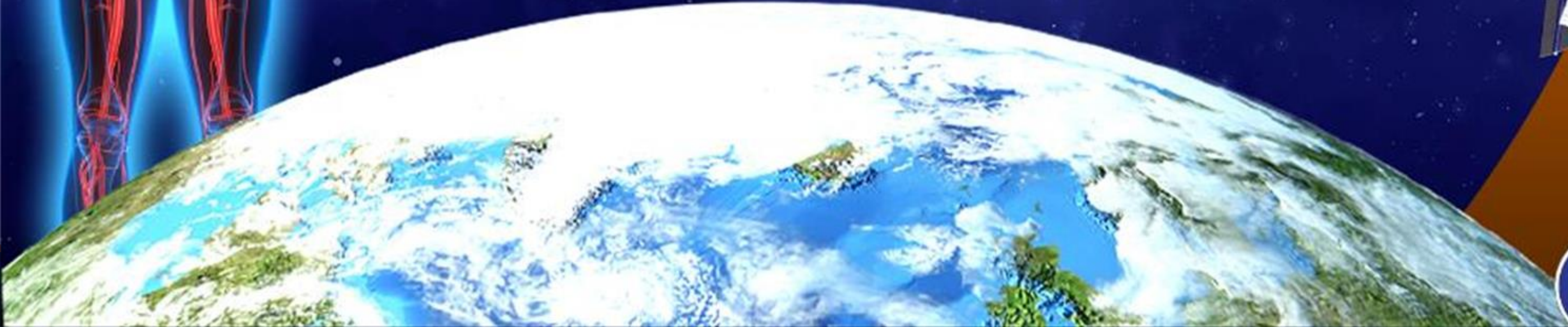
National Aeronautics and
Space Administration

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***

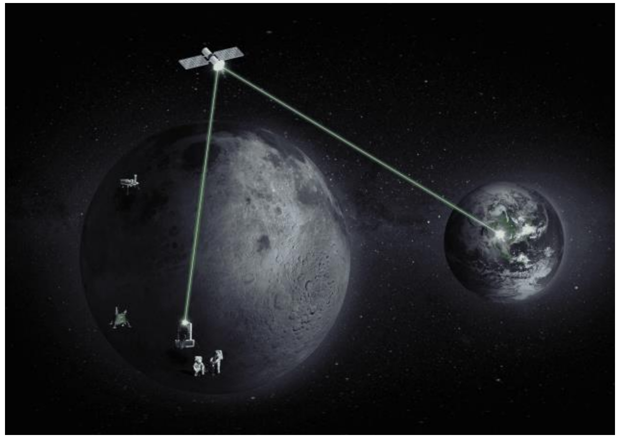
SCaN Human Lunar Return Contributions

Space Communications and Navigation (SCaN)

Human Lunar Return

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

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.



Deep Space Network Lunar Exploration Upgrades (DLEU)

Lunar Communications and Navigation Relay Services (LCRNS)

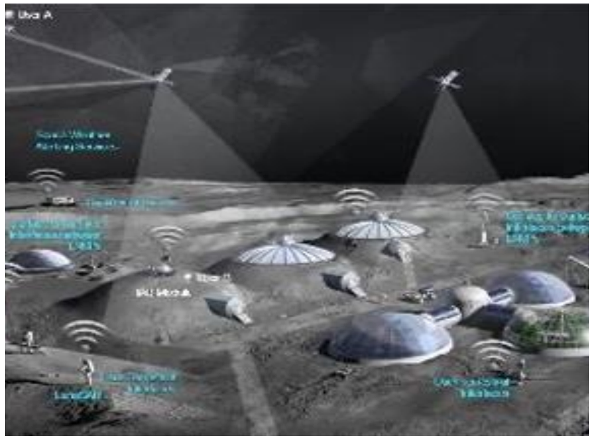
Lunar Exploration Ground Segment (LEGS) *(18-Meter Class Antenna Subnet)*

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