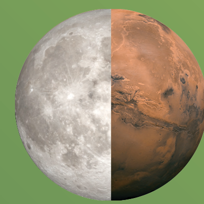
National Aeronautics and
Space Administration



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Moon to Mars
Architecture

white paper

Architecture-Driven Data Gaps

Introduction

Information drives innovation. To enable and realize agency exploration objectives, NASA will look to its partners to help acquire data gathered on and around the Moon and Mars. **Architecture-driven data gaps** represent missing or incomplete information needed to plan, build, deploy, and operate systems in the lunar and Martian environments.

NASA's Architecture Definition Document[1] captures how the agency will accomplish NASA's Moon to Mars Objectives.[2] Revision C of the document includes an initial list of architecture-driven data gaps, which will evolve annually as NASA closes gaps and identifies new ones.

Through the clear demand signal that these architecture-driven data gaps provide, NASA and its partners can better align their data-gathering efforts to support human exploration of the Moon, Mars, and beyond.

Defining Data Gaps

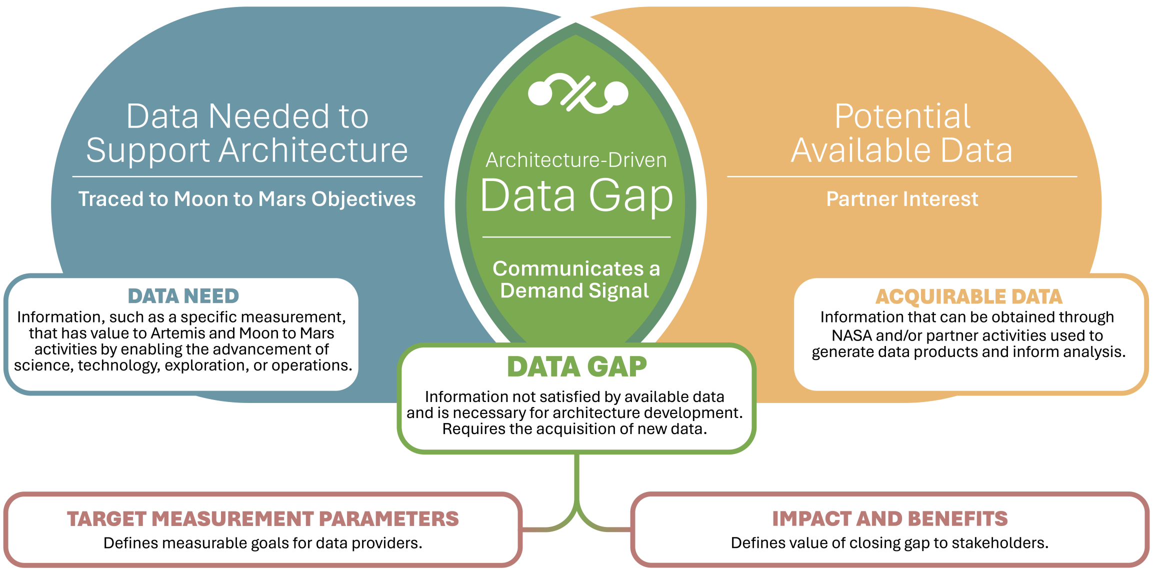
Human exploration missions to the Moon and Mars require a large amount of data across many disciplines. NASA already has access to much of this needed data, but sometimes available data cannot meet mission needs.

Architecture-driven data gaps exist where a lack of knowledge hinders NASA's ability to achieve its Moon to Mars Objectives. In these instances, available data does not fully meet an expressed need for information. This missing information could impact the agency's ability to perform architecture analyses, characterize or reduce mission risk, develop hardware, mature technology, advance science, or enable crew health and performance.[3]

These architecture-driven data gaps are agnostic to how the data should be collected; they identify a need, but do not prescribe how NASA or its partners could acquire the data. The data gaps are not procurement directives, nor do they set a monetary value for needed data. They do not include efforts to enhance data that is already acquired (e.g., post processing).

Instead, the architecture-driven data gaps are meant to spark conversations between NASA and its partners in industry, academia, and the international community. The data gaps communicate a demand signal and indicate partnership potential (as shown in Figure One.)

Figure One: *Diagram illustrating the nature and components of architecture-driven data gaps. (NASA)*



Data Needs

As illustrated in Figure One, architecture-driven data gaps are a subset of **data needs**. A data need is information, such as a specific measurement, that has value to Artemis and Moon to Mars exploration activities by enabling the advancement of science, technology, exploration, operations, or risk reduction. Data needs represent the information that would help NASA accomplish its Moon to Mars Objectives.

Partner Data

NASA's partners can offer data beyond what the agency currently possesses. As partner capabilities grow, NASA can increasingly rely on industry, academia, and the international community for mission-critical data.

For example, industry partners from the CLPS (Commercial Lunar Payload Services) program are gathering potentially valuable data as they deliver payloads to the Moon. Many of these partners have already demonstrated the ability and desire to support NASA's data needs.

The architecture-driven data gaps can help partners better align their data gathering activities with agency needs and can help define mission objectives and payload selections. NASA can acquire this partner data through data-sharing agreements, data buys, or other methods, depending on the specific partner. Acquiring data from a variety of sources will enable better modeling and have benefits that extend far beyond NASA's human exploration architecture.

Data Gaps and Technology Gaps

Along with architecture-driven data gaps, NASA also publishes a list of architecture-driven technology gaps in the Architecture Definition Document.[4] The term "gap" is widely used across NASA and the aerospace industry to describe a difference between an existing capability and a current or expected need.

While technology gaps describe the architecture's *technology development* needs, data gaps describe *information* needed. Technology gaps and data gaps can be connected (e.g., new data is needed to inform performance targets for technology development). As the list of data gaps list evolves or is addressed, NASA will continue to track the connections and dependencies between architecture-driven data and technology gaps.

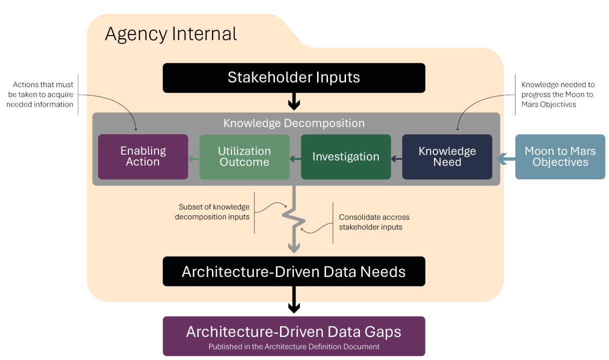


Figure Two: *Diagram illustrating the process for identifying architecture-driven data gaps. (NASA)*

Data Gap Components

Just as NASA understands the architecture's technical needs through a *functional decomposition*, which breaks objectives down into the individual capabilities needed to accomplish them, the agency understands the architecture's data needs through *knowledge decomposition* activities, in which the agency seeks to understand the knowledge needed to accomplish the Moon to Mars Objectives.

As shown in Figure Two, architecture-driven data gaps flow out of this knowledge decomposition, which documents the agency's broad information and research needs. In conducting the knowledge decomposition, NASA coordinates across its mission directorates (i.e., Science Mission Directorate, Space Operations Mission Directorate, Space Technology Mission Directorate, and Aeronautics Research Mission Directorate) to identify the information it needs to plan utilization activities and accomplish its exploration goals. In cases where the agency lacks necessary information, it documents a data gap.

Not everything in the knowledge decomposition evolves into a data gap. However, the knowledge decomposition does inform data gap development.

An Architecture Definition Document appendix contains the most recent list of data gaps, with each gap mapped to related objectives, segments, data types, and need drivers. Each gap description captures the components listed in Table One.

Description	Defines the data needed
Objectives	Provides traceability to the Moon to Mars Objectives in terms of how the data contributes to objective satisfaction
Segment	Provides traceability to the Moon to Mars Architecture in terms of timeframe NASA needs the data
Target Measurement Parameters	Sets the threshold for data quality, establishing a goal for data providers
Impacts and Benefits	Explains the significance the data; usually tied to enabling architecture analyses, characterizing risks, maturing technologies, or advancing scientific understanding
Current State of Data	Describes relevant available data and existing solutions to acquire data; these may not fully satisfy the need or provide a robust, reliable solution

Table One: *Definitions for the components of the architecture-driven data gaps as they appear in the Architecture Definition Document. (NASA)*

Assembling this information into an architecture-driven data gap helps NASA and its partners to understand what data is valuable, why it is valuable, and how the agency measures data quality.

Data Gap Evolution

The list of architecture-driven data gaps — first issued in revision C of the Architecture Definition Document — is a small set meant to inform partners of NASA's high priority, near-term needs. It is not a comprehensive representation of all of NASA's data needs.

The data gaps will evolve as NASA refines the architecture during its annual strategic analysis cycle. NASA will validate, update, add, or close gaps as data as the agency and its partners collect data and as new needs arise. New data gaps will be derived from the knowledge decomposition framework as the agency identifies additional data needs. Annual revisions of the Architecture Definition Document will include updated lists.

Additionally, NASA will engage its partners for feedback, initiating new data gaps and refining existing ones. These discussions with the agency's industry, academic, and international partners will help evolve the preliminary data gaps into a comprehensive list of needs.

ID	Data Gap	Data Utility
DN-002 L	Comprehensive, high-fidelity elevation map coverage of lunar south pole exploration zones and sites	To better enable characterization of lunar landing sites and increase confidence in landing accuracy and mobility system navigation.
DN-007 L	In situ measurements of the horizontal and vertical distribution, abundance, and physical makeup of shallow bulk water ice	To enable better identification of potential sites for in-situ resource utilization activities.
DN-008 L	Geotechnical properties of highland regolith at the lunar south pole	To enable higher certainty in the landing environment to inform lander design and site selection.
DN-017 L	In situ measurement of particle velocity during lunar plume surface interaction (PSI) phenomena	To enable better modelling of the interactions between landers and surface regolith to mitigate risk of damage to hardware.

Table Two: *Representative architecture-driven data gaps and examples of data utility from the preliminary list published in Architecture Definition Document revision C. (NASA)*

Sustained, site-specific sub-meter scale imaging of lunar south pole exploration zones and sites

ID No. **DN-001 L**
Objective **LPS-01 LM, SE-05 LM, LI-03 L**
Data Type **Orbit-to-Surface Imagery**

Gap Description	Need Driver	Segment
Produce optical maps or a set of optical images of the lunar south pole region that can be used to identify surface features, obstacles, and hazards across all Artemis landing regions. These maps and images should be capable of supporting landing site/ellipse design, element placement, and surface traverse planning. Multiple images of the same site should be captured at varying lighting conditions and be higher resolution than currently available.	**Lunar Exploration Surface Site Characterization**	Human Lunar Return

Target Measurement Parameters

Ensure sustained availability of high spatial resolution (<0.5 m/pixel preferred) optical imaging of lunar south pole exploration regions. Additionally, the system should have sufficiently high temporal resolution to collect imagery under varying lighting conditions enabling hazard avoidance, precision landing, and traverse planning. Images should be taken in at least 1-week intervals (every 48 hours preferred) over the course of an entire year.

Impacts and Benefits

Impacts if Data is Unavailable

Additional orbital imagery is not required to land and conduct a nominal surface mission at the lunar south pole. High resolution data collected by LROC NAC over the last 15 years is the primary data set being used to plan missions in the HLR and initial FE segment. However, additional optical imagery is desirable to inform surface element design, such as power systems, energy storage and user operating power especially for winter hibernation. Lack of continued high-resolution data could lead to Element loss due to power failure in winter, unsafe landings, or mission-ending mobility hazards. Overcompensating for uncertainty adds prohibitive mass, while underestimating risks threatens survival and operational success.

Benefits if Data is Available

Enables longer planning safer landings, optimized surface operations, and more accurate traverse planning. Improves situational awareness and hazard avoidance, increasing confidence in mission success.

Current State of Data

No additional orbital imagery is necessary to land and conduct a nominal Artemis surface mission. Data collected by the Lunar Reconnaissance Orbiter (LRO) Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) over the last 15 years is the primary data set being used to plan missions in the HLR and initial FE segment. The highest resolution panchromatic imagery of Artemis landing regions from LROC NAC is ~.5 m/pixel. NASA has the ShadowCam instrument on board the Korean Pathfinder Lunar Orbiter (KPLO) which is designed to collect high resolution images of Permanently Shadow Regions (PSRs) poles, as high as 1.7 m/pixel. However, this is only in low light locations and thus would not provide optimal imagery of a lander or surface operations in illuminated lunar regions. Additionally, JAXA Kaguya orbiter has scanned the lunar surface ~8-10m/pixel. Currently in orbit, is the Indian Space Research Organization's (ISRO) Chandrayaan-2 Orbiter High Resolution Camera (OHRC) which images the lunar surface at ~.3 m/pixel at select areas of the lunar south pole region.

Architecture Definition Document - Architecture-Driven Data Gaps

Figure Three: *"Sustained, site-specific sub-meter scale imaging of lunar south pole exploration zones and sites" (DN-001), an example architecture-driven data gap and associated metrics from NASA's Architecture Definition Document to illustrate the content details for each data gap. (NASA)*

Key Takeaways

Architecture-driven data gaps exist when a lack of information affects NASA's ability to achieve the Moon to Mars Objectives. The gaps represent areas where current and future NASA or partner missions can provide data to support future exploration.

The missing information comprising an architecture-driven data gap could impact the agency's ability to perform architecture analyses, characterize or reduce mission risk, develop hardware, mature technology, or advance science.

The architecture-driven data gaps published in Revision C of the Architecture Definition Document are an initial list of high-priority, near-term items; they are not a comprehensive or prioritized representation of NASA's data needs. Future revisions of the document will update the list of data gaps.

References

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