SAMPLR Mission Progress Report

Presentation to the Space Resources Roundtable XXIII

06 June 2023, Golden CO

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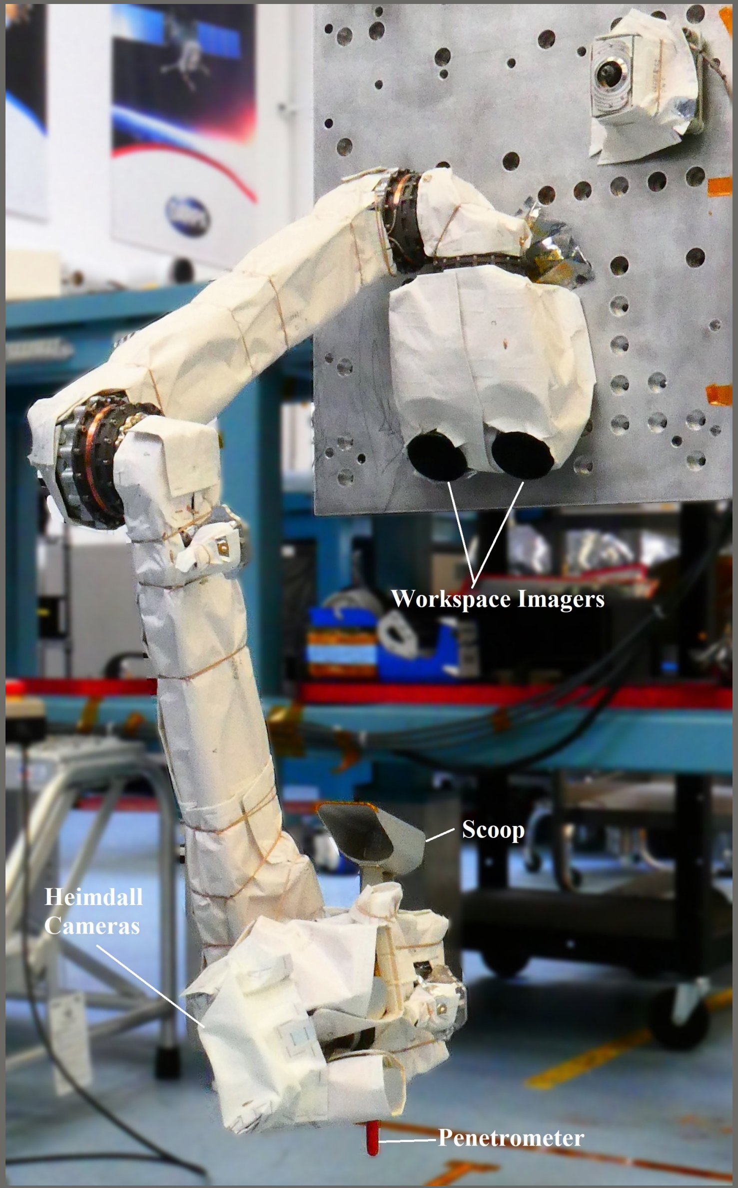

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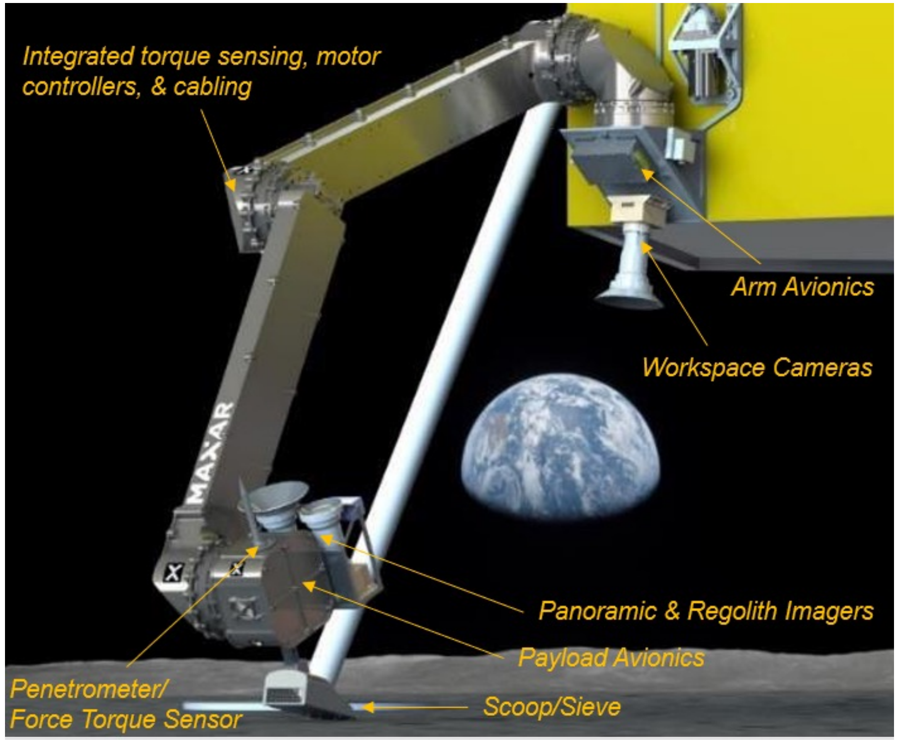
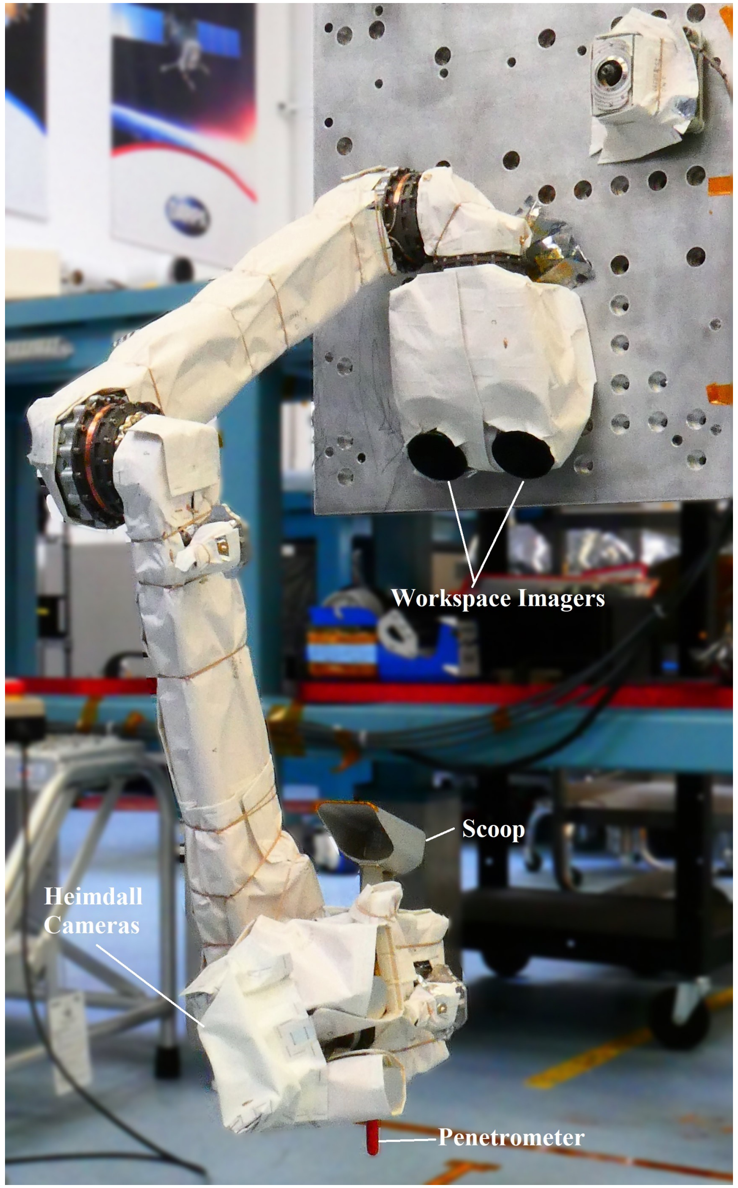
Sample Acquisition, Morphology Filtering, and Probing of Lunar Regolith (SAMPLR)





- Five degree-of-freedom (5DOF) robotic arm that will:
  - Collect samples of lunar regolith for other on-board instrument analysis
  - Demonstrate the use of a robotic scoop that can filter and isolate particles of different sizes
  - Utilize a penetrometer to help determine properties of the regolith
- Sampling technology leverages flight heritage from the Mars Exploration Rover project
- Partners include the Colorado School of Mines and Heimdall.
- SAMPLR is manifested as part of NASA's Commercial Lunar Payload Services Program (CLPS) .

Primary Mission Objectives

- SAMPLR provides a robotic arm and instrument suite to address key strategic knowledge gaps and technology demonstration priorities to meet the following objectives:
  - Demonstrate use of the robotic arm technology on the lunar surface to qualify its mechanisms and topology for use in future missions at varied locations and for use with additional payloads
  - Capture regolith geotechnical data with a novel penetrometer design leveraging a cone probe proven in a simulated lunar environment and a flight force-torque sensor
  - Demonstrate the use of Mars Phoenix Lander derived regolith scoop design with integrated sieves to acquire regolith samples and filter them to isolate size distributions of particles

Mapping of Objectives to NASA Strategic Goals

Objectives	NASA Goals	Success Metric
Demonstrate robotic arm on the lunar surface	TX04.3.4 TX04.4.3 TX07.1.2	Deploy robotic arm. Operate robotic arm in free space (no surface contact). Conduct a minimum of 1 surface contact operation and retraction from surface contact.
Capture regolith geotechnical data with the penetrometer	SKG I-D-3 SKG III-C-2 TX07.1.1	Obtain a minimum of one reading from penetrometer
Demonstrate regolith with integrated scoop to isolate/deliver desired morphologies (particle shape/size)	SKG III-A-4 SKG III-C-2 TX04.3.3 TX07.1.2	Obtain one surface sample of regolith with the sieve scoop. Image contents of the sieve scoop. Attempt a minimum of 1 sieving operation. Image contents of the sieve scoop post sieving motions.

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Optional Secondary Objectives

- SAMPLR will extend the mission capabilities of adjacent instruments and the CLPS lander by enabling optional secondary mission objectives including:
  - Imaging, assessment, and/or mapping of the surrounding terrain and the lander or payloads using arm- and base-mounted visible light cameras.
  - Remove surface regolith using an arm-mounted scoop and study the variation by depth of geotechnical properties using the Regolith Penetrometer
  - Deliver samples to other lander payloads using regolith scoop and integrated sieves
  - Support turret mounted hosted payload (Heimdall Cameras) mission objectives with collaborative operations and instrument pointing.
  - Demonstrate use of variable autonomy technologies to aid telerobotic missions

Arm Capabilities

Designed for modularity
Optimized for:
- Low mass/power, compact, extreme environments

Degrees of Freedom:
- 3 to 7 (5 for first SAMPLR mission)

Reach:
- Adjustable from 0.5 to 2+ meters (1.3m nominal)

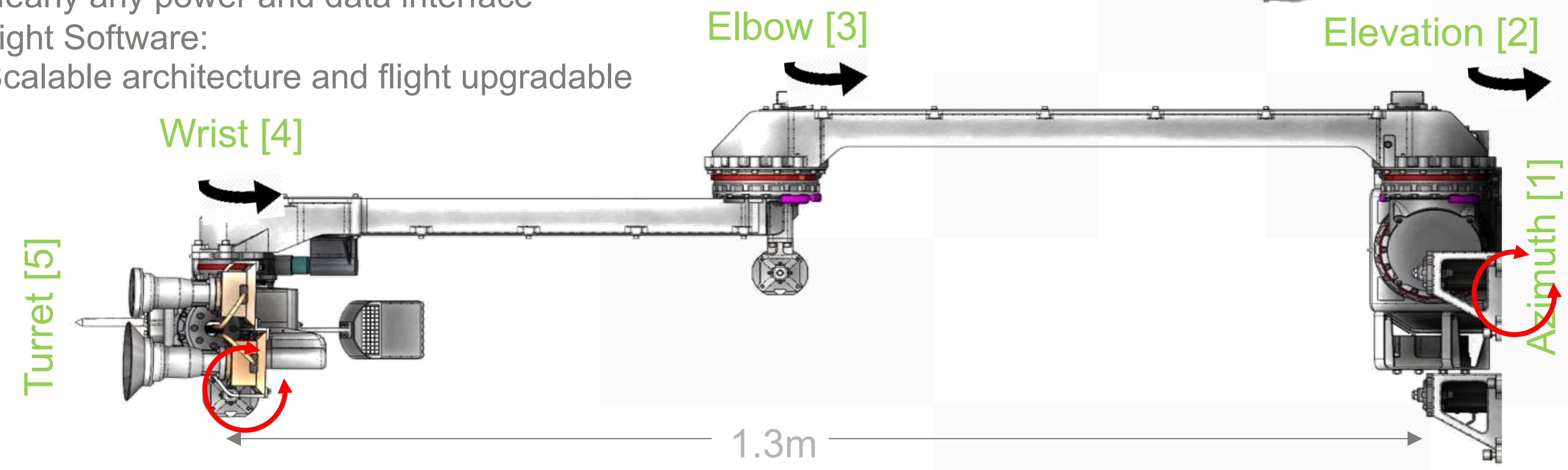
Total End-of-arm Payload Capacity (lunar):
- Depends on reach (25kg nominal)

Force Capability:
- Depends on pose (>80N nominal)

Positioning Repeatability:
- Depends on length (<1mm nominal)

Electrical Accommodations:
- Nearly any power and data interface

Modular Flight Software:
- Scalable architecture and flight upgradable



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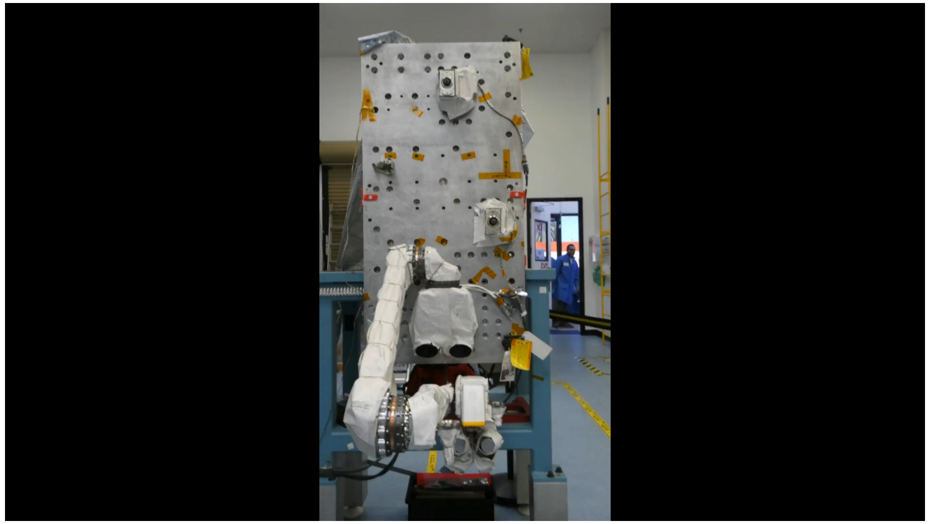
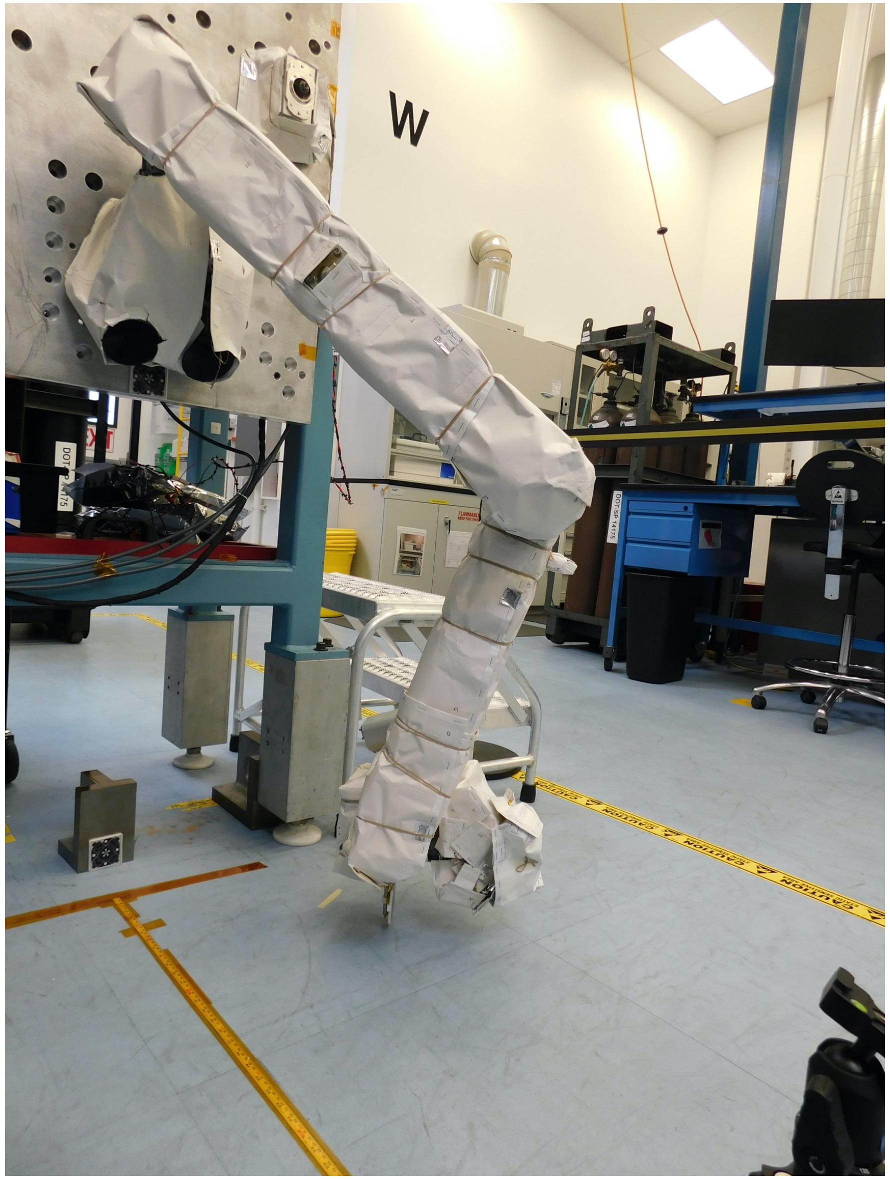
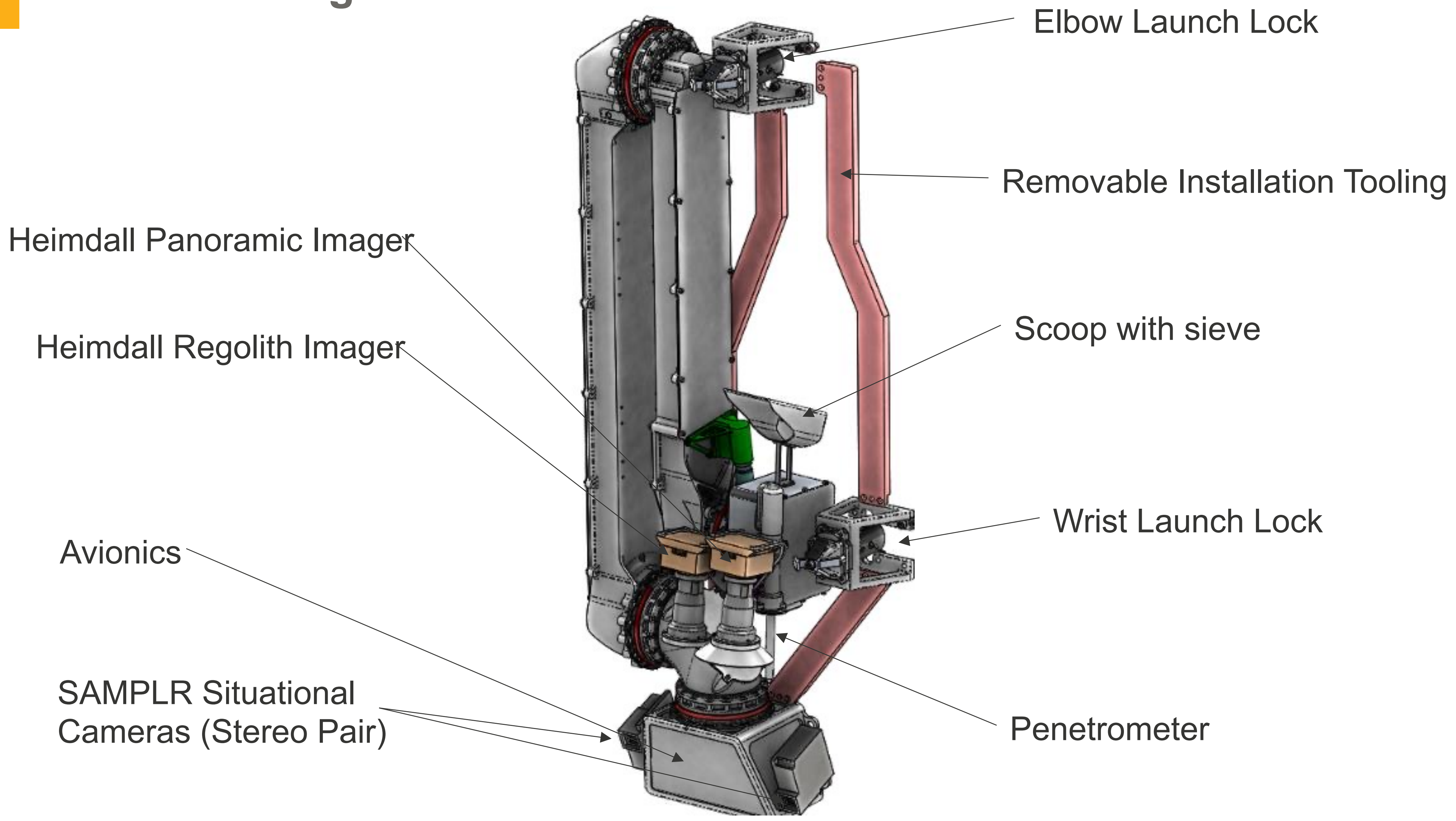
Modular Design

- Allows for
  - Swappable end-effector interface, enabling a wide array of science and infrastructure activities with the current arm layout and associated workspace
  - Additional extension of workspace, dexterity, flexibility, and expanded operational options can be tailored to specific future mission needs.





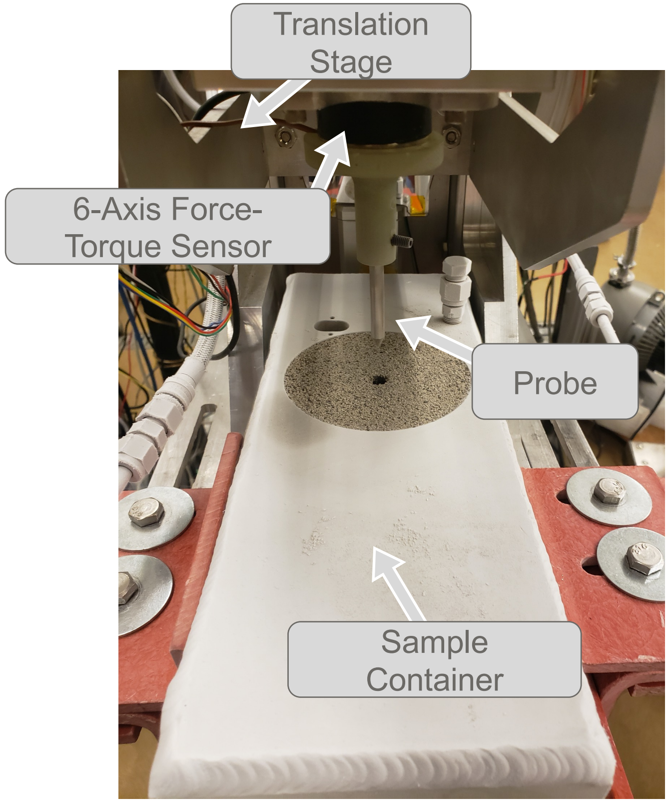
Stowed Configuration

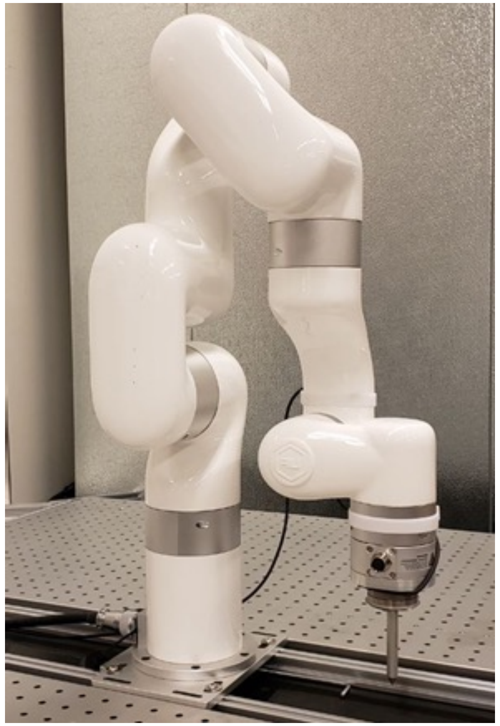


Regolith Penetrometer (Colorado School of Mines)

- Demonstration of specialized penetrometer methods in-situ
- Lightweight and simple to use
- Continuous data collection instead of discrete points
- Data separated into penetration and relaxation response
- Evaluation of fitted Penetration and Relaxation curves

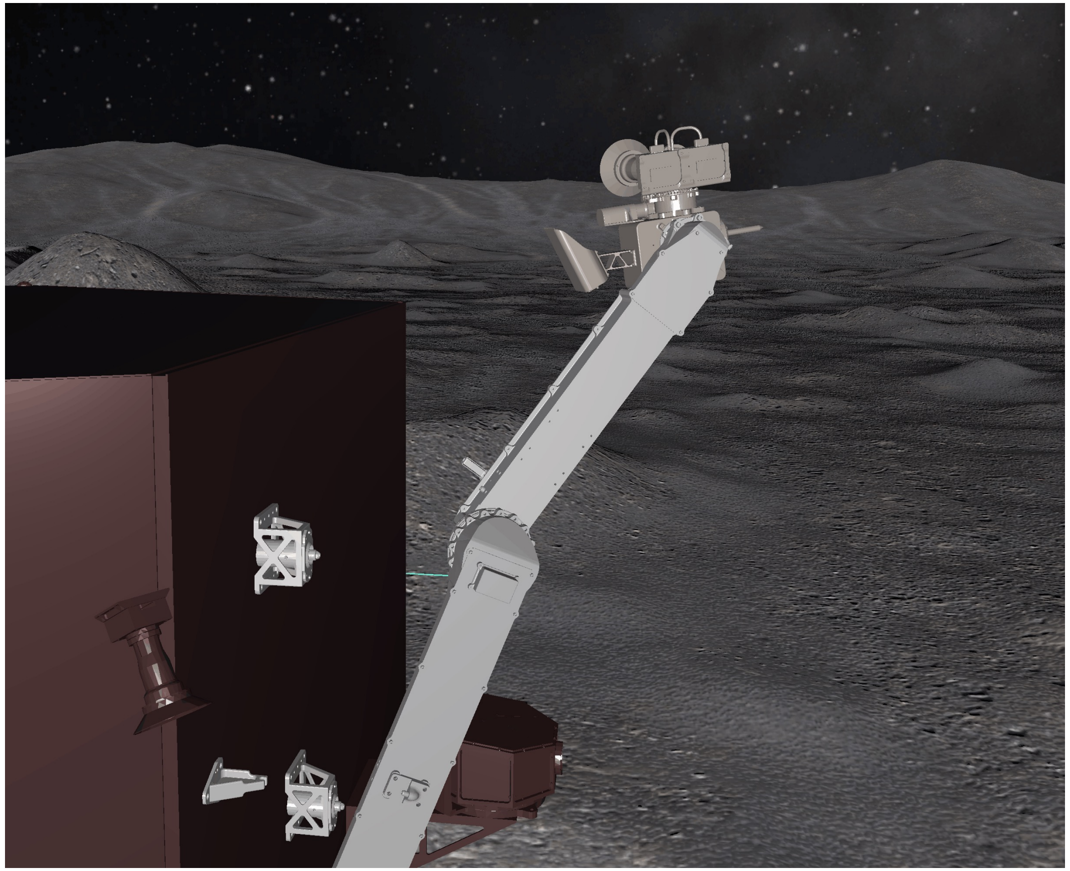
- For more information see *“Poke the Moon”* Poster by Ben Thrift, CSM





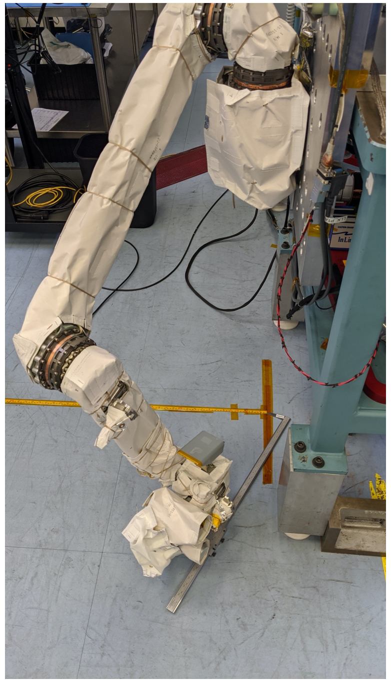
Science Cameras (Heimdall)

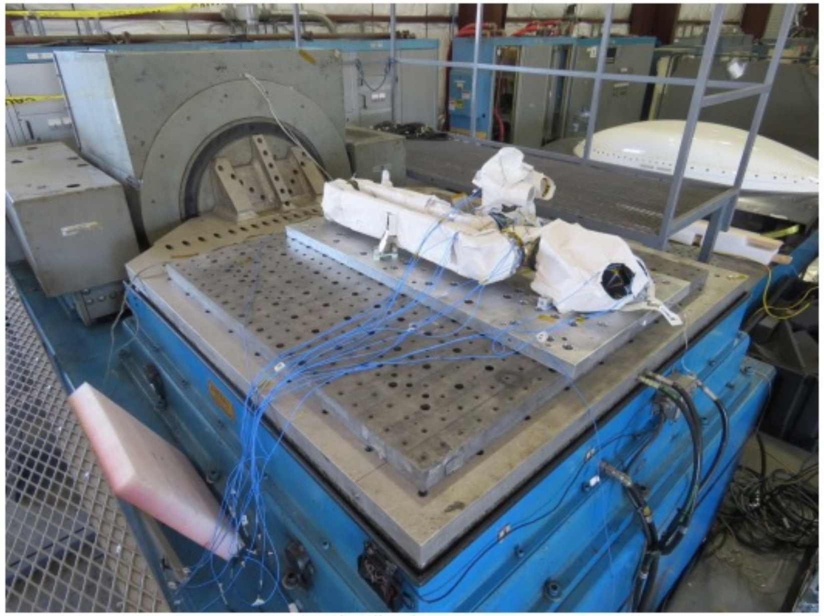
- Turret Hosted Panoramic Imager and Regolith Imager
- Utilizes SAMPLR pointing capabilities for fine regolith imaging and panoramic imaging
- Lander and payload inspection
- Collaborative payload operations



Status

- Originally slated to fly on Masten Space Systems XL-1 to the Lunar South Pole, originally scheduled for launch November 2023.
- Unfortunately, Masten filed for bankruptcy in July 2022 (later acquired by Astrobotic Technologies in September of that year)
- All payloads were de-manifested, including SAMPLR
- As of May 2023, SAMPLR has completed environmental testing and passed its Systems Integration Review / Acceptance Review with NASA.
- Targeting new landing site for 2026 launch





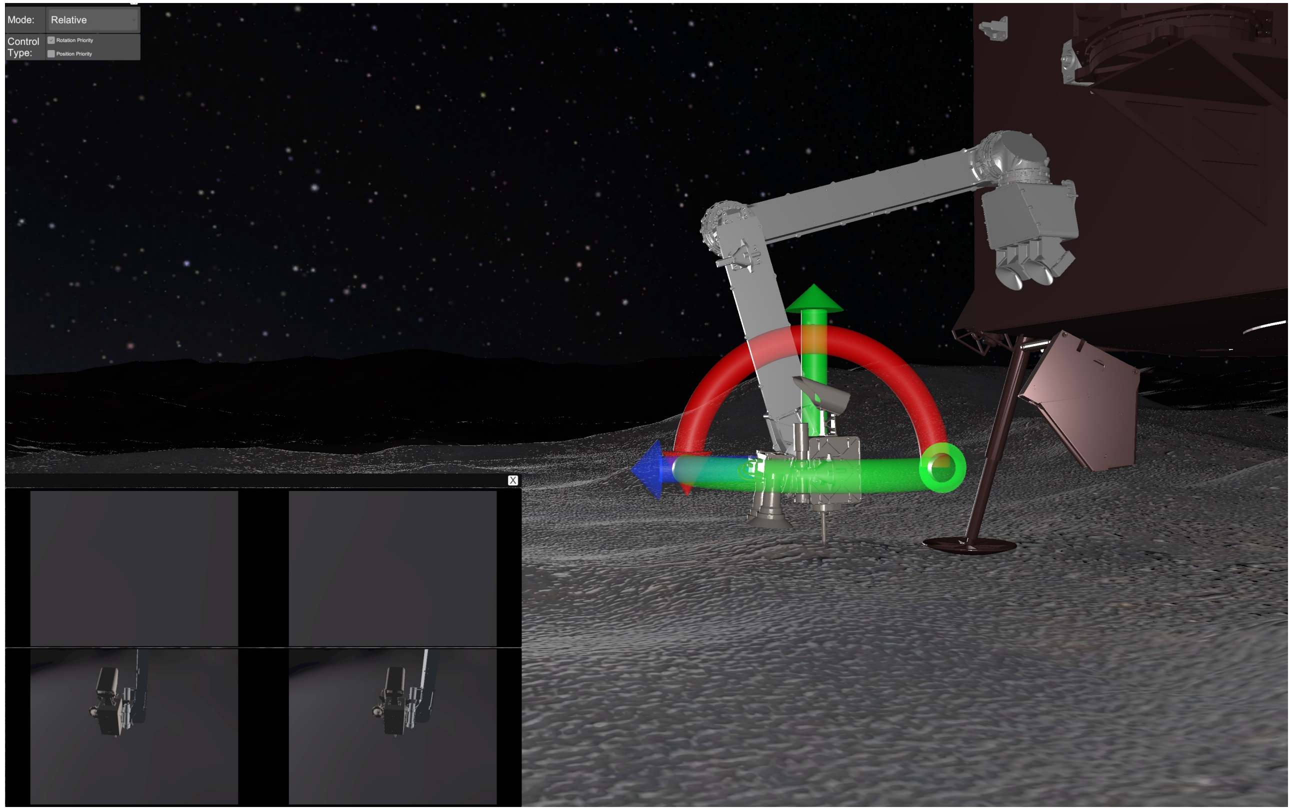
Z-Axis Vibration Test Setup

Storage/Flight Phase (tentative dates)

Milestone	Date
Storage (Pre-Lander Selection)	Jun 2023 – Jan 2024
Lander Selection	Q4 2023 (est)
Storage (Post-Lander Selection, Pre-Int.)	Jan 2024 – Jan 2026
Flight Phase	Jan 2026 – Jul 2027
Flight	2026 (Target)

Future Plans

- SAMPLR will be operated by Maxar Space Robotics
- Will leverage advanced robotic operations tool suites for trajectory planning and situational awareness



Acknowledgements

- Colorado School of Mines (Regolith Penetrometer)
  - Dr. Angel Abbud-Madrid
  - Dr. Chris Dreyer
  - Mr. Ben Thrift
- Planetary Science Institute (Heimdall)
  - Dr. Aileen Yingst
  - Dr. Michelle Minitti

This work was performed under the NASA Research Opportunities in Space and Earth Sciences (ROSES) Lunar Surface Instrument and Technology Payloads (LSITP) Announcement of Opportunity and will be manifested under the NASA Commercial Lunar Payload Services Program (CLPS).

Questions?

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[2] Seibert, M., Dougherty, S., Dreyer, C., Thrift, B., Cohen, B., Atkinson, J., "Sample Acquisition Morphology Filtering, and Probing of Lunar Regolith (SAMPLR) Payload", 51st Lunar and Planetary Science Conference (2020)

[3] J. Foust, Court approves sale of Masten Assets to Astrobotic, SpaceNews. (2023). https://space-news.com/court-approves-sale-of-masten-assets-to-as-trobotic/

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BACKUP SLIDES

NASA Technology Roadmap (2015, Archived)

NASA Goal	Title	Narrative
TA-8.3.3	In-Situ Instruments and Sensors; other	In-situ sensor technologies (for chemical, mineralogical, organic, and in-situ biological samples) include sample handling, preparation, and containment; chemical and mineral analysis; organic analysis; biological detection and characterization; and planetary protection. These technologies need to be applied in extreme temperatures, pressures, and environments.

https://www.nasa.gov/sites/default/files/atoms/files/2015_nasa_technology_roadmaps_ta_8_science_instruments_final.pdf

NASA Strategic Knowledge Gaps (SKGs)

NASA SKG	Title	Narrative
SKG I-D-3	Geotechnical characteristics of cold traps	Landed missions are required to understand regolith densities with depth, cohesiveness, grain sizes, slopes, blockiness, association and effects of entrained volatiles.
SKG III-A-4	Technologies for beneficiation of lunar resources	Sort regolith by material properties (e.g., particle size, density, mineralogy); some techniques utilize gravity and magnetic separation; enhances ISRU process efficiency.
SKG III-C-2	Lunar surface trafficability - in situ measurements	Characterization of geotechnical properties and hardware performance during regolith interactions on the lunar surface.

https://www.nasa.gov/exploration/library/skg.html

NASA Technology Taxonomy

NASA Goal	Title	Description
TX04.3.3	Contact Dynamics Modeling	Contact dynamics modeling provides an understanding of forces/torques generated on objects and platforms through mobility or manipulation. The results can be used to prevent harm to the contacting bodies and assure that the contact characteristics support the mission.
TX04.3.4	Sample Acquisition and Handling	Sample acquisition and appropriate handling includes the actions and means to extract or collect, move, transfer, or modify samples (regolith, cuttings, volatile samples) that have been acquired, loading them into instruments or packaging systems for analysis.
TX04.4.3	Remote Interaction	Remote interaction allows supervisory control of complex remote systems across a space in the presence of varying communication latencies, bandwidths, and dropouts.
TX07.1.1	Destination Reconnaissance and Resource Assessment	Destination reconnaissance and resource assessment technologies characterize, sample, and map the surface environment to quantify the locations and abundances of material and energy resources accessible from the surface. Orbital remote sensing or deployed surface devices and instruments are used to probe, sample, and analyze possible dynamic atmospheric and surface/subsurface material composition and physical/chemical properties. This mapping includes the combination of environmental, terrain, geological, and resource information to estimate accessibility and plan extraction operations.
TX07.1.2	Resource Acquisition, Isolation, and Preparation	Resource acquisition, isolation, and preparation technologies access, extract, isolate, concentrate, modify, and purify resource-bearing materials in preparation for further processing. Resource-bearing materials include locally acquired materials and byproducts of mission operations that become available for recycling.

https://www.nasa.gov/sites/default/files/atoms/files/2020_nasa_technology_taxonomy_lowres.pdf

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