
Introduction: The Sample Acquisition, Morphology Filtering, and Probing of Lunar Regolith (SAMPLR) payload is one of 12 payloads selected as part of NASA’s Lunar Science and Instrument Technology Payload (LSITP) program for flight on a future Commercial Lunar Payload Services (CLPS) mission to the lunar surface. SAMPLR consists of a robotic arm, penetrometer, sieve-scoop, and camera system.

SAMPLR Payload Objectives: The SAMPLR payload objectives were selected to address Lunar Strategic Knowledge Gaps (SKGs), general lunar science, technology development and demonstration, and to be enabling for other payloads.

Primary Objectives. The three primary objectives of SAMPLR are: 1) Demonstrate the next generation Instrument Deployment Device (IDD) on the lunar surface, 2) Capture regolith geotechnical data with the penetrometer, and 3) Demonstrate regolith sieve-scoop to isolate and deliver desired particles to a lander or rover. These primary objectives work to address Lunar SKGs I-D-3 (dependent on landing site), III-A-4, III-C-2 [1], and NASA Technology Roadmap TA-8 for rugged in situ sampling technology. [2]

Secondary Objectives. SAMPLR has several secondary objectives: 1) Imaging of surrounding terrain and the lander or payloads, 2) removing of surface regolith with the scoop and investigations with the penetrometer at depth, 3) enabling other payloads by delivering regolith samples or hosting of additional instruments on the end of arm turret, and 4) demonstrating variable autonomy to aid telerobotic missions. These secondary objectives support mapping of the work volume, support the sieve investigation, provide situation awareness and geologic context, and provide additional data in support of Lunar SKGs I-D-3 and III-C-2.

Robotic Arm: The robotic arm for SAMPLR is an evolution of the Instrument Deployment Device (IDD) robotic arms that Maxar built for NASA’s twin Mars Exploration Rovers, Spirit and Opportunity. This second generation IDD will include updated motors that are compatible with the lunar environment and improve performance while reducing the cost of the robotic arm.

This next generation IDD is designed as a five degree-of-freedom robotic arm, but can be configured with fewer degrees of freedom to reduce the mass and cost of the robotic arm. The end of the robotic arm is equipped with a force-torque sensor and a turret with as many as four radial instrument mounting locations.

The total length of the robotic arm may be adjusted depending on the mounting height above the lunar surface provided by the host lander. Both 1-meter and 2-meter configurations have been designed to support mounting between 0.5 meters and 1 meter above the surface. The robotic arm can be lengthened to support a 2-meter mounting height above the lunar surface.

Instruments and Tools: SAMPLR combines a sieve-scoop, penetrometer, and camera system to perform investigations on the lunar surface. The penetrometer and sieve-scoop use two of the turret locations. The remaining turret locations can be used to host additional instruments.

Sieve-Scoop. The sieve-scoop is based on the Maxar heritage scoop built for the cancelled 2001 Mars lander and later flown on the InSight lander. The SAMPLR scoop modifies this design to incorporate two sieves in the scoop side walls. The two sieves will have different mesh sizes allowing for filtering of two particle sizes, for example, to bracket a size between a large and small size cutoff. This capability will enable delivery of lunar material to analysis instruments (for example, geochronology [3] and trace element analysis [4]).

The scoop will be used to collect regolith samples. Data from the force-torque sensor will be used to determine the mass of regolith acquired. Rotation and vibration of the scoop will be used during sieving operations to induce regolith flow though the sieve.

The scoop will also allow for removal of regolith to provide instruments with access to regolith below the landing surface. To a limited extent the scoop can also be used to prepare the work volume by moving rocks that may preclude use of other instruments or tools.

Penetrometer. The penetrometer is based on the In Situ Experimental Probe (IEP) developed at the Colorado School of Mines as part of the NASA SSERVI IMPACT team [5]. For SAMPLR, the robotic arm functions as the linear translation mechanism for the penetrometer probe. The end of arm force-torque sensor will collect data on surface penetration and relaxation forces. These data will provide estimates of bulk relative density, cohesive behavior, and surface strength of the lunar regolith [6], an example is shown in Figure 1.
The penetrometer measurements are sensitive to the total stiffness of the robotic arm. To meet the stiffness required, the penetrometer measurements have a reduced work volume compared to the sieve-scoop. The penetrometer work volume is limited to a smaller radius from to the shoulder joint cluster’s mounting location below the lander deck.

Camera System. The camera system is used for both engineering support and science data collection. Engineering support includes imaging terrain in the robotic arm work volume for hazards and for generation of 3D terrain meshes to support planning arm surface contact locations.

The camera system will be used to assess scooping and sieving operations. Observations of the scoop contents immediately after scooping will be used to assess the collected regolith sample and determine the volume of regolith acquired. Imaging following sieving activities will be used to determine the volume of regolith remaining in the scoop. This data will be used to determine the volume of regolith removed from the sample by sieving providing an estimated volume of regolith particles at or below the sieve mesh size. Imaging after each sieving command will be used to assess the effectiveness of sieving using the sieve-scoop.

Future SAMPLR Based Payloads: SAMPLR is an important step towards future robotic manipulation systems to enable and enhance future science investigations on the lunar surface. Flying SAMPLR payloads to varying lunar surface locations will allow for data to be on surface properties across the lunar surface with a common instrument/tool suite.

The SAMPLR robotic arm’s tailorable arm length, support for multiple end of arm instruments or tools and adaptability to support instrument deployments will allow it to form the backbone of future lunar payload suites. SAMPLR Team: The SAMPLR team is comprised of organizations spanning commercial, academia, and government. The payload is commercially led by PI Sean Dougherty from Maxar. Co-investigators represent Maxar, Colorado School of Mines, NASA’s Goddard Spaceflight Center, and Olis Robotics.