ROBOTIC REGOLITH SAMPLE COLLECTION DURING CREWED ROVER TRAVERSES.

M. A. Seibert[1] [1]Maxar (1300 West 120th Avenue, Westminster, CO 80234 USA, mike.seibert@maxar.com)

Introduction: Crewed mission to the lunar surface provide several advantages over remotely operated robotic missions. One key advantage is increased rover traverse speeds allowing for greater range and during a given mission duration. These increased traverse capabilities allow for a larger area to explored during the mission.

While crewed rover capabilities allow for a larger area to be explored, a limiting factor is the total crew-time available at each site during a traverse. Robotic systems, autonomous and/or crew operated, can increase the science productivity of each surface mission. Specifically robotic arms and sample manipulation systems can be leveraged to perform regular surface sampling along a rover traverse.

Apollo Context: During the Apollo missions many samples of regolith were collected using bags, scoops, and rakes. Over the course of the six landed missions these sampling tools, sampling methods, and sample handling were improved. Sampling of regolith during early Apollo missions required the participation of both crew members: one to collect the sample with the tool and the other to hold the sample container. [1]

Regolith sampling was conducted at varying depths ranging including 1 cm depth “skim” samples [2], “scoop” samples from between 1 cm and 5 cm depth [2], and samples from a trench dug ~35 cm [3] into the regolith. Common bulk sampling was conducted between 1 cm and 5 cm depth. Raking was used to collect >1 cm rocks from the top several centimeters of regolith. During the Apollo 17 mission a system was devised to allow a single crew member to sample regolith alongside the Lunar Roving Vehicle (LRV) without dismounting their seat.[2]

Proposed System: The robotic sampling system is derived from Lunar Science and Instrument Technology Program’s (LSITP) Sample Acquisition, Morphology Filtering, and Probing of Lunar Regolith (SAMPLR) payload and consists of the following elements: robotic arm, sample storage containers, and control electronics. These elements are mounted to a common baseplate to allow the robotic sampling system to be attached to multiple vehicles including unpressurized rovers, pressurized rovers, CLPS class landers, or to be deployed by crew members a distance from those vehicles if connected to the host vehicle by a power and data tether.

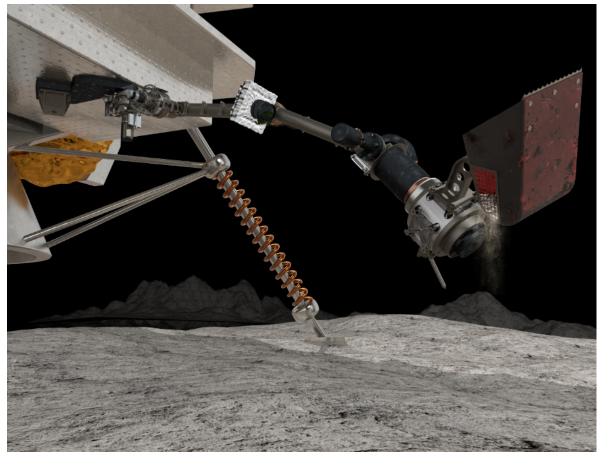

Figure 1 - Artist’s conception of the SAMPLR robotic arm. Image credit: Maxar.

Based on the regolith sampling performed during the Apollo missions, the robotic sampling system will be capable collecting regolith samples in a manner similar to that performed on Apollo. The system will include a scoop with an ability to trench into the regolith, scoop/skim samples from a depth between 1 cm and 5 cm from the sampling surface, and to deposit these samples into appropriate sample containers.

The robotic sampling system can be controlled either directly by one of the rover crew, remotely by an IVA crew member (located in the lander, pressurized rover, or Gateway), by teleoperation from Earth, or using autonomy.

In addition to the sample collection scoop accommodation for other instruments or tools on the end of the robotic arm is possible. A suite of tools measure geotechnical properties is being considered.

System Resource Requirements: The estimated properties of the robotic sampling system are listed below:

Arm Length: 2m
Mass: 20 kg
Power: 45 W operating, 20 W survival
Volume: 80 cm x 120 cm x 30 cm

Note that mass and volume estimates shown are for a traditional 4 or 5 degree of freedom robotic arm (shoulder, elbow wrist). Arm kinematics and packaging can be adjusted to meet crew mission needs and constraints.

Notional Operations Concept: The robotic sampling system can be used in conjunction with either unpressurized or pressurized crew rovers.

Installation and setup. The robotic sampling system mass, volume, and power requirements allow it to be delivered to the Artemis landing site on smaller CLPS class landers. If delivered on a robotic lander, the crew would need to remove the robotic sampling system by disconnecting the single connector power/data cable and removing the mounting fasteners. Transfer to the rover would be performed by the crew carrying the integrated assembly from the landing vehicle to the rover. Installation on the crew rover would reverse the process by installing and torqueing the mounting fasteners and connecting the power/data cable to the rover.

Alternatively, the robotic sampling system may be able to be delivered pre-integrated with the initial unpressurized rover.

Unpressurized Crew Rover Use Case. The robotic sampling system would primarily be used during planned station stops. After arrival at a station (planned or station of opportunity) during a traverse, the crew would ensure that the desired regolith is within reach of the robotic sampling system. Once in position, the robotic sampling system would be commanded to perform the desired sampling operations (e.g. scoop, skim, or trench) in the regolith. During this time the crew members can perform their tasks at the station in parallel with the robotic regolith sampling.

Pressurized Crew Rover Use Case. For use with a pressurized rover the sample collection and storing robotic operations would be similar to the unpressurized rover case. An additional advantage is enabling sample collection without requiring an extravehicular activity (EVA). The crew would be able to use the rover to approach a sampling site, command the sampling, and confirm sample storage from the comfort of the pressurized rover.

Post-Traverse. Upon completion of the traverse the crew members will need to remove the filled sample containers for possible return to Earth. The robotic sampling system will allow for replacement sample containers to be installed allowing for system reuse across multiple crew missions.

Benefits of Robotic Sampling: There are benefits of including a robotic sampling system on crew rover traverses.

Consistent Sampling. Use of a robotic system can ensure that scoop depth into the regolith is consistent across many sample sites. This results in a consistent volume among samples.

Areal Extent of Regolith Samples. Including a robotic sampling system on a crew rover will allow for samples to be collected at stations over a larger area than if installed on a remotely operated rover.

Reduced Dust Contamination of Spacesuits. During Apollo regolith sampling that was not directly collected using a bag-scoop often required two crew members.[2] One crew member to scoop the regolith and the second to hold the sample container. Figure 2 shows how such a sample transfer was achieved during Apollo.

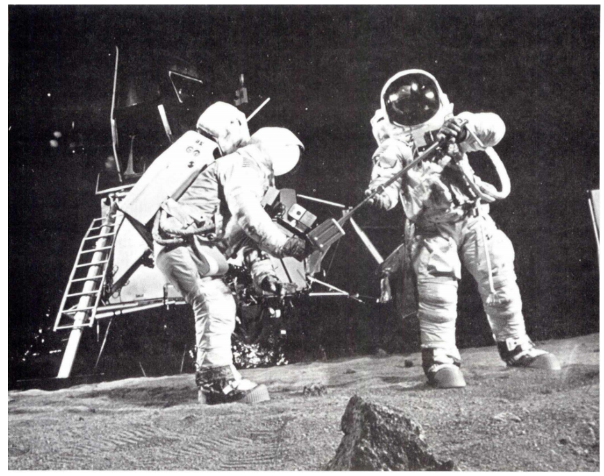

Figure 2 – Astronauts training by rehearing the transfer of a regolith sample from a manual scoop to a sample bag. [2]

Both sample collection and sample transfer require close interaction with loose regolith which can result in dust contamination of the EVA suits. Robotic collection of regolith samples will allow crew members to be a distance from the sampling/storing activities, thus reducing exposure to lose regolith during sample transfer.

Increased Crew Time for Station Unique Investigations. The robotic sampling system is designed to consistently perform a standardized task across many locations. By assigning regolith sampling to a robotic system, the highly trained crew members will be able to focus EVA time on unique science activities at each station along a rover traverse.

References:

[1] J. H. Allton. (1989) *Catalog of Apollo Lunar Surface Geological Sampling Tools and Containers,* 28 [2] R. V. Morris. et al. (1983) *Handbook of Lunar Soils,* iii-iv [3] U. B. Marvin and A. B. Mosie (1980) *Apollo 16 Soil Catalog 61220,* 1.