NASA SBIR 2022 Phase I Solicitation

Z14.01 Lunar Surface Excavation

Lead Center: KSC

Participating Center(s): GRC, JPL, LaRC

Scope Title

Lunar Surface Excavation

Scope Description

NASA is interested in developing excavation technologies to mine frozen volatiles resources by excavating the icy regolith in permanently shadowed regions (PSRs) and surrounding areas.

Currently, excavation robots that have been prototyped have been designed to excavate in dry regolith [1,2,3,4] to extract the oxygen contained in silicates and other minerals. Frozen volatiles, such as water, may act as a binder in the regolith, therefore possibly creating a very hard consolidated material. Existing excavation robots and implements have not been designed to excavate in this icy regolith mixed material.

In addition to icy regolith excavation capabilities, the excavation systems must be capable of operating in the extremely harsh lunar environment, including inside PSRs expected to be as cold as 40 Kelvin [5].

Excavation of lunar regolith is enabling for in situ resource utilization (ISRU), as the regolith will be the source of many feedstocks that can be used to make needed products in this domain.

This subtopic is focused on the following aspects of lunar regolith excavation:

- Excavation devices and sensors/feedback needed to better understand and eventually automate excavation processes for icy regolith excavation.
- Reliability and durability of regolith excavation hardware during excavation of hard/icy regolith containing frozen volatiles.

Proposals must address strategies and designs for both of these focus areas, with a strong emphasis on life-cycle reliability and durability.

For ISRU, excavation technologies are required to mine resources that will have been previously located and identified by resource prospecting methods. For oxygen extraction, the surface regolith may be mined, as the oxygen is ubiquitously present in the form of silicates, whereas volatile resources are thought to be beneath an insulating overburden that may be up to 1 m deep and beyond.

Recent missions to the Moon have identified a high potential for the existence of volatiles resources. The suite of
Lunar Crater Observation and Sensing Satellite (LCROSS) and Lunar Reconnaissance Orbiter (LRO) instruments determined as much as 20% of the material kicked up by the LCROSS impact was volatiles, including methane, ammonia, hydrogen gas, carbon dioxide, and carbon monoxide. The water signature, considered a highly important and strategic lunar resources ore, was 5.6%. Mars mission data (Phoenix, Mars Reconnaissance Orbiter (MRO), etc.) have also shown that there are vast deposits of water ice in the martian subsurface, thus providing Mars-forward linkage for subsurface frozen regolith excavation technologies.

This subtopic is seeking proposals for prototype(s) designs, analysis, hardware, test data, and test reports of excavation devices and sensors related to lunar icy regolith excavation technologies capable of excavating icy regolith to depths of greater than 1 m. The required lifetime of the excavation devices shall be 5 years but may include robotic repair and maintenance.

The amount of regolith that is required to be mined corresponds to an ISRU system that can produce at least 15,000 kg of water over the duration of 225 days of actual operation in a calendar year. Assuming an approximately 3% water yield, it can be assumed that the requirement will be to deliver icy regolith to the ISRU water extraction plant at a rate of 100 kg/hr, without including the dry regolith overburden. Excavation system power needs shall be defined by the proposed designs, and it can be assumed that a NASA-provided electrical power plant and distribution system will be provided. It will supply 10-kW electrical power at 120 VDC, and it will provide continuous power regardless of lighting conditions. A relevant, realistic, and effective lunar concept of operations shall be part of the deliverables. Lessons learned, statistical data studies, and strategies from terrestrial excavation, site preparation, and mining operations are welcomed.

While the exact properties of the lunar regolith [6,7] with frozen volatiles are not yet clear, proposers are requested to research the existing literature and use terrestrial analogs to justify their designs and strategies.

Because the excavation systems will be operating in an extreme lunar environment, possibly inside a PSR, the reliability and durability of regolith excavation hardware will be of critical importance to mission success. This subtopic is also seeking studies and technologies that include strategies and designs to allow lunar icy regolith excavation systems to survive 5 years of continuous operation. Robotic maintenance strategies shall be defined and examined, and methods for robotic servicing shall be identified [8].

**Expected TRL or TRL Range at completion of the Project**

3 to 5

**Primary Technology Taxonomy**

**Level 1**

TX 07 Exploration Destination Systems

**Level 2**

TX 07.X Other Exploration Destination Systems

**Desired Deliverables of Phase I and Phase II**

- Research
- Analysis
- Prototype
- Hardware
- Software

**Desired Deliverables Description**

Phase I deliverables may be a conceptual design or development plan with analysis to show feasibility at relevant scales and/or a small demonstration of the concept or of a subsystem.
Phase II deliverables should be hardware demonstrations at a relevant scale. See Scope Description for additional information on Phase I and Phase II deliverables.

**State of the Art and Critical Gaps**

The state of the art consists of terrestrial prototypes at Technology Readiness Level (TRL) 3 or 4 that have been previously built and tested for SBIR/STTR, NASA Centennial Challenge, NASA competitions for universities, and in-house NASA technology development, such as the Regolith Advanced Surface Systems Operations Robot (RASSOR) 2.0 and the Advanced Planetary EXcavator (APEX).

**Relevance / Science Traceability**

The work desired applies to Technology Taxonomy (TX) Area 7: Exploration Destination Systems. It applies to the 2018 NASA Strategic Plan Strategic Goal 2: Extend Human Presence Deeper into Space and to the Moon for Sustainable Long-Term Exploration and Utilization. It also applies to the Plan's Strategic Objective 3.1: Develop and Transfer Revolutionary Technologies to Enable Exploration Capabilities for NASA and the Nation. It also applies to TX04: Robotic Systems, as the excavation equipment will need to operate without a human crew present during some periods.

**References**


