SBIR/STTR

Small Business Innovation Research / Small Business Technology Transfer

NASA STTR 2021 Phase I Solicitation

T7.04 Surface Construction

Lead Center: KSC

Participating Center(s): GRC, MSFC

Scope Title:

Surface Construction

Scope Description:

Surface construction technologies must be developed to support long-term sustainable human presence on the lunar and eventually Martian surfaces. To enable a sustained human presence on the Moon, multiple assets are likely to be landed proximal to each other. While the Apollo landers demonstrated that it is possible to land on an unprepared surface, landing multiple proximal assets under Artemis will pose an unacceptable risk to nearby hardware.

For this reason, launch and landing pads are a high initial priority due to significant risks associated with these operations. When a lander vehicle launches or lands on an extraterrestrial body, the rocket engine exhaust plume impinges on the surface and interacts with the regolith, and blast ejecta is created along with associated cratering of the surface. Lunar regolith blast ejecta travels at high velocities (>2,000 m/s) for long distances (kilometers) in a vacuum environment creating hazards for surrounding assets. Ejecta can also impact the bottom of the lander vehicle, risking damage to the engines, thermal insulation, and sensors. Regolith ejecta can enter cislunar space as debris if the ejecta is sufficiently energetic to achieve orbit. The cratering can affect the stability of the landing gear and expose subsurface hazards.

As a part of a Launch and Landing Pad (LLP) system, concepts for construction of blast ejecta barriers such as berms, walls, curtains, deflectors, or other solutions are also sought. These blast ejecta barriers will protect the lunar base in the vicinity of the LLP during routine launches and landings and will also provide protection in the event of an anomalous energy release in the lander.

Upon the completion of an LLP system, follow-on surface construction projects will reduce risk to other parts of the lunar infrastructure and are expected to include:

- Stabilized roads and pads to mitigate trafficability and operational risks.
- Radiation shielding for nuclear power plants.
- Trenching for cables and other below-grade operations.
- Site preparation including establishing grade, leveling, compaction, and rock clearing.

- Unpressurized structures for radiation, thermal, and micrometeoroid protection.
- Pressurized structures.

This subtopic is focused on applied research to enable the design, testing, and verification of civil engineering products suitable for use in lunar surface architecture. New analysis methods and specialized construction equipment will be required to meet the unique lunar environment. The desired outcome of this work is the definition of feasible civil engineering system solutions with associated methods, analysis, structural designs, construction equipment concept prototypes, and concepts of operations.

The construction operations shall be robotically competed using indigenous lunar resources to the highest degree possible to minimize crew interaction and minimize the transportation mass from Earth to the Moon. Proposers need to consider operations and hardware designs in a Global Positioning System (GPS-) denied environment for positioning, leveling, and control. In selecting and developing procedures and materials for surface stabilization and landing pad construction, proposers should consider the ability to perform maintenance and repair for long-term operations.

For hardware, processes, and operations that require mobility, proposers should define the interface and operation requirements, but may refrain from designing specific mobility units as these may be available through other development activities. Proposers should also specify the interfaces to other lunar systems that might be required such as power, regolith size sorting, beneficiation, etc., and include the source of all feedstocks for construction materials and associated processing required.

Proposed techniques can utilize Earth-supplied consumables (such as binders, water, purge gases, etc.) but need to quantify the types and amounts needed for the proposed construction operations. Emphasis should be given to consumables that can eventually be extracted or produced from in situ resources. The proposed lunar methods, materials, and technologies shall be traceable to Mars applications to the highest degree possible. The lunar construction technologies proposed should also contain methodologies for verification of the as-built or finished construction to ensure it will perform as required.

Research institute partnering is anticipated to provide analytical, research, and engineering support to the proposers. Examples may include helping apply civil engineering principles and planning methods, identification and development of needed standards or specifications for lunar operations, or the development of analytical and verification methods for the design and prototyping of structures, hardware, and associated software.

Specific figures of merit for proposed solutions include the following for Commercial Lunar Payload Services (CLPS) and human-class landers:

- Performance of infrastructure in intended applications (e.g., under launch/landing conditions).
- Performance under lunar surface environmental conditions (e.g., thermal cycling, ultraviolet (UV), vacuum, and radiation).
- Required payload mass.
- Estimated power requirements.
- Feedstock sources and requirements.
- Construction time.
- Surface preparation/analysis requirements.
- Strategy for verification of as-built structural performance.
- Concepts of operation.
- Expected life of infrastructure.

All proposals need to identify the state-of-the-art of applicable technologies and processes. Prototypes to be delivered at the conclusion of Phase II will be required to operate under lunar equivalent vacuum, temperature, and dust conditions, so thermal management and dust mitigation strategies utilized during the operation of the proposed technology will need to be specified in the Phase I proposal. The Phase I proposals should at least result in a Technology Readiness Level (TRL) of 2 to 4.

Expected TRL or TRL Range at completion of the Project: 2 to 6
Primary Technology Taxonomy:
Level 1: TX 07 Exploration Destination Systems
Level 2: TX 07.2 Mission Infrastructure, Sustainability, and Supportability
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware
- Software

Desired Deliverables Description:

Phase I must include the design and test of critical attributes or high risk areas associated with the proposed surface construction technology or process used to achieve the objectives of the Phase II delivered prototype as described in a final report.

By the end of Phase II, the prototype hardware should be advanced by appropriately justified demonstration(s) to TRL 4 to 6, and be capable of further testing in more relevant environments (TRL 7 to 8) beyond Phase II.

State of the Art and Critical Gaps:

The state of the art for robotic construction on the lunar surface includes regolith excavation and manipulation systems such as the Regolith Advanced Surface Systems Operations Robot (RASSOR). Sintered regolith interlocking pavers and emplacement systems were jointly developed and tested by NASA and the Pacific International Space Center for Exploration Systems (PISCES). Robotic construction of blast ejecta barriers was completed by NASA where a lunar teleoperated robotic bulldozer was able to clear and level an area of 100 by 100 m and then build a 2-m-high berm in the sand dunes of Moses Lake in Washington. Sintered basalt and ablative polymer concrete materials that have been tested at high plasma temperatures in the Arc Jet facility at NASA Ames Research Center performed well as a heat shield material. Specialized concrete formulations and emplacement systems have been developed by Marshall Space Flight Center and others.

Relevance / Science Traceability:

Surface construction of infrastructure directly addresses the STMD Strategic Thrust, “Land: Increase Access to Planetary Surfaces.” It also addresses the strategic thrust of “Explore: Expand Capabilities Through Robotic Exploration and Discovery.” The risks of landing on the Moon were demonstrated in the lunar Surveyor and Apollo missions. The robotic Surveyor spacecraft had difficulty landing safely, and during Apollo, five of six landings had close calls such as avoiding hazardous terrain, dust obscuration during landing, and slopes that tipped the lander as far as 11°, which happened on Apollo 15. The need for trafficability risk mitigation is highlighted by Spirit rover becoming immobilized in Martian regolith. Lunar dust and radiation mitigations are considered major risks for long-term lunar operations.

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