



NASA SBIR 2019 Phase I Solicitation

25.05 Lunar Rover Technologies for In-situ Resource Utilization and Exploration

Lead Center: JSC

Participating Center(s): ARC, GRC, KSC

Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems

Enabling Rover Technologies for Lunar Missions

The objective of this subtopic is to innovate lunar rover technologies that will enable in-situ resource utilization (ISRU) and exploration missions. In particular, this subtopic will develop ideas, subsystems components, software tools, and prototypes that contribute to more capable and/or lower-cost lunar robots for these missions.

A potential lunar ISRU application is the prospecting, characterization, and collection of volatiles that could be processed to produce oxygen, fuel, etc. Recent remote sensing measurements, modeling, and data from the Lunar Crater Observation and Sensing Satellite (LCROSS) indicates that there may be an abundance of volatiles (e.g., hydrogen) near the lunar poles. However, the distribution of the volatiles at and under the surface is unknown. This subtopic seeks new robotic technologies to support ISRU activities. This does not include new ISRU payload and/or excavation technologies, which are solicited under the "Lunar Resources - Volatiles" and "Extraction of Oxygen from Lunar Regolith" subtopics. Additionally, lunar power technologies are solicited in the sub-topic titled "Long Duration Lunar Energy Storage and Discharge."

The expected environment at the lunar poles involves all the challenges observed during the Apollo mission (thermal extremes, vacuum, radiation, abrasive dust, electrostatic dust) plus the addition of low sun angles, potentially less consolidated regolith, and permanently shadowed regions with temperatures as low as 40K. This subtopic seeks new technology to address these challenges.

Phase I success involves technical feasibility demonstration through analysis, prototyping, proof-of-concept, or testing. Phase II success will advance Technology Readiness Level (TRL) to a level of 4-5. Of specific interest are:

- Mobility architectures, including novel mobility mechanisms and lunar dust tolerant mechanisms
- Cryo-capable actuators capable of operating at extremely cold temperatures (in environments as cold as -230°C). Preferably solutions will not include heaters as they significantly increase the power draw for normal operations during the lunar day. Novel materials capable of maintaining metallurgical properties at cryogenic temperatures will be considered. Also desired are cryo actuators featuring dust tolerances and the ability to operate at high temperatures as well (approaching 150°C).
- Magnetic gearing applications for space. NASA and others are developing relatively low ratio (less than 25:1 per stage) concentric magnetic gearing for aeronautics applications. Space applications demand high speed-reduction ratio (often more than 1000:1) and high specific torque ($>50\text{ Nm/kg}$), operation in

environmental temperatures down to -230° C (40K), operation in low-atmosphere or hard vacuum, with high reliability and energy efficiency. Phase I work would include identifying the most suitable magnetic gear topologies to meet these space application needs, defining the technology development challenges including thermal and structural issues, advancing the most critical aspects of the technology, and producing a low-fidelity prototype to prove the feasibility of the concept(s).

- Perception systems and algorithms with a path toward flight for the lunar surface capable of operating in the harsh lighting conditions that might include high dynamic range, shadowed regions, low angle illumination, and opposition effects
- Lunar regolith terramechanical modeling tools and simulations, especially tools that integration with existing commercial and open source robotic analysis and simulation tools
- Rover embedding and entrapment detection and escape approaches including slip monitoring, regolith sensing/modeling, low ground pressure wheels and soft soil tolerant mobility architectures

Example deliverables coming from a successful Phase II within this subtopic, might including some of the following:

- Designs of cryo-capable or dust tolerant mechanisms motor controllers with test data and prototypes
- Prototype rovers or scale versions of prototype rovers showing novel mobility architecture for escaping entrapment in regolith
- Software algorithms including demonstrating slip detection or image processing in harsh lunar lighting conditions
- Software packages either standalone or integrated with commercially available or open-source robotic simulation packages (preferred)
- NASA is also interested in technologies demonstrations that could serve as payloads on commercial landers at the end of Phase II

For all the above, it is desired to have been demonstrated in, or have a clear path to operating in, the lunar environment.

NASA has plans to purchase services for delivery of payloads to the Moon through the Commercial Lunar Payload Services (CLPS) contract. Under this subtopic, proposals may include efforts to develop payloads for flight demonstration of relevant technologies in the lunar environment. The CLPS payload accommodations are yet to be precisely defined, however at least for early missions, proposed payloads should not exceed 15 kilograms in mass and not require more than 8 watts of continuous power. Smaller, simpler, and more self-sufficient payloads are more likely to be accommodated. Commercial payload delivery services may begin as early as 2020 and flight opportunities are expected to continue well into the future. In future years it is expected that payloads of higher mass and with higher power requirements might be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

This SBIR subtopic resides within the Science and Technology Mission Directorate (STMD) as a vehicle for development of technology objectives. It is expected that successful projects would infuse technology into either the STMD Game Changing Development (GCD) or Technology Demonstration Missions (TDM) programs. Technology could also be infused into joint efforts involving STMD's partners (other mission directorates, other government agencies, and the commercial sector). Flights for these technology missions could be supported on small commercial lunar landers (Science Mission Directorate) or possibly mid-size NASA lunar landers (Human Exploration and Operations Mission Directorate).

Potential customers:

- Autonomy and robotics
- Robotic ISRU missions
- Payloads for Commercial Lunar Payload Services landers
- Commercial vendors
- Future prospecting/mining operations

References:

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- <https://www.sciencedirect.com/science/article/pii/S0032063310003065>
 - <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720013192.pdf>
 - https://www.lpi.usra.edu/publications/books/lunar_sourcebook/pdf/Chapter03.pdf
 - <https://www.fbo.gov/index?s=opportunity&mode=form&id=46b23a8f2c06da6ac08e1d1d2ae97d35&tab=core&cvview=0>
 - <https://www.hou.usra.edu/meetings/survivethenight2018/>,
<https://www.nasa.gov/feature/nasas-exploration-campaign-back-to-the-moon-and-on-to-mars> and

<https://www.nasa.gov/sites/default/files/thumbnails/image/nasa-exploration-campaign.jpg>

- Information on NASA's interest in landers that might host the rovers and rover technology demonstrations can be found at the following:
 - <https://www.nasa.gov/feature/nasa-seeks-ideas-to-advance-toward-human-class-lunar-landers>
 - <https://govtribe.com/project/lunar-surface-transportation-capability-request-for-information-rfi>
- See reference about magnetic gearing references below:
 - Tlali, P. M., Wang, R-J., and Gerber, S., "Magnetic gear technologies: A review," 2014 Intl. Conference on Electrical Machines, p. 544-550, Berlin, Germany, Sept. 2 - 5, 2014.
 - Justin J. Scheidler, Vivake M. Asnani, and Thomas F. Tallerico, "Overview of NASA's Magnetic Gears Research," presented at the AIAA / IEEE Electric Aircraft Technology Symposium, Cincinnati, Ohio, July 12 - 13, 2018.
- Vivake M. Asnani, Justin J. Scheidler, and Thomas F. Tallerico, "Magnetic Gearing Research at NASA," presented at the 74th Annual Forum of the American Helicopter Society, Phoenix, AZ, May 14 - 17, 2018.
- Aaron D. Anderson and Vivake M. Asnani, "Concentric Magnetic Gearing - State of the Art and Empirical Trends", NASA TM, in-press.