NASA SBIR 2021 Phase I Solicitation

Z13.02 Dust-Tolerant Mechanisms

Lead Center: KSC

Participating Center(s): GRC, JSC, LaRC

Scope Title:

Dust-Tolerant Joints

Scope Description:

A return to the Moon to extend human presence, pursue scientific activities, use the Moon to prepare for future human missions to Mars, and expand Earth’s economic sphere will require investment in developing new technologies and capabilities to achieve affordable and sustainable human exploration. From the operational experience gained and lessons learned during the Apollo missions, conducting long-term operations in the lunar environment will be a particular challenge given the difficulties presented by the unique physical properties and other characteristics of lunar regolith, including dust. The Apollo missions and other lunar exploration have identified significant lunar dust-related problems that will challenge future mission success. Lunar dust is composed of regolith particles ranging in size from tens of nanometers to microns, and lunar dust concerns are a manifestation of the complex interaction of the lunar soil with multiple mechanical, electrical, and gravitational effects.

Mechanical systems will need to operate on the dusty surface of the Moon for months to years. These systems will be exposed to the harsh regolith dust and will have little to no maintenance. This scope seeks technologies that will protect from or tolerate dust intrusion in the following areas:

- Rotary joints (steering, suspension, hinges, bearings, etc.).
- Linear joints (latches, shafts, restraint systems, landing gear, etc.).
- Static joints (quick disconnects, covers, airlocks, sample tools, etc.).

Successful solutions will enable operation in a lunar environment for 10 to 100 months with limited or no maintenance.

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:
Desired Deliverables Description:

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II demonstration, with delivery of a demonstration package for NASA testing in operational test environments at the completion of the Phase II contract.

Phase I Deliverables: Research, identify, and evaluate candidate technologies or concepts for dust-tolerant mechanisms. Simulations or laboratory-level demonstrations are desirable. Deliverables must include a report to document findings.

Phase II Deliverables: Emphasis should be placed on developing, prototyping, and demonstrating the technology under simulated operational conditions (regolith, thermal, vacuum). Deliverables shall include a report outlining the path showing how the technology could be matured and applied to mission-worthy systems, functional and performance test results, and other associated documentation. Deliverable of a functional prototype is expected at the completion of the Phase II contract. The technology concept at the end of Phase II should be at a Technology Readiness Level (TRL) of 6 or higher.

State of the Art and Critical Gaps:

Previous solutions used in the Apollo program did not address the current need of long-term usage. Terrestrial solutions often employ materials or methods that are incompatible with the lunar environment.

Critical Gaps:

- Rotary joints.
  - Seals: Rotary joints are very common for actuation in dusty environments because of the widespread availability of rotary seals. Most of these seals, however, use elastomers that would off-gas and become brittle in a lunar environment. Solutions are needed that employ materials or nontraditional techniques that can operate in the lunar environment for an extended period of time (months to years).
  - Bearings: Regolith getting past the protective seals of rotary joint bearings is a common failure point. Bearings designs that are highly dust tolerant may be needed to reduce the risk of failures due to dust intrusion.
  - Successful technologies will have operational lifetimes on the order of millions of cycles in a relevant lunar environment.
- Linear joints.
  - Seals: Linear joints are less common in dusty environments because of the challenge of sealing the sliding joints. Similar to rotary seals, linear joint seals are often made from elastomers and would need to be modified to operate in a lunar environment. Solutions are needed that employ materials or nontraditional techniques that can operate in the lunar environment for an extended period of time (months to years).
  - Bearings: Regolith getting past the protective seals of linear joint bearings is a common failure point. Bearings designs that are highly dust tolerant may be needed to reduce the risk of failures due to dust intrusion.
  - Successful technologies will have operational lifetimes on the order of hundreds of thousands of cycles in a relevant lunar environment.
• Static joints.
  - Operations on the lunar surface will include assembly, construction, and extravehicular activity (EVA) tasks. These tasks will involve the mating/demating of various structural, electrical, and fluid connections. Dust on the surface of these joints will impede their proper function and lead to failures. Solutions are needed to protect these joints from dust contamination.
  - Successful technologies will have operational lifetimes on the order of thousands of cycles in a relevant lunar environment.

Relevance / Science Traceability:

Dust will be one of the biggest challenges for operation on the lunar surface for the Artemis program.

“I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust.” Gene Cernan, Apollo 17 Technical Debrief.

References:

Dust Mitigation Gap Assessment Report, International Space Exploration Coordination Group (ISECG):