NASA SBIR 2021 Phase I Solicitation

Z7.04 Landing Systems Technologies

Lead Center: MSFC

Participating Center(s): GRC, LaRC

Scope Title:

Landing Systems Technologies

Scope Description:

Plume-Surface Interaction (PSI) Instrumentation, Ground Testing, and Analysis

As NASA and commercial entities prepare to land robotic and crewed vehicles on the Moon, and eventually Mars, characterization of landing environments is critical to identifying requirements for landing systems and engine configurations, instrument placement and protection, and landing stability. The ability to predict the extent to which regolith is liberated and transported in the vicinity of the lander is also critical to understanding the effects on precision landing sensor requirements and landed assets located in close proximity. Knowledge of the characteristics, behavior, and trajectories of ejected particles and surface erosion during the landing phase is important for designing effective sensor systems and PSI risk mitigation approaches. Mission needs to consider include landers with single and multiple engines, both pulsed and throttled systems, landed mass from 400 to 40,000 kg, and both lunar and Mars destinations.

NASA is seeking support in the following areas:

1. Ground test data, test techniques, and diagnostics across physical scales and environments, with particular emphasis on nonintrusive approaches and methodologies.
2. PSI-specific flight instrumentation, with particular emphasis on in situ measurements of particle size and particle velocity during the landing phase.
3. Solutions to alleviate or mitigate the PSI environments experienced by propulsive landers.
4. Validated computational fluid dynamics (CFD) models and tools for predicting PSI physics for plumes in low-pressure and rarefied environments, time-evolving

cratering and surface erosion, and near-field and far-field ejecta transport.

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 will vary depending on the particular service provider and mission characteristics. Additional information on the CLPS program and providers can be found at this link: https://www.nasa.gov/content/commercial-lunar-payload-services. CLPS missions will typically carry multiple payloads for multiple customers. Smaller, simpler, and more self-sufficient payloads are more easily accommodated and would be more likely to be considered for a NASA-sponsored flight opportunity. 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 larger and more complex payloads will be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

Expected TRL or TRL Range at completion of the Project: 3 to 6
Primary Technology Taxonomy:
Level 1: TX 09 Entry, Descent, and Landing
Level 2: TX 09.3 Landing
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware
- Software

Desired Deliverables Description:

Deliverables of all types can be infused into the prospect missions due to early design maturity.

For PSI ground test data, flight instrumentation, diagnostics, and mitigation approaches, Phase I deliverables should include detailed test plans, with prototype and/or component demonstrations as appropriate. Phase II deliverables should include complete data products, fully functional hardware, and validated performance in relevant environments.

For PSI modeling and simulation, Phase I deliverables should demonstrate proof of concept and a minimum of component-level verification, with detailed documentation on future data needs to complete validation of the integrated model and uncertainty quantification methodology. Phase II deliverables must demonstrate verification and validation beyond the component level, with validation demonstrated through comparisons with relevant data and documented uncertainty quantification.

State of the Art and Critical Gaps:

The characteristics and behavior of airborne particles during descent is important for designing descent sensor systems that will be effective. Furthermore, although the physics of the atmosphere and the characteristics of the regolith are different for the

Moon, the capability to model PSIs on the Moon will feed forward to Mars, where it is critical for human exploration.

Currently, flight data are collected from early planetary landing, and those data are fed into developmental tools for validation purposes. The validation dataset, as well as the expertise, grows as a result of each mission and is shared across and applied to all other missions. We gain an understanding of how various parameters, including different types of surfaces, lead to different cratering effects and plume behaviors. The information helps NASA and industry make lander design and operations decisions. Ground testing ("unit tests") is used early in the development of the capability in order to provide data for tool validation.

The current post-landing analysis of planetary landers (on Mars) is performed in a cursory manner with only partially empirically-validated tools, because there has been no dedicated fundamental research investment in this area. Flight test data does not exist in the environments of interest.

Relevance / Science Traceability:

Current and future lander architectures will depend on knowledge of PSI, such as:

- Artemis Human Lander System (HLS)
- Commercial robotic lunar landers (CLPS or other)
- Planetary mission landers (Mars Sample Retrieval Lander and others)
- Human Mars landers

References:

Lander Technologies: https://www.nasa.gov/content/lander-technologies

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Plemmons, D. H., et al. (2008). Effects of the Phoenix Lander descent thruster plume on the Martian surface. Journal of Geophysical Research: Planets, 113(E3).

Mehta, M., et al. (2013). Thruster plume surface interactions: Applications for spacecraft landings on planetary bodies. AIAA Journal, 51(12), 2800-2818.

Vangen, Scott, et al. International Space Exploration Coordination Group Assessment of Technology Gaps for Dust Mitigation for the Global Exploration Roadmap. AIAA SPACE 2016. 2016. 5423.