NASA SBIR/STTR — Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2020 Phase I Solicitation

Z7.04 Lander Systems Technologies

Lead Center: MSFC

Participating Center(s): GRC, LaRC

Technology Area: TA9 Entry, Descent and Landing Systems

Scope Description

Plume/Surface Interaction Analysis & Ground Testing

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 model and predict the extent to which regolith is 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 descent sensor systems that will be effective. Furthermore, although the physics of the atmosphere, gravitational field, and the characteristics of the regolith are different for the Moon, the tools and analysis capability to characterize plume/surface interactions on the Moon will feed forward to Mars.

Therefore, NASA is seeking support in the following areas:

1. ***To increase analysis capability to model and predict the plume/surface interaction and nature and behavior of the ejecta, for NASA and commercial landing.*** Currently, there are negligible amounts of data collected from planetary robotic landings to develop and validate plume/surface interaction analysis tools. However, the limited data increase the understanding of various parameters, including the various types of surfaces that lead to different cratering effects and plume behaviors. Additionally, the information influences lander design and operations decisions for future missions. Ground testing (â€œunit testsâ€) is also used to provide data for tool validation. Innovative non-intrusive diagnostic development to measure critical parameters in this discipline are also severely lacking and are needed to advance prediction capability. The current post-landing analysis of planetary landers (on Mars) is of limited applicability in reducing risk to future landers, as it is limited to comparisons with only partially empirically-validated tools. Flight test data do not yet exist in the environments of interest.
2. ***The community needs ground test and flight test data, together with comprehensive Computational Fluid Dynamics (CFD) tools and methods, to devise validated models for different conditions that are applicable to a variety of landing missions.*** A consistent tool set is important for assessing risk and is useful to both the commercial sector and NASA.
3. ***Solutions are sought to alleviate the plume-surface interaction environment.*** Solutions should provide novel approaches for propulsion cluster placements, surface ejecta damage tolerant systems, mitigation

shielding, etc. These solutions must be mass-efficient and have minimal interference with vehicle operations.

4. ***Validation data and diagnostic techniques at relevant scales, environments, and degrees of system integration*** are sought to reduce uncertainties in predicted plume-induced environments and subsequently reduce risk to landers and other surface assets. Critical parameters include near-field and far-field particle velocity, trajectories and concentration, erosion rates and transient crater profiles. There are large uncertainties associated with these parameters. Plume-induced environments include cratering, ejecta, aerodynamic destabilization, and elevated convective heating.

Mission needs to consider, in proposing these solutions, include landers with single and multiple engines, both pulsed and throttled systems, landed masses from 400 to 40,000 kg, and both Lunar and Mars destinations.

Innovations for Vehicle Structures

The development of more efficient lander structures and components are sought to improve the mass efficiency of in-space stages and landers. This may include the adoption and utilization of advanced lightweight materials, especially as used in combination with advanced manufacturing to enable reliable, conformal, and lightweight design innovations. Of interest are systems for actively alleviating flight loads and environments, reduce integration complexity, or improve system life, enable reusable landing systems, allow restowage and redeployment of solar arrays for multiple mission usage, and develop mechanisms and couplings for continuous use in the lunar dust environment. Approaches for achieving multifunctional components, repurposing structure for post-flight mission needs, and incorporating design features that reduce operating complexity are also of interest.

Lunar Dust Mitigation

Lunar dust, as experienced during the Apollo program, can have a wide range of deleterious effects on lander subsystems and the people using them. As we head back to the moon with robotic and human landers, the need for effective prevention and/or mitigation measures is needed to ensure long term, nominal operation of lander and surface systems and mission operations. Numerous studies have been performed to characterize dust deposition and potential impacts. Proposals are sought that build on previous studies to better characterize the deposition and impact of dust (see Z13.02 - Dust Tolerant Mechanisms).

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.

References

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

Metzger, Philip, et al. "ISRU implications for lunar and martian plume effects." 47th AIAA Aerospace Sciences Meeting including The New Horizons Forum and Aerospace Exposition. 2009.

Plemmons, D. H., Mehta, M., Clark, B. C., Kounaves, S. P., Peach, L. L., Renno, N. O., ... & Young, S. M. M. (2008). Effects of the Phoenix Lander descent thruster plume on the Martian surface. Journal of Geophysical Research: Planets, 113(E3).

Mehta, M., Sengupta, A., Renno, N. O., Norman, J. W. V., Huseman, P. G., Gulick, D. S., & Pokora, M. (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.

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software, Research

Desired Deliverables Description

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

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 plume/surface interactions 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 data set, 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 (â€œunit testsâ€) is used early in the development of the capability, 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 such as:

- Artemis
- Commercial robotic lunar landers
- Planetary mission landers