NASA SBIR 2019 Phase I Solicitation

Z7.04 Lander Systems Technologies

Lead Center: MSFC

Participating Center(s): GRC, JSC, LaRC

Technology Area: TA9 Entry, Descent and Landing Systems

Plume/Surface Interaction Analysis & Ground Testing

As NASA and commercial entities prepare to land robotic and crewed vehicles on the Moon, it will be important to understand the terminal descent environments to which both the landing vehicle and the surrounding area on the lunar surface will be subjected. The ability to model and predict the extent to which regolith is transported in the vicinity of the lander vehicle will be critical to setting requirements on lander configurations, instrument placement and protection, and landing stability, among other characteristics. Understanding this phenomenon will also influence landing precision requirements on vehicles and assets that are located in close proximity to increase surface operations efficiency. 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.

NASA is looking to increase analysis capability that can be applied to predict the plume/surface interaction and nature and behavior of the ejecta, for landing missions both inside and outside NASA. 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 (“unit tests”) 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. 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 can be applicable to a variety of landing missions. A consistent toolset is important for assessing risk and could be utilized by the commercial sector as well as NASA.

Specifically, NASA is seeking:

- Computational methods and analyses that can be applied to the problem of predicting plume effects at the moon with extension to Mars.
- Low-cost ground testing methods, facilities, and/or diagnostics to produce computational model validation

data.

For item 1, Phase I efforts should produce a model that predicts either crater size and shape or ejecta field, with a validation plan executed in Phase II (this validation could be performed against NASA-supplied or open source data). For item 2, Phase I efforts should prototype or show proof-of-concept in meeting proposed ground test objectives, and Phase II should implement the methods and produce an operational test bed and/or diagnostic method.

High Temperature, Lightweight Nozzle Extensions

Upper stage and in-space liquid rocket engines are optimized for performance through the use of high area ratio nozzles to fully expand combustion gases to low exit pressures, increasing exhaust velocities. Due to the large size of such nozzles, and the related engine performance requirements, carbon-carbon (C-C), carbon-silicon carbide (C-SiC), and carbon matrix composite (CMC) nozzle extensions are being considered to reduce weight impacts. NASA and industry partners are working towards advancing the domestic supply chain for these composite nozzle extensions. New and emerging carbon matrix-based material systems may also enable nozzle extension designs that offer further increased performance at even lower masses. As such, NASA is seeking the following:

- High temperature capable (such as carbon-carbon (C/C), carbon-silicon carbide (C/SiC), Carbon Matrix Composite (CMC), or other materials) nozzle extension design and material capabilities, for use on Liquid Oxygen/Liquid Methane or Liquid Hydrogen engines. Material systems should be capable of withstanding temperatures greater than 3000° F (> 1925 K), with a target of ~4000° F (~2500 K), for durations of 1500 to 2000 seconds with limited erosion characteristics (<2% weight loss). Joint designs and manufacturing scalability should consider applicability to any number of commercially available and/or in-development in-space class engines, although a preliminary target engine size for consideration would be approximately a 25,000 lb (~100-kN) class engine. Nozzle geometries of interest may be traditional bell/conical nozzle shapes or may include altitude compensating shapes, such as aerospike nozzles.
- Specific technologies to address joining CMC, C/C and C/SiC nozzle extension or chamber components to metal engine components, where significant Coefficient of Thermal Expansion (CTE) mismatch may occur. Solutions should describe how they address CTE mismatch, appropriate hot-gas sealing, and high temperature application (>1500 K) while minimizing joint weight relative to state-of-the-art solutions.

Proposers should be prepared to deliver a proof-of-concept prototype with documented results validating predicted performance at the conclusion of Phase I, and a brassboard prototype and demonstration in a defined relevant environment at the conclusion of Phase II.

The expected Technology Readiness Level (TRL) range at completion of the project is 3 to 6. Relevant current and future lander architectures for this technology include: FLEX-1 and subsequent missions, commercial robotic lunar landers, and planetary mission landers.

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.

References:

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