NASA SBIR 2018 Phase I Solicitation

Z7.01 Entry Descent & Landing Sensors for Environment Characterization, Vehicle Performance, and Guidance, Navigation and Control

Lead Center: ARC

Participating Center(s): JPL, JSC, LaRC

Technology Area: TA9 Entry, Descent and Landing Systems

NASA manned and robotic missions to the surface of planetary or airless bodies require Entry, Descent, and Landing (EDL). For many of these missions, EDL represents one of the riskiest phases of the mission. Despite the criticality of the EDL phase, NASA has historically gathered limited engineering data from such missions, and use of the data for real-time Guidance, Navigation and Control (GN&C) during EDL for precise landing (aside from Earth) has also been limited. Recent notable exceptions are the Orion EFT-1 flight test, MSL MEDLI sensor suite, and the planned sensor capabilities for Mars 2020 (MEDLI2 and map-relative navigation). NASA requires EDL sensors to:

- Understand the in-situ entry environment.
- Characterize the performance of entry vehicles.
- Make autonomous and real-time onboard GN&C decisions to ensure a precise landing.

This subtopic describes three related technology areas where innovative sensor technologies would enable or enhance future NASA EDL missions. Candidate solutions are sought that can be made compatible with the environmental conditions of deep spaceflight, the rigors of landing on planetary bodies both with and without atmospheres. Proposers may submit to topic areas 1, 2 or 3 below:

- High accuracy, light weight, low power fiber optic sensing system for EDL instrumentation systems.
- Miniaturized spectrometers for vacuum ultraviolet & mid-wave infrared radiation in-situ measurements during atmospheric entry.
- Novel sensing technologies for EDL GN&C and small body proximity operations.

High Accuracy, Light Weight, Low Power Fiber Optic Sensing System for EDL Instrumentation Systems

Current NASA state-of-the-art EDL sensing systems are very expensive to design and incorporate on planetary missions. Commercial fiber optic systems offer an alternative that could result in a lower overall cost and weight, while actually increasing the number of measurements. Fiber optic systems are also immune to Electro-Magnetic Interference (EMI) which reduces design and qualification efforts. This would be highly beneficial to future planetary missions requiring thermal protection system (TPS).

Fiber optic sensing systems can offer benefits over traditional sensing system like MEDLI and MEDLI2, and can be used for both rigid and flexible TPS. To be considered against NASA state-of-the-art TPS sensing systems for future flight missions, fiber optic systems must be competitive in sensing capability (measurement type, accuracy, quantity), and sensor support electronics (SSE) mass, size and power.

The upcoming Mars 2020 mission will fly the Mars Entry, Descent, and Landing Instrumentation II (MEDLI2) sensor suite consisting of a total of 24 thermocouples, 8 pressure transducers, 2 heat flux sensors, and a radiometer embedded in the TPS. This set of instrumentation will directly inform the large performance uncertainties that contribute to the design and validation of a Mars entry system. A better understanding of the entry environment and TPS performance could lead to reduced design margins enabling a greater payload mass fraction and smaller landing ellipses. Fiber optic sensing systems can offer benefits over traditional sensing system like MEDLI and MEDLI2, and can be used for both rigid and flexible TPS. Fiber optic sensing benefits include, but are not limited to; sensor immunity to EMI, the ability to have thousands of measurements per fiber using Fiber Bragg grating (FBG), multiple types of measurements per fiber (i.e., temperature, strain, and pressure), and resistance to metallic corrosion.

To be considered against NASA state-of-the-art TPS sensing systems for future flight missions, fiber optic systems must be competitive in sensing capability (measurement type, accuracy, quantity), and sensor support electronics (SSE) mass, size and power. Therefore, NASA is looking for a fiber optic system that can meet the following requirements:

- Sensing Requirements:
    - TPS Temperature: Measurement Range: -200 to 1250° C (up to 2000° C preferred), Accuracy: +/- 5° C desired.
    - Surface Pressure: Measurement Range: 0-15 psi, Accuracy: +/-1%

- Sensor Support Electronics Requirements (including enclosure):
    - Weight: 12 lbs or less,
    - Size: 240 cubic inches or smaller,
    - Power: 15W or less,
    - Measurement Resolution: 14-bit or Higher,
    - Acquisition Rate per Measurement: 16 Hz or Higher,
    - Compatibility with other sensors types (e.g.) Heat Flux, Strain, Radiometer, TPS recession.

Miniaturized Spectrometers for Vacuum Ultraviolet & Mid-Wave Infrared Radiation In-Situ Measurements During Atmospheric Entry

The current state-of-the-art for flight radiation measurements includes radiometers and spectrometers. Radiometers can measure heating integrated over a wide wavelength range (e.g., MEDLI2 Radiometer), or over a narrow-wavelength bands (COMARS+ ICOTOM at 2900 nm and 4500 nm). Spectrometers gather spectrally resolved signal and have been developed for Orion EM-2 (combined Ocean Optics STS units with range of 190-1100 nm). A spectrometer provides the gold standard for improving predictive models and improving future entry vehicle designs.

For NASA missions through CO_2 atmospheres (Venus and Mars), a majority of the radiative heating occurs in the midwave infrared range (MWIR: 1500 nm - 6000 nm) [Brandis, AIAA 2015-3111]. Similarly, for entries to Earth, the radiation is dominated by the Vacuum Ultraviolet range (VUV: 100 - 190 nm) [Cruden, AIAA 2009-4240]. Both of these ranges are outside of those detectable by available miniaturized spectrometers. While laboratory scale spectrometers and detectors are available to measure these spectral ranges, there are no versions of these spectrometers which would be suitable for integration into a flight vehicle due to lack of miniaturization. This SBIR calls for miniaturization of VUV and MWIR spectrometers to extend the current state of the art for flight diagnostics.

Advancements in either VUV or MWIR measurements are sought, preferably for sensors with:

- Self-contained with a maximum dimension of ~10 cm or less.

- No active liquid cooling.
- Simple interfaces compatible with spacecraft electronics, such as RS232, RS422, or Spacewire.
- Survival to military spec temperature ranges [-55 to 125C].
- Power usage of order 5W or less.

Novel Sensing Technologies for EDL GN&C and Small Body Proximity Operations

NASA seeks innovative sensor technologies to enhance success for EDL operations on missions to other planetary bodies (including Earth's Moon, Mars, Venus, Titan, and Europa). Sensor technologies are also desired to enhance proximity operations (including sampling and landing) on small bodies such as asteroids and comets. NASA is also looking for high-fidelity real-time simulation and stimulation of passive and active optical sensors for computer vision at update rates greater than 2 Hz to be used for signal injection in terrestrial spacecraft system test beds. These solutions are to be focused on improving system-level performance Verification and Validation during spacecraft assembly and test.

Sensing technologies are desired that determine any number of the following:

- Terrain relative translational state (altimetry/3-axis velocimetry).
- Spacecraft absolute state in planetary/small-body frame (either attitude, translation, or both).
- Terrain characterization (e.g., 3D point cloud) for hazard detection, absolute and/or relative state estimation, landing/sampling site selection, and/or body shape characterization.
- Wind-relative vehicle state and environment during atmospheric entry (e.g., velocity, density, surface pressure, temperature).

Successful candidate sensor technologies can address this call by:

- Extending the dynamic range over which such measurements are collected (e.g., providing a single surface topology sensor that works over a large altitude range such as 1m to >10km, and high attitude rates such as greater than 45° /sec).
- Improving the state-of-the-art in measurement accuracy/precision/resolution for the above sensor needs.
- Substantially reducing the amount of external processing needed by the host vehicle to calculate the measurements.
- Significantly reducing the impact of incorporating such sensors on the spacecraft in terms of Size, Weight, and Power (SWaP), spacecraft accommodation complexity, and/or cost.
- Providing sensors that are robust to environmental dust/sand/illumination effects.
- Mitigation technologies for dust/particle contamination of optical surfaces such as sensor optics, with possible extensibility to solar panels and thermal surfaces for Lunar, asteroid, and comet missions.
- Sensing for wind-relative vehicle velocity, local atmospheric density, and vehicle aerodynamics (e.g., surface pressures and temperatures).