NASA SBIR 2022 Phase I Solicitation

Z7.01 Entry, Descent, and Landing Flight Sensors and Instrumentation

Lead Center: JSC

Participating Center(s): ARC, GSFC, JPL, LaRC

Scope Title

Air Data Sensors to Support Entry, Descent, and Landing (EDL) Environment Characterization

Scope Description

Current NASA state-of-the-art air data sensors for EDL applications are very expensive to incorporate on planetary missions because they must meet functional and performance requirements during and after exposure to loads and environments associated with long-duration spaceflight and atmospheric entry. The dynamic loads and thermal environments encountered prior to arrival at the destination make flight qualification of air data sensors challenging and costly. Scarce commercial options exist for off-the-shelf products with the potential to meet NASA’s requirements for accuracy and survivability. In an effort to bring more commercial options for air data sensors that can be flown on EDL missions as part of an air data system, NASA seeks proposals in two distinct areas: pressure transducers and lidar sensors.

1. Air Data Pressure Transducers

The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) sensor suites flew supersonic-range pressure transducers on the heat shield that were developed in house at NASA Langley Research Center because there was no commercially available pressure sensor that met the mission’s requirements for accuracy and survivability. The hypersonic pressure transducer on the heat shield was a flight spare from the first MEDLI suite, which flew on the Mars Science Laboratory Mission in 2012. In situ pressure measurements on the aerodynamic surfaces of an EDL vehicle capsule, such as the heat shield and backshell, are primarily used to reconstruct the free-stream density and vehicle attitude (angles of attack and sideslip) to isolate aerodynamic performance. NASA seeks pressure transducers that can meet the following requirements:

- **Configuration**: The pressure transducer shall be hermetically sealed. The design space should consider a nonamplified output configuration or a configuration with embedded electronics for an amplified output. The internal temperature shall be monitored. The pressure transducer shall measure absolute pressure, and the housing must be able to be connected to a flared tube fitting. The pressure transducer should have the capability of being mechanically mounted in a 2- or 3-point configuration.
- **Mass**: Less than 300 g if no active electronics; less than 400 g for a unit with active electronics.
- Size: Less than 442 Å c.
- Electrical connections: Electrical interface/connector should be configured for power, ground, analog signal, analog return, and temperature sensor accommodation. Electrical connector pin configurations should allow for interchangeability of mating connectors for all pressure transducers.
- Parts, material, and processes used in the construction of the pressure transducer should be controlled by specification or procedure per AS9100 or equivalent. Any soldering should meet NASA-STD-8739.3 or IPC J-STD-001 with space addendum, and any fusion welding should follow AWS D17.1.
- The pressure transducer should meet MIL-STD-461 for electromagnetic interference (EMI) compliance (amplified units only).
- Axial loading capability: Minimum 15 g (Venus missions could require 100 g or higher).
- Temperature capability: Operating temperature range of -120 to 80 °C. It is desired that the unit can survive temperatures as cold as -130 °C in a nonoperating condition. It is also desired that the unit can survive a dry heat microbial reduction temperature of 104 °C for 200 hr, or 110 °C for 100 hr.
- Functional characteristics:
  - Input voltage: Up to 10 Vdc for a nonamplified unit or 12 to 36 Vdc for an amplified unit.
  - Input current: Should not exceed 7 mA for a nonamplified unit or 30 mA for an amplified unit.
  - Output impedance: Should not exceed 10 kilohms for a nonamplified unit or 1 kilohm for an amplified unit.
  - Output voltage: Minimum output of 1.2 mV/V (nonamplified unit).
  - Measurement range: 0 to 1.0 psia for a supersonic range pressure transducer; 0 to 5.0 psia for hypersonic range pressure transducer. Zero psia is considered to be less than 10^{-5} torr.
  - Accuracy: Provide a description of the approach to quantify and demonstrate accuracy of the pressure transducer.
  - Static error band should be no greater than ±0.3% of full scale based on an unweighted least-squares straight-line fit. The static error band includes errors due to nonlinearity, hysteresis, and nonrepeatability.
- Cost: Fully qualified first-unit target of ~$500K.

2. Air Data Lidar Sensors

Air data lidar sensors have the potential of providing more accurate velocimetry data than pitot tubes for Mars landing and Earth reentry vehicles. Furthermore, a lidar-based air data sensor can eliminate the aerodynamic influences of pitot tubes, particularly in the supersonic velocity regime. NASA seeks proposals for air data lidar sensors that can provide critical air-vector velocity data during the atmospheric entry and descent phases of the spacecraft. An ability to provide other relevant air data, such as atmospheric pressure, is viewed favorably if it can enhance and/or complement the air velocity measurement capabilities. The proposed lidar sensor must be compact and efficient with a clear path to spaceflight units meeting physical and environmental constraints of landing vehicles.

Expected TRL or TRL Range at completion of the Project

2 to 4

Primary Technology Taxonomy

Level 1
TX 09 Entry, Descent, and Landing

Level 2
TX 09.X Other Entry, Descent, and Landing

Desired Deliverables of Phase I and Phase II
Analysis

Prototype

Hardware

Desired Deliverables Description

Phase I Goals: Design and proof of concept, including the production approach to achieve the cost goals.

Phase II Goals: Prototype/breadboard validation in laboratory environment.

State of the Art and Critical Gaps

NASA now requires instrumentation on all EDL missions, including competed science missions, and these cost- and mass-constrained missions cannot use the state-of-the-art instrumentation. Very few commercial options exist for air data sensors that can meet accuracy and survivability requirements.

Relevance / Science Traceability

EDL instrumentation directly informs and addresses the large performance uncertainties that drive the design, validation, and in-flight performance of planetary entry systems. Improved understanding of entry environments and real-time measurement knowledge could lead to reduced design margins, enabling a greater payload mass-fraction, and smaller landing ellipses for placing advanced payloads onto the surface of atmospheric and airless bodies.

References


Scope Title

Novel Lidar Component Technologies Applicable to Guidance, Navigation, and Control (GN&C) for Precise Safe Landing

Scope Description

NASA is seeking the development of component technologies for advanced lidar sensors that will be utilized within entry, descent, and landing (EDL) and deorbit, descent, and landing (DDL) GN&C systems for precise safe landing on solid solar system bodies, including planets, moons, and small celestial bodies (e.g., asteroids and comets). The EDL phase applies to landings on bodies with atmospheres, whereas DDL applies to landings on airless bodies. For many of these missions, EDL/DDL represents one of the riskiest flight phases. NASA has been developing technologies for precision landing and hazard avoidance (PL&HA) to minimize the risk of the EDL/DDL phase of a mission and to increase the accessibility of surface science targets through precise and safe landing capabilities. One flight instrumentation focus of PL&HA technology has been in the development of lidar technologies that provide either terrain mapping (range point cloud) capability or direct velocity measurement. The
continued maturation of these technologies is targeting (1) multimodal operation (i.e., combining mapping and velocimetry functions); (2) reduction of size, mass, and power; and (3) multicomponent integration.

This solicitation is requesting specific lidar system components and not complete lidar solutions. To be considered, all component technologies proposed must show a development path to operation within the applicable EDL/DDL spaceflight environment (radiation, thermal, vacuum, vibration, etc.). The specific lidar component technologies desired include the following (proposals can be to either or both):

1. Dense focal plane arrays for simultaneous ranging and Doppler velocimetry with the following characteristics:

   - Simultaneous measurements from each pixel or from subsets of pixels.
   - Functionality (when integrated into a lidar system) for measuring range up to 8 km.
     - Range precision less than 5 cm, 1-sigma, for 3D image frames up to 1 km.
     - Range precision less than 1 m, 1-sigma, for ranges up to 8 km.
   - Functionality (when integrated into a lidar system) for measuring velocity from 0 to 200 m/sec (or greater) along the line of sight (LOS).
     - Doppler velocity precision on order of 1 cm/sec, 1-sigma, from ranges of 4 km or greater.
   - Rejection of false locks on dust or plumes from the spacecraft exhaust.
   - Implementation for low power, mass, and size.

2. Readout integrated circuit (ROIC) consisting of preamplifiers and switching fabric, capable of operating at cryogenic temperatures, with the following characteristics:

   - Preamplifiers: Array of low-noise transimpedance preamplifiers, one for each detector element.
     - Electrical bandwidth: >150 MHz.
     - Transimpedance gain: >300 kV/A.
     - Input current noise: <1.5 pA/Hz\(^{1/2}\).
     - Input voltage noise: <10 nV/Hz\(^{1/2}\).
     - Output: Analog pulse waveforms, DC coupling.
     - Electrical power: <2 mW per element.
   - Network switching fabric: Connection of a subarray of the detector elements to the output terminals.
     - Switch speed: >5 MHz with settling time <40 ns.
     - Number of input channels: Up to 2x320.
     - Number of output channels: Subarray of the input signals up to 16 channels.
     - Interchannel isolation: < -37 dB @ 1 GHz.
     - Insertion loss: <1 dB.
     - Total electrical power: <0.05 W.

**Expected TRL or TRL Range at completion of the Project**

4 to 6

**Primary Technology Taxonomy**

**Level 1**

TX 09 Entry, Descent, and Landing

**Level 2**

TX 09.X Other Entry, Descent, and Landing

**Desired Deliverables of Phase I and Phase II**
**Desired Deliverables Description**

The following deliverables are desired for Phase I: (1) Hardware demonstrations of sensor components and applicable support hardware and/or (2) Analysis and software simulations of component proofs of concept within simulated environments. Responses must show a path for the proposed capabilities to be compatible with the environmental conditions of spaceflight.

The following deliverables are desired for Phase II: (1) Hardware demonstrations of sensor components and applicable support hardware and (2) Analysis of components in laboratory or relevant environment (depending on TRL). Phase II products will need to demonstrate a path for the capabilities to be compatible with the environmental conditions of spaceflight.

**State of the Art and Critical Gaps**

For more than a decade, the EDL GN&C and sensors community has been developing the technologies to enable precise safe landing. Infusion of these capabilities into spaceflight missions and spinoff into the commercial sector remains the critical gap. Bridging this gap requires additional component technology advancements for specific lidar sensors that enhance operational performance, increase dynamic envelope, reduce size/mass/power/cost, and enable spaceflight qualification.

**Relevance / Science Traceability**

GN&C/PL&HA technologies for precise safe landing are critical for future robotic science and human exploration missions to locations with hazardous terrain and/or pre-positioned surface assets (e.g., cached samples or cargo) that pose significant risks to successful spacecraft touchdown and mission surface operations. The PL&HA technologies enable spacecraft to land with minimum position error from targeted surface locations, and they implement hazard-avoidance diverts to land at locations safe from lander-sized or larger terrain hazards (e.g., craters, rocks, boulders, sharp slopes, etc.). PL&HA has maintained consistent prioritization within the NASA and National Research Council (NRC) space technology roadmaps for more than a decade, and multiple planetary landers such as Mars 2020 and upcoming Commercial Lunar Payload Services (CLPS) are starting to infuse some of the PL&HA capabilities.

**References**
