NASA SBIR 2016 Phase I Solicitation

H7 Entry, Descent, and Landing

In order to explore other planets or return to Earth, NASA requires various technologies to facilitate entry, descent and landing. This topic, at this time, is supported by two subtopics. Â

The first subtopic calls for the development, modeling, testing, and monitoring of ablative thermal protection materials, high char yield adhesives and/or systems that will support planetary entry. NASA has been developing new ablative materials, some based on a 3-D woven reinforcement, either dry woven or impregnated, and some based on felt reinforcements. In order to develop heatshield systems from these materials, joining techniques are required. Â As new materials are developed, improved analytical tools are required to more accurately predict material properties and thermal response in entry conditions. Light weight, low power instrumentation systems for measuring the actual surface heating, in-depth temperatures, surface recession rates during testing and/or flight are required to verify the response of the materials and to monitor the health of flight hardware.

The second subtopic calls for the development of improved diagnostics for ground test facilities providing hypervelocity flows. Â As we try to understand the effects of hypersonic flow fields on entry vehicles, ground testing is often used to compare test data to predicted values. Â Improvements in diagnostic measurements in facilities such as NASAâ€™s high enthalpy facilities, which include the Electric Arc Shock Tube (EAST), Arc Jets, Ballistic Range, Hypersonic Materials Environmental Test System (HyMETS), and 8â€™ High Temperature Tunnel (HTT) could provide data that will beÂ used to validate and/or calibrate predictive modeling tools which are used to design and margin EDL requirements. This will reduce uncertainty in future mission planning.

Subtopics

H7.01 Ablative Thermal Protection Systems Technologies

Lead Center: ARC

Participating Center(s): GRC, JPL, JSC, LaRC

The technologies described below support the goal of developing advancements in polymers for bonding and/or gap-filling ablative materials, instrumentation systems, and analytical modeling for the higher performance Ablative Thermal Protection Systems (TPS) materials currently in development for future Exploration missions. Â Â The ablative TPS materials currently in development include felt or woven material precursors impregnated with polymers and/or additives to improve ablation and insulative performance, along with the block form of Avcoat ablator for MPCV. Â Â

Two classes of materials are currently in development for planetary aerocapture and entry. Â The first class is for a rigid mid L/D (lift to drag ratio) shaped vehicle with requirements to survive a dual heating exposure, with the first at

heat fluxes of 400-500 W/cm^2 (primarily convective) and integrated heat loads of up to 55 kJ/cm^2, and the second at heat fluxes of 100-200 W/cm^2 and integrated heat loads of up to 25 kJ/cm^2. These materials or material systems are likely dual layer in nature, either bonded or integrally manufactured.Â The second class is for a deployable aerodynamic decelerator, required to survive a single or dual heating exposure, with the first (or single) pulse at heat fluxes of 50-150 W/cm^2 (primarily convective) and integrated heat loads of 10 kJ/cm^2, and the second pulse at heat fluxes of 30-50 W/cm^2 and heat loads of 5 kJ/cm^2. These materials are either flexible or deployable.

Also currently in development is a third class of materials, for higher velocity (>11.5 km/s) Earth return, with requirements to survive heat fluxes of 1500-2500 W/cm^2, with radiation contributing up to 75% of that flux, and integrated heat loads from 75-150 kJ/cm^2. These materials are currently based upon 3-D woven architectures.

Technologies sought are:

- The development of a high char yield, flexible polymer with high strain-to-failure for used in bonding and/or gap fills for tiles of advanced TPS for extreme entry conditions.Â While high char yield (comparable to phenolic) and high strain-to-failure (>1%) are key requirements, additional goals would include some or all of the following: high decomposition temperatures (comparable to phenolic or higher); room temperature cure preferred; manufactured in air (inert environment not required); stable at ambient conditions (not overly sensitive to moisture in cured or un-cured state); compatible with cured epoxy, phenolic, and/or cynate ester, extended out-time; and very low glass transition temperature to retain flexibility in space.
- Development of in-situ sensor systems including pressure sensors, heat flux sensors, surface recession diagnostics, and in-depth or structural interface thermal response measurement devices, for use on rigid and/or flexible ablative materials. Individual sensors can be proposed; however, instrumentation systems that include power, signal conditioning and data collection electronics are of particular interest. In-situ heat flux sensors and surface recession diagnostics tools are needed for flight systems to provide better traceability from the modeling and design tools to actual performance. The resultant data can lead to higher fidelity design tools, improved risk quantification, decreased heat shield mass, and increases in direct payload. The pressure sensors should be accurate to 0.5%, heat flux sensors should be accurate within 20%, surface recession diagnostic sensors should be accurate within 10%, and any temperature sensors should be accurate within 5% of actual values. These should require minimum mass, power, volume, and cost; MEMS-based, wireless, optical, acoustic, ultrasonic, and other minimally-intrusive methods are possible examples. All proposed systems should utilize low-cost, modular electronics that handle both digital and analog sensor inputs and could readily be qualified for the space environments of interest.Â Typical sensor frequencies are 1-10 Hz, with up to 200 channels of collected data. Consideration should be given to those sensors that will be applicable to multiple material systems.
- Advances are sought in ablation modeling, including radiation, convection, gas surface interactions, pyrolysis, coking, and charring for low and mid-density fiber based (woven or felt) ablative materials.Â There is a specific need for improved models for low- and mid-density as well as multi-layered charring ablators (with different chemical composition in each layer). The modeling efforts should include consideration of the non-equilibrium states of the pyrolysis gases and the surface thermochemistry, as well as the potential to couple the resulting models to a computational fluid dynamics solver.
- Advances are sought in modeling mechanical properties of 3-D woven materials.Â Tools that analyze and predict the effects of different fibers on the warp and fill directional properties that could help in fiber selection and weave design are sought.

Starting Technology Readiness Levels (TRL) of 2-3 or higher are sought.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware/software demonstration with delivery of a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables:

- *Advanced Polymer* - Polymer system with demonstration of desired char yields, along with a test plan to be executed in Phase II demonstrating its usability and compatibility with various NASA provided composite materials
- *Sensors* - Sensor system design, including electronics, with specified measurement performance, mass,

power, and volume. Proposed test approach for Phase II that will demonstrate system performance in a relevant environment (arcjet or combined structural/thermal test). Plans should consider testing at the largest scale and highest fidelity that the Phase II funding constraints allow.

- *Ablator and Mechanical Modeling* - Software and architecture development plan, along with a validation test plan, to be executed in Phase II. The Phase I report should provide evidence that the mathematical approaches will improve the state-of-the-art.

Phase II Deliverables:

- *Advanced Polymer* - Aerothermal and structural testing to validate usability and compatibility of the polymer with various NASA provided composite materials
- *Sensors* - Working engineering model of a sensor system with the proposed performance characteristics. Full report of system development, architecture, and measurement performance, including data from completed test proposed in Phase I (TRL 4-5). Potential commercialization opportunities and plans should also be identified and summarized.
- *Ablator and Mechanical Modeling* - Prototype (Beta) software and results from the validation test cases.

H7.02 Diagnostic Tools for High Velocity Testing and Analysis

Lead Center: ARC

The company will develop diagnostics for analyzing ground tests in high enthalpy, high velocity flows used to replicate vehicle entry, descent and landing conditions. Diagnostics developed will be tested in NASAââ#128;™s high enthalpy facilities, which include the Electric Arc Shock Tube (EAST), Arc Jets, Ballistic Range, Hypersonic Materials Environmental Test System (HyMETS), and 8ââ#128;™ High Temperature Tunnel (HTT).Â

Development of improved diagnostics for hypervelocity flows allows us to better understand the composition and thermochemsitry of our ground test facilities and are important for building ground-to-flight traceability. Characterizations in facilities may be used to validate and/or calibrate predictive modeling tools which are used to design and margin EDL requirements. This will reduce uncertainty in future mission planning.

Diagnostics of interest include measurement of temperature, velocity, electron number density, and information regarding byproducts of pyrolysis and ablation in CO_2 or air environments. Due to variation in facility operations, the diagnostics are required to obtain reasonable signals in test times down to approximately 4 μs with resolution on sub-μs time scales. Secondary methods of interest would relate to the detection of the shock front edge arrival to high accuracy (< 0.1 μs). Proposals should detail information such as detection limits, expected signal to noise ratios and data acquisition frequency. Data acquisition channels with up to 200 MHz sampling rate are available.Â

Deliverable will be in the form of a diagnostic hardware system that can be employed by NASA engineers/scientists in the test facility.