NASA SBIR 2015 Phase I Solicitation

H7 Entry, Descent, and Landing Technologies

Lead Center: ARC

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. The first subtopic calls for the modeling, testing, monitoring, and inspection of ablative thermal protection materials 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. 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. Inspection of thermal protection material/aeroshell interfaces is critical to assure quality and is extremely difficult for porous, low density composites.

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The second subtopic calls for the development of improved diagnostics for ground test facilities providing hypervelocity flows. 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. 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 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.Â Â Â

Subtopics

H7.01 Ablative Thermal Protection Systems Technologies, Sensors and NDE Methods

Lead Center: ARC

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

The technologies described below support the goal of developing advancements in instrumentation systems, inspection techniques, and analytical modeling for the higher performance Ablative Thermal Protection Systems (TPS) materials currently in development for future Exploration missions. 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.

Two classes of materials are currently in development for planetary aerocapture and entry. 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. 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:Â

- 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. 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.
- Non Destructive Evaluation (NDE) tools for evaluation of bondline and in-depth integrity for light- weight rigid and/or flexible ablative materials. Non Destructive Evaluation (NDE) tools are sought to verify design requirements are met during manufacturing and assembly of the heat shield, e.g., verifying that anisotropic materials have been installed in their proper orientation, and that the bondline as well as the TPS materials have the proper integrity and are free of voids or defects. Void and/or defect detection requirements will depend upon the materials being inspected. Typical internal void volume detection requirements are on the order of 6 mm on a side (6x6x6), and bondline defect detection requirements are on the order of 25.4 mm by 25.4 mm by the thickness of the adhesive.
- 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. 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. 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:Â

- *Sensors* - Sensor system design, including electronics, with specified measurement performance, mass, power, and volume. Proposed test approach for Phase II, which 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.
- *NDE* - Detection technique/process and equipment design, to meet the specified requirements. Validation test plan, to be executed on relevant materials in Phase II.
- *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:Â

- *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.
- *NDE* - Working engineering model of the detection system with the proposed performance characteristics. Full report of development, architecture, and measurement performance, including data from completed test proposed in Phase I (TRL 4-5).
- *Ablator and Mechanical Modeling* - Prototype (Beta) software and results from the validation test cases.Â

H7.02 Diagnostic Tools for High Velocity Testing and Analysis

Lead Center: ARC

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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 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).

Development of improved diagnostics for hypervelocity flows allows us to better understand the composition and thermochemistry 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.

The range of diagnostics to be considered is not restricted. Examples of diagnostics of interest include those that characterize high enthalpy flows (e.g., temperature, velocity, electron number density, pyrolysis/ablation byproducts) or characterization of test articles (recession, thermal emission, etc.). Proposals for adapting existing techniques to unique aspects of the facility (e.g., free flight in ballistic range, or short duration in shock tubes) are of interest, as well as the development of new techniques. Proposers are encouraged to contact operators and users of individual facilities to understand their specific challenges and requirements, and for details of interfacing into the existing systems.

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