NASA SBIR 2019 Phase I Solicitation

Z7.03 Deployable Aerodynamic Decelerator and Weave Diagnostic Technology

Lead Center: LaRC

Participating Center(s): ARC, LaRC

Technology Area: TA9 Entry, Descent and Landing Systems

NASA is advancing deployable aerodynamic decelerators to enhance and enable robotic and human space missions. The benefit of deployable decelerators is that the entry vehicle structure and thermal protection system (TPS) is not constrained by the launch vehicle shroud. It has the flexibility to more efficiently use the available shroud volume and can be accommodated within a smaller volume for Earth departure than a traditional rigid heat shield. For Mars, this technology enables delivery of very large (20 metric tons or more) usable payloads, which may be needed to support human exploration. The technology also allows for reduced cost access to space by enabling the recovery of launch vehicle assets. The specialized equipment used to weave 3D woven preforms is based on standard textile equipment that is substantially modified to allow hundreds of layers to be interwoven together. As these complex woven structures are scaled up, it is critical to understand the dynamics of the 3D weaving equipment/hardware and how interactions between different components affect the unit cell of the woven structure and ultimately the material properties. This subtopic area solicits innovative technology solutions applicable to 3D woven TPS and deployable entry concepts. Specific technology development areas include:

- Advancements in textile manufacturing technologies that can be used to simplify production, reduce the mass, or reduce the stowed volume of mechanically deployed structures, inflatable structures, or their flexible TMS are of interest. Thermal protection concepts can also lead to improvements in thermal management efficiency of radiant and conductive heat transport at elevated temperatures (exceeding 1200° C). Concepts can be either passive or active dissipation approaches. For smaller scale inflatable systems, less than 1.5 meters in diameter, thin-ply or thin-film manufacturing approaches that can be used to reduce the minimum design gauge are of particular interest for inflatable structures. Focus of Phase I development can be subscale manufacturing demonstrations that demonstrate proof of concept and lead to Phase II manufacturing scale-up for applications related to Mars entry, Earth return, launch asset recovery, or the emergent small satellite community.
- Concepts designed to augment the drag or provide guidance control for any class of entry vehicle are of interest. Concepts can be either deployable or rigid design systems that are suitable to deployable vehicle designs, including methods that modulate vehicle symmetry or adjust lift for active flight control to improve landing accuracy. Designs that decrease the ballistic coefficient by a factor of two to three times are to be considered. Of particular interest are concepts that can be used to modulate the life or drag of a vehicle for enhanced control. Phase I proofs of concept and preliminary design efforts that will lead to, or can be integrated into, flight demonstration prototypes in a Phase II effort are of interest.
- High temperature capable structural elements to support mechanically deployable decelerators that surpass the performance capability of metallic ribs, joints, and struts are of interest to NASA. High speed entry at Venus or return from cislunar space will require advanced hot structures to enable these future missions. Significant mass savings can be achieved with the utilization of lightweight composite materials that utilize

continuous fiber or 3D woven fiber preforms. The composite systems should maintain structural integrity at operating temperatures from 900-1400° C. This subtopic seeks innovative manufacturing approaches that significantly improve in-plane and through the thickness material properties over laminated composite structures. The goal is to achieve at least 50% mass savings over conventional metallic structural elements made from aluminum, titanium, and steel. Anticipated systems would include composite elements such as flanges, tubes, ribs and struts comprised of 3D woven net shape preforms. Design, analysis, and manufacturing demonstration would establish feasibility in Phase I towards providing test coupons and a scaled-up manufacturing demonstration unit in Phase II.

- Until now, off the shelf 3D weaving equipment has typically been over-designed for the small, relatively thin materials woven commercially. However, the high fiber volume 3D woven TPS that is proposed for future NASA missions will exceed the capability of commercial machines and will require the development of new equipment. Predicting the forces required to interlace these complex 3D woven structures is crucial to a successful build. Furthermore, aspects of the weave change constantly in conventional weaving and adjustments are constantly being made. The material that will be supplied from future equipment must be uniform with predictable material properties and must also be weavable in a predictable time frame with minimum defects. Clearly, many variables dynamically interact with each other during a weaving cycle to create a given unit cell. In this subtopic NASA would like to understand the variables controlling a typical 3D woven unit cell and develop real time measurement systems to ensure that high quality material is consistently produced; without this diagnostics data, it is difficult to make the correct adjustments to ensure consistent material is produced. These data will also feed into computational models of the materials necessary for system performance. Anticipated diagnostic systems could include (but are not limited to) instrumentation to track the load and position of individual beams, beat up bars, take up and other parameters of interest to allow fast reaction time to correct any detrimental changes in the woven product during manufacturing. Phase I awards would perform an assessment of potential diagnostic techniques, and Phase II is expected to produce a prototype and/or actual production instrumentation installed on a weaving machine demonstrating increased control capabilities.

NASA needs advanced deployable aerodynamic decelerators and advanced weave diagnostic technology to enhance and enable robotic and human space missions. Applications include Mars, Venus, Titan, as well as payload return to Earth from orbit and beyond. NASA's Space Technology Mission Directorate (STMD), Human Exploration and Operations Mission Directorate (HEOMD), and Science Mission Directorate (SMD) can all benefit from this technology for various exploration missions.

The expected Technology Readiness Level (TRL) range at completion of this project is 1 to 4.

References:

- Hughes, S. J., et al, “Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Technology Development Overview,” AIAA Paper 2011-2524
- Bose, D. M, et al, “The Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Mission Applications Study,” AIAA Paper 2013-1389
- Hollis, B. R., “Boundary-Layer Transition and Surface Heating Measurements on a Hypersonic Inflatable Aerodynamic Decelerator with Simulated Flexible TPS,” AIAA Paper 2017-3122
- Cassell, A., et al, “ADEPT, A Mechanically Deployable Re-Entry Vehicle System, Enabling Interplanetary CubeSat and Small Satellite Missions,” SSC18-XII-08, 32nd Annual AIAA/USU Conference on Small Satellites