Phase IIe Project Summary

Firm: CFD Research Corporation
Contract Number: NNX11CA28C
Project Title: Integrated Inflatable Ballute for Planetary Entry

Identification and Significance of Innovation:
Inflatable structures have emerged as a promising enabling technology for future planetary exploration. An inflatable structural enclosure can potentially provide a lighter weight design than a rigid structure of the same size and drag coefficient due to the inherent rigidity of a pressurized vessel. Inflatable Aerodynamic Decelerators (IADs) are launched in its collapsed configuration to a destination in space where the structure is subsequently deployed to full size to increase the drag area of a vehicle at Mach numbers and dynamic pressures considerably higher than those possible using parachutes. This is a result of their increased drag effectiveness and improved structural efficiency.

CFD Research Corporation (CFDRC), in collaboration with subcontractor Thin Red Line Aerospace (TRLA), through NASA SBIR Phase I, II and II-E programs (NNX11CA28C) have developed, designed and tested a highly scalable, mass-optimized inflatable structure that makes maximum utilization of materials in providing tailored stiffness and rigidity for hypersonic entry vehicles. The developed hypersonic entry vehicle was designed based on TRLA's unique Ultra High Performance Vessel (UHPV) technology. UHPV technology permits manufacture of robust pressure vessels with unprecedented accuracy and dimensional stability. Its performance has been mathematically verified and test-validated as the only high shell load containment architecture offering fully determinate load pathways and mass-optimized structural design.

Technical Objectives and Work Plan:
The main objective of this Phase II enhancement effort is to mature the developed IAD technology for planetary entry. The objective will be achieved through the following work plan; 1) Extended performance analysis of the original UHPV-based IAD model under typical non-symmetric loading conditions and to conduct parametric study on the inflation pressure; 2) Development of a single body sphere cone IAD based on the UHPV technology; and 3) Support the NASA-ARC Adaptable Deployable Entry and Placement Technology (ADEPT) project by demonstrating carbon heat thread stitching capability applied to 3D woven carbon fiber heat shield materials suitable for a broad spectrum of atmospheric decelerator programs. The Phase II enhancement effort will leverage relevant past work by the research team in inflatable structures. The computational tools will be used to optimize the configuration and evaluate the load pathway of the design. Phase II enhancement effort will demonstrate the feasibility of the UHPV technology for hypersonic entry systems from the stand point of aerodynamics, structural dynamics, and stability.

Technical Accomplishments:
All the tasks of Phase II-E effort were accomplished successfully. An extended performance analysis of the IAD design developed under the Phase II program was conducted using a highly scalable production-quality CFD solver and then coupling it to the FEM solver with two way exchange of grid deformation and consequent load changes. Tests were conducted at various Angles of Attack to determine effects of grid deformation on the structural deflections. Next, the feasibility of joining samples of woven carbon fabric using carbon fiber based threads was studied thoroughly. Advanced carbon fiber stitched seams were developed and applied to a large number of carbon fabric heat shield test articles. Samples possessing the required design features were evaluated and structural assessment parameters identified. Additionally longer seams derived from the primary and alternate stitch designs identified in this effort were studied. Successful seams were ultimately developed for ArcJet testing at NASA-ARC. Finally, a new sphere-cone UHPV-based IAD inflatable design architecture was developed featuring fully determinate load paths, predictable, scalable performance. An integrated multidisciplinary coupled-physics computational analysis was conducted. CFD analysis of the design shows that the shape is highly suited to the role of an inflatable aerodynamic decelerator and has a coefficient of drag that is comparable to the IRVE-3 design.

The structural analysis shows that the underlying UHPV architecture behaves in a nearly rigid manner to the applied loads.

NASA Application(s):
The proposed integrated hypersonic inflatable entry system will have an immediate application in delivering large payload masses to the surface of Mars, and is adaptable and scalable for application to other planetary atmospheres. This will reduce the number of launches required for the mission completion and total mission costs. The proposed technology will find direct applications with present and future NASA and industry inflatable structures programs, such as those seeking to provide deceleration and precision landing capability for large scale mass return from Earth orbit to Earth surface, or for missions to many of the potential atmosphere-endowed solar system destinations. Other NASA applications include large aperture antenna reflectors, solar collectors, cryogenic propellant tanks, lander air bags, and rover vehicles.

Non-NASA Commercial Application(s):
Additional application areas include hardware development and analysis of space-based inflatable structures such as telescopes and mirrors, satellite solar panels and military reentry vehicles and inflatable decoys, etc exposed to dynamic atmospheric entry environments. The aeroelastic analysis of parachutes and parafoils and the analysis of high-altitude endurance airplanes with flexible wings will be improved. Further military applications include stabilization and deceleration of ordnance with attached inflatable decelerators. Other non-NASA applications include satellite de-orbit devices; compressed air energy storage; high pressure and cryogenic tanks; high altitude airships; fuel and other liquid storage containment, orbital and otherwise; helicopter and other motor vehicle crash air bags; and launch vehicle payload fairings.

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