Phase I Project Summary

Firm: CFD Research Corporation
Contract Number: NNX10CC55P
Project Title: Integrated Inflatable Ballute for Planetary Entry

Identification and Significance of Innovation:
NASA is conducting an Entry, Descent and Landing Systems Analysis (EDL-SA) Study to determine the key technology for enabling the landing of large payloads on Mars for both human and robotic missions. Inflatable Aerodynamic Decelerators (IADs) are one of the candidate technologies. The primary challenge of deployable space inflatable design is to demonstrate robust predictability and scalability of the inflatable's integrated structures. CFDRC and Thin Red Line Aerospace (TRLA) proposed model is a hybrid mass-optimized pressure restraint inflatable structure, utilizing the unique UHPV technology. The model employs an impervious cloth-reinforced barrier structure enveloped by an integrated array of high-tenacity tendons. The external grid of cordage tendons provides mass- and load optimized containment of the structure's global pressure loads. The segregation of material functions provides greater design flexibility to meet stiffness and thermal protection requirements. This hybrid design with its external grid of high-strength cordage also easily accommodates the attachment of specialized extreme high-temperature tiles to provide increased tolerance to high re-entry heating rates. Once the envelope is pressurized, the external grid of cordage is tensioned and is capable of supporting load bearing attachments for guidance and control hardware. Computational physics-based modeling and simulation are proposed to investigate, understand and optimize the inflatable design.

Technical Objectives and Work Plan:
The objective of this SBIR project is to develop, design, test, and demonstrate an integrated hypersonic inflatable structure for planetary entry complete with thermal protection hardware and load bearing, attachment fittings for guidance/control hardware. Verification and optimization of the hardware design will be conducted using an integrated coupled-physics analysis for aerodynamics, thermal, dynamic and structural dynamics. The work plan for Phase I included a) requirements review for hypersonic entry systems to define the design environment and design drivers such as total mass, volume, and payload mass; b) Design configuration development; c) materials selection and evaluation using computational nonlinear modeling and simulation; and d) integrated structural design development including prototype demonstration and coupled aeroelastic analysis of the inflatable structure.

Technical Accomplishments:
During the Phase I, a requirements review was conducted with NASA to define the design environment and design drivers for hypersonic entry system. The NASA requirements were taken into account to develop an initial design and packaging configuration using the UHPV technology. Axi-symmetric CFD analyses were conducted to evaluate the aerodynamic characteristics of several inflatable concepts, including several concepts of the UHPV design. Several fluid-structure simulations were then conducted to evaluate the preliminary sub-scale and full-scale structural dynamic design requirements for the UHPV inflatable decelerator. The design configuration was reevaluated based on these results and an extensive materials selection and evaluation study was conducted to select the best material for the UHPV inflatable design. A prototype of the proposed UHPV inflatable model was also fabricated and demonstrated. The feasibility of this technology was also demonstrated using a coupled 3D fluid structure interaction (FSI) simulation based on developed design. The UHPV decelerator geometry is obtained with a single inflatable envelope and does not require an awkward assemblage of toroids. No interface loads are transferred to the barrier structure - entirely eliminating the trauma potential associated with conventional decelerator designs. The coupled fluid-structure interaction simulations showed that the tendons effectively carry a significant portion of the aerodynamic loads especially at lower inflation pressures

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. 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): (Limit 200 words or 2,000 characters whichever is less)

Additional application areas include analysis of space-based inflatable structures such as telescopes and mirrors, satellite solar panels and military reentry vehicles (inflatable decoys, etc) exposed to the atmosphere. 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 device, compressed air energy storage, high altitude airships, oil storage containers, helicopter and motor vehicles crash air bags and launch vehicle payload fairings.

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