Enabling Future Venus In-situ Missions – Heat-shield for Extreme Entry Environment Technology (HEEET) Progress Towards TRL 6

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Introduction: Heat-shield for Extreme Entry Environment Technology (HEEET) has been in development since 2014 with the goal of enabling missions to Venus, outer planets and high-speed sample return missions. It is nearing successful completion and will be delivered by March of 2019.

Background: HEEET utilizes 3-D weaving as the basis for the highly capable TPS. An integrally woven dual-layer ablative material system is produced by the three-dimensional weaving process . The outer layer, high density carbon yarn weave, offers protection against the extreme external environment during entry. The inner insulating layer, lower density composite yarn weave, is adhesively bonded to underlying structure, protects the structure and science payload from the heat that penetrates the outer layer. The dual layer system is both robust and mass efficient. The HEEET material has been woven and tested for thermal performance at NASA Ames and DoD's AEDC arc jet facilities. These tests confirmed the two layer system to be very efficient and capable of withstanding extreme entry heating.

Component Manufacturing, Heat-shield Integration and Testing: A primary objective of the project has been to establish the manufacturing and integration processes necessary to build a heat-shield system, which is typically a blunt sphere-cone. The 3D material is woven as flat panels that have to be formed to match the surface profile of the sphere-cone. The formed panels are subsequently resin infused and cured, producing rigid tiles that are machined and bonded to the carrier structure.

The requirements for the gap filler are that: a) it must be compliant enough to accommodate the strain in the heat shield during all mission phases (acreage tiles are very stiff) and b) gap filler must have similar aerothermal performance (recession) as the acreage material, to minimize formation of local steps in the system that can lead to augmented heating during entry. The integration approach is required to end up with a very thin adhesive layer between the acreage panels and the gap filler material to prevent augmented recession of the lower density adhesive that could result in augmented heating of the structure. Development of the gap filler material and integration procedures was the most significant challenge the project encountered.

Validation of manufacturing/integration processes was demonstrated by the fabrication and testing of a 1m diameter "flight like" Engineering Test Unit (ETU). The ETU has undergone static load tests, point load tests, thermal vac tests and finally another round of point load tests. Preliminary data shows the ETU performed well and the comparisons of the data with predictions will be used to validate the structural design tools.

In addition, a series of arc jet tests were recently completed. These tests, conducted at the AEDC facility and NASA Ames' IHF were successful in establishing the heat-shield design features are capable of withstanding extreme entry environment. Testing in the IHF arc jet achieved heat fluxes of ~ 6500 W/cm2 and pressures of 5.5 atm. The test articles included acreage specimens, and seam specimens that incorporated the adhesive between acreage tile and gap filler. The model was 1" in diameter the small size is required to achieve the high test conditions. As part of the technology development, Bally Ribbon Mills has scaled up the weaving from 1" thickness and 6" width to 2" thickness at 24" width, requiring a loom that can manage tens of thousands of yarns. The heat-shield architecture and manufacturing/integration processes utilized in the 1m ETU is designed to be scalableto much larger sized vehicles. As part of the ETU build the HEEET team has successfully transferred the molding and resin infusion techniques to Fiber Materials Inc. (FMI). FMI then fabricated the piece parts for the ETU as a way to validate they can make parts necessary to assemble flight heat-shield for future missions. With the technology transfer to Industrial partners, and the successful testing and demonstration of the 1m heat-shield, HEEET team is nearing completion of achieving TRL 6.

Mission Infusion: HEEET was offered as a new technology and incentivized for mission use in the New Frontiers 4 AO by NASA. The HEEET Team worked closely with multiple NF-4 proposals to Venus, Saturn and has been supporting recent Ice-Giants mission studies and as a result, the technology delivered will be mature and ready for mission infusion

The full presentation will report on the HEEET development completed to-date and also remaining testing and documentations prior to delivery of a TRL 6 technology.