

## Progress Towards providing Heat-shield for Extreme Entry Environment Technology (HEEET) for Venus and other New Frontiers Missions.

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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, Saturn and other high-speed sample return missions. It is offered as a new technology and incentivized for mission use in the New Frontiers 4 AO by NASA. The current plans are to mature the technology to TRL 6 by FY'18. The HEEET Team has been working closely with multiple NF-4 proposals to Venus, Saturn and has been supporting recent Ice-Giants mission studies. This presentation will provide progress made to date and the plans for development in FY'18.

**Background:** HEEET utilizes 3-D weaving as the basis for the highly capable TPS. An integral dual-layer ablative material system is produced by the three-dimensional weaving process. The outer, which is woven with high density carbon yarn, offers protection against the extreme external environment during entry. The inner insulating layer, made of much lower density composite yarn, is adhesively attached to underlying structure, protects the structure and the science payload from the heat that penetrates the outer layer. The dual layer system is both robust and mass efficient.

**Progress and Plans:** 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. The challenge has been in the design and development integrates the material into a heat-shield system that conforms to the entry vehicle shape, which is typically a blunt sphere-cone, as shown in Figure 1.. Flat panels are 3-D woven to produce preforms that are porous, with yarn that can move under load. The flat panels have to be formed to match the surface profile of the sphere-cone. The formed panels are resin infused and cured, which produces so as to rigid tiles that can be machined and bonded to the carrier structure. This integration requires gaps between panels to accommodate differential strains between the thermal protection material and the structure, which arise under mechanical and thermal loads. The gaps are filled with compliant seams, which need to remain intact throughout the mission to prevent heat from penetrating between acreage tiles. In addition, the seam and the acreage tiles have to have very similar performance,

both in terms of recession and thermal conduction, so that local steps are not created, because such features can cause severe heating augmentation in a local region. Hence the seam material is created by working acreage material to break up the phenolic resin matrix and thereby increase compliance without much change in thermal properties. The seam material is wrapped in tape adhesive and inserted in the gaps, with lateral clearance between gapfiller and tiles, and excess height for the gap filler. When the adhesive is cured in an autoclave at high pressure, the load at the outer surface causes the gap filler to decrease in height and expand laterally, to close the gap and load the adhesive that bonds the seam material to the acreage tiles. This process permits very thin adhesive layers to be used, and the thermal response across the joint is almost continuous..

The integration of the molded panels and seam material requires complex bonding, curing and routing operations that requires high precision. The integration is illustrated in Figure 1. The HEEET team has completed the manufacturing of all the parts needed to assemble a 1m heat-shield. The integration process that is currently in progress will be completed by February, 2018. The assembled heatshield will then undergo a series of testing at full scale.

The 1m heat-shield is designed to be capable of enduring Saturn entry conditions, so the test load levels should bound those for most future mission need. Missions to Venus, Saturn and other destinations will likely use a heat-shield design that differs in some ways from the Engineering Test Unit. The HEEET integration processes for the ETU are designed to be relevant for different structural arrangements, and for both areal and thickness scale-up.

The full presentation will report on the testing at relevant scale in relevant environments that will deliver system TRL of 6 by the end of FY'18.



Figure 1. HEEET integration with the carrier structure. Molded and resin infused tile panels are bonded and routed precisely for integration of seam between the acreage tiles.