3-D Woven TPS Enabling Solar System In-Situ Science Missions

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NASA developed 3-D Woven thermal protection systems offer a mass efficient and robust protection against extreme entry environment for in-situ missions to Venus, Sample Return, Saturn, Uranus, and Neptune and for aerocapture missions.

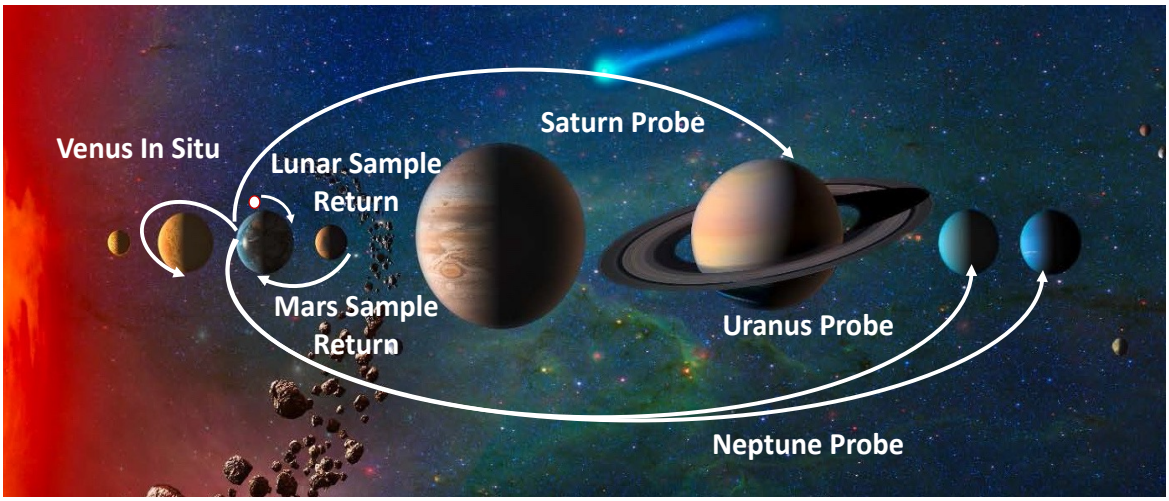

Fig. 1 Extreme environment missions requiring mission enabling ablative TPS.

3-D Woven TPS is an enabler for these destinations as there are no alternatives available today. Though Galileo and Pioneer-Venus missions were successfully executed, the carbon-phenolic heatshield capability has atrophied and as a result, extreme entry environment missions were lacking thermal protection technology. This led NASA to develop the 3-D Woven TPS. NASA has offered 3-D Woven as an incentivized technology in the previous New Frontiers and Discovery AOs in the past.

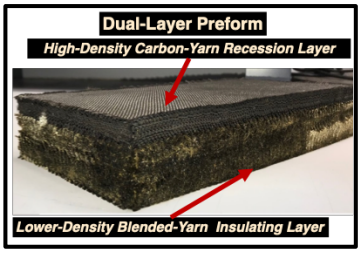

Fig. 2 Dual-layer, 3-D Woven TPS.

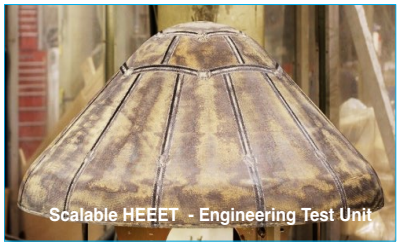

Fig. 3. Scalable HEEET

Fig. 4 Seamless 3MDCP

There are two variants of 3-D Woven TPS available today that are at high technology readiness level. Heatshield for extreme entry environment technology (HEEET) is a dual-layer, integrally woven, tiled TPS system capable of scale-up to any diameter. Bally Ribbon Mills established a 24" wide loom and is currently weaving HEEET (Fig. 2). The scalable HEEET engineering test unit (ETU) is shown in Fig. 3.

The second 3-D Woven TPS is a single layer system that only uses the insulating layer of the dual-layer HEEET. The single layer 3-D Woven is referred to as 3MDCP (3-D, mid-density, carbon-phenolic) by Mars Sample Return (MSR) and is the TPS for the Earth Entry System (EES) that protects the sample. T.E.A.M. Inc has established a weaving capability for ~ 80" wide preform. High technology readiness level, mass efficiency and robustness to micro-meteorite impact were factors that led to 3MDCP baselined as the TPS by MSR. The 3MDCP heatshield size is limited by the width of the preform and the infusion infrastructure. It is scalable up to ~ 1.25m diameter heatshield (Fig. 4)

The 3MDCP and HEEET share a lot in common in terms of manufacturing. The weaving, molding of the preform and resin infusion are the process have commonality. The integration of the HEEET system is complex due to seam but the molding of tiles is simpler. HEEET system is certified by an independent review board and reached TRL 6 maturity in 2019. 3MDCP system will be at TRL 6 at the time of the hardware delivery for MSR EEV in 2024.

Based on our assessment, the following missions listed on the SMD Technology Showcase will need 3-D Woven TPS and we look forward to meeting with the mission teams at the showcase in January 2023.

Outer Planets	
1	New Frontiers Titan Orbiter
2	Rideshare4OuterPlanets
3	Small Next-Generation Atmospheric Probe (SNAP) for Ice Giant
4	Uranus Orbiter and Probe (UOP)
5	Saturn Probe
Venus	
6	SAEVe: Seismic and Atmospheric Exploration of Venus
7	V-BOSS: Venus Bridge Orbiter and Surface System
8	Venus In Situ Explorer (VISE)
9	Cupid's Boomerang
Sample Return	
10	Ceres Sample Return
11	Comet surface sample return (CSSR)