WOVEN TPS –AN ENABLING TECHNOLOGY FOR MARS SAMPLE RETURN, IN-SITU SCIECNE AND HUMAN EXPLORATION MISSIONS

E. Venkatapathy[1], M. Stackpoole[1], J. Feldman[1], J. Kowal[2], and M. Munk[3], [1]NASA Ames Research Center, Moffett Field, CA 94035 [2]NASA Johnson Space Flight Center, Houston, TX 77058, [3]NASA Langley Research Center, Hampton, VA 23681

Summary: Woven TPS (WTPS) technology addresses Challenge Area 2: *Safe and Accurate Landing Capabilities, Mars Ascent, and Innovative Exploration Approaches:* ***High-reliability sample return capsules suitable for Earth entry****, with special attention on assured containment of returned samples, and preservation of sample integrity*. This abstract outlines how the current OCT investment in Woven TPS, a competitively selected proposal under the Game Changing BAA, has the potential to meet the needs of Mars Sample Return (MSR), in-situ Science missions to Venus, Outer Planets and high-speed sample return missions in the near term, to enable human missions beyond the Moon in the mid-term, and to enable human Mars missions in the longer term. If selected, the presentation will focus on WTPS technology and the myriad of mission applications, including MSR, it enables.

Introduction: Bringing samples back to Earth from Mars for detailed examination is both a great vision of human exploration and a grand challenge. Planetary protection requirements for the MSR earth entry vehicle have a reliability of 0.999999, higher than any planetary entry vehicle to date, including entry capsules for human missions. The design challenges for protecting the sample and achieveing this reliability during atmospheric entry, descent, and landing have been detailed in numerous studies[1-3]. Areas of increased focus on proposed MSR entry vehicles include micrometeroid and orbital debris (MMOD) protection, thermal protection, and selection of appropriate structural materials for limiting the impact of landing.

The thermal protection system (TPS) protects the sample and the containment vessel from reentry heating. For MSR, the earth entry heating will be ~ 1500W/cm^2. At present, there is no off-the-shelf, flight proven TPS for missions that require aeroshells larger than 1m diameter, peak entry heating > ~1000 W/cm^2, and peak pressure > 1 atm., other than heritage carbon phenolic (see Fig.1). The reliability requirements cannot be met by a single-string TPS, even though heritage carbon phenolic (HCP) has the most extensive properties and flight performance database, due to its use by NASA for the Pioneer Venus (P-V) and Galileo probes over 40 years ago and its continued use by DoD in ballistic missiles. MMOD impact damage to the heatshield is a primary concern with MSR, but P-V, Galileo and DoD mission designs have had no such constraint. In addition, depending on the location on the forebody heatshield, two different types of carbon phenolic are required for an MSR TPS: a tape-wrapped (TWCP)version for the frustum and a chopped-molded (CMCP) version for the spherical nose cone where the nose geometry precludes tape-wrapping as a suitable manufacturing route. DoD does not use the chop molded form and NASA missions have not required it since Galileo. Given these issues, a dual string TPS is required to meet the reliability for MSR. WTPS is a multifunctional system capable of providing both TPS and structural protection. When doubled up with carbon phenolic, it can provide high reliability with lower mass and be designed to provide MMOD protection as well.

What is Woven TPS (WTPS): Woven Thermal Protection Systems (WTPS) is a novel TPS concept that provides tailored TPS solutions by using precisely engineered 3D weaving techniques to create material structues with the customized characteristics needed to meet specific mission requirements. Currently funded by NASA's Office of the Chief Technologist (OCT) Game Changing Division, WTPS leverages the mature, sustainable state-of-the-art weaving technology that has evolved from the textile industry and is currently used by aircraft industry in advanced, light-weight composite structures. WTPS is made with commercial manufacturing processes, thereby relieving NASA of the need to maintain manufacturing capabilities used for NASA-unique materials and/or relieve the risk associated with restarting material processing lines - challenges currently being encountered with CMCP and TWCP materials. Because WTPS can be designed to perform optimally for a wide range of entry conditions, this novel technology can change the way NASA develops, certifies, and integrates TPS into mission life cycles. TPS can move from being a mission constraint to a mission enabler, filling the current ablative TPS gap (Fig.1).

To date, samples of WTPS have been processed and tested to evaluate thermal and mechanical properties (Fig.2). Exploratory ablative and mechanical characterization (arc-jet) testing has been completed, and, as anticipated, the 3-D WTPS is mechanically strong and thermally comparable to heritage material. By the end of 2012, more aggressive testing will compare performance with heritage CP and establish the capability limit of WTPS. As a result of preliminary data, WTPS has been identified as a candidate for the Multi-Purpose Crew Vehicle (MPCV) compression pad design upgrade for Lunar Return (LR) missions. MPCV and the WTPS team will be working together on this effort and WTPS is expected to see first flight in 2017. The compression pad is both a structural and TPS functional hardware that has to withstand pyroshock. The successful MPCV Lunar Return flight test will establish the multifunctional capability of WTPS and its applicability for a human mission - although smaller than MSR scale – by providing higher robustness than that required for robotic missions.

WTPS Development and Mission Insertion Plans: WTPS development and mission applications timeline currently envisioned are shown in Table 1.

Unlike HCP, 3-D Woven TPS is scalable and mission tailorable. WTPS is mass efficient because its performance can be tailored to withstand higher heat loads without significant mass penalties. Further, it facilitates the use of shallower entry trajectories that reduce g-loads, which is a science mission enabler when using g-limited instruments or protecting sensitive samples. In the recent Carbon Phenolic and Beyond Workshop held at NASA Ames (April 3-4, 2012) and attended by over 130 scientists and engineers, a major conclusion was that WTPS has the potential to be a replacement for HCP. Given the significant advanatages of the technology, success of the exploratory effort this year could lead to WTPS being matured to a TRL of 6 by 2015-2016. At the same time, WTPS is expected to be developed and, if it meets the design requirements, will be flown on MPCV as compression pads on a uncrewed flight test in 2017 for LR missions.

New Frontier (NF) or Discovery missions that require heatshields to withstand more than 1000 W/cm^2 currently have very limited material choices (See Fig.1). The success of WTPS as part of MPCV, coupled with technology maturation by 2016 and its unique mission enabling characteristics could lead to adoption by one or more of the competed proposals to Venus, Saturn, and/or high speed Sample Return missions. The timeline for these missions is around 2020-2022. Any one of these SMD NF missions will demonstrate WTPS at a more stressing environment than MPCV.

In addition, other potential WTPS application opportunities include human and robotic exploratory missions in the longer term such as:

- NEO Missions which would benefit from a mid-density TPS capability and robustness
- SMD Flagship mission demonstrating mass/cost efficiency

Although newly identified in 2011 and in need of continued investment by NASA for technology maturation, we believe, WTPS can play a critical role in the design, development, testing and eventual flight of the Mars Sample Return Earth Entry Vehicle.

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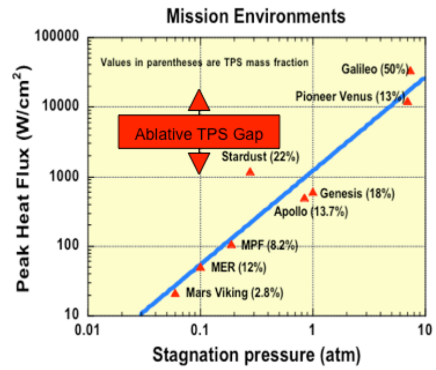

Figure 1. The ablative TPS gap. NASA does not have flight proven, off-the-shelf TPS for future Venus, Saturn, high speed sample return, or Human missions beyond Lunar or Mars Sample Return Missions, other than heritage Carbon Phenolic which has not been made in over 40 years. This TPS gap can be filled by Woven TPS.

Figure 2. Woven TPS comparable to Fully Dense Carbon Phenolic as well as mid-density TPS has been manufactured and tested both mechanically and thermally.

Mission	Timeline
Demonstration	('12)
TRL 4 forMPCV Compression Pad	('13)
WTPS Tech Maturation (TRL6)	('13-'16)
MPCV Lunar Flight Test	('17)
NF AO & Step 1 &2 (Application)	('15 - '17)
Venus	('15 - '17)
Saturn	('15 - '17)
High Speed Sample Return	('15 - '17)
NF In-Situ Sciecne Mission	~2021
NEA Human Missions	Beyond 2021
Mars Sample Return	Beyond 2021
Human Mars Return	Beyond 2030

Table 1. Woven TPS development timeline leading to its application to MSR.