Recent Advances in Ablative TPS in the U.S. for In-situ Exploration of Giant Planets.

E. Venkatapathy, NASA Senior Technologist for Entry System, MS 229-3, NASA Ames Research Center, Moffett Field, CA 94035. E-mail: Ethiraj.venkatapathy-1@nasa.gov

Abstract

The Decadal Survey report released [1] prioritizes Uranus as the highest priority Flagship class mission to be explored with an orbiter and a probe and it also recommended Saturn Probe under New Frontiers mission class. Thermal protection system (TPS) is essential for Uranus and Saturn probe missions. The two cardinal requirements are that it must be fail-safe and yet be mass efficient. The Decadal Survey report also pointed out the readiness of heatshield for extreme entry environment technology (HEEET) at TRL 6 for probe missions at Gas Giants.

HEEET relies on 3-D weaving and is shown to be a robust and mass efficient TPS through ground testing and analysis. HEEET was matured to TRL 6 in 2019. HEEET was reported at the Ice Giant Workshop in 2019 at Marseille [2] [3].

Since 2019, significant advances have been made primarily because of Mars Sample Return (MSR) mission. MSR baselined 3-D Woven TPS as its heatshield for the earth entry system. MSR earth entry system (EES) requirements and the resulting heatshield/TPS requirements are most stringent of all entry missions. This is a result of backward contamination protection which classifies MSR as a "restricted class 5" mission to safeguard the accidental release of potentially hazardous Mars Sample into Earth's atmosphere. Complex requirements for the heatshield start with micro-meteor impact tolerance followed by the requirement for steep entry to minimize the size of the impact footprint which results in extreme heating. The heatshield is part of the impact attenuation system. The EES architecture does not use a parachute and is designed to tolerate impact loads. Hence heatshield TPS selection and design becomes one of the key challenges.

After completion of the HEEET technology maturation in 2019, IRAD efforts focused on assessing the 3-D Woven family of TPS to MSR EES. After nearly two years of evaluation of alternate TPS such as carbon phenolic, C-C hot structure, PICA, and 3-D woven family of TPS, a single layer 3-D woven TPS derived from the dual-layer HEEET was down selected and is currently the baseline. A new loom capable of weaving the single-layer 3-D woven preform at 80" wide has been designed, assembled and is currently on the verge of weaving the MSR EES TPS.

During the HEEET maturation and the follow-on development, the single-layer TPS has been tested at extreme heating conditions. As a result, single layer TPS was recommended and evaluated during the Planetary Mission Concept Studies funded by NASA in preparation for the Decadal committee. In addition, in anticipation of Saturn mission proposals, single layer was evaluated as well.

Aerocapture can reduce the trip time, also allow bigger payload fraction and in addition, it allows for the possibility of probe delivery once the spacecraft is in orbit. This can lead to obtaining both in-situ data as well as data from orbit simultaneously. Since Aerocapture depletes energy/velocity, probe delivery from orbit reduces the demand on TPS. Aerocapture was mentioned in the Decadal Study report as ready for implementation, but due to perceived risk it is not adopted by the mission designers. Establishing TPS readiness for aerocapture missions will be addressed. Going one step beyond aerocapture is aerogravity assist if fast return is the goal. Recent studies [4] looked at aerogravity assist and the TPS readiness. This talk will highlight both aerocapture and aerogravity assist from a TPS perspective.

The main objective of this proposed talk is to present a comprehensive picture of the SOA TPS technology including recent developments. The talk will highlight advances in manufacturing, results from the Decadal White Papers, PMCS and other studies, and aerocapture and aerogravity assist that could play a role in the near or far term in-situ exploration.

References:

[1] Decadal Survey Report, "Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032 (2022)"
[2] Venkatapathy, E., " *SSR,* 216.2 (2020).
[3] Prabhu, Dinesh K. *FAR 2019*.
[4] Arnold, et. al., White Paper to the Decadal Survey.