

## PARAMETRIC ANALYSIS OF ENTRY VEHICLES FOR GIANT PLANET MISSIONS

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**Brief Presenter Biography:** Joshua Monk is Materials Engineer at NASA Ames Research Center working in the Thermal Protection Materials Branch. Josh has a Ph.D. in Materials Science & Engineering from Virginia Tech.

**Introduction:** The Planetary Science Decadal Survey [1] has identified Uranus and Saturn as high priority destinations for a flagship and New Frontier missions respectively in the decade 2023-2032. The proposed presentation will focus on the entry and descent aspects of the entry vehicles design, considered as part of Giant Planet probe mission concepts, and associated trades for viable trajectory options.

**Giant Planet Entry Vehicle Parametric Study:** Launch vehicle capabilities are evolving and provide an opportunity to increase instrumented probe dimensions. To assess the impact of larger aeroshell designs, a parametric study was conducted to understand the impact on aerothermal environments, TPS options, and TPS mass over a range of 1.0m to 2.0m aeroshell diameters for Uranus and Saturn probe concept missions.

The 45° sphere-cone geometry is a legacy configuration that has demonstrated static stability and been used successfully in missions to Venus (Pioneer-Venus) and Jupiter (Galileo) [2]. A nose radius of 0.4 m was considered primarily to reduce the heat flux at the stagnation point [3] compared to the smaller radii used in the Venus and Jupiter missions. Representative inertial velocities are chosen from a prior NASA Ames study [4]. Viable entry trajectories to meet concept mission and science objectives were developed using the tool POST2 [5].

The newly developed thermal protection material called HEEET (Heatshield for Extreme Entry Environment Technology) [6] was considered in the study. This material, which is at a technology readiness level (TRL) of 6, is highly customizable and available in two varieties: (i) a dual-layer version consisting of recession layer on top of an insulative layer, and (ii) a single-layer version consisting of the insulative layer alone, termed 3-dimensional Mid-Density Carbon Phenolic (3MDCP)[7]. Both options were considered for the forward heatshield (the sphere-cone part) in the present study.

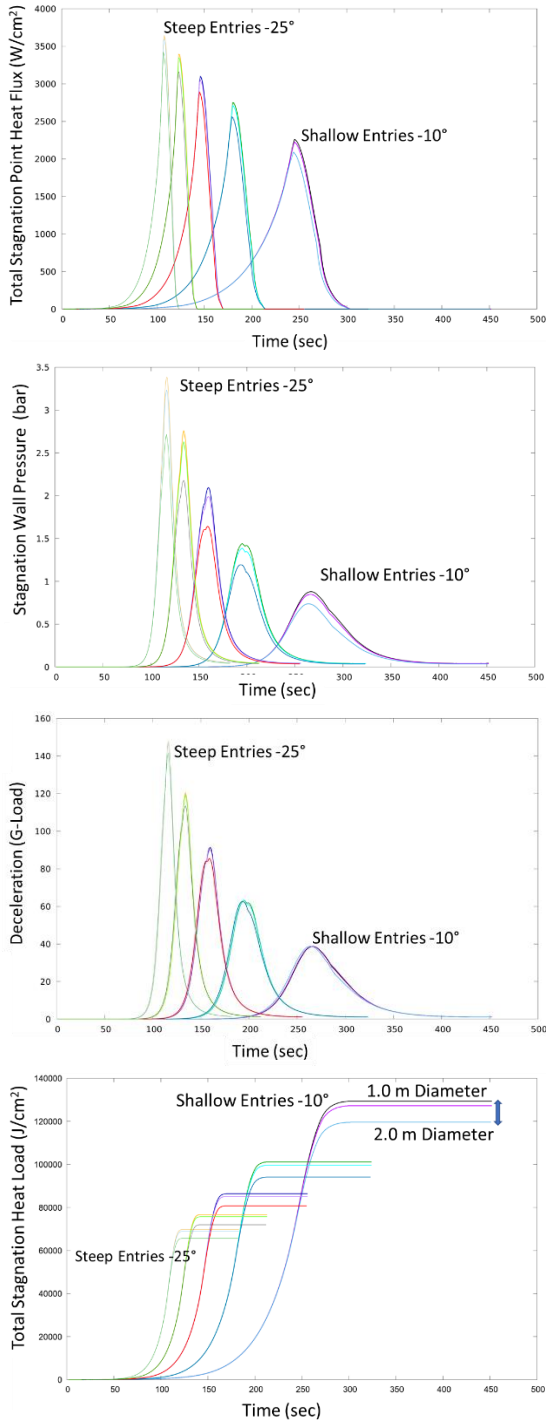
**Thermal Protection Sizing Processes and Results:** To provide TPS mass estimates for the entry vehicles the TPS material was sized to ensure the bondline

temperatures did not exceed the limitations of the adhesives between the TPS and structure. The requisite aerothermal parameters (pressure, recovery enthalpy, and film coefficient) for the stagnation point were determined using engineering correlations built into NASA Ames's 3DOF trajectory code called Traj [8] with scaling factors informed by higher fidelity CFD [3].

The aerothermal environments over the entire configuration were determined through the application of the high-fidelity flow solver Data Parallel Line Relaxation code (DPLR) [9]. Flow computations, including laminar, turbulent, and turbulent with surface roughness, were performed at select points along flight trajectories for a subset of the entry vehicles. NASA's 1D Fully Implicit Ablation and Thermal (FIAT) response program [10] was used with the predicted heating environments to size the heatshield and backshell thermal protection material and predict recession. TPS sizing for the heatshield and backshell followed best practice margin and sizing policies [11].

Aerothermal results of a near equatorial entry case for Saturn is shown in Fig. 1. Stagnation point heat flux and pressure peaks are used to downselect TPS materials, while peak g-load and total heat loads are commonly an inversely coupled trade by missions. Entry states with lower entry flight path angles result in lower g-loads which are important to qualify instrumentation. However, shallower entries result in elevated in-depth temperatures in the thermal protection material leading to increased thickness and increased TPS mass as a consequence. Reductions in entry ballistic coefficient, due to increased aeroshell size, exhibit a reduction in heat load ~8% for the presented case study which could be an opportunity for the shallower entries that have higher total heat loads.

The proposed presentation will review the lessons learned from this parametric study for two case studies to inform the community for future giant planet missions.



**Fig. 1: Nominal cold wall stagnation aerothermal environments for Saturn near equatorial entry case study with varying aeroshell diameters and entry flight path angles**

**References:**

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