AEROTHERMAL DESIGN OF A COMMON PROBE FOR MULTIPLE PLANETARY DESTINATIONS.

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Introduction: The idea of a single design of a capsule, for atmospheric entry at Venus, Jupiter, Saturn, Uranus, and Neptune and delivery of payloads for *in situ* scientific experiments, is currently being pursued by a team of scientists and engineers drawn from four NASA centers – Ames, Langley, JPL, and Goddard [1].

For notional suites of instruments [2] (the selection depending on the destination), interplanetary trajectories have been developed by team members at JPL and Goddard [3]. Using the entry states provided by these trajectories, 3DOF atmospheric flight trajectories have been developed by Langley [4] and Ames [5]. The range of entry flight path angles for each destination is chosen such that the deceleration load lies between 50 g (shallow) and 150-200 g (steep) for a 1.5 m (diameter) rigid aeroshell based on a 45° sphere-cone geometry (Fig. 1) and an entry mass of 400 kg.

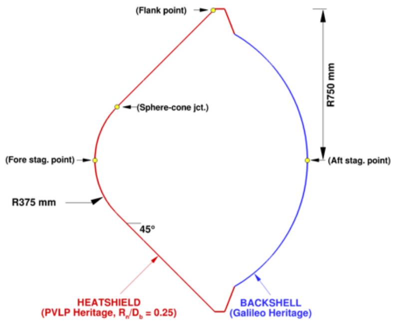

Figure 1. Reference geometry for the Common Probe. The backshell shape is notional.

Given the ambient densities and velocities along each of the flight trajectories from the 3DOF analyses, the aerothermal environments are estimated using standard correlations – Sutton-Graves [6] for convective heating, and Tauber [7] for radiative heating. The thermal protection materials are then sized using *FIAT* [8] together for several candidate materials for the heatshield and backshell: (i) fully-dense carbon phenolic (used on the Pioneer-Venus & Galileo probes); (ii) a dual-layer woven material called HEEET (new NASA technology); (iii) PICA (used on the Stardust probe); and (iv) appropriate backshell material(s).

Proposed Paper/Presentation: The presentation will focus on: (a) definition of aerothermal environments and associated uncertainties at – (i) the stagnation point, (ii) a point on the conical flank, and (iii) a point on the backshell for the various flight trajectories; (b) candidate materials and uncertainties in materials properties; and (c) margining policy. Margined TPS thicknesses that result from the analysis will be presented, along with the sensitivity of those thicknesses to: (i) the initial soak temperature, (ii) the maximum bondline temperature, and (iii) choice of structural material. Choosing the largest fully-margined thickness as the basis for the design of the TPS of the Common Probe, the design will be evaluated at all destinations to determine the degree of sub-optimality in the design.

As an example, results of zero-margin TPS mass estimates for fully-dense carbon-phenolic (FDCP) are presented in Table 1, along with mass estimates for HEEET for Venus (other destinations are still being analyzed). The sizing computations assume an aluminum structure to which the TPS is bonded.

Table 1. Results for zero-margin sizing of FDCP (all destinations), and HEEET for the case of Venus only.

Planet	V_E km.s^{-1}	γ_E deg	**Dec.** g	m_{TPS} kg	**Mat.**
Venus	10.93	-9	53	59.0 *27.3*	FDCP *HEEET*
		-16.8	135	39.0 *18.3*	FDCP *HEEET*
Jupiter	59.68	-4.1	73	165.6	FDCP
		-6.5	206	108.6	
Saturn	35.66	-11.9	51	102.4	FDCP
		-25.0	168	61.2	
Uranus	22.34	-16.5	51	101.5	FDCP
		35.0	205	54.9	
Neptune	24.73	-16.0	52	88.5	FDCP
		-23.0	177	57.0	

References:

[1] Hwang, H. H., *et al.* (2018) *15th IPPW*, Boulder, CO, June 11–15. [2] Atkinson, D. H., *et al.* (2018) *15th IPPW*, Boulder, CO, June 11–15. [3] Lobbia, M. A., *et al.* (2018) *15th IPPW*, Boulder, CO, June 11–15. [4] Dwyer-Cianciolo, A. *et al.* (2018) *15th IPPW*, Boulder, CO, June 11–15. [5] Allen, G. A., Jr., *et al.* (2005) NASA/TM-2005-212847. [6] Sutton, K. and Graves, A. G., Jr. (1971) *NASA TR-R 376*. [7] Tauber, M. E., *et al.* (1999) NASA/TM-1999-208796. [8] Milos, F. S. and Chen, Y.-K. (2013) *J. Spacecraft and Rockets*, **50**(1), pp.137-149.

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