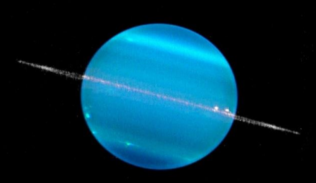
ENTRY PROBE STUDIES FOR ICE-GIANTS



Parul Agrawal[1*], Gary Allen Jr.*, Milad Mahzari, Helen Hwang, Don Ellerby, Ethiraj Venkatapathy

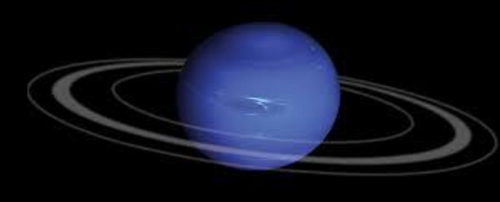
NASA Ames Research Center, Moffett Field, CA, 94035 * AMA

Nitin Arora, John Elliott

Jet Propulsion Laboratory, Pasadena, CA 91109

1. POC: parul.agrawal-1@nasa.gov

Phone: (650)-604-3764



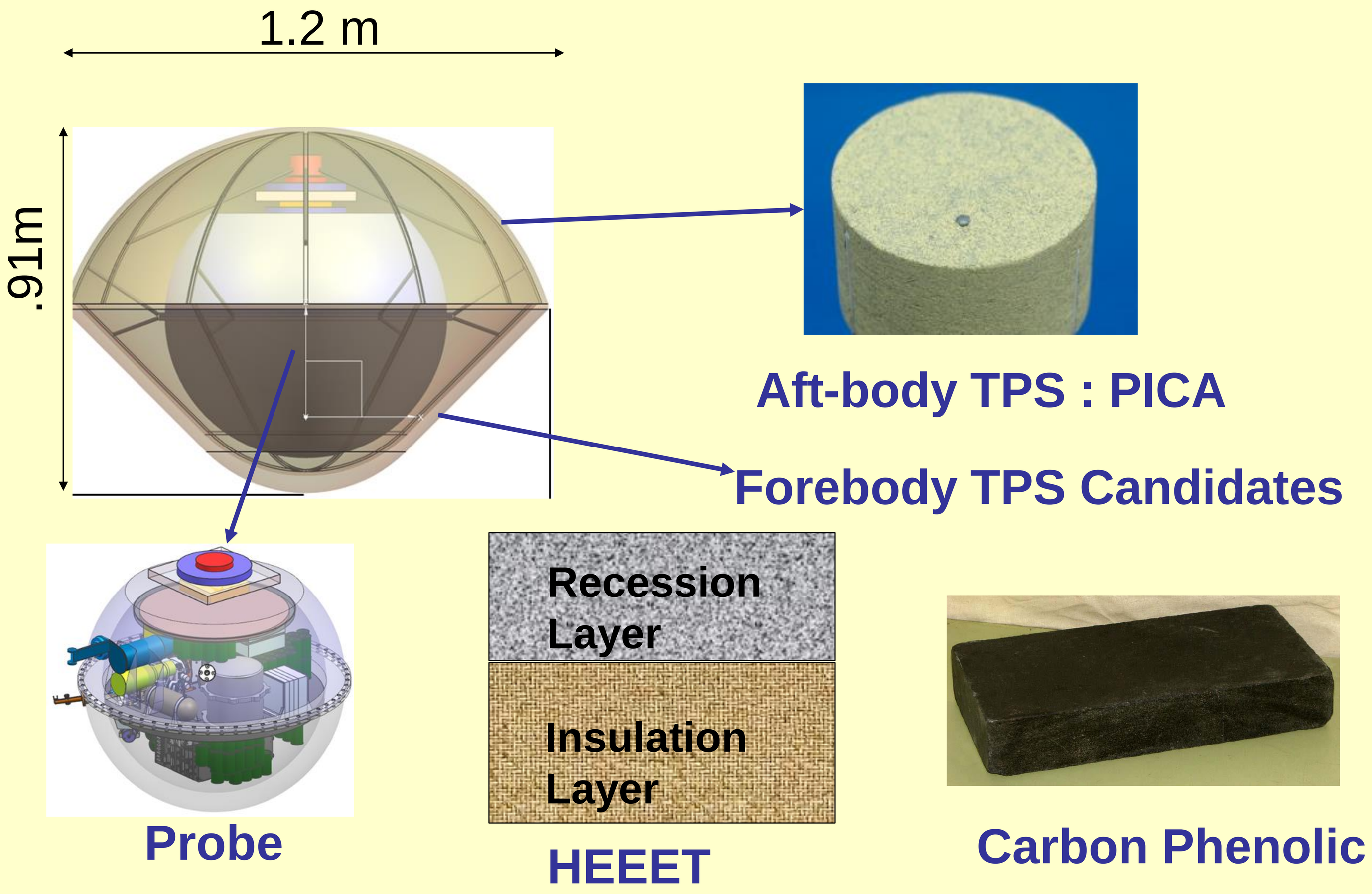
INTRODUCTION

- The Ice Giants Pre-Decadal Study was requested by NASA HQ as a new look at potential missions to the Ice-Giants
- Feasible mission concepts were investigated including probe entries
- The present study is part of the above study focusing on atmospheric entry analysis of the probes

OBJECTIVES

- Establish atmosphere definitions for probe entry analysis
- Investigate viable trajectory options for direct ballistic entry
- Determine feasible thermal protection (TPS) material
- Identify entry technologies that can be leveraged to enable a viable mission to Ice-Giants

PROBE WITH AEROSHELL



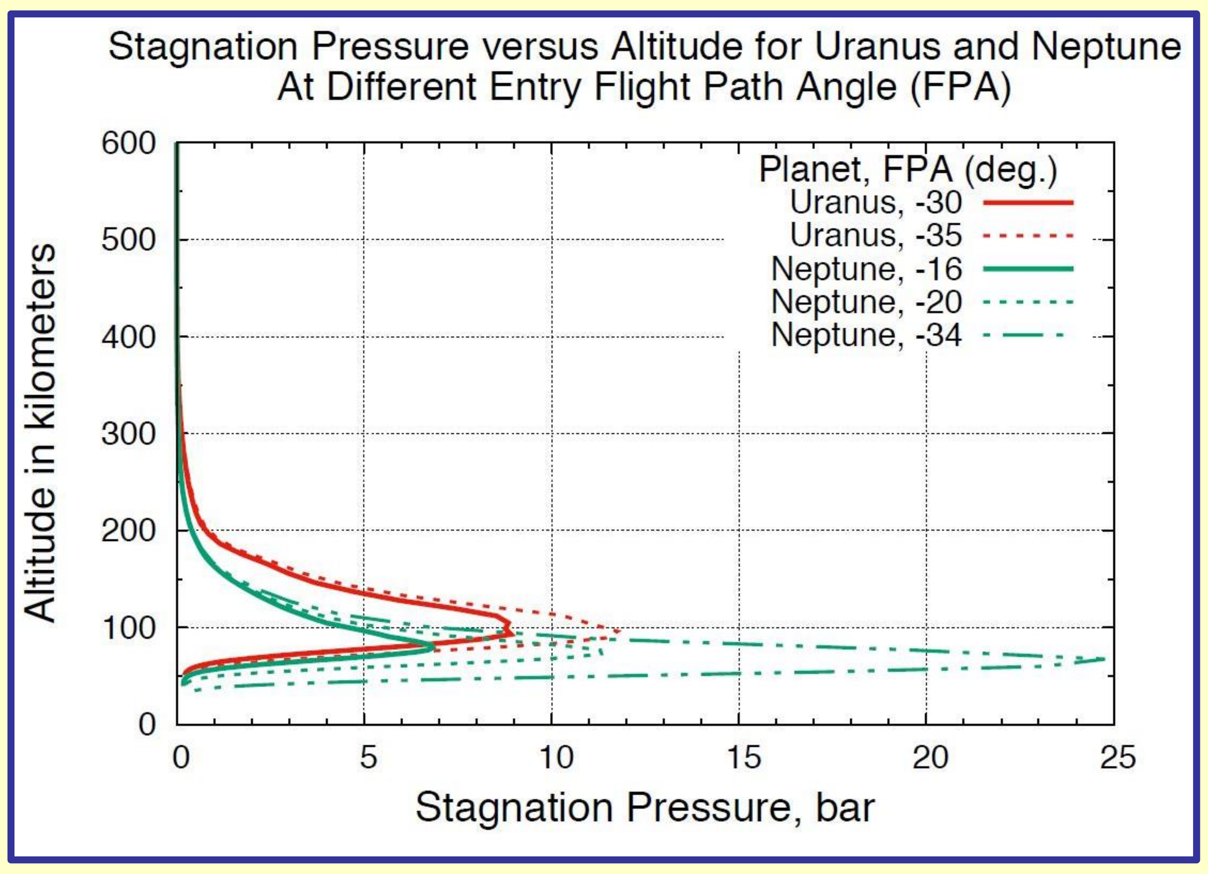
- 1.2 m diameter, 45 deg. sphere-cone scaled from Galileo with spherical backshell
- Total entry mass : ~325kg
- Probe mass of ~200kg delivered at 10bar

POINT DESIGNS FOR ENTRY TRAJECTORIES

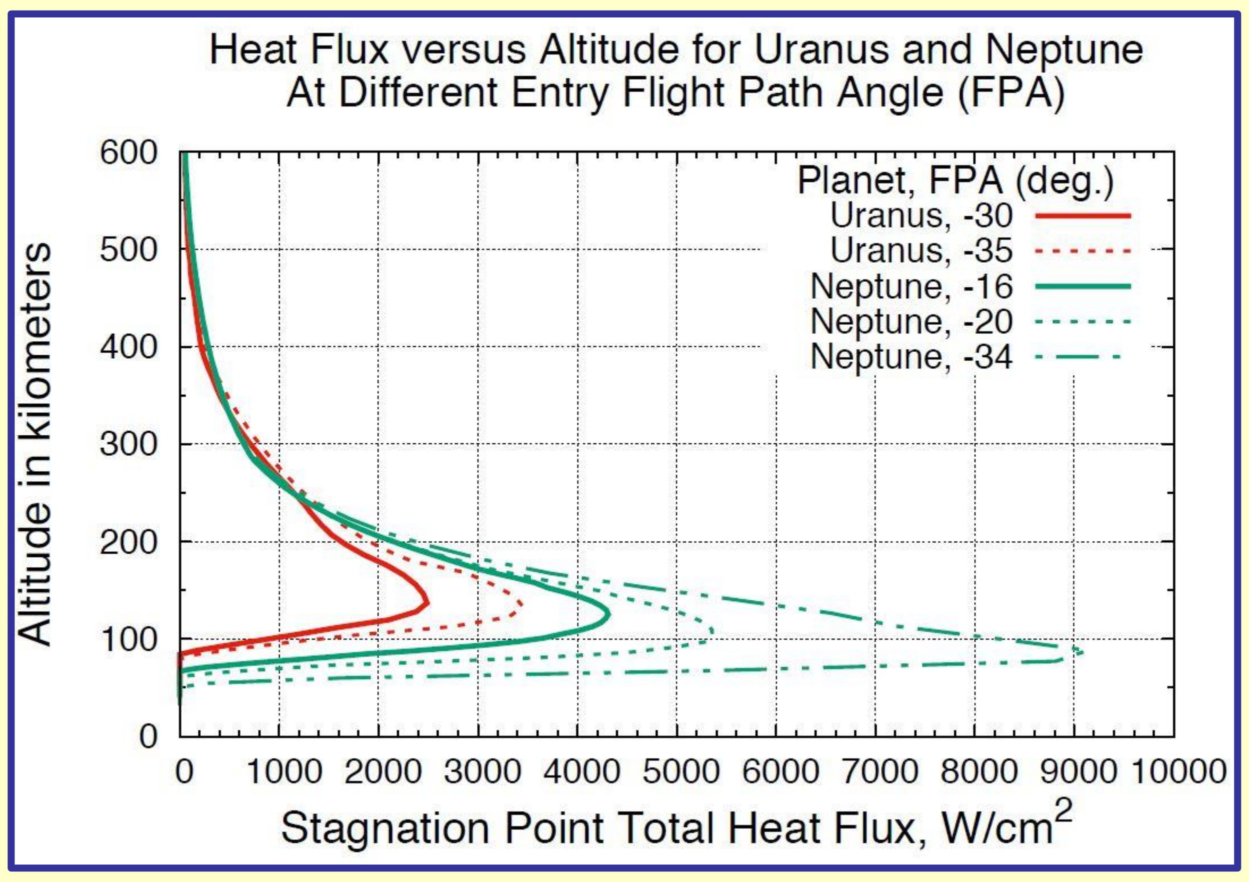
Planet	Uranus	Uranus	Neptune	Neptune	Neptune
Entry Parameters	Design # 1	Design # 2	Design # 3	Design # 4	Design # 5
Hyperbolic excess velocity (km/s)	9.9	8.4	12.3	11.3	11.4
Relative entry velocity (km/s)	23.1	21.9	28.8	28.4	28.5
Entry Flight Path Angle, gamma (deg)	-35.0	-30.0	-34.0	-20.0	-16.0
Max deceleration (g loads)	216.7	164.8	454.9	208.7	124.5
Stg Pressure (bar)	12.0	9.0	25.0	11.5	6.8
Total Peak Heat Flux (W/cm^2)	3456.0	2498.0	9635.0	5461.0	4379.0
Total heatload (J/cm^2)	43572.0	41114.0	81476.0	109671.0	133874.0
HEEET TPS Mass (kg)	Not Computed	29.0	Not Computed	39.0	47.0
CP TPS Mass (kg)		60.0		73.0	88.0
Feasible Design	Maybe	Yes	No	Maybe	Maybe

- Neptune has higher entry velocity compared to Uranus that causes significantly higher heat flux, deceleration and stagnation pressure for the same Entry Flight Path Angle (EFPA) .
- Shallower EFPA are needed for Neptune to have a viable TPS material. However, shallower trajectories are not ideal for communications. Further concept development is required to achieve a closed Neptune design.
- Based on stagnation point heating, simplified sizing was performed. Carbon Phenolic (CP) is twice as heavy compared to HEEET.

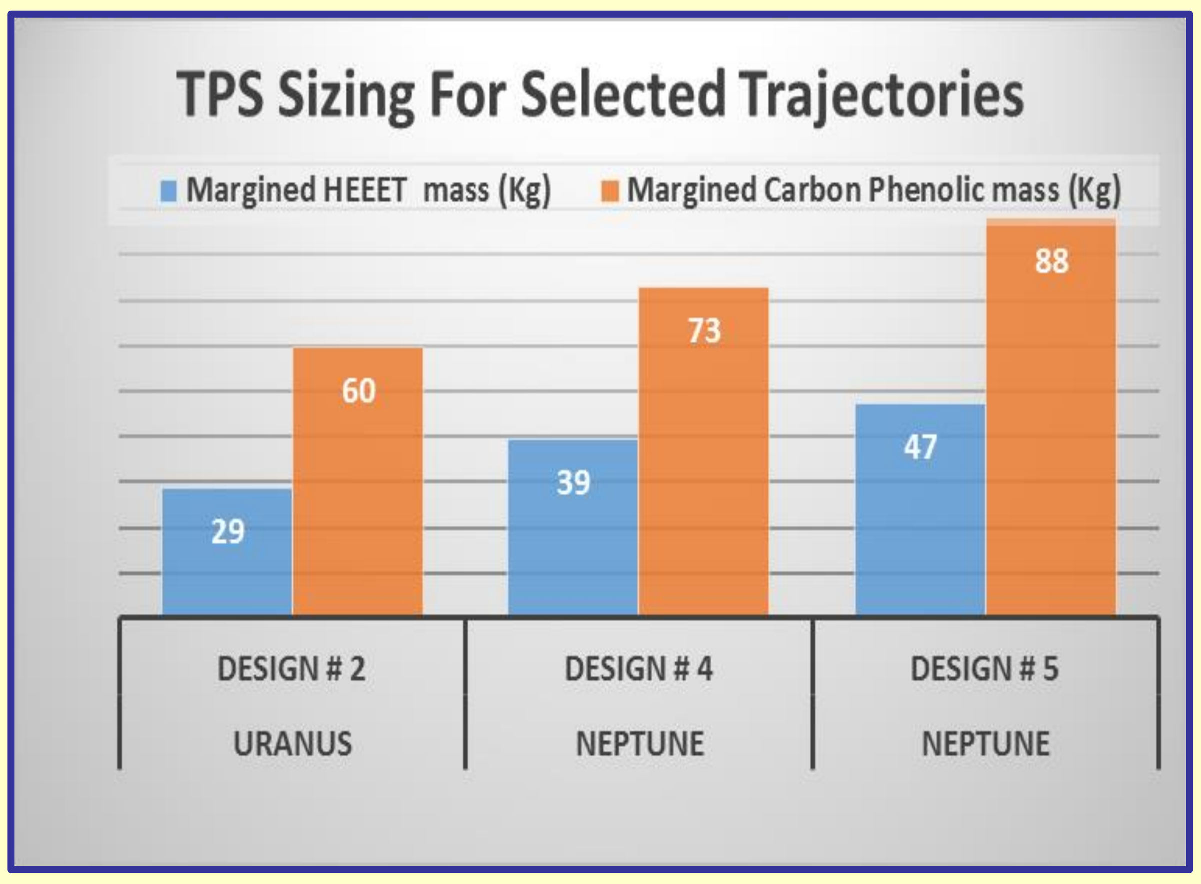
STAGNATION PRESSURE



ENTRY HEATING



TPS MASS



CONCLUSIONS

- Feasible mission design has to protect the probe and simultaneously allow sufficient time for communications
- We have a feasible design for Uranus entry. However, Neptune studies are incomplete and further work is needed to close the design
- While CP has flown at extreme conditions, heritage CP is no longer available. HEEET, a more efficient TPS is under development. It is anticipated that we will have extended performance envelope for HEEET in the next decade

RECOMMENDATIONS

- Design trades for EFPA, need to be performed early in the study to ensure proper communication and viable entry solution from TPS perspective
- The peak heating environments likely to change with higher fidelity CFD analysis. It is recommended as part of the next phase of the study
- Current ground test facility does not encompass relevant (H_2/He) testing. Investment in ground test capability at flight relevant conditions is recommended as part of future development

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