ENTRY PROBE STUDIES FOR ICE-GIANTS

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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

STAGNATION PRESSURE

ENTRY HEATING

• 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

TPS MASS

• 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

ACKNOWLEDGEMENTS: We acknowledge the support of NASA’s Science Mission Directorate and Jet Propulsion Laboratory for funding this study.

POINT DESIGNS FOR ENTRY TRAJECTORIES

<table>
<thead>
<tr>
<th>Planet</th>
<th>Entry Parameters</th>
<th>Design # 1</th>
<th>Design # 2</th>
<th>Design # 3</th>
<th>Design # 4</th>
<th>Design # 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>URANUS</td>
<td>Hyperbolic excess velocity (km/s)</td>
<td>9.9</td>
<td>8.4</td>
<td>12.3</td>
<td>11.3</td>
<td>11.4</td>
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<tr>
<td></td>
<td>Relative entry velocity (km/s)</td>
<td>23.1</td>
<td>21.9</td>
<td>28.8</td>
<td>28.4</td>
<td>28.5</td>
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<td></td>
<td>Entry Flight Path Angle, gamma (deg)</td>
<td>-35.0</td>
<td>-30.0</td>
<td>-34.0</td>
<td>-20.0</td>
<td>-16.0</td>
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<td></td>
<td>Max deceleration (g loads)</td>
<td>216.7</td>
<td>164.8</td>
<td>454.9</td>
<td>208.7</td>
<td>124.5</td>
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<tr>
<td></td>
<td>Stg Pressure (bar)</td>
<td>12.0</td>
<td>9.0</td>
<td>25.0</td>
<td>11.0</td>
<td>6.8</td>
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<tr>
<td></td>
<td>Total Peak Heat Flux (W/cm$^2$)</td>
<td>3456.0</td>
<td>2498.0</td>
<td>9635.0</td>
<td>5461.0</td>
<td>4379.0</td>
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<td>Total heatload (J/cm$^2$)</td>
<td>43572.0</td>
<td>41114.0</td>
<td>81476.0</td>
<td>109671.0</td>
<td>133874.0</td>
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<td>HEEET TPS Mass (kg)</td>
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<td>Not</td>
<td>39.0</td>
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<td>CP TPS Mass (kg)</td>
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<td>Computed</td>
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<td>88.0</td>
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<td>Feasible Design</td>
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<td>No</td>
<td>Maybe</td>
<td>Maybe</td>
</tr>
</tbody>
</table>

CONSULTATION

B. Machhi, T. Nguyen, Meinzer, R. Arora, J. Elliot

RECOMMENDATIONS

1. Further concept development is required to achieve a closed Neptune design
2. Based on stagnation point heating, simplified sizing was performed. Carbon Phenolic (CP) is twice as heavy compared to HEEET.

Graphs showing stagnation pressure and entry heating for Uranus and Neptune at different entry flight path angles (EFPA) are included. TPS mass comparison is also shown for selected trajectories.