A Common Probe Design for Multiple Planetary Destinations

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Introduction and Background

The Planetary Science Division of the NASA Science Mission Directorate funded a study from October 2017 – June 2018, involving 4 NASA Centers (ARC, GSFC, JPL, and LaRC), to address if a common aeroshell design could be utilized at multiple destinations instead of optimizing a design for a specific mission. If this common design were built with several copies, what efficiencies and risks would be involved?

Study Scope and Assumptions

- Venus, Jupiter, Saturn, Uranus, and Neptune considered as destinations
- Atmospheric probe missions (no large landers at Venus)
- Carrier Spacecraft provides power and telecommunications (details not studied)
- Details of science instrumentation and descent vehicle not studied
- Leverage previous mission designs and high-fidelity analysis; use mid-fidelity tools for design estimates

Interplanetary Trajectories

Assumptions:
- Launch vehicle with current all-chemical capabilities (AV)
- Time of flight < 15 years
- “Shallow” (50-g) and “steep” (150 – 200-g) trajectories for each destination

Entry and Descent Concept of Operations

- Two different scenarios examined:
  - 1 main conical ribbon parachute, 2 m diameter
  - 1 pilot (1 m) + 1 main, sized for each destination
- Both options are feasible, indicating mission design flexibility.

Strawman Payloads

Descent module of 0.75 m diameter estimated to accommodate Tier 1 and Tier 2 science instruments to all destinations

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurement</th>
</tr>
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<tbody>
<tr>
<td>Tier 1</td>
<td></td>
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<tr>
<td>Mass Spectrometer</td>
<td>Elemental and isotopic composition, especially noble gases, and trace volatiles</td>
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<tr>
<td>Atmospheric Structure Instrument (ASI)</td>
<td>Temperature and pressure, especially noble gases, and trace volatiles</td>
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<tr>
<td>Radios Science Experiment</td>
<td>Atmospheric, composition, and physics of the atmosphere</td>
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<td>Nephelometer</td>
<td>Cloud structure, vertical number density, and characteristics</td>
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<td>Net Flux Radiometer</td>
<td>Net radiative fluxes, thermistor, solar visible</td>
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<tr>
<td>Tier 2</td>
<td></td>
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TPS Sizing

- Aerothermal environments (radiative + convective heating) estimated on the forebody stagnation point using a 3DOF simulation, TRAJ
- 2 forebody materials considered: HEEET and FDCP, sized using FIAT
- Backshell TPS assumed to be PICA: mass estimated based on forebody stagnation point environments
- Common TPS thickness viable for 4 destinations but not Jupiter (heat loads 10x higher)
- TPS mass fraction in-family with historical missions

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Assumptions:
- Estimated 10-100x savings could be realized using a common design
- Leveraging previous design and high-fidelity tools (CFD, structural analysis) for better mass estimates
- Design can alleviate sustainability issues, but introduces new risks:
  - Long term storage and aging of the system
  - Will HEEET and a cyanate ester composite structure age at the same rate when bonded together?
  - Can accelerated aging coupon tests be performed?
- Galileo and Phoenix are data points for ground storage
- Quality of the design across multiple destinations
- Preliminary costing which estimates the non-recurring vs recurring engineering portions indicates that cost savings could be realized by building multiple units at the same time

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Study Team Members

NASA Ames Research Center
- NASA Goddard Space Flight Center (GSFC)
- NASA Langley Research Center (LaRC)

Jet Propulsion Laboratory (JPL)
- David A. Atkinson
- Bernie J. Binstock
- John O. Elliott
- Mark D. Hofstadter
- Marcus A. Lobbia
- Kim R. Rh

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Summary and Future Work

- A common atmospheric probe design for Venus, Saturn, Uranus, and Neptune missions is feasible
- Missions to Jupiter should be considered separately due to out-of-family heat loads
- Follow-on activities are recommended:
  - Should a smaller descent module and aeroshell be studied?
  - Higher fidelity tools (CFD, structural analysis, etc) for better mass estimates
  - Better cost estimates
- Final report is in progress, will be submitted to PSD
- Community feedback is desired—what other activities are desired by mission designers?

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