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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

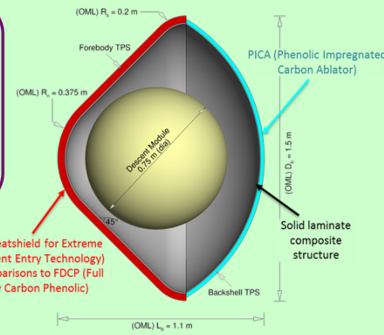
Study Team Members

NASA Ames Research Center (ARC)
- –Gary A. Allen, Jr. (AMA, Inc.)
- –Antonella I. Alunni (AMA, Inc.)
- –Jay D. Feldman
- –Frank S. Milos
- –Keith H. Peterson
- –Dinesh K. Prabhu (AMA, Inc.)
- –Todd R. White

NASA Goddard Space Flight Center (GSFC)
- –Michael J. Amato
- –Greg C. Marr
- –Kyle M. Hughes

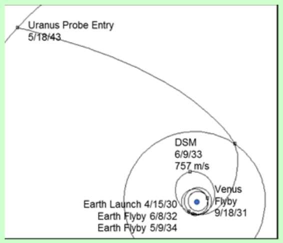
NASA Langley Research Center (LaRC)
- –Juan R. Cruz
- –Robert A. Dillman
- –Soumyo Dutta
- –Alicia Dwyer-Cianciolo

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



	Base diameter (m)	Nose radius (m)	Ballistic Coefficient (kg/m²)	Entry mass (kg)
Common Probe	1.5	0.375	216	400
PVLP	1.42	0.36	188	316
Galileo	1.26	0.222	256	335

Interplanetary Trajectories



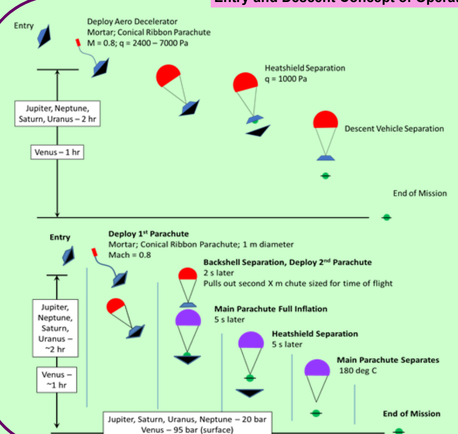
Assumptions:
- Launch vehicle with current all-chemical capabilities (ΔV)
- Time of flight < 15 years
- "Shallow" (50-g) and "steep" (150 – 200-g) trajectories for each destination

Strawman Payloads

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

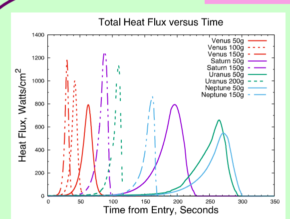
	Instrument	Measurement
Tier 1	Mass Spectrometer	Elemental and chemical composition, especially noble gases and key isotopes
	Atmospheric Structure Instrument (ASI)	Pressure and Temperature → Thermal Structure, Density, Stability Entry Accelerations → Density
Tier 2	Radio Science Experiment	Atmospheric dynamics: winds and waves; atmospheric absorption → composition
	Nephelometer	Cloud structure, aerosol number densities & characteristics
	Net Flux Radiometer	Net radiative fluxes: Thermal IR, solar visible

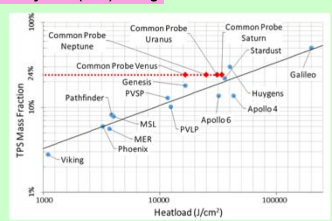
Entry and Descent Concept of Operations

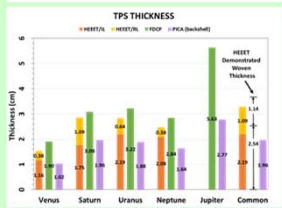


- Two different scenarios examined:
  - 1 main conical ribbon parachute, 2 m diam
  - 1 pilot (1 m) + 1 main, sized for each destination
- Both options are feasible, indicating mission design flexibility.

Thermal Protection System (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

Risks and Efficiencies

- Typically, probes are designed and optimized based on specific mission needs.
- Building a probe once a decade has sustainability issues
  - Maintaining heritage material availability (e.g., precursor and constituents to carbon phenolic)
  - Skilled labor for assembly and integration (HEEET requires use of gap fillers and specially-developed integration techniques)
- Building multiple copies of a common design can alleviate the 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
  - Qualification 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

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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Is it possible to “disrupt” the atmospheric probe mission design paradigm by designing and building an aeroshell that could be flown at Venus, Jupiter, Saturn, Uranus, and Neptune? Come find out!