



Thermal Testing of Planetary Probe TPS in Extreme Entry Environments

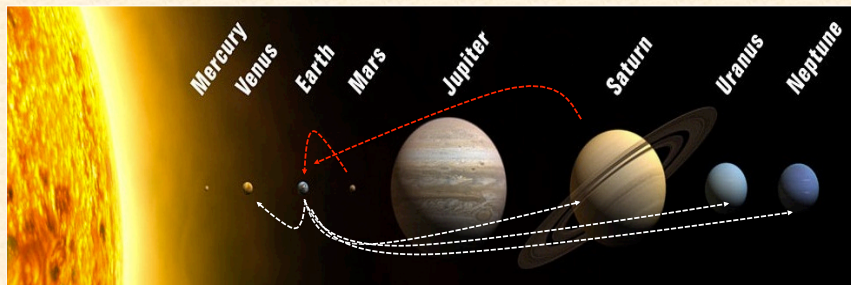
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Introduction – Need for Extreme Entry Environment TPS

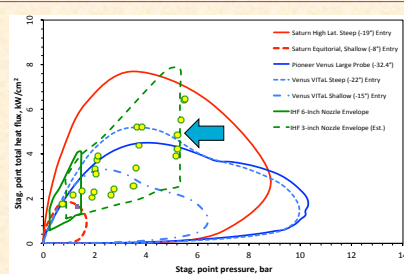
- In 2013 the National Research Council (NRC) Planetary Science Decadal Survey (PSDS) committee recommended several in-situ robotic science missions to the inner and outer planets
- Desired missions include:
 - Venus probes and landers
 - Saturn probes
 - Uranus probes
 - High speed sample return missions from Mars or moons of the outer planets

- The missions proposed by the PSDS require TPS capable of extreme environments
- Since there have been no missions to Venus or the Outer Planets since the Galileo mission to Jupiter in the 1980's, NASA has had to re-invest in methods to certify TPS for extreme entry conditions

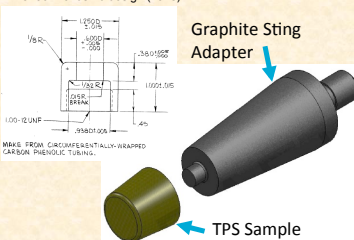


Testing Approach

- Drew upon heritage Pioneer Venus / Galileo test configurations to design test article geometries
- Utilized modern CFD capabilities to refine test article configurations, position within test facilities and estimate arc heater settings
- IHF 3-inch nozzle design and fabrication was supported by NASA's SMD
- Model design and test support modifications for AEDC testing supported by AEDC/DoD
- LHMEL testing utilized heritage Carbon Phenolic test techniques used to qualify material for Shuttle solid rocket motors
- Test articles included fully dense tape wrap and chop molded carbon phenolic as well as novel 3D woven TPS sample from the Heatshield for Extreme Entry Environment Technology (HEEET) project



Pioneer Venus AJ design (1978)

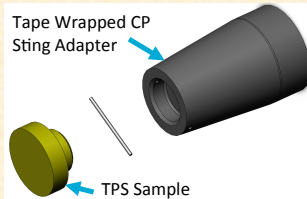
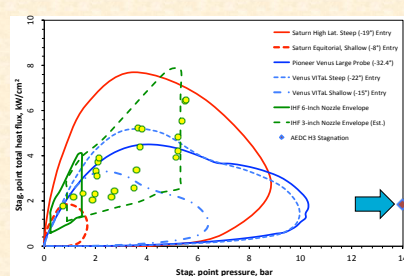


Arc Jet (IHF 3-Inch Nozzle, NASA)

Testing Conditions:

- Cold Wall Heat Rate: ~5000 W/cm²
- Stagnation pressure ~ 5 atm, air
- 1-Inch diameter flat face model geometry

Benefits	Drawbacks
<ul style="list-style-type: none"> High heat flux and pressure in a simulated entry environment 	<ul style="list-style-type: none"> Small PV-like sample required for high heating Limited instrumentation or testing of seams (e.g. non-creage features)

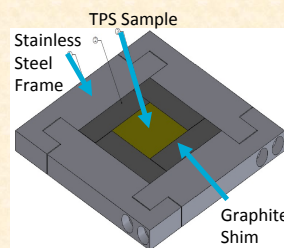
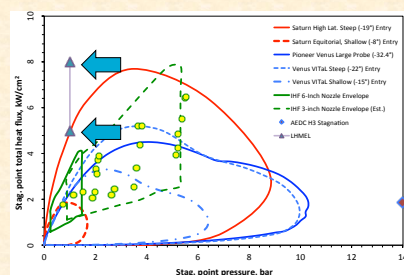


Arc Jet (H3, AEDC)

Testing Conditions:

- Cold Wall Heat Rate: ~1850 W/cm²
- Stagnation pressure ~ 14 atm, air
- 2-Inch diameter flat-face model geometry

Benefits	Drawbacks
<ul style="list-style-type: none"> Highest pressure capability in a simulated entry environment 	<ul style="list-style-type: none"> Slight over-test of pressure



Laser (LHMEL 2, WP Air Force Base)

Testing Conditions:

- Cold Wall Heat Rate: 5000 & 8000 W/cm²
- Stagnation pressure 1 atm, N₂
- 1.5-Inch square flat-face model geometry

Benefits	Drawbacks
<ul style="list-style-type: none"> Extremely high heat flux on relatively large samples Used to screen out failure modes in carbon phenolic for DoD RV's 	<ul style="list-style-type: none"> Limited to 1 atm Cross-flow of N₂ not representative of hypersonic entry

Summary

- Testing of TPS for extreme entry environments is required for any future missions to Venus or the outer planets as recommended in the 2013 Planetary Science Decadal Survey
- New testing capabilities at NASA/AEDC/LHMEL show encouraging results evaluating TPS in extreme environments. Very high heat flux testing at LHMEL has heritage in evaluation of carbon phenolic screening; demonstrated TPS capability at highest Venus and Saturn heating

Acknowledgements

This work was performed under the STMD/GCDP funded Heatshield for Extreme Entry Environment (HEEET) Program. SMD supported the HEET formulation activity and funded the 3-in nozzle. Special thanks to Dinesh Prabhu for CFD analysis in support of these IHF and AEDC test advancements. Thanks also to the staff at AEDC and NASA Ames and LHMEL for all of their amazing test support.