VENUS INSTRUMENTATION FOR THERMOPHYSICS AND AEROSCIENCES

VISTA Overview

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NASA Ames Research Center | Langley Research Center | Goddard Space Flight Center | Lockheed Martin | DAVINCI

Background

- DAVINCI (Deep Atmosphere Venus Investigation of Nobel gases, Chemistry, and Imaging) was selected from the 2019 Discovery Program solicitation.
- Engineering Science Investigation (ESI) was required for mission concepts involving Entry, Descent, and Landing (EDL).
- VISTA (Venus Instrumentation for Thermophysics and Aerosciences) is the ESI instrumentation suite for the DAVINCI mission.
- VISTA will be the first EDL aeroshell measurements recorded at Venus since NASA's Pioneer Venus Program in 1978!
  - The Thermal Protection System (TPS) was carbon-phenolic and the instrumentation included 1 thermocouple (TC) near the stagnation point and 1 TC near the shoulder [Ref. 2].

Excerpt from the Engineering Science Investigation (ESI) Goals and Objectives document for the 2019 Discovery program

> Clearly, obtaining EDL data is critical to designing and executing future missions; moreover, missions that involve entering planetary atmospheres are rare opportunities to collect relevant EDL flight data. Mission concepts for this Discovery opportunity that involve EDL into an atmosphere of a Solar System object (including the Earth) shall include an Engineering Science Investigation (ESI), to be funded outside of the cost cap, to obtain diagnostic and technical data about vehicle performance and entry environments. Details on the goals and objectives of this ESI are given in the following sections.

Ref. 1

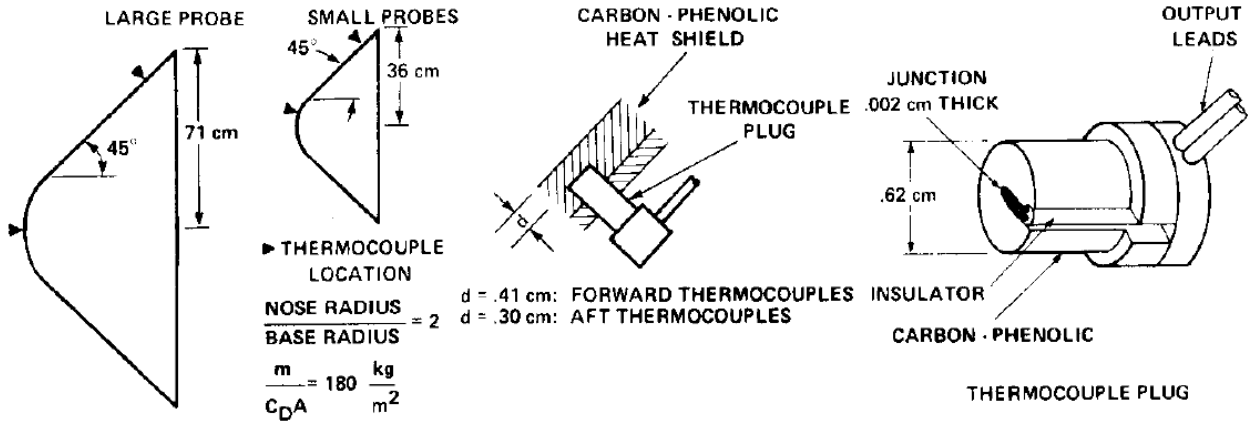
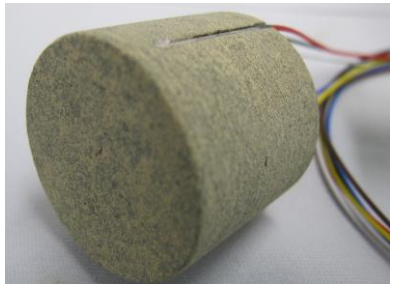


Fig. 2 Details of entry probes and heat-shield thermocouple installations. Ref. 2

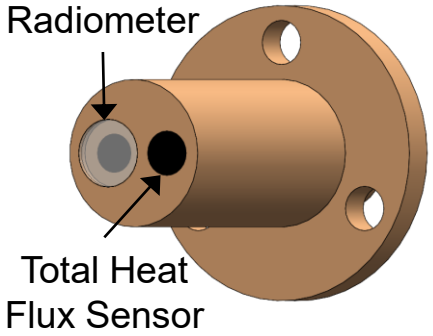
VISTA Instrumentation Suite

- Thermocouple (TC) Plug
  - TCs embedded at two depths within forebody Thermal Protection System (TPS) plugs. Enables aerothermal environment reconstruction and TPS material response validation.



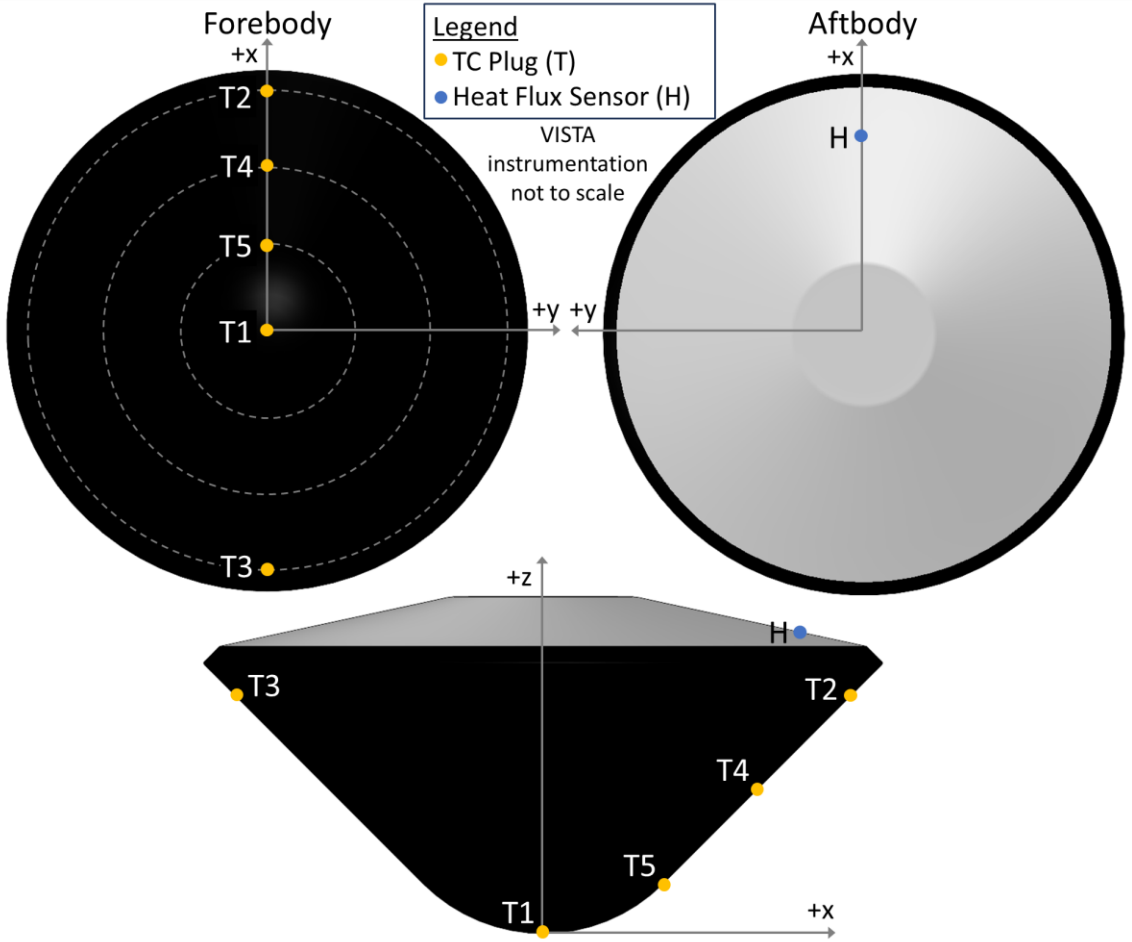
Example TC plug from MEDLI2

- Dual Heat Flux Sensor
  - Total and radiative heat flux sensor in the same housing mounted flush with the backshell TPS. Enables understanding radiative and convective heating at the same location on the vehicle.



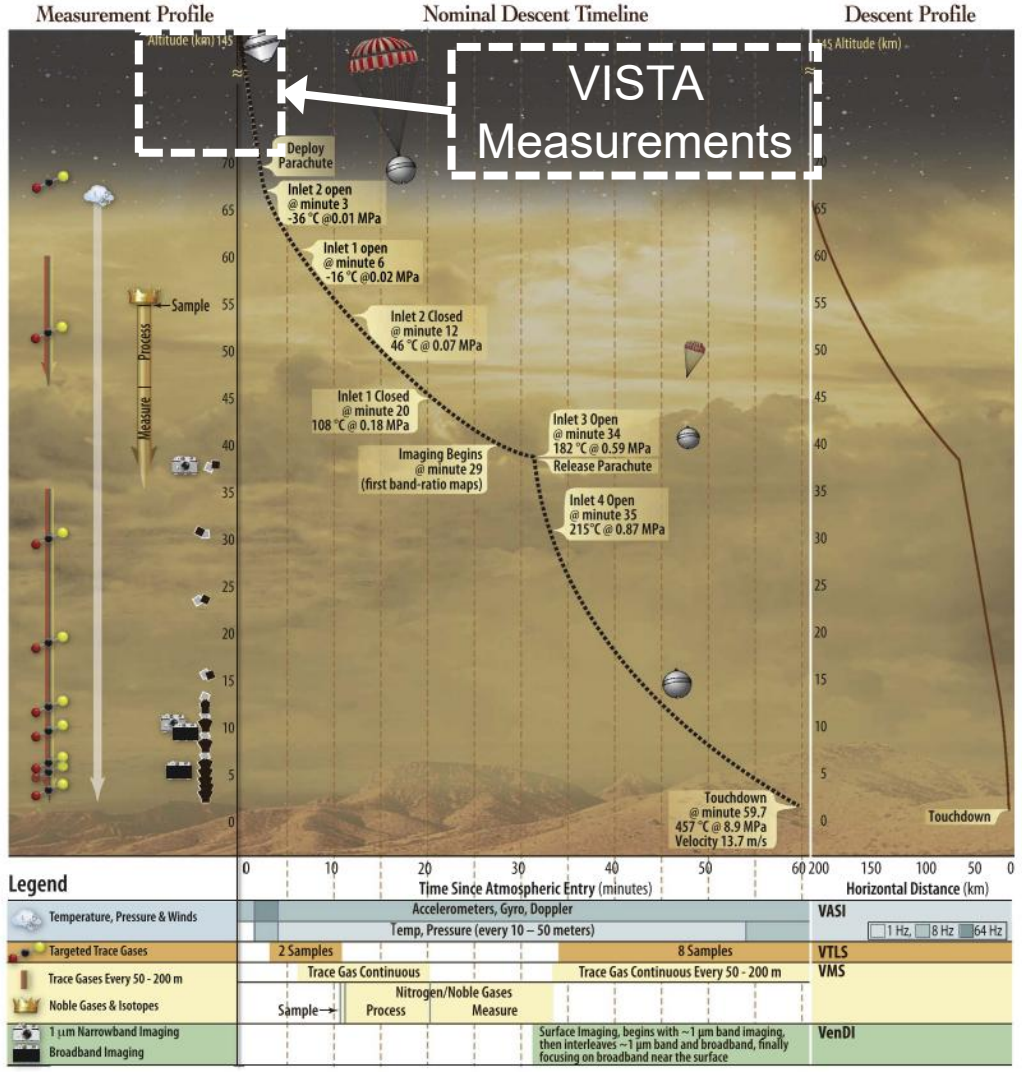
Example Dual Heat Flux Sensor

Proposed VISTA Sensor Layout



ConOps and Trajectory

- Timeline
  - VISTA sensor data acquisition begins prior to Venus atmospheric entry interface and continues down to ~70 km when the backshell separates, pilot/main parachutes deploy, and the heatshield is jettisoned
- Data Acquisition
  - Entry System (ES) avionics reads and conditions the VISTA data
  - ES avionics transmits the data to the Descent Sphere (DS)
  - DS relays data via telemetry and S-band RF system to the spacecraft
  - Spacecraft transmits data back to Earth
- Entry Trajectory Reconstruction
  - Venus Atmospheric Structure Investigation (VASI) is one of the primary instruments on the DAVINCI DS [Ref. 3]
    - VASI's primary objective is to characterize the structure & dynamics of Venus's atmosphere (every ~15m from 67 km to surface)
    - Atmospheric pressure and temperature sensors, atmospheric wind measurements, accelerometers, and angular rate sensors
  - Accelerometers and angular rate sensors are powered on prior to atmospheric entry and used for entry trajectory reconstruction



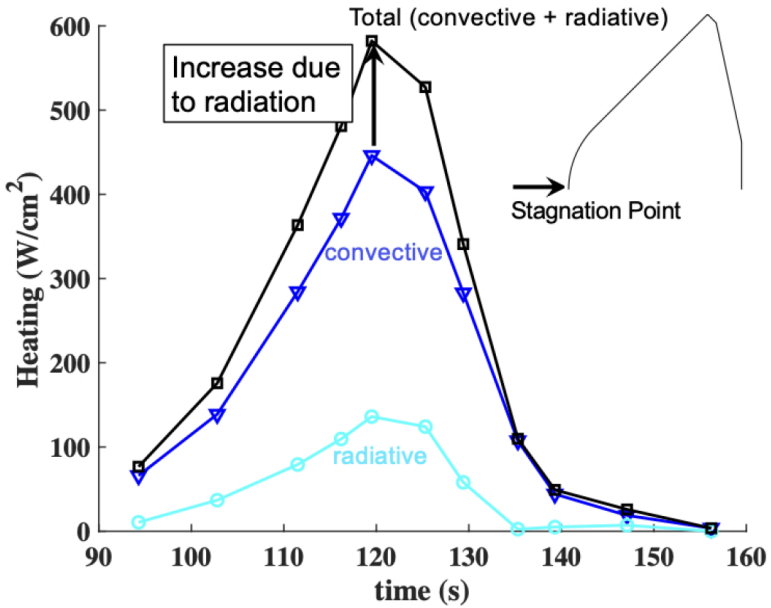
Adapted from Ref. 4

Science Objectives: TC Plugs

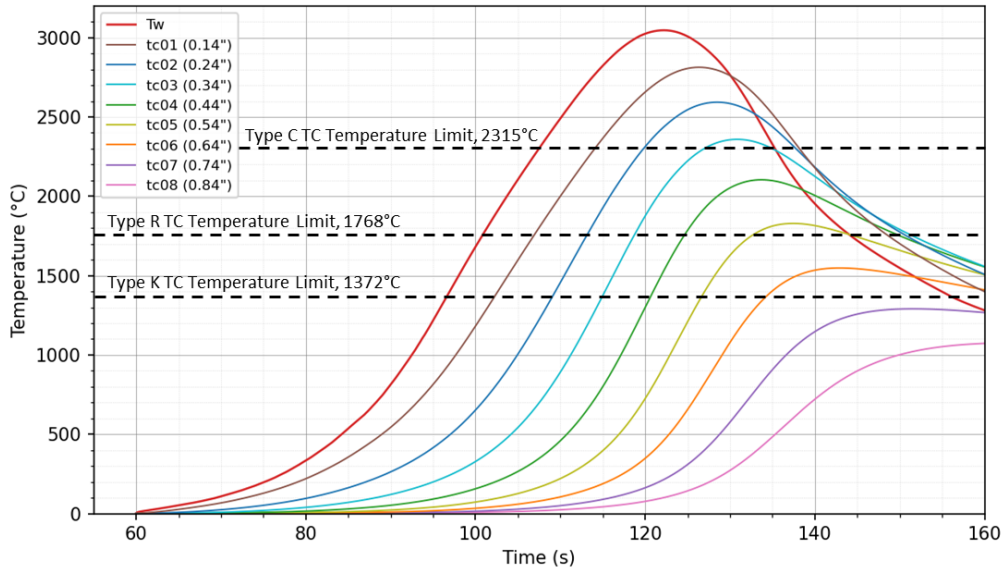
- Infer the aerothermal environment across the forebody through inverse analysis using near surface TCs
- Determine when the flow across the forebody transitions away from laminar flow using near surface TCs
- Assess the heatshield TPS material response performance using near surface and in-depth TCs

	Nominal Peak Heating (W/cm^2)	Uncertainty Bounds (%)
Convective	446	+30/-64
Radiative	136	+134/-50

Initial Stagnation Point Heating Predictions



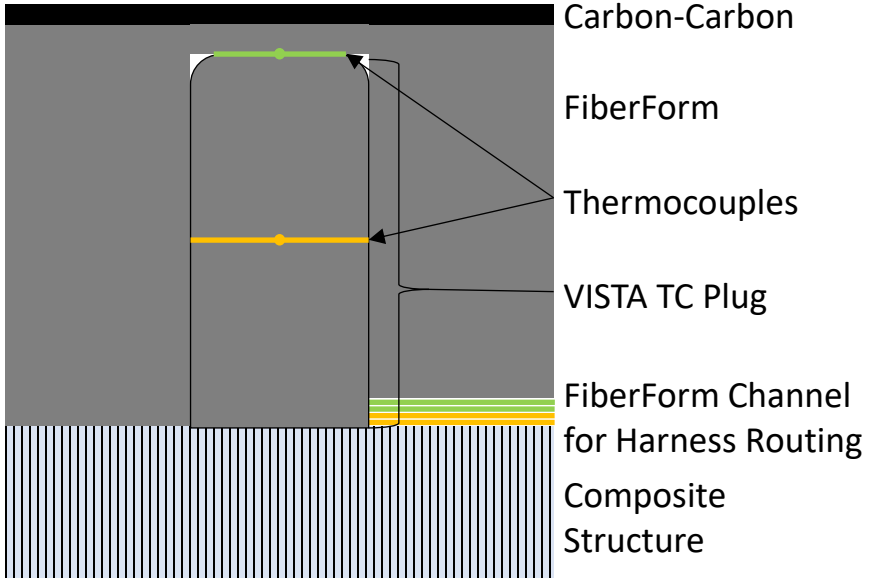
Initial Stagnation Point In-Depth Thermal Predictions



Improve Venus aerothermal models and Carbon-Carbon/FiberForm material response models

Technical Approach: TC Plugs

- TC plug embedded in the FiberForm TPS on the forebody
  - Installed from the Inner Mold Line (IML) side of the TPS material stack-up
  - 1 near-surface TC and 1 in-depth TC
- TC plugs at five locations on the heatshield
- TC plug fabrication leverages NASA ARC in-house processes based on experience from prior missions (e.g., MEDLI, MEDLI2, DrEAM)
- Lockheed Martin Space (LMS) installs the VISTA TC plugs on the heatshield



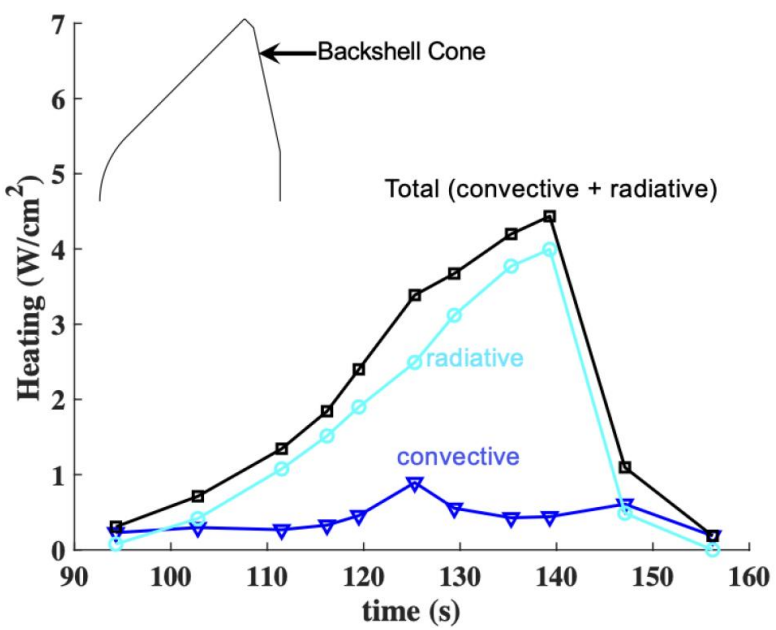
- VISTA is conducting a pathfinder test campaign to define technical details of the TC plug design and interface with the FiberForm
  - Includes suite of developmental tests: shock, vibration, TVAC, bending test, and HyMETS arc jet
- Recommendation of plug geometry, required tolerances, and TC types will be made after concluding the pathfinder tests

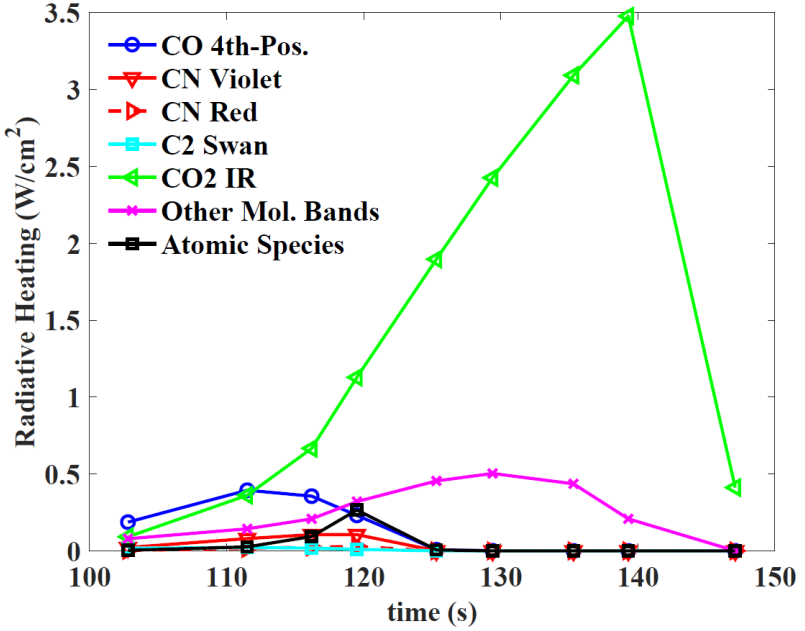
Science Objectives: Dual Heat Flux Sensor

- Measure the aftbody aerothermal environment using a dual heat flux sensor

	Nominal Peak Heating (W/cm^2)	Uncertainty Bounds (%)
Convective	1.0	+70/-25
Radiative	4.0	+72/-50

Initial Backshell Cone Heating Predictions





Improve Venus entry backshell aerothermal models

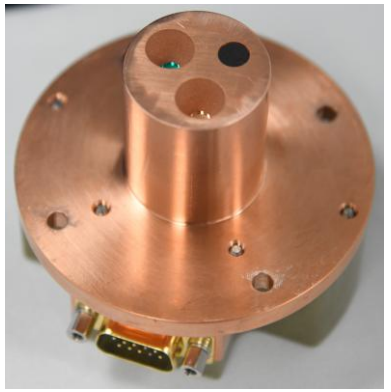
Technical Approach: Dual Heat Flux Sensor

- MEDLI2 flew 2 backshell total heat flux sensors and 1 radiometer as separate units [Ref. 5]
- DrEAM will fly combined total heat flux sensor and narrowband radiometer units on the Dragonfly backshell [Ref. 6]
- DAVINCI has the same backshell TPS as Mars 2020 and Dragonfly (SLA-561V). Plan to use same heat flux sensor integration method as MEDLI2 and DrEAM.
  - Installation on the backshell will be performed by LMS
- Environmental loads for DAVINCI compared to previous missions will be evaluated and required testing determined.

Mars2020 Forebody and Backshell

MEDLI2 Total Heat Flux Sensor

MEDLI2 Radiometer



DrEAM Total Heat Flux Sensor and Narrowband Radiometers

Summary

- The VISTA instrumentation suite will collect valuable data during DAVINCI's entry in the Venusian atmosphere
- VISTA's 5 forebody TC plugs and 1 backshell dual heat flux sensor will enable aerothermal model improvement, reduce heating uncertainty, and Carbon-Carbon/FiberForm material response model validation
- Hardware Investment
  - Previous entry instrumentation suites included TC plugs which were integrated from the Outer Mold Line (OML). VISTA TC plugs will be installed from the IML.
  - VISTA is pushing the envelope of TC plugs and is developing new installation methodologies and exploring TCs with higher temperature measurement ranges.
- Science Investment
  - Previous entry instrumentation suites taught us a lot about calibration, manufacturing, and data analysis. These data are being used to develop and validate models used for subsequent missions.
  - However, the physics and chemistry mechanisms are significantly different at Venus.

References

1. “Entry, Descent and Landing (EDL) Instrumentation Engineering Science Investigation (ESI) Goals and Objectives for Discovery”, NASA, May 2019, Version 1.1.
2. Lorenz, R. D., et al., “Venus Atmospheric Structure Investigation (VASI) on the DAVINCI Probe: 4 Years Post-Selection,” IEEE Aerospace Conference, Big Sky, MT, March 2026.
3. Wakefield, R. M., and Pitts, W. C., “Analysis of the heat-shield experiment on the pioneer-Venus entry probes,” AIAA 15th Thermophysics Conference, Snowmass, CO, July 1980.
4. Garvin, J. B., at al., “Revealing the Mysteries of Venus: The DAVINCI Mission,” The Planetary Science Journal, 3:117, 2022.
5. Miller, R. A., et al., “Aftbody Heat Flux Measurements During Mars 2020 Entry,” JSR, Vol. 61, No. 2, 2024.
6. Brandis, A. M., et al., “DrEAM Status Approaching Aeroshell Integration,” 23rd International Planetary Probe Workshop, Washington, DC, June 2026.

Thank you!
Questions?