

HEATING AND SAMPLING EFFICIENCY EVALUATION FOR THE NEPHELE VENUS CLOUD SAMPLING MISSION CONCEPT.

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Brief Presenter Biography: Dr. Arnaud Borner is the Technical Lead for the Thermal Protection Materials Branch at NASA Ames Research Center. His research interests combine DSMC, microscale materials modeling, and Venus mission concepts.

Mission Concept Summary: Nephele [1] is a descent probe concept with a unique combination of entry (3D-CC+HEET), sampling (flow-through passive impactors), and optics (laser-induced breakdown spectroscopy, or LIBS, and surface-enhanced Raman spectroscopy, or SERS), technologies with two key innovations (Figure 1). The first is the integration of the aerosol sampling inlet into the aeroshell body, allowing the possibility of sampling during passive descent without separation. The second is the use of the aerosol capture surface as an optical analysis substrate, allowing fast-cadence aerosol analysis via a dual optical spectrometer instead of mass spectrometry.

Although this concept shares some features with other efforts such as Cupid's Arrow [1] (single-body sample capture system), DAVINCI [2] and Venera-D [3] (use of an optical spectrometer), Nephele is unique in its physical integration of the sonde body, aerosol and gas sampler, and analysis instrumentation. This innovation is designed to eliminate the need for a controlled descent to achieve a detailed atmospheric aerosol transect, which offers *in situ* planetary science in a small spacecraft envelope. Aeroshell designs with inlets for free-falling sondes are well-understood, though not yet assessed for aerosol capture efficiency. A HEEET aeroshell with a specialized nose inlet material comprised of Carbon-Carbon is proposed for this mission concept.

Objectives & Technical Approach: Challenges unique to planetary environments that this work addresses include (1) the short time and high speed of a descent trajectory and (2) the residual heat and rapid cooling experienced post-entry. We performed hypersonic flow simulations in order to address the first major potential risk identified for the mission concept: characterize the kinetic heating at the inlet to avoid sample destruction. Additionally, we then performed material response simulations for our heat shield materials in order to assess the surface temperature in the inlet throughout our entry trajectory. Finally, we coupled the CFD and material response simulations in

order to assess outgassing contamination in the sampling inlet.

A second major objective of this work aims at demonstrating capture efficiency and delivery for aerosol mixtures to be sufficient for elemental and molecular characterization. To that effect, we performed particle tracking simulations using OpenFOAM to simulate the subsonic flow through the sampling path. In the future, matching experiments will be performed in the NASA Ames' Fluid Mechanics Laboratory wind tunnel. The matching parameters will be the Reynolds and Stokes numbers. This latter study will allow us to optimize the geometry of the sampling inlet in order to maximize the sampling efficiency.

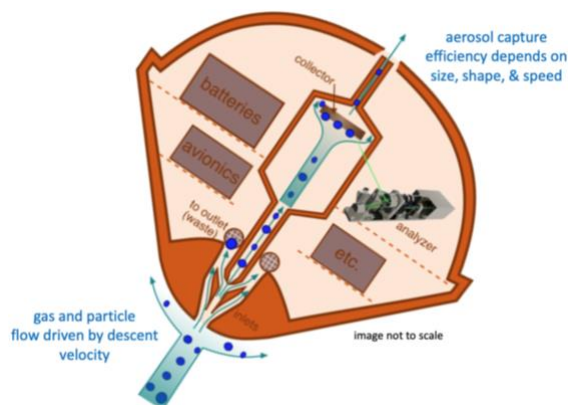


Figure 1 - Nephele entry vehicle / atmospheric sonde concept: simple diverging inlet, transfer inlets, and single impactor. VOLTR dual laser spectrometer (LIBS/SERS) as notional payload.

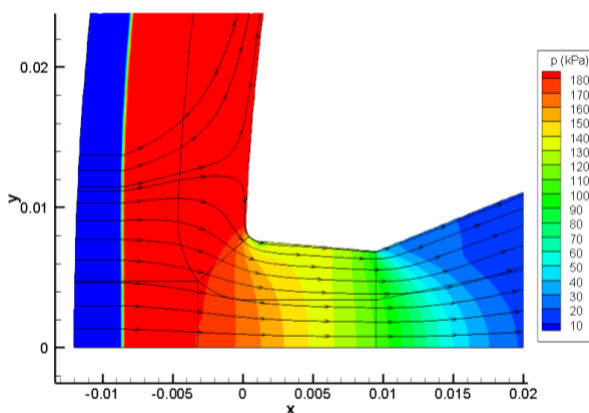


Figure 2 - Pressure contours from the hypersonic modeling of the current inlet geometry. The contours

show the flow-field around the inlet and highlight both the bow shock off the aeroshell as well as the flow expansion within the inlet.

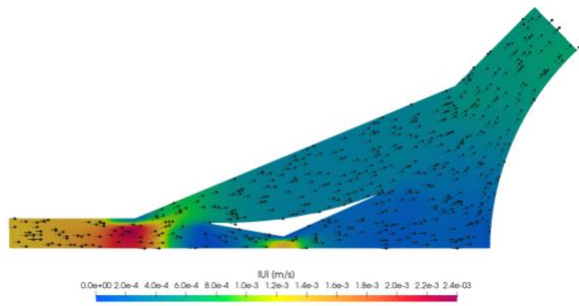


Figure 3 – Velocity contours and vectors for the inlet internal flow simulation.

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References: [1] Gentry D. M. et al. (2021) *VEXAG Annual Meeting*. [2] Baker J. et al. (2021) *43rd COSPAR Scientific Assembly*. [3] Garvin J. B. et al. (2022) *Planet. Sci. J.*, **3** 117. [3] Zasova L. et al. (2019) *Venera-D Joint Science Definition Team*, Moscow, Russia.