

REAL TIME CLOUD COMPOSITION PROFILES WITH AN OPTOFLUIDIC INSTRUMENT.

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Closing Key Knowledge Gaps: VOLTR (Venus Optofluidic Liquid TRap) seeks to identify unknown UV absorbers, characterize the atmospheric constituents, and detect traces of extant or extinct life in potential habitable zones in Venus' clouds (~50 km, 1 atm and 60°C). VOLTR does this by collecting cloud aerosols, acquiring ultrafast (<1s) surface-enhanced Raman (SERS) and laser-induced breakdown (LIBS) spectra, and interpreting spectral data in real time during descent through the clouds of Venus (Figure 1).

VOLTR Innovations: VOLTR is a scientific payload that takes advantage of [1] the unique ability of Raman spectroscopy to qualitatively determine molecular composition and structure and organic functional groups; [2] SERS technology pioneered by our team that enables (at least) ppb-level quantitative analysis; [3] sub-ppm LIBS elemental quantitation; and [4] at-the-edge computing technologies also developed by our team for onboard lossless spectral data processing and compression.

Under the hood, VOLTR integrates an aerosol trap that captures particles and passively samples atmospheric aerosols during descent. The trap is made of plasmonic materials that enable SERS and LIBS measurements immediately as aerosols adhere to the trap, without the need for sample manipulation. VOLTR utilizes a customized 515 nm pulsed laser for these

measurements whose characteristics (adjustable rep. rate and a pulse energy) enable self-cleaning of the trap, a necessary innovation for repeated sampling-measurement cycles replacing resource-taxing mechanical systems for sample holder management.

VOLTR Performance: The optical trap is developed specifically to collect pristine aerosol samples in the size-range predicted for Venus's atmosphere (0.3 to 8.0 μm mean diameter). The physical properties of the trap enable particle capture while retaining the nanotexturing necessary to provide strong Raman signal enhancement. Based on preliminary tests, VOLTR is capable of ppb-level detection of organic functional groups, elements, and other trace compounds with a recycling capability enabling at least three reuses of the SERS-active surface, sufficient for a pathfinder-type dive-in mission to characterize the chemical composition of Venus' cloud deck.

Significance: VOLTR addresses the need for high sensitivity compositional analysis of Venus' atmosphere and answers a key astrobiology question: what is the mysterious UV absorber? VOLTR is a low-SWaP subsystem that can be configured for a variety of mission architectures to enhance the sensitivity of Raman instrumentation to trace compounds, organics, and biosignatures during aerosol capture on Venus and Titan or plume sampling in other Ocean Worlds.

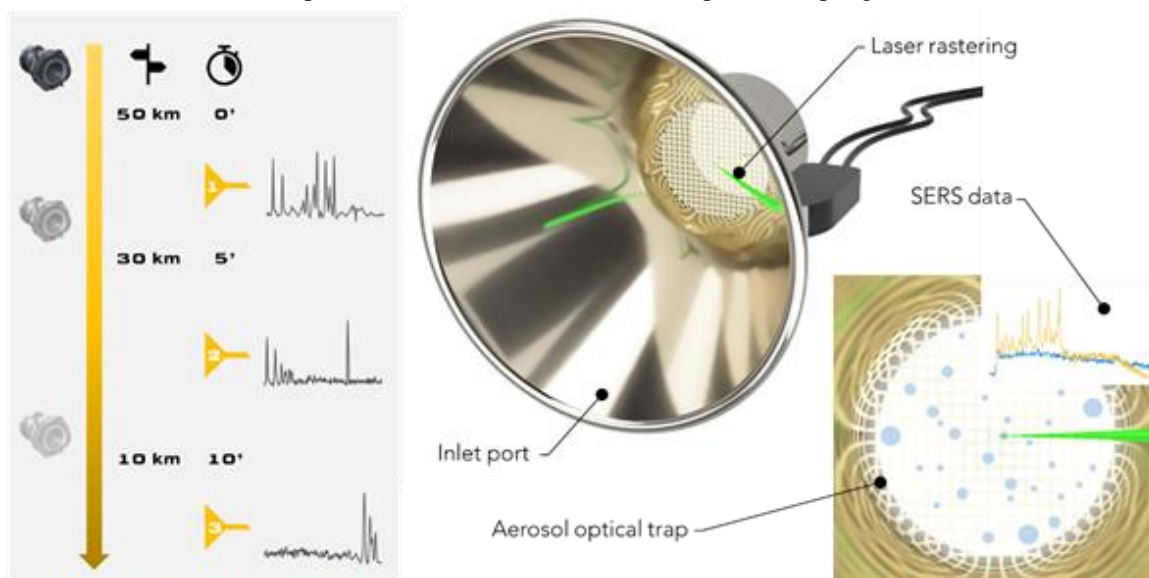


Figure 1. VOLTR concept of operation. As spacecraft or probe descends through the cloud deck, inlet funnels aerosols into an optical aerosol trap (< 10 mm diameter). The laser rasters the trap and conducts SERS measurements continuously throughout the duration of the mission. An in-situ cleaning method makes the trap reusable, enabling at least three discrete sampling and subsequent measurement events. SERS measurements enable high sensitivity (sub-ppm) detection and identification, through Raman spectral fingerprinting, of molecular functional groups and specific molecular identities.