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VICI: Venus In situ Composition Investigations

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Abstract

The overarching goal of the proposed New Frontiers Venus In situ Composition Investigations (VICI) mission is to answer long-standing questions about the origins and evolution of our sister planet and provide new insights needed to understand terrestrial planet formation, evolution, and habitability [1-3]. To address this goal, VICI sends two identical landers to unexplored tessera regions that may hold the key to understanding Venus' geologic history prior to volcanic resurfacing. The two landers gather comprehensive atmospheric composition and structure information during two descents, while also quantifying the similarities and differences in surface chemistry, mineralogy, and morphology at multiple independent, representative tessera landing sites.

1. Introduction

Venus remains one of the least understood planets in our solar system, and many significant questions regarding its atmosphere, surface, and interior remain unanswered. Lack of understanding of this major silicate planet not only limits our understanding of evolutionary pathways Earth could experience, but also suggests we are ill-equipped to understand the evolution of other star systems with similar-sized planets.

1.1 Mission Concept

VICI is a proposed NASA New Frontiers mission addressing the Venus In Situ Explorer (VISE) objectives [3] that would launch in December 2024. The spacecraft delivers the landers on two separate Venus fly-bys. The landers are delivered to representative tessera sites in January 2027 and April 2028, respectively. VICI would be the first mission to land on the Venus surface since 1985, and the first U.S. mission to enter the Venus atmosphere in 49 years. VICI is designed to study the chemical and isotopic composition of Venus' atmosphere at a level of detail that has not been possible on earlier missions. In addition, VICI images the tessera surface during descent enabling detailed topography to be generated using the latest Shape from Motion (SfM) techniques [4]. Finally, VICI makes multiple elemental chemistry measurements, including depth profiles through the weathering rind and subsurface, and the first ever direct mineralogy measurements on the Venus surface. The four major VICI science objectives are:

- Atmospheric origin and evolution: Understand the origin of the Venus atmosphere, how it has evolved, including how recently Venus lost its oceans, and how and why it is different from the atmospheres of Earth and Mars, through *in situ* measurements of key noble gases, nitrogen, and hydrogen.
- Atmospheric composition and structure: Reveal unknown chemical processes and structure in Venus' deepest atmosphere through two comprehensive, *in situ* vertical profiles.
- Surface properties and geologic evolution: For the first time ever, explore the tessera from the surface, specifically to test hypotheses of ancient content-building cycles and erosion using multi-

point mineralogy, elemental chemistry, imaging and topography.

- Surface-atmosphere interactions: Characterize Venus' surface weathering environment and provide insight into the sulphur cycle at the surface-atmosphere interface by integrating rich atmospheric composition and structure datasets with imaging, surface mineralogy, and elemental rock composition.

1.2 Payload

VICI's payloads build on the success of the Mars Science Laboratory (MSL) by carrying the same instrumentation that has delivered high-impact science results on Mars [5-11]. For example VICI employs the same neutral mass spectrometer (built by NASA's Goddard Space Flight Center, GSFC) and tunable laser spectrometer (built by the Jet Propulsion Laboratory, JPL) that are the heart of MSL's Sample Analysis at Mars (SAM). Borrowing from MSL's ChemCam and the Mars 2020 SuperCam that is in development, VICI uses the same Raman and Laser-Induced Breakdown Spectroscopy (LIBS) built by Los Alamos National Laboratory (LANL) (with contributions from Institut de Recherche en Astrophysique et Planétologie, IRAP) to provide surface mineralogy and elemental composition, avoiding complex sample ingest and enabling multiple measurements at each landing site. A gamma-ray spectrometer (built by Johns Hopkins University Applied Physics Laboratory) complements the LIBS with bulk measurements of naturally radioactive elements to a depth of ~10 cm. A descent imager also plays an important role.

1.3 Payload

VICI leverages NASA GSFC internal investments in Venus pressure vessel designs as well as substantial analysis and drop testing [12] to demonstrate the resiliency of the Lander design to safely land on rugged tessera terrain. VICI also leverages NASA investment in the Heatshield for Extreme Entry Environment Technology (HEEET).

2. Summary and Conclusions

By definitively measuring atmospheric and surface composition at two sites, VICI goes beyond the Venus exploration goals of NASA's Planetary Decadal Survey, revealing how and why Earth's sister is not her twin.

Acknowledgements

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