

Input to the Decadal Survey Inner Planets Panel

**Mission Concept: Venus in situ Explorer (VISE)**

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Venus is a world almost unimaginably different from our own. At the bottom of an ocean of gases ( $P \sim 96$  bars) lies a surface as hot as a self-cleaning oven ( $T \sim 740$  K). Enormous volcanic edifices and flows cover thousands of  $\text{km}^2$ , and shimmer visibly through the thick fluid, a supercritical mixture of  $\text{CO}_2$ ,  $\text{N}_2$ ,  $\text{H}_2\text{O}$  and sulfur gases. Dante's vision of hell is real, and it is the planet next door. Yet, for all their stunning contrasts, Venus and Earth share a heritage closest of any planets. Being the same size and born in the same neighborhood of the solar nebula, they were most likely constructed from similar planetary building blocks. The Venus surface shows familiar geological processes, and its climate, like Earth's, may be driven by feedback between the atmosphere, surface, and interior. Recent understanding of the evolution of Earth's greenhouse has shown that understanding of nonlinear feedbacks is crucial to our ability to predict the influence of natural and anthropogenic climate perturbations on Earth. Studying climate evolution on Venus will increase our understanding of nonlinear planetary climate systems, including the Earth's.

The study of Venus is essential to understanding the evolution of terrestrial planets (Esposito et al., 2007). Addressing the question of how Venus and Earth diverged is key to comprehending when and if planets develop and maintain habitable zones (Grinspoon and Bullock, 2007). Many key questions must be answered to achieve this goal: What was the early evolution of Venus like? Did it have a dynamo, perhaps driven by plate tectonics, and an early ocean resulting from interior outgassing? If so, why did plate tectonics shut down and how was the ocean lost? Are tessera remnants of an earlier, wetter Venus? How was the greenhouse effect initiated and how has climate evolved? What is the feedback between climate and tectonics? What resurfacing processes erased the early geologic record? How geologically active is Venus today? What volatiles are retained in the interior? What are the current drivers for the climate system? What drives super rotation of the atmosphere?

Some questions will be difficult or impossible to answer, such as did Venus have plate tectonics. On Mars, crustal remanent magnetization demonstrates that a dynamo existed; plate tectonics might have provided the heat engine to drive the needed convection in the core (Nimmo and Stevenson, 2000). The high surface temperature on Venus likely prevented magnetization of the crust if Venus did have a dynamo.

A capable surface lander could address a majority of the key questions about the evolution of Venus. The increasing recognition of the interaction between volatiles, the interior and climate evolution as modulated by geology and tectonics (Phillips et al., 2001; Smrekar et al., 2007; Lenardic et al., 2008) make an integrated study essential to making progress on understanding planetary systems. Early processes likely left their chemical fingerprint in atmospheric gasses and surface elemental composition, including evidence whether or not an ocean was ever present. A landed mission would examine the current combination of atmospheric gases, surface mineralogy and weathering processes to better define drivers in the climate system, which in turn informs past climate processes. Able to land in a hotspot region, it could examine, for example, a region of high emissivity as seen by the VIRTIS instrument on Venus Express, which Mueller et al. (2008) interpret as being a less weathered, and thus relatively young site. Hotspot volcanism has a geochemical signature that directly reflects mantle processes. Thus, such a landing site would offer essential new insights into whether Venus is active, what types of volcanism are occurring, and how they are contributing to resurfacing the planet.

The further exploration of Venus will illuminate the origins of our world, and perhaps others like it around distant stars. Was Venus ever like Earth? Could it, too, have incubated life in a volcanic, aqueous past? Will Earth some day become like Venus? What determines whether a rocky world forming around a nearby star evolves to a warm wet world like Earth, or to the sulfurous, desiccated hell that is Venus? Decades of Soviet and U.S. exploration have brought us to the brink of finding answers to these questions. A lander mission can explore the planet's surface and atmosphere in order to understand how terrestrial planetary environments arise and evolve.

A mission concept to address these questions, the Venus in situ explorer (VISE) was described by the previous Decadal Survey. The mission concept was refined by the SAGE Proposal Team, as follows.

A capable lander to measure atmospheric and surface composition, with the following science objectives:

1. Measure noble gases and their isotopes to constrain Venus history
2. Measure trace gas profiles and sulfur compounds for chemical cycles and surface-atmosphere interactions
3. Take meteorological measurements to the surface
4. Measure surface and sub-surface composition
5. Constrain the coupling of radiation, dynamics and chemistry of the surface and atmosphere
6. Using the mission results, compare the terrestrial planets in detail to predict and characterize extra-terrestrial planets

Questions this mission could answer: What can Venus tell us about the accretion of the terrestrial planets; Did Venus have an ocean; What is the surface weathering on Venus; What's the style of emplacement and composition of volcanics; How did the atmospheric chemistry evolve?

VISE results will allow us to model the past Venus history and extend it to the future of Venus, and possibly Mars and Earth. The models will provide the capability to define the observable characteristics of extrasolar planets like Venus.

Implementation: Descender/lander.

It is essential to land safely and to survive on the surface for some hours to make the required measurements. The lander instrumentation would photograph and sample the surface and the sub-surface near the lander.

Instrumentation: Cameras, spectrometers, NMS, meteorology package, instruments to determine mineralogy and surface texture. Capabilities of these experiments far exceed that of the last Russian landers, more than two decades ago.

Mission class: New Frontiers

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