VENUS DEEP ATMOSPHERE DESCENT PROBE (VDAP)

James B. Garvin[(1)], Lori Glaze[(1)], Paul Mahaffy[(1)], Natasha Johnson[(1)], Michael Amato[(1)], Tim Van Sant[(1)]

[(1)]*NASA Goddard, Greenbelt, MD 20771 USA; Email: james.b.garvin@nasa.gov*

The deep atmosphere of Venus remains largely unexplored in terms of the details of its trace gas chemistry. The history of key volatile reservoirs and surface-atmosphere-interior exchange processes is also poorly established on the basis of existing data. Noble gases within the bulk Venus atmosphere, as well as isotopes of hydrogen, oxygen, and sulfur, are essentially unmeasured to the degree required to address fundamental questions about the evolution of the planet, as prioritized in the latest planetary Decadal Survey by the US National Academy of Sciences. For these reasons, we have developed a mission concept for a Venus deep atmosphere descent probe (VDAP) that leverages existing and emergent technologies associated with entry-descent-touchdown, instrumentation, and flight system avionics. The intent is to define a low risk, cost-effective mission concept for achieving the recently outlined priorities for Venus atmospheric chemistry and dynamics, many of which date back to the early 1980's in the aftermath of the US *Pioneer Venus* mission (PV) and contemporaneous Soviet *Venera* landers.

Science objectives for the VDAP concept require state-of-the-art neutral mass spectrometer capabilities to achieve seminal measurements of noble gas isotopes including xenon (Xe), while also allowing for high mass resolution and time rate sampling of trace gases from beneath the Venus cloud deck to the surface. Instruments recently developed at NASA's Goddard Space flight Center are well-suited to achieve these pivotal observations. Key to measuring the *in situ* chemistry of the atmosphere is a robust approach for sampling that avoids the clogging issues that befell the *Pioneer Venus Large Probe*, and which permits access to atmospheric gas samples from within the clouds as well as repeatedly within the lowermost scale height (i.e., from 16 km to the surface). Coupled to the requirement for *in situ* mass spectroscopy is the desire for direct observation of isotopes of hydrogen, oxygen, and sulfur. This is optimally accomplished by means of tunable laser spectrometer instrumentation, similar in capability to that which is part of NASA's Mars Science Laboratory (MSL). The physical context for the required atmospheric chemistry measurements is an essential part of the scientific measurement strategy and can take advantage of the current state-of-the-art in atmospheric structure instrumentation for pressure, temperature, and accelerations. The photometry of the atmosphere beneath the cloud deck, as well as imaging of surfaces in regions not explored by the Soviet Venera landers (i.e., such as highlands) represents another opportunity for new science, and is enabled by descent imaging systems such as those flown on NASA's Phoenix Mars polar lander and on the upcoming MSL mission. These scientific measurement approaches can be combined into an optimized "descent sphere" within a probe flight system that includes an aero-entry capsule with a thermal protection system and parachutes to provide approximately an hour worth of pioneering observations about Venus to form the basis from which future missions can be designed.

The VDAP architecture enables observations that were not possible during the first era of *in situ* Venus reconnaissance (i.e., *PV*, *Venera*), and which go beyond what orbital or flyby remote sensing can achieve. Such observations would form essential boundary conditions and constraints for models of atmospheric and climate evolution, as well as some aspects of surface-atmosphere-interior interactions. Furthermore, the suggested VDAP approach is a natural pathfinder for larger-scale landed missions or to Flagship-scale missions involving orbiters, balloons, and landed probes. Finally, direct, *in situ* observation of the chemistry of the atmosphere, as well as of the meter-scale morphology of the surface in rugged regions is only possible with extant technology from a deep atmosphere descent probe. Our concept for VDAP is based upon NASA Goddard Space Flight Center investments in combination with those of mission concept partners within the US. We believe the VDAP approach is the lowest risk and most cost-effective approach to resolving key scientific issues for Venus within the context of competed mission programs at NASA. Now is the time for a next-generation probe mission to Venus if future Flagship-class missions to our sister planet are to be implemented in the 2020's by the world community.