Sampling Venus' atmosphere with a low-cost, free-flying Smallsat probe mission concept

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Abstract

The Venus Exploration Advisory Group (VEXAG) has elevated to a very high priority the need to measure the relative abundances of Neon, Argon, Helium, Krypton and other noble gases in the planetary science community's efforts to understand how Venus' atmosphere formed and has evolved. The underlying objectives are to determine if Venus and Earth formed from the same mix of solar nebular ingredients, and whether comets played a substantial role in delivering volatiles. To be truly representative of the noble gases and their isotopic ratios, a sample of the atmosphere has to be acquired where the atmosphere is well-mixed: at an altitude below the homopause, which for Venus is around 120 km.

This paper describes a novel, low-cost, Smallsat architecture for a standalone mission that would sample the noble gases and their isotopic ratios at Venus. Sampling would be achieved by a compact, ion-trap mass spectrometer incorporated into a small probe that skims through the atmosphere, targeting a closest approach altitude above the surface below the nominal 120 km. Following acquisition, the gas sample would be analyzed over a period of ~60 minutes, then results would be relayed via a UHF comm link to the microsat carrier spacecraft that escorted the atmospheric entry probe to Venus. Data would then be relayed back to Earth via an X-Band downlink.

The Venus probe + carrier spacecraft are assumed to launch together on a Type I trajectory towards Venus, on a dedicated Pegasus launch vehicle with a STAR-1 motor developed by Orbital Sciences Corporation. The combined probe + carrier spacecraft mass is estimated at less than 55 kg. The compact mass spectrometer instrument mass is estimated at 8 kg. En route to Venus the carrier spacecraft would execute pre-planned TCM maneuvers for a total Delta-V of about a hundred m/s. On approach, the carrier spacecraft would spin up to rotate at ~10 rpm, then release the probe on its path to skim through the atmosphere. The carrier spacecraft would then execute a small maneuver (with a few m/s Delta-V) to fly past Venus above the atmosphere. Following the probe skim-through and data analysis, results would be returned to Earth via a UHF/X-Band relay, similar to that developed for MarCO.

Carrier spacecraft and probe costs are assumed to be kept low by using avionics, telecom and other subsystems developed for other NASA/JPL planetary cubesat missions, including INSPIRE and MarCO. Launch windows for Type I trajectories to Venus, which have the lowest transfer energy, fewest maneuvers, and shortest transit time, occur roughly every 19 months.

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