TEST FLIGHTS AND ALTITUDE CONTROL DEMONSTRATION OF A PROTOTYPE VENUS AEROBOT

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Introduction: The clouds of Venus offer a unique environment: ample sunlight, Earth-like temperatures and pressures, and strong zonal winds that can carry an in situ aerial platform around the planet in just a few Earth days. This cloud layer is key to moderating the solar radiative balance of the planet, the transport of materials between the atmosphere and the ground, and the interactions (physical, chemical, and possibly biological) between atmospheric constituents. The two VeGa balloon flights in 1985 [1], launched by the Soviet Union, successfully flew in the Venus clouds using superpressure balloons, which nominally have a relatively fixed buoyancy and provide access to only a single altitude.

JPL is pursuing the technologies required to design a buoyant "aerobot" (aerial robotic balloon), with a lifetime of months, to perform targeted science in the Venus clouds. Because of the extremely strong and consistent zonal winds on Venus, any aerobot is expected to circumnavigate the planet passively every 5 to 7 Earth-days. In contrast to its VeGa predecessors, the JPL aerobot is a controllable variable-altitude balloon [2]—providing access to a broad altitude range over the course of the flight, and a consequently increased science return [3]. This science return advantage has been well received by the Venus community. In preparation for the 2023–2032 Planetary Science and Astrobiology Decadal Survey, NASA commissioned two mission studies that elected to utilize a variable-altitude aerobot for Venus: a many-asset Venus Flagship Mission (VFM) [4] and an aerial platform with orbiter mission under New Frontiers [5].

Objective: The objective of this work is to develop the variable-altitude Venus technology for a competed-mission class aerobot [6]. The architecture consists of two balloons: an outer, metallized Teflon-coated unpressurized balloon (which protects against sulfuric acid aerosols and sunlight), and an inner Vectran-reinforced pressurized balloon which acts as a helium reservoir. Transferring helium between the inner and outer balloons modulates the buoyancy and altitude. For Venus, an aerobot of 12–15 m diameter [7] is desired for a carrying capacity of 100–200 kg, consistent with a major scientific investigation of and from the cloud layer, with a 10 km-wide altitude-control capability from 52 km to 62 km.

Figure 1: Prototype one-third-scale Venus aerobot in flight above the Blackrock desert, Nevada. The aerobot includes a metalized-Teflon outer envelope and an internal helium reservoir.

Results: We will discuss the subscale prototype fabrication and test flight efforts pursued as a collaboration between JPL and Near Space Corporation. Two prototypes have been built so far [7,8] at approximately 1:3 scale to the Venus design points, with a third prototype in progress. These prototypes are of increasingly higher fidelity, with balloon envelopes and seams capable of withstanding the high-temperature (~100°C), high-pressure loads (~30 kPa), sulfuric-acid environment (94% concentration), and solar radiative heating (2300 W/m^2) needed for flight in the Venus cloud layer. We will report on recent test flights of these prototypes on Earth (Figure 1) at atmospheric densities equivalent to 54–55 km above the Venus surface, the coupon-level testing of balloon materials, and the application of these results to the performance at full scale on Venus.

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