RELEVANT ENVIRONMENT TESTING AND FABRICATION OF PROTOTYPE VENUS AEROBOTS

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Introduction: The clouds of Venus offer a unique extra-terrestrial environment to explore: ample sunlight, Earth-like temperatures and pressures, and strong zonal winds that can carry an in situ aerial platform around the planet. This cloud layer is key to moderating the 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 for 46 hours with a small 7kg payload, which nominally operated at only a single altitude.

JPL and Aerostar LLC are pursuing the technologies required to fly a larger “aerobot” (aerial robotic balloon), with a lifetime of months, to perform targeted science in the Venus clouds (Figure 1). Because of the extremely strong and consistent zonal winds, a Venus aerobot is expected to circumnavigate the planet every 5 to 7 Earth-days. In contrast to its VeGa predecessors, this new aerobot is a controllable variable-altitude balloon [2], providing access to a broad altitude range over the course of the flight, with a consequently increased science return [3].

Objective: The objective of this work is to develop the variable-altitude Venus technology for multiple mission opportunities [4, 5, 6]. The architecture consists of two balloons: an outer, metallized Teflon-coated unpressurized balloon (which protects against sulfuric acid aerosols and sun-light), and an inner, Vectran-reinforced pressurized balloon that serves 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 necessary for a carrying capacity of 100–200 kg, consistent with a major scientific investigation of and from the cloud layer, with a 10 km-range altitude-control capability from 52 km to 62 km.

Results: Three subscale aerobot prototypes have been built so far. These prototypes are of increasingly higher fidelity [7, 8], with balloon envelopes and seams capable of withstanding the high-temperature (~100 °C), sulfuric-acid aerosols (96% concentration), and solar radiative heating (2300 W/m^2) environmental conditions that will be encountered when flying on Venus. Our presentation will report on inflation trials, dynamics model validations from flights (Figure 1), testing of balloon materials in combined acid/tensile/thermal conditions (Figure 2), and our fabrication of a TRL5-demonstrator prototype.

Figure 1: Prototype Venus aerobot in flight above the Blackrock desert, Nevada. This flight demonstrated altitude control at identical atmospheric densities (and balloon dynamics) as 54–55km above the Venus surface.

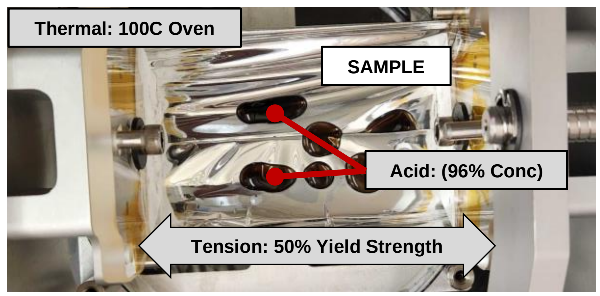

Figure 2: Combined simultaneous environment exposure of balloon material to tensile stress, 100 °C thermal conditions, and concentrated sulfuric acid droplets.

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References: [1] Huntress & Marov. Soviet Robots in the Solar System. Springer 2011. [2] Hall, J. L., et al. "Altitude-Controlled Light Gas Balloons for Venus and Titan Exploration." AIAA Aviation 2019 Forum. 2019-3194. [3] Venus Aerial Platforms Study Team, “Aerial Platforms for the Scientific Exploration of Venus”, JPL D-102569, Oct 2018. [4] Gilmore, M. et al. "Venus Flagship Mission Planetary Decadal Study, a Mission to the Closest Exoplanet." 2020 [5] O’Rourke et al., “Assessment and Discovery of Venus’ Past Evolution and Near-Term Climatic and Geophysical State”. 2021. [6] Cutts, J. et al. "Exploring the Clouds of Venus: Science Driven Aerobot Missions to our Sister Planet." 2022 IEEE Aerospace Conference 2022. [7] Hall J L., et al. "Prototype Development of a Variable Altitude Venus Aerobot." AIAA Aviation 2021 Forum. 2021-2696. [8] Izraelevitz, J et al. " Subscale Prototype and Hangar Test Flight of a Venus Variable-Altitude Aerobot." 2022 IEEE Aerospace Conference 2022.