SUSTAINED *IN SITU* EXPLORATION OF VENUS' CLOUD DISCONTINUITY

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Science Motivation: Direct sampling and analysis of Venus' clouds and atmosphere are necessary for understanding how cloud processes, radiation, and dynamics are coupled on that planet. We discuss how an aircraft can harvest energy in Venus' atmosphere for sustained flight, and perform crucial *in situ* scientific experiments around the planet.

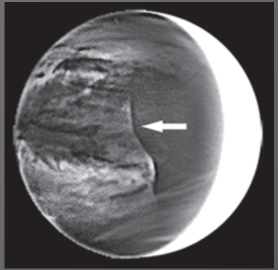

Figure 1. Lower cloud discontinuity from 2.26 μm images of the night side of Venus [2]. Flights transecting this boundary can measure the pressure, temperature gas, aerosol, radiance and winds on either side. Similar data on other atmospheric features will help elucidate the global dynamics and radiative and chemical feedbacks.

Flight in the Clouds of Venus: By dipping into and out of the shear layer at around 60 km, a specifically designed aircraft can stay aloft in Venus' atmosphere without expending energy, much the way an albatross can cross the ocean without flapping its wings [1] . The horizontal winds and vertical shear in Venus' atmosphere, from the IPSL Venus GCM at the equator, at midnight [2], is shown in Fig. 2. The red dashed line marks the vertical shear that is necessary for propulsion-less dynamic soaring for an aircraft with a ratio of coefficient of lift to coefficient of drag of about 50. Our design achieves a CL/CD of ~70. The shear layer at 60 km is present at all times of day at low latitudes, with shear strengths of > 10 m/s-km. Sustained flight and high cadence of in situ measurements will be possible at 60 km, near the bottom of the upper cloud. Brief excursions to the shear layer at 40 km may be possible if sufficient energy can be extracted from the winds (Fig. 3). Chemical and aerosol measurements throughout the cloud column will then be possible. Geological mapping of the surface from below the clouds at near-IR wavelengths would provide a window on the surface that has never before been possible. Multicolor near-IR images of Venus' surface, without the intervening, scattering of the clouds, would enable broad swaths of Venus surface to be imaged at 20 m/pixel. This is 4 times the resolution of Magellan Synthetic Aperture Radar images that are available today [3]. The Magellan images are insufficient for resolving fundamental geologic relationships. Imaging at near-IR wavelengths from below the clouds would revolutionize our understanding of Venus' geology.

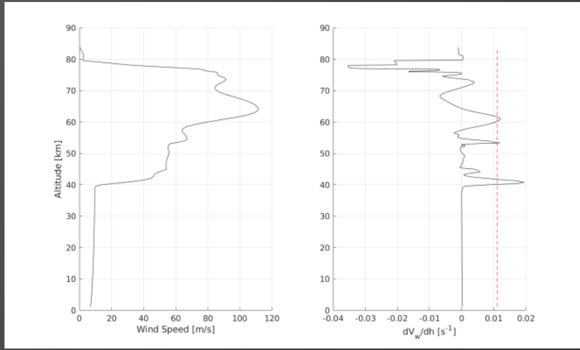

Figure 2. IPSL GCM winds and vertical shear at midnight at the equator, as functions of altitude [2]. The red dashed line marks the shear that is necessary for sustained dynamic soaring for an aircraft with a CL/CD of 50. Sustained flight and high data cadence.

Science Capabilities: An important advantage of fixed wing aircraft over other instrument platforms is its high degree of navigability. Dynamic soaring aircraft can be flown to specific features in the atmosphere of Venus to make measurements. For example, the tilted horizontal streaks in the clouds at mid-latitudes are most likely caused by baroclinic instability in this region of the atmosphere [6]. In situ wind and chemical heterogeneity measurements would reveal the nature of these disturbances. One special region of Venus' atmosphere is shown in Fig. 1, where a long-lived cloud discontinuity has developed, propagating faster than the superrotation [7].

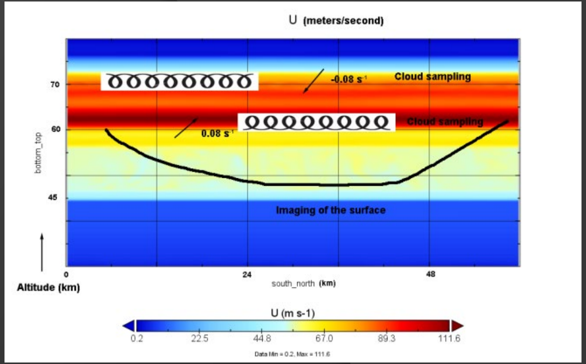

Figure 3. Possible dynamic soaring trajectories in Venus' atmosphere. Background color is wind speed. Dynamic soaring is accomplished by dipping in and out of the shear layer at ~60 km. Occasional forays below the clouds to image the surface may be possible.

Scientific Payload: A minimal but scientifically useful payload would consist of atmospheric structure (pressure, temperature, accelerometers) and MEMS chemical sensors for parts-per-billion measurements of atmospheric gases. A single chip ultrastable oscillator would enable the accurate determination of position, using radio techniques from either Earth-based radio dishes or a relay probe in orbit around Venus.

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References: [1] Lebonnois, S. et al., (2010), Journal of Geophysical Research (Planets). 115, 6006. [2] Peralta, J. et al., (2020), Geophysical Research Letters. 47, e2020GL087221. [3] McGouldrick, K., et al., The Planetary Science Journal. 2, 153. [4] Barstow, J.K. et al., Icarus. 217, 542-560. [5] Baines, E.K.H, et al., (2021) Astrobiology.