LONG DURATION *IN SITU* SCIENCE IN VENUS' CLOUDS ENABLED BY DYNAMIC SOARING.

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Introduction: In regions with high vertical shear, it is proposed that gliders in Venus' atmosphere can soar for as long as conditions persist. This will allow for in situ sampling and analysis of the atmosphere and aerosols at several important levels in Venus' clouds. At the equator, the top of an unstable atmospheric layer at about 55 km above the surface marks the top of the middle cloud. This unstable layer is deeper at higher latitudes, but persists through day and night. Above this, a persistent layer of vertical shear at 55 km produces ideal conditions for energy harvesting flight.

Dynamic soaring above the large convection cells of Venus' middle cloud gains access to this vital region. The condensation and evaporation of cloud particles happen here, and reactions with photochemical products from above drive the atmospheric and cloud chemistry.

Typical flight paths would enable periodic measurements and sampling of Venus' middle and upper cloud atmosphere as the aircraft circles the planet. Practical payloads and sampling schemes have the potential to achieve most of the VEXAG Objectives on the chemistry, dynamics, and cloud processes of Venus' atmosphere.

Science: The VEGA balloons in Venus' atmosphere were tracked by a global network of radio receivers, including in the US, in 1986. The resulting tracks of the VEGA balloons as they floated in Venus' clouds are by far the most detailed dynamical information we have of the middle cloud environment. Each balloon's 4 Watt transmitter was tracked from Earth for the entire 48 hours of duration of operation, until their batteries died. The VEGA 1 and 2 balloons entered on the night side of Venus, at 7°N and 7°S, respectively. They both continued to operate and return data as they drifted onto the day side, traversing about 30% around the planet.

Numerous authors have pointed out that the dynamics of Venus' atmosphere can't be understood without direct measurements of its winds. While VEGA acquired 48 valuable hours of dynamical data in the clouds, much longer and more widely dispersed measurements are needed. Fixed wing aircraft using autonomous dynamic soaring with no propulsion can linger for weeks or months in the stable layer above the middle cloud at about 55 km above the surface. The average temperature here is 8°C and the atmospheric pressure is 500 mbar. If an aircraft with a single 4W transmitter could be tracked from Earth for 30 days, it will have circled Venus 5 times.

At low latitudes, an additional unstable region at 63 km develops at night, and disappears in the morning. Horizontal winds increase rapidly above 63 km, providing ideal conditions for dynamic soaring. At higher latitudes, this unstable region with vertical shear above may persist for most of the day. This region in the upper cloud is where the sulfuric acid particles are made, among other photochemical products. Flying in this region offers the opportunity to sample and analyze upper cloud constituents and products of photochemistry. At 63 km, the average temperature is -32°C and the ambient pressure is 150 mbar.

To harvest energy from the atmosphere, the aircraft flies a corkscrew path into and out of a vertical shear layer. Vertical travel along a typical path may be about 1 km, providing a sampling grid of measurements 1 km wide over 55-56 km, all the way around the planet with the prevailing winds.

Instruments: Aside from a low power transmitter for tracking from Earth, some very simple and inexpensive instruments can be deployed for in situ measurements judged as high priority science by VEXAG. Temperature, pressure, accelerometry and relative wind speed would provide fundamental thermodynamic quantities for 5 circuits around the planet. A solid state inertial navigation system would be necessary for autonomous navigation and reconstructing the flight path between transmissions. Miniature atmospheric structure instrument suites are available that weigh 200 g. A single chip IMU may also be 200 g,

Atmospheric composition measurements of specific gases can be performed by MEMS sensors to the parts per billion level. The substantial questions about the atmospheric sulfur cycle can be answered by the monitoring of S, Cl, and C gases in the cloud during flight around the planet. The sensors are about 10 g each, so a suite of 12 would have a mass of 120 g.

Simple optical instruments that measure the light field from UV to near-IR in several directions as the aircraft flies through the clouds would enable a much better understanding of Venus' atmospheric energy balance and the role of scattering. The optics and detector for each direction may weigh 150 g. At least 3 directions (up, down, forward) will be required, or 450 g.

Another optical device that could be carried on each aircraft is a nephelometer - a hoop through which cloud particles flow, lined with lasers and detectors to measure their sizes, number densities, indices of refraction, phase functions, and polarimetric measurements . The characterization of cloud particles as the aircraft flies through the middle cloud will test long-standing uncertainties about the composition of some of the size modes, and the existence of trace species such as $FeCl_2$ and elemental sulfur. With 12 scattering angles and hence 12 solid state lasers and 12 detectors, such an instrument might weigh 4 kg.

The next step up in instrument mass would be an aerosol collection system for microscopic imaging, polarimetry, and fluorescence. Insoluble cores, if they exist, and coatings on the aerosols (such as Sn) would be visible, and measurable. The collection system maybe 2 kg, and the microscope with filters and light sources may be 1 kg, for a total of 3 kg. All these sensors and instruments come to 7.97 kg.

Truly revolutionary science could be done with a state-of-the-art miniaturized gas chromatograph, particularly if it was able to separate out the aerosols and analyze them separately. Such an instrument would provide a continuous inventory of the gases and aerosols of the middle cloud, as the aircraft speeds through the 6 day day and night cycle, circling the planet.