AFTER MAGELLAN: CONCEPTS FOR THE NEXT GENERATION OF VENUS SPACECRAFT.
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Spacecraft exploration of the planets historically evolved through the sequence of flyby, orbiter, and lander, reflecting the growing engineering capabilities during the pioneering days of the Soviet and American space programs. Although Venus has passed through each of these stages of exploration, its extremely hostile surface environment has minimized the opportunities to resolve major questions that might be answered with fully instrumented, long-lived in-situ probes. A sample return mission ultimately will be critical for validating theories concerning the composition, heat flow, and age of Venus, but such a mission has many engineering difficulties to overcome, not the least being an ascent through the planet's dense atmosphere towards an Earth rendezvous. Such a Venus sample return mission is clearly many years in the future. Traditionally, surface landers have had difficulty in long-duration survival. Another class of spacecraft - the balloon-suspended platform - is a more tractable engineering problem; is uniquely suited to Venus, and could gather data applicable to important scientific problems. The Soviet experience with the Vega 1 and 2 spacecraft demonstrated the proof of concept for balloon-borne atmospheric research, and the US Border Patrol Aerostat Surveillance System is an operational example of a long-duration highly instrumented remote sensing probe. We propose a similar but larger balloon probe (VIMP = Venus Blimp) for geophysical research of Venus.

A balloon-tethered remote sensing platform has many advantages for Venus. With average wind speeds of 240 km/hr at its ~50 km altitude, the Vega balloon probes drifted over 11,000 km during 46 hrs [1]; thus even a relatively short-lived balloon-borne geophysical probe could acquire global scale transects of high resolution data. Because atmospheric temperature and pressure both generally decrease upward in Venus' atmosphere, instrument life could be prolonged by selecting an altitude with relatively benign P,T conditions. For example, at ~55 km above the surface, Venus' P,T are nearly the same as at sealevel on Earth. With these two factors neutralized, only the corrosive atmosphere would have to be designed for, and the SO2 concentration is only ~5 ppm, considerably less than nearer the surface [2]. By rising to 70 km altitude, SO2 is further reduced to 10^-1 ppm.

The basic balloon-borne VIMP would consist of a main instrument package suspended in a gondola. There are many possible additions: penetrator clusters could be added for short duration surface exploration (i.e. a Venusnet), a tethered surveillance pod (using the high strength/low weight Kevlar lines developed for the Border Patrols Aerostat system) for sub-cloud deck multispectral surface imaging and VLF radio experiments utilizing the extended tether lines.

Possible instruments for a Venus atmospheric platform include: (1) microbarograph to detect volcanic eruptions, meteor entry, and meteorological changes; (2) laser altimeter for high precision topographic mapping along drift paths of craters, volcanoes, tessera, flow fronts, etc; (3) side-looking radar mapper for meter-scale imaging of topography (like the terrestrial Gloria side scan sonar); (4) magnetometer; (5) atmospheric probes, including instruments for measuring temperature, composition, lightning and radiation flux. There would obviously be competition for instrument berths on the floating platform, but it would not have to devote as much weight for protection against T,P conditions more space would be available for science. Depending on the altitude within the Venus clouds, the VIMP could use solar panels (built onto the upper surface of the balloon) or RTGs (contamination problem?) for energy. An orbiting satellite in a highly elliptical orbit would be necessary to relay data back to Earth. As with the Vega balloons, a network of terrestrial antenna could track the probe using very-long-baseline interferometry to achieve locational accuracy of 10 km [1].
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Any newly proposed spacecraft mission must hold the promise of answering important unresolved questions. Despite the astounding success of Magellan and earlier Venera spacecraft, many uncertainties remain concerning Venus. Probably the most critical is the question of whether Venus is currently active volcanically and tectonically. Circumstantial evidence for volcanic activity is strong, but any activity is expected to be very difficult to observe [3]. On Earth, the two most important detection techniques are visual recognition of an eruption plume on a weather satellite image or Space Shuttle photograph, and recognition of a SO2 anomaly by the NOAA TOMS sensor. On Venus, the likelihood of detecting a thermal anomaly or an eruption plume are very small because of the high temperature and constant cloudiness of the atmosphere. Variations in SO2 concentrations in the atmosphere of Venus have been measured by the Pioneer-Venus orbiter [4], but the magnitude of SO2 is very high by terrestrial standards, and the likelihood of the inferred explosive eruptions is small [5]. A second method for detecting active volcanism on Venus is the imaging of new lava flows during the Magellan mission that are not extant on Venera or early Magellan images [3]. But as previously pointed out, if Venus' volcanic activity is similar to Earth's, detection of new flows is unlikely over a short period of only a few years. During the last 100 years on Earth, ~65% of erupted flows are smaller in area than 10 km² and thus could easily escape detection on Venus. Estimates of a low long-term eruption rate on Venus [6] suggest that the interval between detectable eruptions may be even longer on Venus. In any case the recent failure of Magellan limits the timeline for seeing differences.

Detection of volcanic activity on Venus could be attempted, however, by a technique used to detect submarine eruptions on Earth. Even relatively small eruptions, both explosive and effusive, have been recognized by their pressure waves that propagate widely throughout the ocean. A microbarograph high in the atmosphere of Venus could, after sufficient use to understand meteorologic variations, be the only remote sensing technique to test for active volcanism on Venus. The same pressure sensor could also detect incoming meteorites, as on Earth for the 1908 Tunguska event, and for smaller entries [7]. Wetherill and Revelle [7] used military barographic records to infer the global influx rate of large meteoroids; similar data from Venus would provide an independent assessment of the cratering rate at Venus, which is critical for understanding the chronology and evolution of the planet.

Every good mission needs a name, even in the ultra-preliminary stages of advocacy. For our VIMP probe, we propose Drake, named for Sir Francis Drake, who followed Magellan with the second expedition around the Earth. Hopefully, a Venusian Drake will not occur as it did on Earth, 50 years after Magellan.