New Power Architecture for Venus Aerial Missions

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In-situ exploration of Venus is challenging due to its severe environment, which is benign (~25ºC) at an altitude of 55 km, but rapidly becomes more hostile at lower altitudes. The temperature increases at ~7ºC/km to ~465°C, with the pressure reaching 90 bars at the surface.[1] These challenging conditions have limited *in-situ* exploration missions to high altitude balloons at 55 km (above the clouds) that lasted for 48 h, or even shorter duration surface missions that survived for two hours.[2,3] The high-altitude (55-65km) balloon missions are stymied by the opaqueness of the Venusian clouds, which underlines the need for long-duration and deep atmosphere missions for a better understanding of the Venus atmosphere across the cloud layers and below, as recommended by the Venus science community, Venus Exploration Analysis Group (VEXAG).[4] Long-duration variable-altitude balloons (VABs) extending below the clouds have gained particular interest. Durable VABs would allow i) long-term measurements across Venus clouds, ii) determination of chemical species and isotopes underneath the clouds, iii) transport to different longitudes on the planet and measure atmospheric flow patterns, especially with the altitude control, iv) probing the interior structure through close-range imaging, and v) investigation of the seismic activity from acoustic measurements at various altitudes.

For these missions, conventional power technologies are not adequate, e.g., the performance of photovoltaics (PV) is hampered by the decreasing solar flux deeper in the clouds, the selective loss of short wavelength radiation, and the performance loss from the high temperatures.[5] An energy storage system tolerant to high temperatures is needed to compensate for the reduced power generation of PVs at low altitudes, and to support nighttime operations. In this paper, we will describe a novel power architecture we have developed for Venus VABs under NASA Innovations and Advanced Concepts (NIAC) program. The probe concept utilizes: i) PV to provide power at high altitudes, ii) Solid oxide fuel cell (SOFC)[6] operating at 800 °C to provide power at low altitudes, iii) H_2 storage bed for on-demand storage or release of H_2,[7] using chemical (metal) hydrides and iv) a balloon filled with hydrogen and with hydrogen buoyancy-based altitude control system. Both H_2 and O_2 would be regenerated through electrolysis of the water produced in the fuel cell (a closed–system) at high altitudes. Because of the innate thermal and chemical stability of the components, the VAB will operate for multiple altitude excursions on Venus and facilitate long-term exploration of the Venus atmosphere from 55 km to 20 km.

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