AN AIRBORNE TURBINE FOR POWER GENERATION ON VENUS J. SAUDER, B. WILCOX, J. CUTTS[1]
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Introduction: While there are a number of questions about Venus that can be answered by orbiters and high altitude balloons, many science questions (such as geology) require surface access. All prior Venus surface missions and most current surface mission proposals have a lifetime of 2 to 24 hours. However, this stands to change with the advent of silicon carbide and gallium nitride electronics, which have been demonstrated to operate for thousands of cycles above 460C. As the projected life of lander concepts extend from hours to months [1]–[3], providing power to the lander becomes a challenge.

Power Challenges: Standard approaches to power planetary landers would utilize a radioisotope thermoelectric generator (RTG) or solar panels. Although RTG's have parts which operate the hot side of the thermocouples at high temperatures, no RTG has yet been designed for and tested in the Venus environment and development would require significant investment. Also, unlike recent RTG systems that have a multi-mission focus, an RTG for Venus presents a much more limited use case. While an RTG would provide an elegant power solution, a full development and qualification of one for the Venus environment is uncertain.

A second option would be to utilize solar panels on Venus, which is appealing since it should be possible to make them survive the Venus surface environment.[4]. However, there are several key problems with this approach. First, because of the dense cloud layer, the solar flux measurements on the surface of Venus averages 33 W/m^2[5], compared to the ~ 1360 W/m^2 a spacecraft in orbit around the earth can access. Further, because of the extreme heat, solar panel efficiency is reduced from approximately 30% to a 7-10% [4]. Finally, the Venus day is approximately 60 days, which means there is a 60 day night period during with the solar panels would not function. Some of these problems can be mitigated by buoyant vehicles that are designed to operate only during the Venus day and cycle between the surface where they perform science and the 30 km level in the atmosphere where they generate power but a long duration surface power source is clearly of great interest.

An Airborne Turbine: Placing a stationary airborne turbine in the Venus atmosphere has to the potential to generate sustained power to operate a lander. The turbine would fly between ten to several hundred meters off the ground, where there is an opportunity to obtain higher wind power than what a surface lander could access. At such an altitude, a 3-meter diameter turbine with an assumed efficiency of 42% could produce 12 watts of power at 0.5 m/s and almost 100 watts at 1.0 m/s. The basic concept would be to have the turbine tethered to a heavy lander. The turbine would be initially launched via a metal bellows filled with helium or water vapor, but then would support itself in the air with an aerodynamic surface much like a kite. This would prevent it from being dependent on maintaining buoyancy despite eventual loss of the lifting gas at Venus temperatures, and thus extend its life.

Design Considerations: The specific wind speed on the surface of Venus remains a significant question, and means the design has to make considerations for wind speeds from approximately 0.3 m/s to 2.8 m/s [6]. The key driving factors are those of power, force of the wind speed, and lift. While power scales with velocity cubed, force and lift scales with velocity squared, and all are a multiple of density and area. This has a significant implication in comparison Earth based airborne turbines. While the amount of power is less than what could be generated on Earth because of Venus's much lower wind speeds (even when accounting for the increase in density), a wind turbine would have to be designed to take forces similar to those on Earth.

Science Applications: In addition to generating power, the airborne turbine would also be able to measure wind speed at an altitude in the Venus atmosphere. The force on the tether and/or total power generated can measure wind speed. Better wind speed information would not only help us to better understand Venus weather data, but would also provide critical data required to estimate the moment of inertia of the planet, which in turn could help us understand more about Venus's core.

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