UNSPOOLING GENERATORS FOR VENUS MISSION POWER APPLICATIONS. Tomasz M. Kott (tomek.kott@jhuapl.edu), Noam R. Izenberg, Stergios J. Papadakis, and Robert E. Gold; The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: The need for long term (days to months) power (one to several watts) for planetary missions where solar power is difficult and other alternative power sources are expensive, risky, or complex is a challenge for missions to targets such as the surfaces of Venus [1,2]. We explore a technology that can produce power even in harsh conditions and does not rely on incompletely understood, possibly stochastic processes like surface or near-surface winds. Surface pressure on Venus is relatively constant, with a well-characterized lapse rate; we can take advantage of this environment and use the upward force of buoyancy to drive a mechanical generator to power a variety of long-term missions.

Unspooling Power: This method uses the buoyant force of a balloon in the dense (95 bar at mean surface) Venus atmosphere to unspool a cord attached to a generator to provide electrical power. Figure 1 shows a conceptual system block diagram. The balloon provides an upward force F_b, which is transferred to a drum, rod, or spool by the attached cord. The drum rotates slowly, and is mechanically stepped to an alternator/generator. The generator feeds through a boost regulator to the equipment and/or an energy system, possibly with voltage control.

The system is a low-mass relative to potentially hundreds of kilograms of batteries required for medium and long duration missions to the surface of Venus. It is low-risk, both in terms of development and cost, relative to advanced systems like radioisotope powered sterling coolers. The system can be idle indefinitely without losing stored energy. It could also be used to generate short bursts of power greater than RTGs or batteries can provide, for intermittent tasks such as data transmission.

The amount of energy available from this technique can be estimated by integrating over the rise of the balloon. A Venus lander system with 50% generation efficiency, and a 10 m^3 balloon rising for 10 km over a year could provide nearly 600 mW of power continuously, with a balloon rise rate of 0.3 mm/s. The mass of the balloon itself and the cord that connects it to the lander are small compared to the buoyant force. A high-performance cord of appropriate tensile strength will weigh about 1% of the buoyant force. At Venus, a water balloon may be more practical, with a concomitant reduction in total available power, and/or duration of mission.

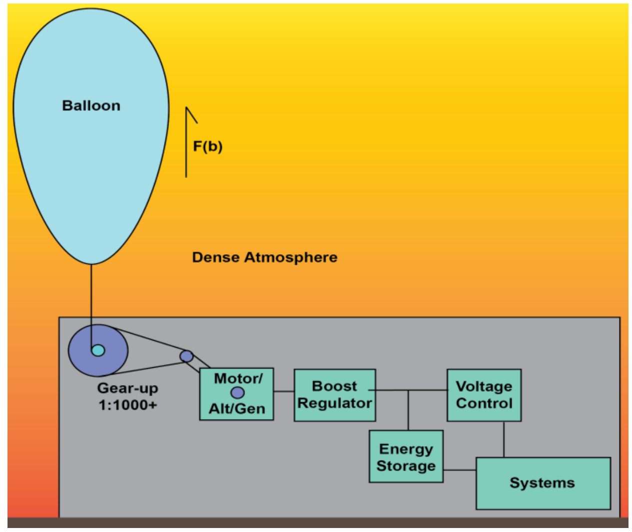

Figure 1. Schematic of buoyant unspooling power system.

Proof of Concept Study: From commercial off the shelf components, we created an in-lab dry prototype, using heavy weights to simulate the forces of a buoyant object. We demonstrated mechanical to electrical energy transduction efficiencies of nearly 30%.

The prototype uses a magnet rotor with 6 coils with iron centers. We used industrial gearboxes, stripped of most bearing grease, for the gearing ratios; 100:1 or 1000:1 depending on the experiment. To test the efficiency of the setup, we connected load resistors to the coils, and measured the power dissipated in the resistors, altering weights, gear ratios and the resistors in different trials. Weight was considered a proxy for different buoyant forces. To change the speed of the falling weight, we changed the electrical load on the coils. Resistances varied between 2.3 Ω (for the slowest speed) to 330 Ω (for the fastest speed), approximating short-circuit and open-circuit configurations. We were able to show that most of the inefficiency at low unspooling rates was due to friction, attributed to leftover grease in the gearboxes.

Conclusion: Unspooling power shows promise as a potential low complexity, low cost, and possibly lower overall risk "clockwork planetary probe" for long sojourns on Venus and other solar system targets with dense atmospheres.

References: [1] E. Kolawa et al. (2007) *JPL Pub.* D-32832. [2] G.A. Landis & K.C. Mellott (2007) *Acta Astronomica* 61, 995-1001.