RIPS (Rotor/Impeller Power System) for Planetary Atmosphere Descent Probes. N. R. Izenberg[1], T. M. Kott[1], S. J. Papadakis[1], [1]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA, noam.izenberg@jhuapl.edu

Introduction: The Rotor Impeller Power System (RIPS) [1] uses counter-rotating rotors in place of a parachute to provide power to a planetary atmospheric entry probe while also slowing the probe descent. Two rings of rotors blades with magnets turning around the exterior of a spherical or other solid shape drive current through coils on the interior without the need for hull penetrations. The power generated by such a system is limited by the size and strength of the blades, and the optimization of their angle of attack during descent of an increasingly dense atmosphere. The NIAC Phase I point study for RIPS is a Saturn descent probe modeled after the atmospheric probe of the Galileo mission, however, the technology is applicable to any solar system body with an atmosphere. Modern atmospheric probe's instrumentation advances mean a 1m^3 spherical RIPS-powered probe could provide increased science output for the same payload mass, or equivalent science output from a smaller probe, or other advantages such as improved data transmission, or multiple smaller probes at multiple target locations for equivalent cost.

Initial modeling of RIPS generation looked at power generated from descent of a Galileo-size descent probe over a descent from 100 mbar to 50+bar of Saturnian atmosphere over a period of hours, producing multiple kW during this fall. Though we went into the greatest detail for a Saturn probe, we performed first order evaluations of power at the other giant planets as well.

RIPS Power: The rotor-impeller power system has a specific energy nearly 20 times greater than batteries while generating up to 10 kW of continuous power through a multi-hour mission.

Figure 1 shows the concept for a RIPS descent probe. Two counter-rotating rings of blades generate power and slow descent. Since the power generation system to provides descent control, we compare the proposed solution to the energy provided and mass used by battery systems *and* parts of the descent module.

Using blade element theory [2], we calculate the speed of descent for probes through the atmospheres of the four gas giant planets. From the speed, we calculate the mission time and generated energy when the probe falls to a depth corresponding to 50 bar. For the probes, we consider 8 blades with a length of 100 mm each and two different blade profiles. We consider two probes:

•RIPS-L (large) probe of 0.9 m diameter and total rated power of 10 kW; it has a mass of 219 kg, and

•RIPS-S (small) probe of 0.5 m diameter and a total rated power of 3 kW; it has a mass of 91 kg

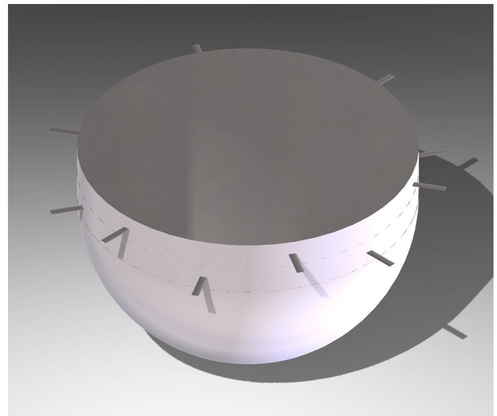

Figure 1. A RIPS-powered probe schematic.

We compare this to the Galileo probe as a reference. The descent module on Galileo was ~43 kg, with another 49 kg in the parachute, separation, and harness for the deceleration module [3]. We estimate that our power generator would replace the descent module as well as 50% of the mass of the deceleration module. Thus, the total mass of the Galileo structure we would be replacing is about 70 kg. The results for specific energy are shown in Table 1.

Table 1. Specific energy (Wh/kg)of probes during descent to gas giant atmospheric pressure of 50 bar

Probe Planet:	Saturn	Jupiter	Neptune	Uranus
RIPS-L (10 kW)	260	109	138	182
RIPS-S (3 kW)	285	120	150	198
Galileo	-	6.2	-	-

Nearly all descent profiles are between 2-5 hours. Our RIPS design provides more than 20x the specific energy while providing 10 kW of continuous power for communications and scientific instruments. The small probe concept allows for the possibility of sending three small probes with similar total mass as one Galileo probe to a target gas giant to provide a more distributed understanding of a single planet.

We also find that we need 2-6kW for direct to earth data transmission or 100-700W for relay communications from atmospheric depths up to hundreds of km (at Saturn). A high continuous power capability might therefore enable completely new mission concepts.

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References: [1] Izenberg et al., 2020, RIPS NIAC Phase I Final Report. [2] Modenini et al., (2018) Adv. Astronaut. Sci. 162, 765–776. [3] Givens, (2008) Pioneer Venus & Galileo Probe Development: Comparison/Assessment.