LUNAR POWER ANYWHERE, ANYTIME.

Michael H. Hecht[1] and Philip Lubin[2]. [1]MIT Haystack Observatory, Westford, MA, mhecht@mit.edu, [2]Univ. of California at Santa Barbara, lubin@ucsb.edu.

Scenario: *A solar-powered prospecting rover prowls the stark lunar landscape in the two-week lunar night. For 4 minutes every two hours an artificial sunbeam tops the horizon and settles on its solar panels for a quick recharge. Today, it is observing changes in surface tribology that can only be seen when the solar wind is shielded by the bulk of the planet. Tomorrow, it will descend into a Permanently Shadowed Region in search of accessible ice.*

The technology: While solar power satellites have long been promoted for terrestrial use [1], they are far more appealing for lunar applications where orbital facilities are less expensive and simpler to emplace than ground facilities. While beamed power systems for the moon (and Mars) have been studied in the past [2], the confluence of several factors now make them practical for solar system exploration in the near-term.

Since the divergence of a power beam is proportional to the wavelength, the need to limit the size of the surface receiver favors optical over microwave transmission. Fortunately, advancements in laser communication (lasercomm) and in directed energy (such as the Breakthrough Starshot project) have established the feasibility of transferring laser energy in a precision manner from place to place.

In this presentation we offer a point design that provides average power comparable to an MMRTG to a 2.5 m^2 photovoltaic array on the surface from a SmallSat-class orbiter at a perilune height of 200 km that is equipped with 6 square meters of solar panels, a small battery, a 7-kW fiber laser, a 20-cm focusing mirror, and 1 arcsec pointing accuracy (Fig 1). The solar panels would charge the battery during most of each orbit, except when in eclipse, and would discharge for ~4 minutes during each pass over the landed station. With a 2.2 hr orbital period, this strategy corresponds to a 3.2% duty cycle. The optical system would project ~6 kW to the surface, illuminating a spot as small as 1 m (though in practice, 2-3 m is more realistic due to jitter, aberration, and elongation from an angle up to 45º). On the surface, this flux density is comparable to overhead sunlight.

Laser power of 3-6 kW can be readily achieved today by joining the outputs of multiple fiber lasers via spectral combining [3], a technique capable of producing tens of kW of output. Other components needed for an operable system, including steerable optics compatible with high power loads, are commercially available for space applications. The telescope, pointing and tracking elements, radiator, battery, and solar panels are high TRL commercial components that can be adapted to a free-flyer platform. Thermal management of the laser system, can notionally be accomplished with phase change materials.

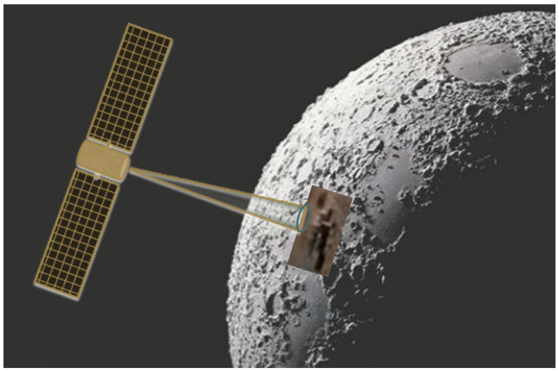

Fig.1. A laser-equipped SmallSat illuminates the photovoltaic panels of an InSight-like lander from low orbit.

Assets needed on the ground are comparable to those used on a typical solar-powered mission, such as the 2.1 m UltraFlex deployable solar arrays used for the Phoenix and InSight missions, though for this application they would be optimized for the laser wavelength. Pointing feedback is most easily provided via radio link from the lander to the orbiter, directing the beam to optimize received power with input from photocells at the edges of the surface solar collector.

Acknowledgements: We appreciate the advice and guidance of T.Y. Fan and Alan Wirth of MIT Lincoln Laboratory in formulating this concept and helping us understand the available technology.

References: [1] Glaser, P.E., Davidson, F.P, Csigi, K.I., (1997) Solar Power Satellites: A Space Energy System for Earth, Wiley-Praxis. [2] e.g. M. W. Stavnes, NASA Contractor Report 191072, 1992. [3] S. Redmond, K. Creedon, T. Y. Fan, A. Sanchez, C. Yu, and J. Donnelly (2013), in Coherent Beam Combining, A. Brignon ed. Chapter 4 (Wiley-VCH).