Data Encoded Laser Wireless Power (DELWP) For Lunar Polar Applications. Dennis Poulos, Poulos Air & Space, Inc., 4084 Preservation Cir, Melbourne, Fl 32934; dpoulos@pouloscorp.com

Background: Laser wireless power (LWP) for Lunar exploration was proposed by the Communications Working Group (WG2) of the 2008-2009 International Lunar Network (ILN) Study. Jim Schier, NASA, Chief Architect, Space Communications and Navigation, Human Exploration and Operations Mission Directorate described the ILN findings in a "Concept for Lunar Power and Communications Utility" briefing on Oct 14, 2015[1]. Critical technologies have matured to the point where this architecture is commercially viable and could be deployed to support Lunar missions.

High Power Fiber Laser for Wireless Power: Fiber laser technology has evolved so that power levels of 10's of kW can be efficiently generated and transmitted with very high quality and wall plug efficiencies (WPE) approaching 30% or higher[2,3]. Assuming power satellite use conventional solar panels, with an efficiency of 25%, to generate power, the size of a solar panel assembly to support a 10 kW fiber laser is 100 m^2. [For comparison, the area of the ISS solar panel assembly is 3,246 m^2 and the ISS generates 120 kW to 84 kW.] A high-power fiber laser can be modulated with a high data rate signal and multiple channels of data can be multiplexed into a single beam using wavelength division multiplexing (WDM).

Advanced High Efficiency, High Power Tuned Photovoltaic Power Receivers: Photovoltaic (PV) cells are being developed for power transfer. Mature Vertical Multijunction (VMJ) cell technology is currently used for commercial applications. VMJ cells receive monochromatic (laser) power at irradiancies greater than 18.6 W/cm^2 (150 times more intense than sunlight) at 975 nm (IR band) with efficiencies of over 36%[4]. Newer technology Vertical Epitaxial Heterostructure Architecture (VEHSA) PV technology has demonstrated operation at irradiance levels 1,000 times solar intensity, with power efficiencies of 70%[5]. VMJ or VEHSA power panels on mobile rovers or at fixed Lunar outposts illuminated by high intensity monochromatic laser light would provide hundreds or thousands of times the power of equivalent solar panels.

Aperture and Landed Mass: Diffraction limited gaussian laser power beams with no atmospheric absorption loss focus 86% of the transmitted power in the central beam (the beam "spot"). An 850 nm laser beam from a 1 m aperture transmitter on a satellite with an apoapsis of 9,381 km would have a 17.9 m diameter (251 m^2) spot on the lunar surface. A VMJ or VEHSA optical power receiver that size could generate hundreds or thousands of kW of power. The spot size for an equivalent 10 GHz (X Band) RF power beam with a 30 m transmitting antenna would be 21 km (346 km^2).

"Frozen" Elliptical, Inclined Polar Orbits: Classes of "Frozen" Lunar polar orbits were identified by Dr Tod Ely[6] and Erica Lieb[6] as part of the 2004 Vision for Space Exploration (VSE) studies. These frozen elliptical orbits are long-term stable. Nominal eccentricity is between 0.6 and 0.7 with an apoapsis between 6,111 km and 9,381 km. Inclination is between 51° and 56° (or higher) and they have line-of-sight (LOS) coverage of the complete polar region. Pointing and tracking at those ranges to rovers or outposts on the lunar surface is challenging but doable. A constellation of three laser power satellites deployed in a "Frozen" orbit will provide simultaneous coverage of polar regions by two power satellites for enhanced safety and reliability.

Survival and Operation through the Lunar Night. These technologies, combined into a Data Encoded Laser Wireless Power (DELWP) system, will generate significantly more power than equivalent Solar panels and provide bi-directional high-speed data links, both key enablers for exploration of the dark Lunar polar regions and operation and survival through Lunar night. Deployed on the polar crater rims, DELWP will provide LOS power and data deep into the permanently dark craters enabling extended range and time on station for prospecting rovers without relying of large, heavy batteries for mere survival, cabling, or radioisotope thermoelectric generators (RTG). Waste heat will be harvested to provide thermal conditioning for rovers. A three-satellite constellation of laser power satellites flown in "Frozen" Lunar orbits would provide continuous (day/night) optical wireless power across the Lunar polar regions. Laser systems, compared to RF, minimize transmitting and receiving apertures, minimize landed mass, and maximize data transfer speeds. Multiple sites or rovers can be serviced simultaneously by additional beam transmitting apertures or by beam scanning.

References: [1] Jim Schier (NASA) (Oct, 14, 2015) Concept for Lunar Power and Communications Utility briefing. [2] Kuniharu Himeno (2016), Fujikura Technical Review, No 44, March 2016. [3] John Wallace (2016), LaserFocusWorld, Vol 52 #3, 29-26. [4] Mico Perales (02/17/2015) LaserFocus-World, Vol 51 #2, 29-32. [5] York M. C. A. and Fafard S. 2017 J. Phys. D 50 173003. [6] Dr Tod Ely and Erica Lieb, Jet Propulsion Laboratory, The Journal of the Astronautical Sciences, Vol 53, No3, July-September 2005, "Stable Constellations of Frozen Elliptical Inclined Lunar Orbits"; pp. 301-316.