Scalable Wireless Charging System for Lunar Rovers

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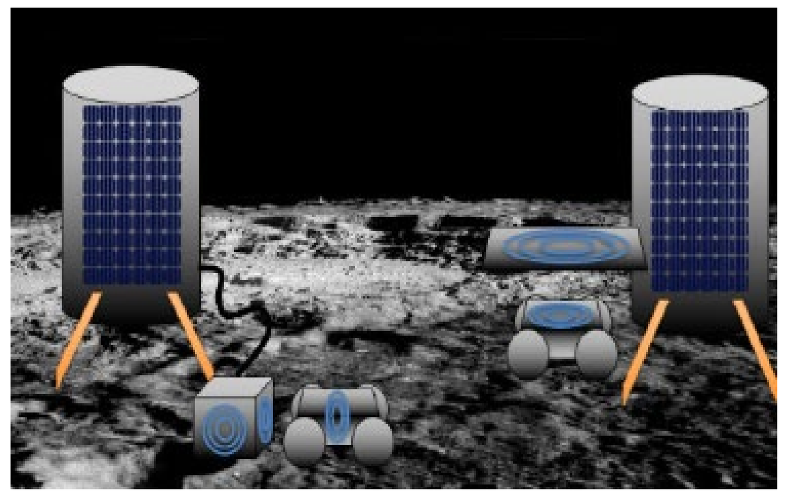
Introduction

Generating, storing, and transmitting power is a critical infrastructure need for all human and robotic activities. Traditional space systems operate through nuclear, solar, or tethered power mechanisms that require great complexity and process to qualify and operate. Tethered systems are hindered tremendously by mechanically mated components that are prone to regolith incursion. Regolith clinging is a significant risk for mobile assets such as lunar rovers that must either restrict the surface operation speed or employ expensive counter-measures to control the clinging effects of the abrasive lunar regolith. An alternative solution to mitigate these risks is to transfer power and data wirelessly. Trends in the miniaturization of electronics and increasing efficiency of switching components, enable proximity charging to be a viable option for space applications. Systems such as WiBotic's wireless charging platform would weigh up to10 kg and consist of a base station and power receiver (.04 kg) that can be configured in many orientations to transmit up to 1.5 kW of power. Astrobotic is partnered with WiBotic to develop this system for space applications.

Fast and Scalable Charging Applications

There are several applications that necessitate proximity chargers in space. In relation to the Moon, these include supporting marsupial roving missions, enabling robotic systems that do not contain onboard nuclear or solar power generators, charging toolkits on crewed lunar terrain vehicles (LTVs), powering the heaters of critical devices to survive the lunar night, supporting exploration sorties in lava tubes and pits. Marsupial missions have been proposed in the past with large rovers and scouts that deploy from them (such as Astrobotic's 300 kg Polaris rover and 3.5 kg CubeRover) to explore the lunar surface. These scouts could be used for resource prospecting and hazard avoidance for larger, expensive assets. If a proximity charger were mounted to the base of a larger rover then scouts could be recharged by the larger rover directly through its onboard power source. Similarly, proximity chargers could simplify the designs of large rovers by removing the need to contain onboard power systems and instead receiving power from a proximity charger affixed to a lander or deployable solar array. Larger implementation of proximity charging could transfer multi-kilowatt power to these systems. Finally, proximity chargers can address aspects of Lunar SKGs defined by LEAG, specifically, Theme III-D-1 Lunar dust remediation, through the sealed recharging system interactions with lunar regolith.



Wireless charging concepts from landers to rovers such as Astrobotic's CubeRovers.

About Astrobotic's Planetary Mobility and WiBotic

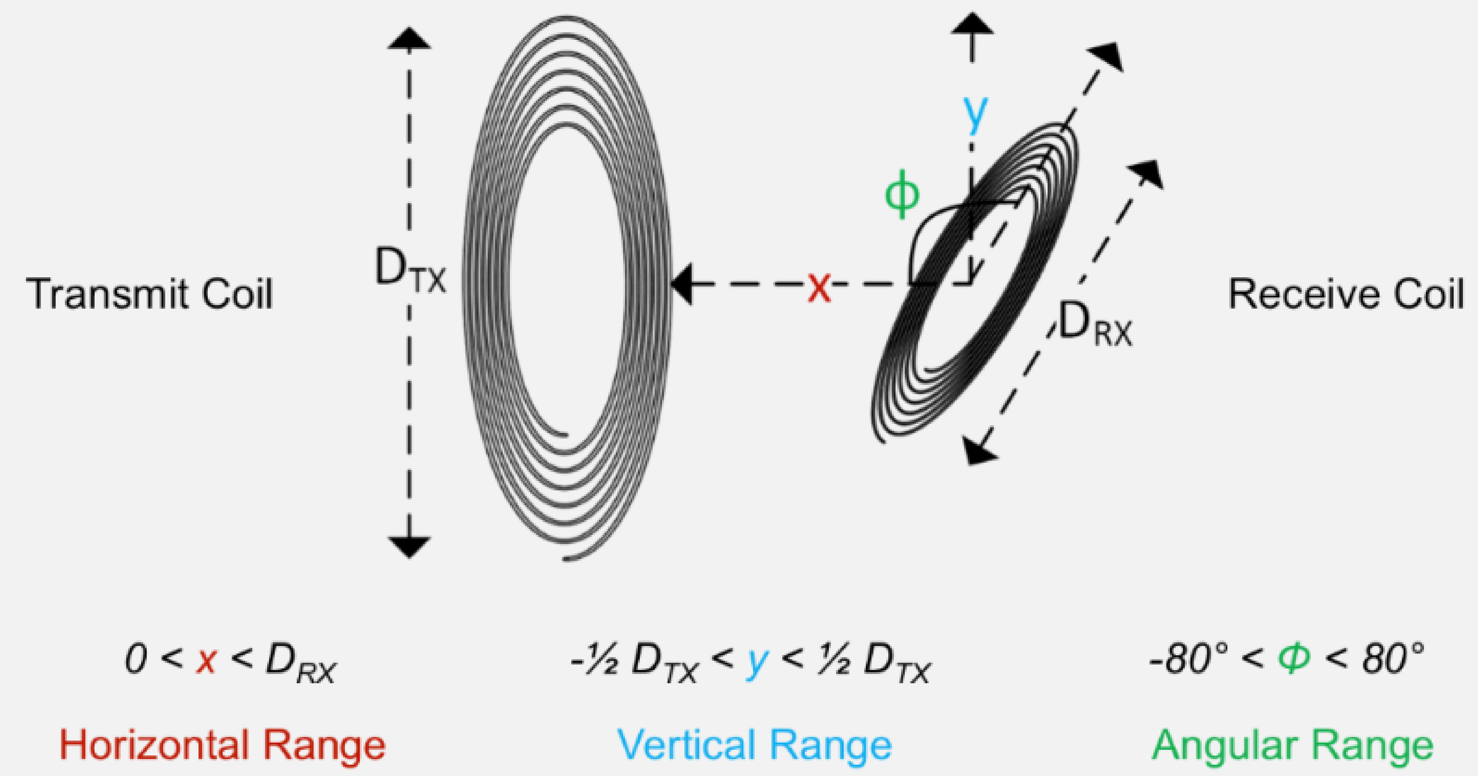
Astrobotic's Planetary Mobility team is reducing barriers to entry for mobility services on planetary bodies. From rovers, to wireless chargers, to ground software, we deliver cutting edge technology that pushes the envelope of what's possible for science and technology investigations. Email us at pm@astrobotic.com.

WiBotic is transforming the most critical infrastructure for autonomous systems: power. For unmanned aerial vehicles, ground based robotics, underwater vehicles, industrial automation equipment, and now space systems, autonomous battery charging and reliable power management onboard any battery-powered vehicle remains a major challenge. Email us at info@wibotic.com.

Performance Specifications

Target performance of the magnetic resonance system is as follows:

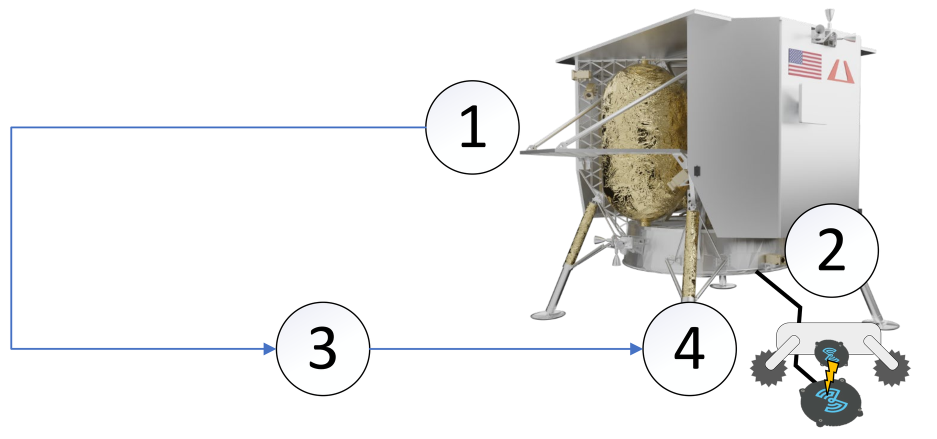
- Charging range of 0-4cm (horizontal spacing), +/-5cm (lateral misalignment), 0-70deg (angular misalignment)
- Charging rate of 1-1.5 kW
- Dust tolerant design for 1 μm lunar regolith particles
- Transmitter mass of 10kg
- Compact base station size of 29 x 37 x 33 cm and power receiver size of 12 x 18 x 3 cm
- Operational temperature range of -200C to +86C to enable operations at the lunar pole and equator



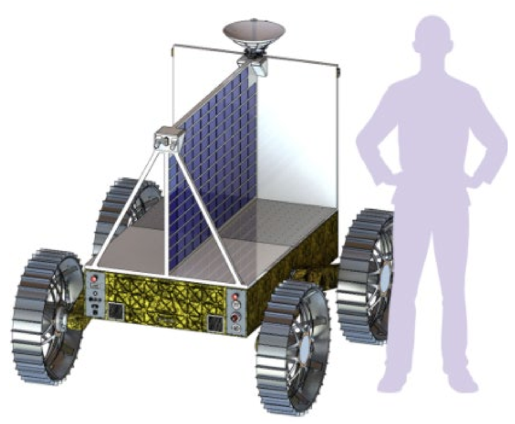
The range and positional flexibility of WiBotic's wireless charging systems. The horizontal range (x) is driven by the diameter of the receive coil. The vertical range or offset (y) is determined by the diameter of the transmit coil. The angular misalignment is independent of coil size.

Concept of Operations

Step No.	Concept of Operation Step
1	ROVER DEPLOY
2	TRANSMITTER DEPLOY
3	ROVER DRIVE AND RETURN
4	ROVER CHARGE



This system is capable of mounting to a lunar lander and other large structures available during a mission, such as a deployable solar array acting as a power source. The above ConOps illustrates how a rover could utilize the charging system once it is deployed from a lunar lander. Rovers such as Astrobotic's Polaris rover at right could increase its mission capabilities by supplementing or replacing solar charging with a fast, lightweight proximity charging system.



System Overview and Current Status

(Top images): The WiBotic wireless power system showing a robotic arm installing the receiver antenna 800 m under the ocean. This maneuver is remotely performed by a human pilot at the surface and is far simpler than plugging in an underwater physical connector. (Bottom left): WiBotic's existing set of charging solutions comprising a power transmitter and receiver. (Bottom right): A 300 W transmitter charging a rover.

The lightweight, ultra-fast charging solution, comprised of a base station and power receiver, are the first of their kind in space proximity charging products. Based on magnetic resonance charging technology developed at the University of Washington, WiBotic now commercially offers these products in global industrial markets. These units are being developed to withstand the harsh environments of launch, cislunar transit, and the lunar surface. WiBotic has deployed wireless charging systems in industrial and underwater environments that are TRL 9 for terrestrial applications. One of these units utilizes a 1atmosphere 1000 meter rated underwater sealed housing and is operational 800 m under the ocean surface.

The materials and structures of the base station and power receiver will be evaluated to ensure they are capable of surviving launch and the extreme thermal vacuum environment. Heaters will be selected and integrated to ensure sensitive electronic components remain within thermal operational limits. Sealing will be re-evaluated to mitigate lunar dust incursion. The baseplate design will be updated and fabricated so that it can conductively dissipate heat from the charging electronics and subsequently radiate it to space. This baseplate will be optimized for mounting to a lunar lander as a design reference. A stowage and deployment system for the base station as well as mounting hardware for the power receiver will be designed and fabricated. Radiation shielding for sensitive components will be evaluated..

Technology Advanced Through Investment

The Commercial Lunar Payload Services (CLPS) program plays a pivotal role in enabling these precursor missions. NASA has funded Astrobotic and WiBotic to co-develop a high-power density wireless charging solution through the SBIR program.

Acknowledgement

Thank you to the NASA SBIR program for funding the development of this platform.