WIRELESS POWER AND DATA TRANSFERS FOR AUTONAMOUS MOBILE SYTEMS. K. S. Wallace, NASA Marshall Space Flight Center, Mail Stop ES30, Huntsville, AL 35812, kevin.s.wallace@nasa.gov .

Introduction: Future human exploration will make increasing use of small-scale autonomous mobile systems to support and enable the exploration objectives, including both surface and free-flying platforms. These systems can support a variety of objectives for Mars exploration, such as reusable landers, lightweight aerial instruments, and robotic scouting of the Martian moons or nearby asteroids. The goal of the Wireless Power and Data Transfer (WPDT) initiative is to mature and integrate the technologies for remote power transfer, and optical communication links. With these capabilities, the autonomous remote units are enabled for independent short-term operations, and then return to within range of a designated "home base" (which can be either a surface facility or a "mother ship" orbital system) for power and data transfers. In this scenario, the remote units utilize battery power, and is not limited to solar illuminated locations, allowing it to perform its' designated purpose, such as scientific data collection, transportation of samples or materials, or repair/assistance to another element of the infrastructure. Prior to depletion of its' power, the remote unit then travels (if necessary) to within the range and line-of-site of the home base. The home base then transmits power to recharge the battery of the remote unit, collects data, and the remote unit is ready to return to the field for further operations.

This project will enable new capabilities for Mars exploration by enabling operations inside shadowed zones (for example inside a craters where resource extraction may be taking place, e.g. water) that are not able to maintain powered operations thru solar generation.

Affordability of these future exploration systems is improved by enabling a new class of autonomous systems. The remote units can be kept simple, with necessary complexity consolidated into the home base, capable of servicing multiple remote units that have the capability to perform maintenance, exploration, and resource extraction under situations not previously possible without larger, more complex systems.

Technical Approach: The technical approach for this project matures three underlying technologies: the power transfer mechanism, the data transfer mechanism, and the method for obtaining precise alignments. These three technologies are combined into an operational concept for home base operations, which will be implemented into a ground-based demonstration with an identified path for upgrades to space-environment capable implementations in time to allow these technologies to be implemented into future missions.

Technology 1 – Power Transfer. The power transfer task will look at several options including concentrated/reflected light and laser based illumination, to determine the best implementations in various scenarios. Factors to consider in this study include complexity of the overall design, as well as the side-effects of thermal heating at the receiver. Laser-based systems offer the potential for greater power transfer rates over concentrated solar reflections, but introduce additional efficiency losses, and will require a detailed understanding of the thermal effects, in order to avoid overheating the receiver. Alternatives to consider include the use of optical fibers for transmitting the incident illumination to the conversion points. This approach may be useful in some ground based, short-range missions (such as inside a permanent shadowed crater) but would necessitate range limits based upon the practical lengths of the fibers. The Army FOG-M program has done work with deployed fibers that can be investigated for leverage.

Technology 2 – Passive Optical Data Transfer. The project will look at 'passive' optical data transfers, where the laser sources are solely on the home base, and the autonomous target simply modulates the reflected laser. This approach offers a lower power solution to an active laser on the remote unit, and potentially can save power over a more traditional radio-frequency communication system. This can be done in ground demonstration with simple commercial liquid crystal displays (LCD) that alternate between the binary states of "solid white" and "solid black", with paths to flight thru electrically polarizable materials. Data flows into the remote unit again use laser sources on the home base, with the rover detecting the modulated pulses directly.

Technology 3 – Base/Remote Unit Alignment. The challenge for both the data and power transfer is alignment of the home base systems to the targets on the remote unit. If the two systems are not sufficiently aligned, valuable power will be wasted rather than transferred, data may be lost, and there will be secondary undesirable effects thru thermal heating of the systems and perhaps setting up scattering in an internally 'dark' environment that may be disruptive. To address this, while keeping the remote unit as simple as possible, the proposed approach will use a corner-cube and video target (leveraged from sensing applications used for automated rendezvous and docking) to precisely locate the remote unit once it comes within the range of the home base. Once located, the home base will align the power and data transmitters to precisely match the known locations on the target, and begin transfers. A clear field of view, as well as angular confinement of the optical beam will determine achievable range, with a goal of up to 1-2 km for eventual application.

Operational Concept and Home Base Development. The Home Base will have the majority of the complexity of the system with requirements to detect the remote unit, align the transfer sources to the targets, and execute the transfers. The implementation approach will be to use modular reconfigurable computing elements to minimize the unique part counts required for logistics and maintenance. Where possible, these can be made common with those on the remote units. These electronics will be candidates for implementation with new technologies in low-temperature and radiation hardened electronics, such as Silicon-Germanium, and other emerging technologies.

Demonstration. To demonstrate these technologies, we will utilize existing Marcbot robots as platforms to represent the autonomous remote systems. These units will be modified to host the optical power/data components. Demonstration runs will consist of increasing distances with the Marcbot travelling autonomously, then at a set time, or based upon battery charge, return to the range of the home base for transfer. The home base can be located either at ground level, or elevated to a rooftop to extend the range available without the obstructions of buildings and trees that would not be present in a space based implementation. Figures of metric will include both the speed at which power can be transferred, and the achievable ranges.

Subsequent Developments: Building upon the results of these early technology maturations, WPDT can be matched to the actual mission architectures for Mars Exploration and implemented into specific systems. Ideally the home base concept can service multiple remote units covering the needed range of surface rovers, aerial vehicles (gliders, balloons, etc.), and excavations in deeply shadowed regions. Particularly for the latter case, multiple bases may be needed to cover the wider range of potentially interesting sites to explore. Alternatively, passive or semi-passive optical reflector chains could be used to extend the range from the base unit, retaining concentrated complexity at a single or fewer base stations in order to reach remote sites that are shadowed permanently or for long durations. At this phase, commonality of the electronics hardware can be extended to encompass commonality across other aspects of the Mars exploration architecture.

Partnerships: This concept is currently being developed by a collaboration of the Marshall Spaceflight Center, Kennedy Space Center, and Glenn Research Center. Additional agency teaming and partnerships with academic and industry partners are still being explorered.