Surface Networks

Exploration of lunar and planetary surfaces will require short-range (~ 25 km), bi-directional, and robust multiple point links to provide on-demand, disruption-tolerant, and autonomous interconnection among surface-based assets. Some of the nodes will be fixed, such as base stations and relays to orbital assets, and some will be moving, such as rovers and humans. The ability to meet the demanding environment presented by lunar and planetary surfaces will encompass the development and integration of a number of communication and networking technologies and protocols, including:

- Low power, space-rated Application-Specific Integrated Circuits (ASICs) and Field Programmable Gate Arrays (FPGAs) for wireless network products: short range (Fixed, long range (Integrated tracking, timing, and navigation services which will determine locations of human and robotic assets on the lunar surface, providing them to relevant entities;
- Self-healing, ad hoc, disruption tolerant network protocols for intelligent, autonomous link management and reliability;
- Non-line-of-sight communication between stationary and moving assets, outside or inside lunar craters;
- Autonomous surface navigation and hazard avoidance systems for robotic and fixed assets;
- Analog voice-only radio service to the lunar outpost and the lunar relay satellite at the highest network priority for HF, UHF, or S-band.

In addition, to meet the stringent demands of continuous interoperable communications, human exploration needs to develop delay and tolerant networking (DTN) protocols that exploit persistent storage on mobile and stationary nodes to ensure timely and reliable delivery of data even when no stable end-to-end paths exist. Many networks straddle a continuum of disruption, from an almost-always connected network where a contemporaneous end-to-end path does exist, to highly intermittently connected networks where such a path seldom exists. More than
disruption tolerant, solutions must exploit stability when it exists to nearly approximate the performance of conventional Mobile *Ad hoc NETwork* (MANET) protocols. Proposals should address the following areas:

- Technical challenges posed by the design considerations enumerated above and assess tradeoffs of disruption, load, storage, topology, and delivery ratio;
- Demonstrate adaptive DTN routing via simulations;
- Develop proof-of-concept nodes complete with the networking algorithms developed as part of the funded work;
- Demonstrate unique communications in networks that suffer from severe disruptions and delays with adaptive routing developed in Phase 1;
- Develop a prototype convergence layer adapter plug-in for an Extra-Vehicular Activity (EVA) radio.

**Orbit Access Links**

Lunar and planetary surface networks will need to seamlessly interface with communications access terminals and orbiting relays that can provide autonomous and disruption tolerant connectivity to Earth-based assets. The access link communications system will encompass the development and integration of a number of communications and networking technologies and protocols such as:

- Autonomously reconfigurable receivers capable of automatic link configuration and management;
- Microwave ranging hardware built into the communication system for rendezvous and collision avoidance;
- *Ad hoc*, long-range spacecraft-to-spacecraft network protocols to initialize links on demand such that each node can route data through to another node.

The effort will leverage on the following technologies addressed under other SBIR subtopics:

- Antennas for surface and orbital access communications required for the aforementioned goals shall be developed under subtopic O1.04.
- Radios for surface and orbital communications required for the aforementioned goals shall be developed under subtopic O1.06.
- Optical transceivers required for the aforementioned goals shall be developed under subtopic O1.08.
- Any high rate, low power, efficient amplifiers or transponders required for the aforementioned goals shall
be developed under subtopic O1.09.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware demonstration that will, when appropriate, deliver a demonstration unit for testing at the completion of the Phase 2 contract.