To develop safe and sustainable exploration capabilities at minimum cost, while maximizing return, an incremental spiral development process will guide a build out of an integrated communication, navigation, networking, computing, informatics, and power architecture that supports all surface and proximity nodes, including humans in spacesuits, robots, rovers, human habitats, satellite relays, and pressurized vehicles.

The architecture will enable operational activities in which both fixed and mobile nodes with vastly differing communications requirements are seamlessly interoperable. Nodes are simultaneously connected to each other, to Earth, and to the CEV via in-space relay orbiters, and via wired and wireless networks that provide the bidirectional voice, video, and data needed. The need to be self-sufficient during exploration requires local control and an unprecedented level of autonomous operation to seamlessly connect the nodes and reduce operations cost. The Moon and Mars environments require SEU and extreme temperature-tolerant equipment tightly constrained by power, mass, and volume. Human presence requires at least one usable bidirectional link to the communications network at all times and high definition video to engage the public interest.

This subtopic focuses on the modular, reconfigurable RF communications and networking technologies needed to support a human presence on remote lunar and planetary surfaces with surface-to-surface and surface-to-orbit (access) communications.

**Surface Networks**

The complexity of astronaut excursions, habitats, surface manned and unmanned rovers, and landers make surface operations and man-occupation complex and daunting tasks. Exploration of planetary surfaces will require short-range, bidirectional, multi-point links to provide on-demand, autonomous interconnection among surface-based assets. Some of the nodes will be fixed (base stations) and some will be moving (rovers and humans). This will encompass a number of communications and networking technologies for communications in the 2.4 Ghz range, including: integrated low mass, low power (100’s of milliwatts) transceivers for very short-range interfaces with sensors and other small devices; power-efficient, miniature, modular transceivers for short-range communications among large (e.g., lander) and medium-sized (e.g., rover) surface assets; reconfigurable directionally selectable, multi-frequency arrays for wide coverage, high-gain links among surface assets; miniaturized modular antenna technology for surface-to-surface communications among mobile and fixed nodes; wireless products integrated with low-power space-rated ASICs and FPGAs; short (~1km) range access point...
base stations, or wireless router bridges for extending surface network coverage; fixed, long (~50km) range, wireless network terminals for extending high data rate communications over large distances; self-healing ad-hoc network MAC and protocols for intelligent, autonomous link management; and networking technologies to enable autonomous, seamless interconnectivity among all nodes.

**Access Links**

To interface with orbiting relays, terminals capable of providing seamless connectivity between surface networks and orbiting relays will be positioned on lunar and planetary surfaces and in orbit. Such an access link communications system will include: high rate, efficient, solid state amplifiers capable of very high data rates over 1,000-10,000 km distances with ranging signals embedded; very low-power data rates, and cost inter-spacecraft S-band transceivers/transponders for inexpensive spacecraft; optical transceivers capable of very high data rates over 1,000-10,000 km distances; SEU and solar flare tolerant transponders capable of: programmable wide-carrier frequency ranges from S-band to Ka-band, taking GPS measurements, and handling IP at the digital level; micro software radio technology for autonomous and intelligent space applications; low mass, volume, power, and cost-stable oscillators to provide accurate time and frequencies for autonomous operations; autonomously reconfigurable receivers capable of automatic link configuration and management; microwave ranging hardware built into communication systems for rendezvous and collision avoidance; and ad hoc long range spacecraft-to-spacecraft network protocols to setup links on demand, such that each node can route data through to another node.