NASA is planning a series of short and long duration human and robotic missions to explore the Moon and later Mars. The lunar and Mars surface and access network architectures will enable operational activities in which nodes are simultaneously connected to each other, to Earth, and to the Crew Exploration Vehicle (CEV) via in-space relay orbiters, and wired and wireless networks that provide the bidirectional voice, video, and data services. This subtopic is divided into the surface networks and access link domains (surface to orbiting assets).

**Surface Networks**
Exploration of lunar and planetary surfaces will require short-range, bidirectional, and robust multi-point links to provide on-demand, disruption tolerant, and autonomous interconnection among surface-based assets. Some of the nodes will be fixed (base stations and relays to orbital assets) and some will be moving (rovers and humans). The ability to meet the demanding environments presented by lunar and planetary surfaces will encompass the development and integration of a number of communications and networking technologies and protocols, including:

- Low mass/power (100's of milliwatts) transceivers for very short range interfaces with sensors and other small devices to enable communications among humans, robots, and access network terminals;
- Reconfigurable, directionally selectable, steerable, multi-frequency switched patch or multiple-in multiple-out antenna arrays for human helmets, robots, and fixed structures (e.g. habitats);
- Miniaturized planar, omni-directional, dual-polarized, self-orienting, and sector antennas for surface-to-surface communications among mobile and fixed nodes;
- Low power space rated ASICs and FPGAs for wireless network products; short (Fixed, long (up to 50km) range, wireless network terminals for extending high data rate communications over large distances;
- Integrated, autonomous tracking and navigation architectures and technologies;
- Self-healing, ad-hoc, disruption tolerant network protocols for intelligent, autonomous link management and reliable throughput.

**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:

- High rate, efficient solid state amplifiers capable of very high data rates over 1,000 - 10,000 km distances with ranging signal embedded;
- Very low power, data rate, and cost inter-spacecraft S-band transceivers for inexpensive spacecraft;
- Optical transceiver capable of very high data rates over 1,000 - 10,000 km distances;
- Agile, multi-beam antennas; mesh or other material flexible reflector unfurlable antennas for Ka-band and lightweight scanning phased array antenna systems;
- SEU and solar flare tolerant transponder capable of programmable wide carrier frequency range 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 system for rendezvous and collision avoidance;
- Ad-hoc, long-range spacecraft to spacecraft network protocols to set up links on demand such that each node can route data through to another node.