Surface Communications Network Architectures for Exploration Missions

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Outline

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  - Infrastructure
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Integrated Communications Architecture for NASA Exploration Missions

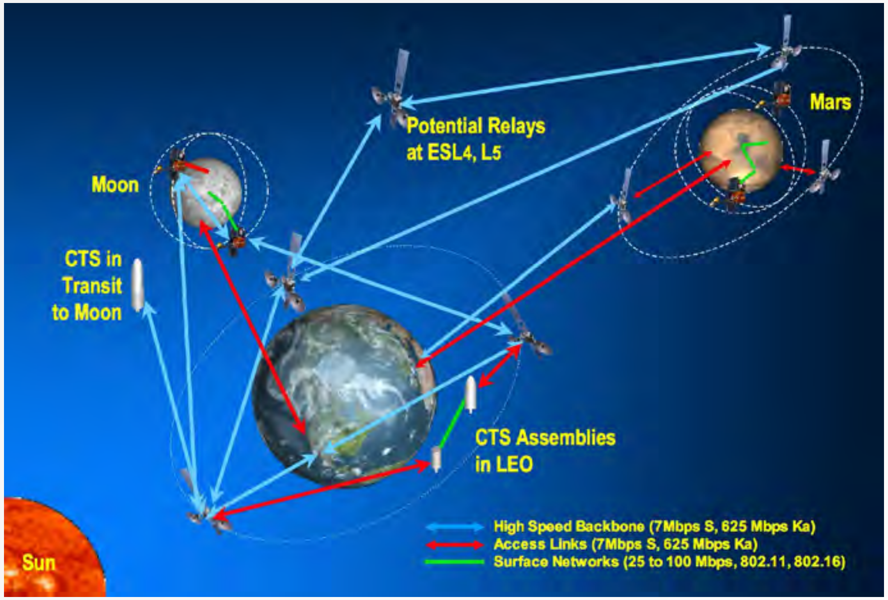
Vision for Space Exploration directs NASA to explore the Moon, Mars, and beyond with missions that are:

- Safe
- Sustainable
- Affordable

To achieve sustainable and affordable missions, a non-mission specific communications architecture is under development to address the needs of exploration. This infrastructure will be deployed once but used by multiple missions.

Architecture elements include:

- High Speed Backbone (space-to-space)
- Access Links (space-to-surface)
- Surface Links (surface-to-surface)



The surface communications system will use access links to seamlessly interface with the overall architecture and move data among key areas of exploration and Earth to achieve a complete reliable and robust communications network.

Assumed Exploration Requirements
Surface Missions

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Lunar (2018+)

EVA – Provide voice, data, and 2-way video conferencing links in lunar orbit and on the lunar surface to support EVA operations up to 15 km from the base camp during sortie missions, and 60 km during outpost missions.

Mars Testbed – Develop and test the communication and navigation network for use on Mars and other destinations.

Public Outreach – Provide HDTV coverage of critical operations for the public.

Short and Long Duration – Support both short (4-7 day) and long (42-98 day) duration surface stays

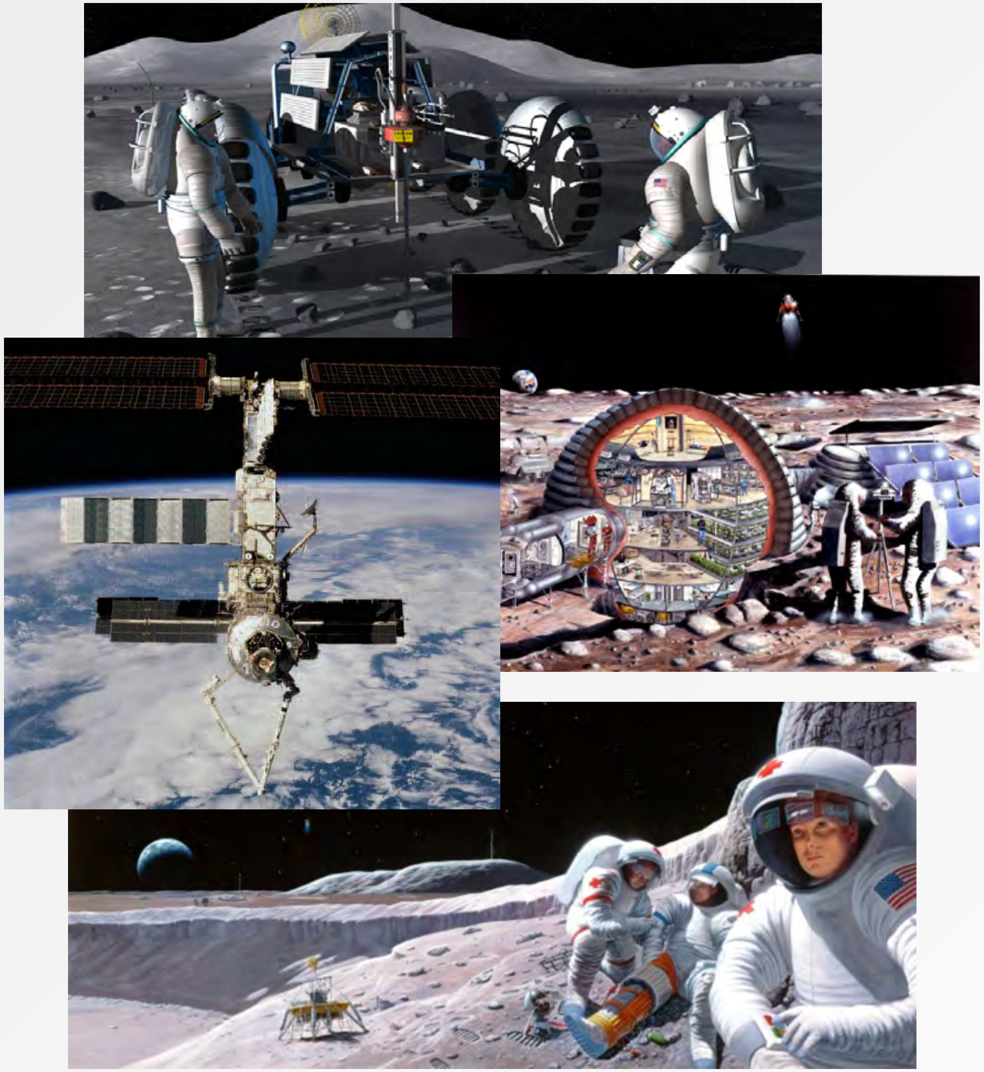
Mars (2030+)

Autonomous Maneuvers – Provide navigation for autonomous orbit maneuvers and precision landing

Autonomous Operations – Provide services for surface activities to take place autonomously, with no real-time Earth interaction.

Long Duration – Support extended duration surface stays

Assumed Exploration Requirements
Surface Network Infrastructure



Multiple Activities – Enable simultaneous operations for human and robotic missions.

Continuous Comm – Provide continuous global communication for critical events, including those taking place without Earth line of sight, and when humans are onboard.

Redundancy – Provide physical and logical redundancy for terrestrial communication paths and functions and diverse routing of data links for all human crewed vehicles.

Evolvability – Provide communication and navigation support for lunar robotic missions by 2008, human missions consisting of 4 crew by 2018, and sustained human operations by 2022.

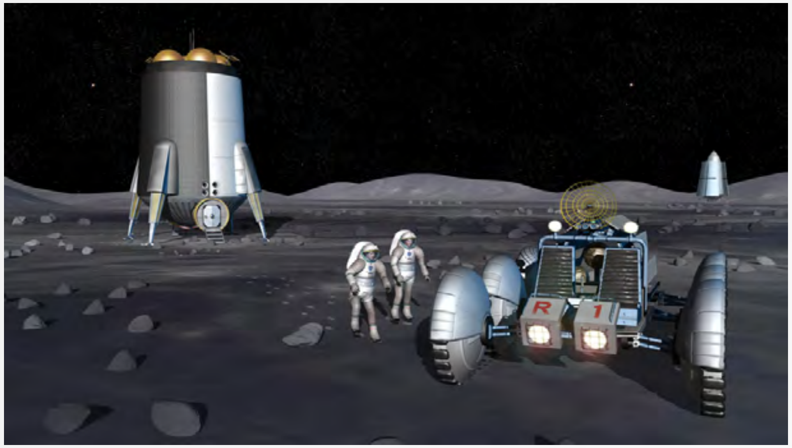
Assumed Exploration Requirements
User Requirements

Audio Conferencing – Provide low and high quality audio interconnectivity among lunar users and the Earth with a high degree of conversational freedom.

Video Conferencing – Provide real-time multi-user moderate and HD rate video conferences for private medical communications, families, coverage of critical operations, collaboration of activities, and teleoperation of robots, rovers, and instruments..

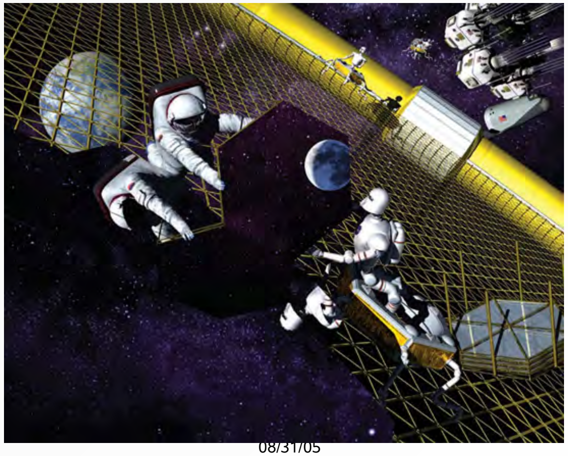
Health Monitoring – Provide continuous health monitoring services for all critical assets.

Software Upgrades – Provide remote software upgrades with minimal human intervention.



Navigation – Provide real time absolute and relative navigation (position and velocity) to spacecraft guidance systems on the surface and in the exploration vicinity.

Data Delivery – Provide on-demand bidirectional exchange of science data, e-mail, Internet service, and electronic libraries based on priorities, schedules, and demand access.



Why a network?

- A *networked architecture* is defined here as one in which addresses are used to identify communications endpoints, and users of the network need only have a connection to any other node in the network and know the address of the destination node to exchange data.
- **Simplified collaboration, complex systems –** Cooperation among exploring mobile nodes and systems engaged in complex tasks and dispersed over short and long distances, necessitates a means to simply, seamlessly, reliably, and intelligently select and disseminate critical information with minimal burden on the users.
  - A networked architecture addresses these issues with a platform that: is inherently and economically scalable, is reliable in that it is proven on Earth, facilitates autonomous surface operations by allowing on-demand localized connections, and is simple and efficient for users to operate.
- **Inclusive communications –** Networking provides exploration systems with the ability to join multiple assets operating over different physical media into one unified infrastructure. Each node in a network possesses the ability to communicate with any other node on the network regardless of where on the network it is located or how it is connected.
- **Devices and subsystems –** Not only can astronauts communicate with one another, but any system or subsystem requiring data exchange can communicate with any other system or subsystem on demand without the burdens of command set knowledge or scheduling placed on intermediate nodes.
  - For example, using a network, the sensors on EVA suits could detect a loss of oxygen and broadcast an alarm to a nearby astronaut, to the habitat, and to computerized monitoring stations on Earth. The habitat could automatically prepare the airlock without the need for human intervention so that the astronaut in trouble could enter with minimal delay.

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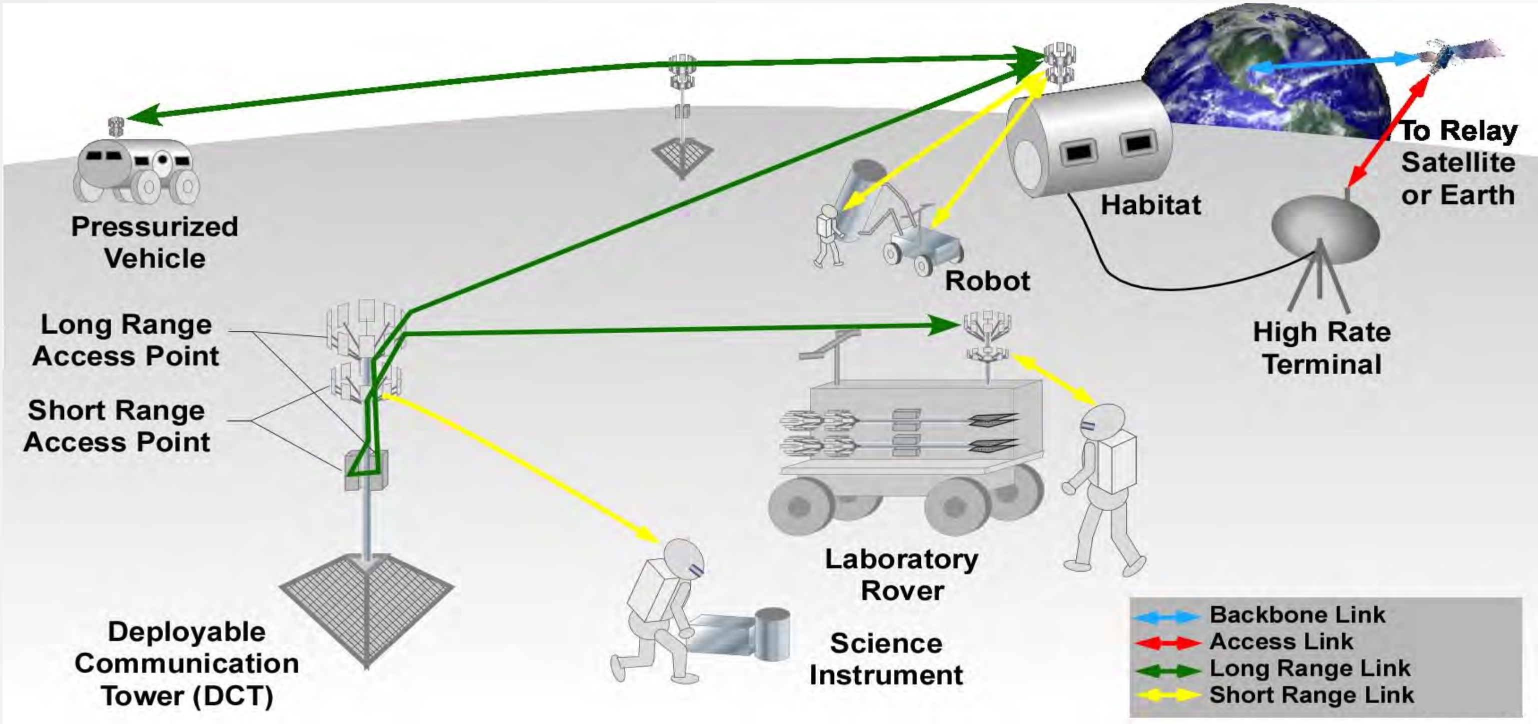
Surface Network Operational View



Diverse link types are required to support operational needs

- Large assets (e.g. habitat, orbiting relay) can support the power, mass, and volume required for long range, long distance communication and will require high data rates for high definition video and science data from multiple surface-based assets simultaneously.
- Small, mobile assets (e.g. robot, astronaut, instrument) are much more limited in power, mass, and volume and must support communications at data rates to support single high definition video and science data streams.
- Very small assets (e.g. sensors) are extremely limited in power, mass, and volume, and will require low data rates.
- Low data rate, reliable emergency communications

Surface Activities

- Maintenance Functions
  - Initial surface operations
  - Inspection, maintenance, and repair
  - Health/medical operations
  - Off duty/recreation
- Field Work
  - Exploration of the surface via EVA
  - Sample curation
  - Surface transportation
- Telerobotic Exploration
  - Robotic/autonomous deployment
  - Teleoperation of robotic assets
- Laboratory and Intravehicular Activities
  - Sample analysis
  - Life science experiments
  - Toxin and biohazard assessment
- Preparation of Materials for Return to Earth

System Nodes

Robotic

- Robots
- Science instruments
- Communication elements to Orbiter and Direct to Earth (integrated as part of Rovers/Robots)
  - Antenna (uplink and downlink)
  - Storage for temporary data buffer

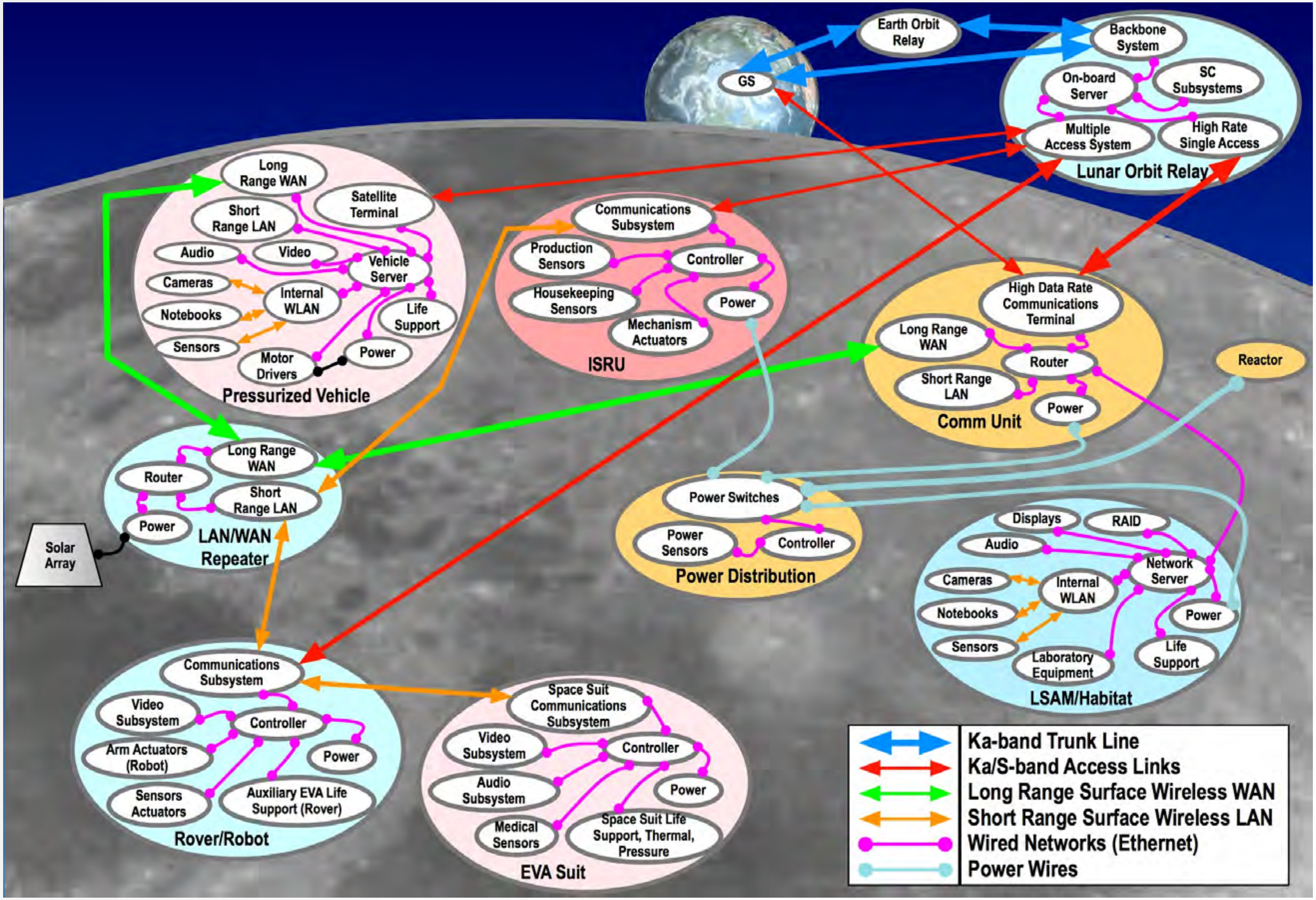
Short Duration

- Robots
- Science instruments
- Lander
- Rover
- 4-6 astronauts
- Navigation
- Communication elements to extend range of network

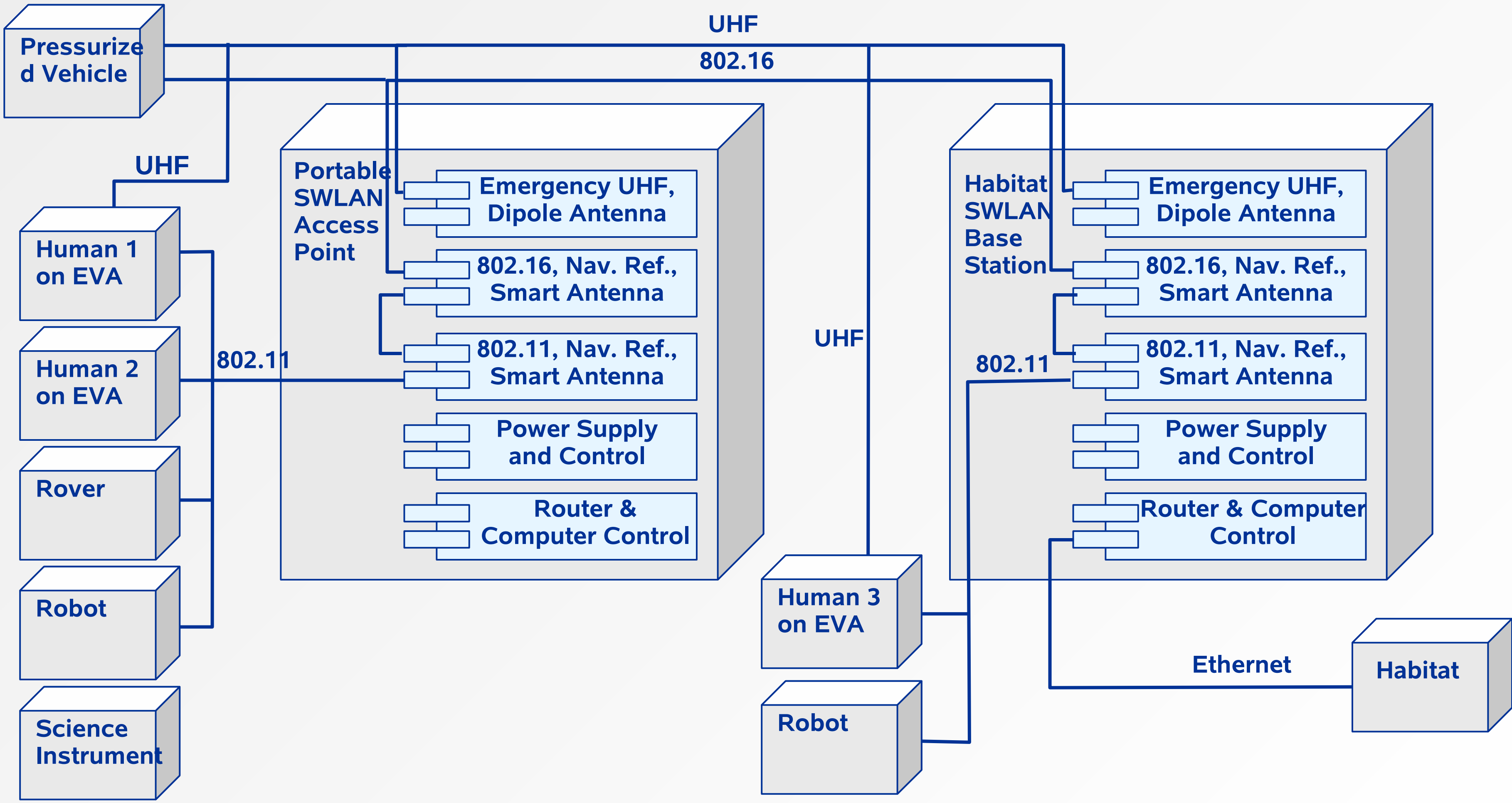
Sustained

- Robots
- Science instruments
- Lander
- 4-6 astronauts
- Pressurized and unpressurized rovers
- Communication and navigation infrastructure
- Habitat
- Power plant
- Data storage systems
- In-situ resource utilization systems

Surface Network Architecture Overview



Surface Network System Interfaces



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Surface Network System Data Rates

Data rate chart is from Noreen, G, et. al. *Integrated Network Architecture for Sustained Human and Robotic Exploration*, 2005 IEEE Aerospace Conference, Big Sky, MT.

User	Channel Content	# Channels	Channel Rate	Total Rate
Base	Speech	2	10 kbps	20 kbps
	Engineering	1	100 kbps	100 kbps
Astronauts	Speech	4	10 kbps	40 kbps
	Helmet camera	4	100 kbps	400 kbps
	Engineering	4	20 kbps	80 kbps
Human Transports	Video	2	1.5 Mbps	3 Mbps
	Engineering	2	20 kbps	40 kbps
Robotic Rovers	Video	4	1.5 Mbps	6 Mbps
	Engineering	4	20 kbps	80 kbps
Aggregate				10 Mbps
Base	HDTV	1	20 Mbps	20 Mbps
Human Transports	HDTV	1	20 Mbps	20 Mbps
	Hyperspectral Imaging	1	150 Mbps	150 Mbps
Robotic Rovers	Radar	1	100 Mbps	100 Mbps
	Hyperspectral Imaging	1	150 Mbps	150 Mbps
Aggregate				440 Mbps

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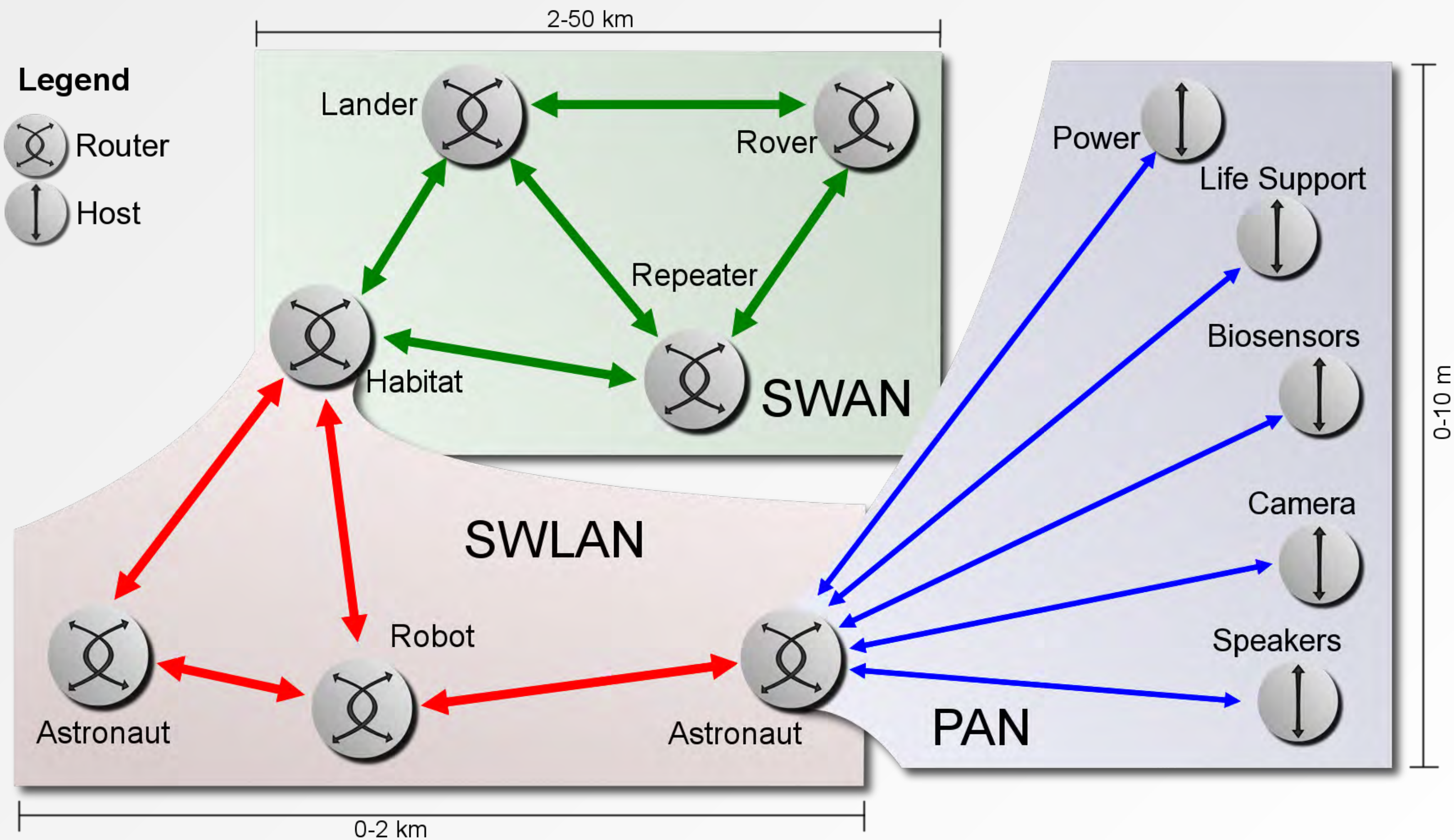
Surface Network Design



Surface Network Design Elements

- The ***Surface Wide Area Network*** will interconnect large, high powered systems such as the habitat, rover, pressurized vehicle, lander, and relay satellites
  - Long distance on the surface (2-50 km) and includes access to orbiting relay satellites
  - High data rate, high capacity network to support multiple voice, high definition video, science data, and other data streams
  - Provides connectivity among surface wireless local area networks
  - Seamlessly interfaces with backbone network for communications with Earth
- The ***Surface Wireless Local Area Network*** will interconnect moderate powered systems such as astronauts, robots, and science instruments
  - Moderate distance (0-2 km)
  - ~50 Mbps data rate network to support single voice, high definition video, and data streams
  - Automatic network node discovery and configuration
  - Provides connectivity among personal area networks
  - Seamlessly interfaces with the surface wide area network for long range communications
- The ***Personal Area Network*** will interconnect small devices such as sensors, instruments, and subsystems.
  - Short distance (>10m)
  - Wireless or wired
  - Automatic network node discovery and configuration
  - Seamlessly interfaces with the surface wireless local area network for non-localized communications

Surface Network Technologies

	Space Proximity	Surface Wide Area Network	Surface Wireless Local Area Network	Vehicle Local Area Network
Physical Layer	Ka-band, S-band, UHF, smart or dir. antennas	Ka-band, S-band, UHF, smart or dir. antennas	S-band, UHF, smart/omni/dir. antennas	UHF, S-band, copper, fiber, omni antennas
Data Link Layer	CCSDS proximity 1, IEEE 802.16 (WiMAX), Frame relay/HDLC, ATM/SONET, DVB	CCSDS proximity 1, IEEE 802.16 (WiMAX), IEEE 802.11 (Wi-Fi), Frame relay/HDLC, ATM/SONET, DVB	CCSDS proximity 1, IEEE 802.11x (Wi-Fi), Lower Power Wireless Sensor Network (802.15.4 Zigbee)	IEEE 802.3 (ethernet), IEEE 802.11x (Wi-Fi), IEEE 802.15 (bluetooth), IEEE1394 (Firewire), IEEE1355 (spacewire), FDDI, SOIF
Network Layer	CCSDS SCPS-NP, IP (RFC 791), AODV, TORA, DSR, OSPF, RIP	CCSDS SCPS-NP, IP (RFC 791), AODV, TORA, DSR, OSPF, RIP	CCSDS SCPS-NP, IP (RFC 791), AODV, TORA, DSR, OSPF, RIP	CCSDS SCPS-NP, IP (RFC 791), spacecraft bus, AODV, TORA, DSR, OSPF, RIP
Transport Layer	CCSDS SCPS-TP, UDP, TCP	UDP, TCP, SCPS-TP	UDP, TCP, SCPS-TP	UDP, TCP, SCPS-TP

Future Work

- Integrated navigation
- Architecture trades to assess the best means of extending the range of the surface network beyond line of sight from the base camp
- Simulation and emulation to evaluate candidate technologies – antennas, transceivers, digital signal processing, link management, networking, routing
- System analysis and trade studies based on emerging NASA requirements