LUNAR SURFACE FIELD EXPLORATION INFRASTRUCTURE SYSTEMS REQUIREMENTS DEVELOPMENT – RESULTS OF A DECADE OF ANALOG LUNAR SURFACE EXPLORATION. S. P. Braham[1] and M. P. Pires[1], [1]PolyLAB for Advanced Collaborative Networking, Simon Fraser University Vancouver, 515 West Hastings Street, Vancouver, BC, Canada V6B 5K3, *exsoc@polylab.sfu.ca*.

Introduction: The Simon Fraser University (SFU) PolyLAB for Advanced Collaborative Networking, a unit of the SFU Telematics Research Laboratory, has over a decade in experience in understanding the requirements for collaboration and mission operations in critical environments. This knowledge has been utilized in support of NASA and other space agencies in analogue mission operations. The underlying work at SFU has allowed a detailed understanding of Lunar field surface systems requirements to be developed. The technologies deployed in the field environment are being found to be increasingly critical to high-fidelity robotic and human analog planetary surface exploration studies, and naturally define a set of requirements for corresponding lunar exploration. Presently the technology compliment deployed by SFU in human analog exploration studies is the most sophisticated in any high-fidelity studies, worldwide.

SFU provides internationally-recognized development of advanced analogue mission operations systems and highlights the capabilities of analogues to provide platforms for the demonstration and development of sophisticated next-generation mission operations concepts, surface exploration technologies, and science operations methodologies. This is especially true in the case of human exploration of the Moon and Mars and, combined with the rich plethora of analogue activies in Canada, has been a major impetus for the formation of the Canadian Analogue Research Network (CARN) by the Canadian Space Agency (CSA) [1].

SFU work at the Mars Institute's Haughton-Mars Project Site on Devon Island, in particular, has allowed for extensive development of requirements for surface computing, communications, and general mission infrastructure for support of surface activities on the Moon, especially science-driven field exploration activities.

The result has been the creation of the CSA-funded Exploration Systems Operations Center (ExSOC) at SFU. ExSOC focuses on providing exploration systems knowledge and systems concepts for analogue missions inside CARN, supporting complex mission operations with multiple remote mission operations centers, and proving in-field engineering management and support for analogue field activities.

New integrated support systems have been developed at ExSOC to allow advanced analogue mission operations systems to be deployed at other sites in Canada in the future, with an aim of supporting analogue missions at international locations.

Many important lessons have been learned from SFU analogue mission operations activities, in particular in the area of surface communications infrastructure and corresponding "ground" systems infrastructure for next-generation mission operations, by learning to support actual field exploration activities with live mission operations.

Purpose of ExSOC: The concept of ExSOC is to support the integration and management of space exploration technologies in the analogue exploration activities environment. Supported systems can range from advanced radio and space communication systems to new paradigms for computing and networking in the space and field exploration environment. ExSOC infrastructure and personnel function as a Systems Engineering and Integration (S&EI) facility and Remote Missions Operations Support Centre (RMOSC) for CSA-funded and other scientists working on Planetary Exploration Science projects that wish to support exploration systems research in their field environment, or wish to have their field science supported using technologies consistent with planetary surface exploration activities.

The SFU laboratories supporting ExSOC have the largest, world-class, set of systems for field and remote mission support of exploration research in Canada. The facilities may all be used to support exploration science work, within funding and other project requirements.

ExSOC personnel support field and laboratory activities, and can utilize the SFU AMECom research vehicle for local field system tests in preparation for field deployment. ExSOC has a range of base test systems and field support systems, and users are able to provide systems to ExSOC so that they may be preconfigured for field deployment, ready for support by ExSOC personnel.

ExSOC Services for Exploration Science Support: ExSOC base costs are covered by the Canadian Space Agency, which covers much development work for support designs for field activities, but does not include the actual field deployments, or corresponding equipment base, themselves. The latter are funded through supported projects. Services that have been developed are as follows:

Safety Technology Support and Development. Safety technology is the first need for support of exploration in hostile environments. To support a field site, constant testing, integration, and improvements are needed in the field safety communications system. ExSOC uses results from field activities to select appropriate solutions for radio repeater, power, GIS and GPS technologies to support safety requirements. Help is provided to sites to help them implement appropriate safety infrastructure. SFU has integrated state of the art audio interoperability sysrems into field networks, providing end-to-end Mission Control to field voice support, with end-to-end digital signal processing and delivery, for life-critical operations, based on standards used in safety-oriented agencies, such as those working in Homeland Defense, Fire, Police, Ambulance, and other such fields. These techniques allow human life-critical COTS technologies to be adapted to human spaceflight, and corresponding requirements to be developed.

Vehicle-based Technology Testing and Support. AMECom, the SFU TRL research vehicle, has allowed the development of integrated computing, communications, power, and other infrastructure for support of fieldwork. The vehicle can support small field projects, and allows concept development for larger projects. The vehicle provides a complete mission operation support infrastructure, including safety, wireless network, and space-based networking systems, and up to 20 kW of power. Development of concepts for new vehicles, and experiments in vehicles, is also supported at ExSOC, building upon extensive SFU experience.

Science Data Systems. Sophisticated exploration support requires recording, transmission, and manipulation of scientific data. Communications, computing, distributed telemetry technologies, autonomous data collection systems, data conversion systems, and database systems are being developed by the international exploration community for next-generation space exploration analogue missions [1,2]. ExSOC has been providing the basic support expertise, facilities, and HQP training required for such projects, to allow exploration science researchers to utilize these technologies appropriately, and maintain the level of field support required for modern exploration field sites.

Space Communications. For field exploration, space communication technologies need to be cheaper, easier to set up, and easier to manage. ExSOC has built on previous study results to accomplish this, working with a range of partners in the Space Internet development community. New network systems are available, and have been tested for the field environment, to provide services for aiding field sites in their system purchases, and then supporting those choices in the field. ExSOC has been critical in development an understanding of the need for commercial off-the-shelf (COTS) networking technologies in developing and deploying advanced mission operations solutions in surface environments, in particular for human mission operations on the Moon, including fully-emulated space network conditions. SFU results have influenced many space agencies in concept development for human exploration missions for planetary surfaces [3].

Robotics and other Exploration Technologies Support. Analogue field sites can be an important testing ground for new robotic exploration technologies. New technological thrusts have been identified to improve the teleoperation and communication infrastructure needs for robots and human explorers, providing complex end-to-end missions operations test environments for next-generation science operations development.

Field Network Communications. A major result from SFU research and support activities has been that the biggest single need in field traverse networking is for radio modulation techniques that increase range, data rates, and decrease size and power usage of surface-based radio communication systems. The capabilities of the communication systems between humans, or between landers and robots, are a prime limit determination for exploration [4]. ExSOC thus has a large focus on deploying appropriate communication technologies for Moon/Mars analogue research. This includes next-generation video and audio communications architecture, improving science and mission management operations and providing major educational outreach. The result has been the utilization of enterprise-grade network infrastructure, with advanced multi-layer IP-based networks and a combination of physical layers from wireless networking through to optical fiber-based systems, to address the complex requirements of quality of service, security, and flexibility in the modern exploration environment.

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