THE CANADIAN ANALOGUE RESEARCH NETWORK EXPLORATION SYSTEMS OPERATIONS CENTER AND ADVANCED LUNAR/MARS ANALOGUE MISSION SYSTEMS. 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.

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) [1,2]. SFU has supported multiple analogue mission-type experiments, including many with end-to-end fully emulated connectivty to remote mission operations centers located at facilities such as NASA Ames Research and Johnson Space Centers, and the CSA Payload Telescience Operations Center.

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 and corresponding "ground" systems infrastructure for advanced 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 SFU's 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. SFU facilities include a small, but critical, amount of equipment to aid service development, and mission operations support, including workstations and display equipment, but also including field communications, camping, and other field requirements.

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 and integration is needed in the field safety communications system. ExSOC uses results from field activities to select appropriate solutions for radio, power, GIS and GPS technologies to

support safety requirements. Help is provided to sites to help them implement appropriate safety infrastructure.

Vehicle-based Technology Testing and Support. AMECom, the SFU TRL research vehicle, is available for testing of technologies in support of fieldwork. The vehicle can support small field projects, and will allow 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, and database systems are being developed by the international exploration community for next-generation space exploration analogue missions [1,3]. ExSOC has been providing the basic support expertise, facilities, and HQP training required for such projects, to allow Canadian and international exploration science researchers to utilize these technologies appropriately, and maintain the level of field support required for modern exploration field sites, while ensuring Canadian sites are capable of supporting the research needs of the international exploration science and systems community.

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 [4].

Robotics and other Exploration Technologies. 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 for robots and human explorers. ExSOC supports integration of these technologies into a site, 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 [5]. 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.

Wearable and Mobile Computing. Once communication problems are solved, the next issue is increasing the computing power available in the field Decreasing computing size, improving software technology development methods, increasing reliability, and reducing power needs while improving capability are all essential needs for space exploration and for support of Earth-based analogue space science field activities. ExSOC supports a wide range of technologies developed and investigated in the laboratory, and provided by industrial and international space agency collaborators. Personnel computing and Internet access are supported, and computing methodologies are supported and deployed for human-crewed rovers, spacesuits systems, and other field system requirements.

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