**EVALink**

**Concept of Operations**

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*NOTE:*

*A Concept of Operations (“ConOps”) is a description of the desired target-state capability, device, or system. The system described below does not exist today, but rather is written as though it did. The purpose is to help stakeholders get a shared vision and understanding of what the system is about, the kinds of things it should do, the environment in which it will be used, who its users are, and an idea about its lifecycle.*

EVALink is an integrated system to enable coordinated real-time field science between physical space analog research facilities, and virtual reality digital-twins. This also improves science, situational awareness, and crew member safety at analog research stations, such as MDRS. Integration with virtual reality extends the analog research capability to a much wider audience, while also opening the door to previously impossible scientific collaboration. Finally, when deployed and networked across multiple analog research facilities concurrently, planetary-scale simulations are possible for the first time.

EVALink includes wireless terminals for crew on EVA, wireless networking hardware, an on-premises server, and associated infrastructure and end point application software.

The first goal of EVALink is to help improve crew member safety. The terrain surrounding analog stations may include hazards such as rock slips, crevasses, steep climbs, and rocky bluffs. These are made worse by land features which limit the effective range of line -of-sight radio communications. EVALink improves safety by providing long range, low power digital connectivity over ad hoc mesh network topologies. This enables short messages, such as an SOS, to be shared amongst users of the system, even if beyond line of sight.

The second goal of EVALink is to improve situational awareness. This is achieved two ways. First, location telemetry of crew members is automatically collected and aggregated by a computer server deployed at the analog facility. There it is logged and displayed for other crew members in real time. In the event of an accident or other need for assistance, crew members will know the locations of crew members in real time. Other data could be relayed as well, such as if the crew member is driving one of the ATV's, time of last movement, suit status, or weather conditions at crew location.

Also enhancing situational awareness is that the position and activity of separated crew member groups can be relayed in real time to one another elsewhere on EVA, and displayed on the endpoint terminal. That is, crew members on concurrent but separate EVA would be aware of each other's location and activity. Similar telemetry from rovers and drones could also be accessed. The crew member's GPS location could also be shown against topographical maps, weather forecasts, waypoint markers, etc

The third goal of EVALink is to improve science. Specialized end point software can be accessed via the hand held terminals for the crew member to document samples and observations made in the field, in situ. This software can be tailored for the type of science, such as geology, biology, or astronomy. It could even be further customized by or to the requirements of crew member organizations. Samples can be labeled with the time, GPS location, and crew member at collection. Additional details could be included in the input form as desired with development. Collected data will be saved in an EVALink server.

The fourth goal of EVALink is to enable coordinated science between an analog astronaut on EVA in the physical world, and a virtual reality user in a digital twin of the same analog research facility. For example, an analog astronaut collecting rock samples at MDRS will be able to interact with a user in a high-fidelity digital twin of the exact same location. The location and orientation of the analog astronaut will be accurately displayed in VR, and they will be able to converse in real-time of radio / voice, and data can be shared in real-time between them.

A fifth stretch-goal of EVALink is to enable coordinated science between multiple analog research facilities. For example, analog astronauts at MDRS and at FMARS would be able to share knowledge, and conduct experiments that span facilities, geography, and time zones. Consider unique seismic or meteorological studies that could be conducted by researchers in disparate facilities at the same time, with even more collaborators engaged remotely via virtual reality.

The physical users of EVALink will be analog astronaut crew members. All members of a crew will be assigned an EVALink radio module attached to their suit, and an end-point Android device. They may opt to use a compatible personal end-point device if they choose, but correct operation must be affirmatively verified before the crew arrives at MDRS. Regardless of device, however, all crew members must have an EVALink network node configured to report telemetry back to the EVALink server and other EVALink nodes, including crew member GPS location and other safety-critical data. All crewmember EVALink modules must also participate as full peers on the mesh network, including packet routing and forwarding.

EVALink could follow a client server architecture, with mobile endpoint device deployed with each crew member on EVA. This end point device will be running the open source application, such as CivTAK, which provides rich GIS-aware functionality. It will also support custom plugins, which are what enable the custom science data modules described herein. Yet more advanced functionality can be developed natively for the mobile device if necessary.

The mobile end-point device is connected using Bluetooth to a LoRa-capable wireless networking module. The module is physically mounted to the MDRS EVA suit, in a way that facilitates the maintenance and servicing of each as needed. The network module is configured in a meshed topology with other such modules in and around the MDRS compound. Such a mesh network avoids the need for elaborate physical or logical topology planning, and scales up and down gracefully based on nodes.

Virtual, or remote, users will access EVALink via a virtual reality application, such as MarsVR. Voice and data communications will be integrated to allow information sharing and communications between the physical- and digital- environments.

Crew members on EVA will be operating in conditions that are very dusty, potentially windy, and with wide potential temperature swings. The EVALink server may be subject to lesser, but still real, environmental challenges as well. These conditions may impose significant challenges to the reliability and lifespan of EVALink components.

A LoRa-compatible antenna is deployed at a high point on the habitat's exterior, and connected to a computer within the habitat. This computer functions as a server to the mobile end point devices. It has telemetry logging and analysis software, display tools for crew location and activity on screen, and runs Electronic Laboratory Notebook (ELN) and knowledge management systems. The EVALink application on the end point device communicates over an API with the ELN.

The ELN system is open source and can save, store, and retrieve any of the data submitted by appropriately configured EVALink endpoint modules. Data can later be exported by crew members for use in their research and analysis at MDRS and after mission conclusion.

Organizations sponsoring crew members may also provide their own Electronic Laboratory Notebook (ELN) server. For example, an independent ELN server may be desired by organizations or individuals with specific intellectual property requirements. Compatibility and safe interoperability on the MDRS network and with the rest of the EVALink system must be verified before crew arrival. It also must comply with all applicable MDRS technical, security, and safety requirements.

Maintenance and upgrades of the EVALink system will be provided by volunteers or organizations designated by The Mars Society. The maintenance will include battery replacements, system checks, physical integrity checks, software upgrades, physical case maintenance, etc. and would be performed between crew seasons. This also includes re-execution of Integration, Validation, and Verification activities to ensure correct operations during crew season. Full spares for two crew members will be kept at MDRS. Basic troubleshooting instructions for radios, end-point devices, and the server will be kept on site at MDRS and two members of each crew will be trained to troubleshoot. Remote support for EVALink will be provided by the same maintenance team, channeled through normal mission support communications, for any issues beyond on-site troubleshooting.

EVALink as contemplated has a target lifespan of three years from initial production deployment, with annual system maintenance. In addition to maintenance and support, that time period will be spent planning for system extension, upgrade, retirement, or replacement. Feedback from MDRS crews, system log data, and maintenance learnings will help inform those later stage decisions.

EVALink enables interesting future extensibility opportunities beyond the primary goals. For example, possibilities include:

* Telemetry logs and science data could be imported into the MDRS VR environment to enable virtual analysis or recreate EVA's for training purposes.
* As discussed, a benefit of the client server architecture is that alternative ELN software could be deployed on another networked server, and accessed via a crew member-provided custom EVALink module. This would enable completely private data collection, storage, and access for MDRS crews with specific IP protection requirements.
* IoT sensors and actuators, and fixed LoRa nodes could be deployed around the MDRS compound. For example, moisture sensors in the GreenHab, perimeter security sensors, etc.
* EVALink server replication and synchronization with servers in other locations (such as at other analog stations) could simulate in-space operations by injecting communications delays into the external internet link.