

**In Situ Geophysical Exploration by Humans in Mars Analog Environments.** B. R. Shiro<sup>1,2</sup> and K. L. Ferrone<sup>3,4</sup>,  
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**Introduction:** We carried out three geophysical experiments in Mars analog environments in order to better understand the challenges future astronauts will face when conducting similar surveys on Mars or the Moon. The experiments included a passive seismometer deployment and a time domain electromagnetic survey on Devon Island, Canada and an active seismic refraction survey in southeastern Utah. The poster will highlight preliminary results and lessons learned from a human factors standpoint.

**FMARS:** The Flashline Mars Arctic Research Station (FMARS) is a facility built by The Mars Society in 2000 to help develop key knowledge about Mars exploration and to inspire the public to this cause. It is located on Devon Island in Nunavut Territory, Canada about 1600 km from the North Pole at 75°25' N, 89°49' W. The remote outpost is located on the western rim of the 23 Ma Haughton Crater in a polar desert environment geologically and biologically similar to Mars.

In July 2009, the twelfth crew inhabited the remote outpost for a month-long simulated Mars expedition. We lived in the small habitat, observed strict communication delays with “Earth” and conducted daily EVAs wearing spacesuits to learn how humans might live and work on Mars. Two of the research experiments carried out in 2009 were a passive seismic and time domain electromagnetic survey. More information about the mission is available on the crew website at <http://fmars2009.org/>.

*Passive Seismic Deployment.* A key to understanding the origin and evolution of planets is characterizing their interior structure, and seismology provides the most complete view of planetary interiors [1]. Analysis of data collected by the Apollo Seismic Experiment has provided most of our knowledge about the interior structure of the Moon, but compromises made in the Viking Seismic Experiment rendered its data unusable [2]. Deploying a seismic network on Mars is therefore a high priority. Even a single station can provide important information to constrain estimates of seismicity, crustal thickness, mantle models, and core radius [3].

We deployed a Nanometrics Trillium Compact seismometer 3 km west of FMARS near an outcrop known as Marine Rock. This instrument incorporates a symmetric triaxial force feedback sensor with a flat velocity response from 120 seconds to 100 Hz. With its small size (128 mm × 90 mm), extremely low power consumption (160 mW) and easy deployment using a leveling cradle and transport case that doubles as an insulated seismic vault, this instrument is a good analog for those that will likely be deployed on the Moon or Mars [4]. We used a solar-powered Taurus seismograph to power the station and record the data and an Ethernet radio to transmit the data back to FMARS in real time.



**Figure 1:** Brian Shiro and Christy Garvin test the seismometer (upper left) before burying it.

*Time Domain Electromagnetic Survey.* Electro-magnetic sounding has been recognized as the most promising exploration method to detect subsurface water on Mars, and efforts are underway to develop hardware for a future lander [5, 6]. The time domain electromagnetic (TDEM) method uses a large transmitter loop to supply a source electromagnetic field. When the current is abruptly turned off, eddy currents in the ground induce magnetic fields that are detected by a smaller receiver loop. This allows for measuring ground conductivity as function of depth.

We completed the TDEM survey on the Haynes Ridge next to the FMARS habitat using a TEM47 transmitter and PROTEM receiver on loan from Geonics Limited. The 120-meter profile was oriented per-

pendicular to the Haughton Crater rim and was chosen to overlap a 2001 seismic refraction experiment [7]. We deployed three  $40 \times 40$  meter square loops over the course of four EVAs to complete the experiment. For each of the three stations, we took a suite of measurements with the receiver loop in the center and two off-set positions perpendicular to the profile azimuth.



**Figure 2:** Brian Shiro takes some TDEM soundings with the FMARS habitat in the background.

**MDRS:** The Mars Desert Research Station (MDRS) is a facility very similar to FMARS that was built by The Mars Society in 2002 in the remote Utah desert near the small town of Hanksville at  $38^{\circ}24' N$ ,  $110^{\circ}47' W$ . The sedimentary canyon formations and sparse biology of the area provide a good analog Mars environment for conducting simulated EVA operations.

From 23 January through 6 February 2010, the 89<sup>th</sup> crew inhabited the MDRS for a two-week mission. With living and working arrangements much like FMARS, we carried out a number of experiments on simulated EVAs, including an active seismic survey. More information about the mission is available on the crew website at [http://wkiri.com/mdrs\\_crew89/](http://wkiri.com/mdrs_crew89/).

*Active Seismic Survey.* Active seismic experiments have long been used to obtain high resolution characterizations of subsurface stratigraphy. Although past teams have deployed geophones wearing spacesuits, none have yet worked with the newer land streamer technology [8]. Land streamers are similar to marine streamers that allow for easy towing of hydrophones behind boats for marine seismic surveys. They enable geophysicists to efficiently deploy and move an array of geophones in a less labor-intensive way compared to traditional deployment methods.

We obtained a 2-D profile of the subsurface near MDRS using a Geostuff Land Streamer with twenty-four 4.5 Hz geophones spaced 1.5 meters apart. We towed the streamer along the ground using one of our ATV Mars rovers. A sledgehammer striking a metal plate served as the seismic source.

**Conclusion:** In general, we learned that instrument user interfaces need to be as simple as possible to maximize astronaut efficiency during EVAs. In particular, buttons should be large and easily depressed, and screens should be easily readable even through a spacesuit helmet. Ideally, there would be some way to interface the control system to a heads up display in the spacesuit helmet itself. Menu systems for configuring equipment should be as minimal as possible and should preferably be pre-configurable so that the astronaut in the field only needs to position the instrument and turn it on. Laying out a large loop by hand for TDEM work is probably not a practical or efficient use of astronaut time, so automating that process with robotics or by making the loop mobile on a rover would be better strategies. Land streamers are much easier to deploy than individually planted geophones, but they are heavy and bulky to handle. Wireless geophones could be deployed in a more versatile sensor web framework while also saving valuable mass and volume.

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