SCIENTIFIC HYBRID REALTIY ENVIRONMENTS (SHyRE): BRINGING FIELD WORK INTO THE LABORATORY.

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Introduction: The use of analog environments in preparing for future planetary surface exploration is key in ensuring we both understand the processes shaping other planetary surfaces as well as develop the technology, systems, and concepts of operations necessary to operate in these geologic environments [1], [2]. While conducting fieldwork and testing technology in relevant terrestrial field environments is crucial in this development, it is often the case that operational testing requires a time-intensive iterative process that is hampered by the rigorous conditions (e.g. terrain, weather, location, etc.) found in most field environments. Additionally, field deployments can be costly and must be scheduled months in advance, therefore limiting the testing opportunities required to investigate and compare science operational concepts to only once or twice per year.

To overcome these inherent challenges, SHyRE (Scientific Hybrid Reality Envirionments) is a Planetary Science and Technology from Analog Research (PSTAR) funded, multi-year campaign aimed at developing a scientifically-robust analog environment using a new and innovative hybrid reality (HR) setting that addresses these limitations and enables frequent operational testing and rapid protocol development. HR is unique in that operators not only work within a virtual environment, but physical objects, advanced tracking systems, and various other technologies (e.g. procedure assistant, voice recognition, torso/limb/finger tracking, etc.) are also incorporated to create a highly realistic and immersive simulated environment (Fig. 2). The application of this analog environment has immediate implications and opportunities to inform future planetary missions and science investigations by rapidly prototyping and testing new scientific instruments with relevant data processing activities (e.g. archiving and analysis) embedded within realistic/envisioned flight operational constraints.

The SHyRE program objectives are divided into two main categories: Technology development of the HR environment and Scientific Operations development of operational constraints consistent with crewed planetary surface exploration (e.g. planetary extravehicular activity). To facilitate these objectives, an Earth-based analog environment is leveraged to construct a realistic HR environment and preliminary concepts of operations are constructed from a combination of existing spaceflight architectures and prior analog studies.

This abstract briefly summarizes the HR environment development process as well as the preliminary EVA science operations envisioned within this digital setting with an emphasis on demonstrating development throughout this multi-year campaign.

Hybrid Reality Development: To produce a scientifically-relevant environment in HR, we selected the December 1974 (D1974) flow located in the SW rift zone at Kilauea Volcano, HI. This site was selected because 1) it serves as a realistic analog to Mars surface conditions and 2) has extensive existing prior field study data. Existing data sets were leveraged from multiple prior field deployments during the SSERVI RIS^{4}E (Solar System Exploration Research Virtual Institute; Remote, In Situ and Synchrotron Studes for Science and Exploration) program. These data sets consisted of field portable handheld x-ray fluorescence (hXRF), x-ray diffraction (XRD), light detection and ranging (LiDAR; for surface texture), and in-situ spectroscopy (VIS/NIR) [3]. To complete this suite of data sufficient for HR development, the SHyRE team performed one final field deployment to the D1974 flow where additional portable geochemical field instrument data using Laser Induced Breakdown Spectroscopy (LIBS) and additional XRF were collected in addition to supplemental LiDAR scans.

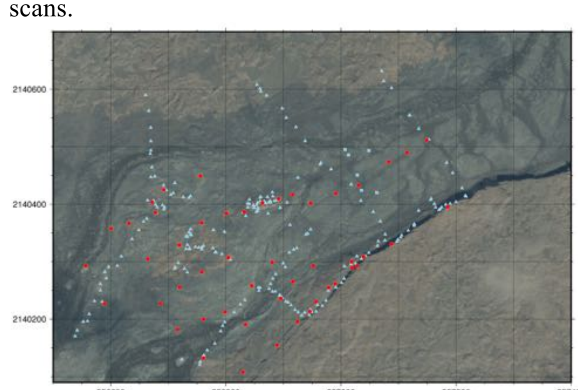

Figure 1. Geochemistry data (blue triangle) and LiDAR (red circle) GPS locations on the D1974 flow.

The SHyRE goal is to translate in situ instrument data taken from the D1974 flow and render the millimeter scale resolution of LiDAR data with geochemical signatures from the XRF, LIBS, and XRD instruments within the SHyRE HR environment, a process currently underway. As shown in Figure 2, the HR environment can already render Internation Space Station modules with handheld instruments such as the pistol grip tool (PGT).

Figure 2. NASA's HR lab showing a user viewing a photorealistic pistol grip tool (PGT) inside an HTC Vive headset, while manipulating a 3D printed PGT that allows for physical feedback.

Science Operations Development: Numerous prior NASA analog programs have already started to investigate crewed scientific planetary surface exploration architectures [4], [5]. SHyRE builds upon these prior tests and is being built instead to focus on how a crew will operate in the absence of real-time science backroom support (Fig. 3), as would likely be the case in the long communications latency (40+ mins round-trip) in Mars operations.

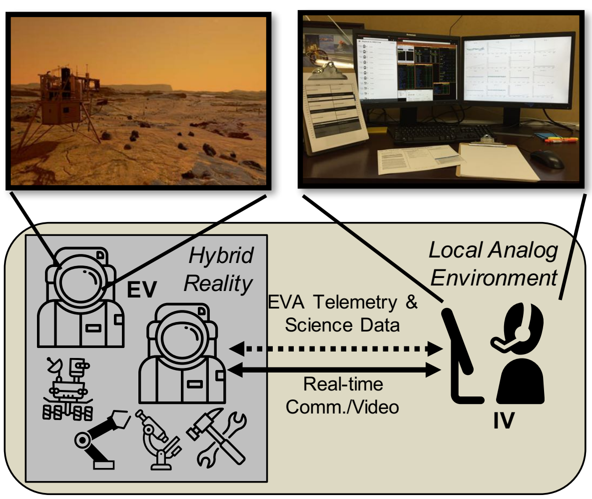

Figure 3. SHyRE concept of operations utilizing extravehicular (EV) crew in collaboration with an intravehicular (IV) crewmember to conduct EVA.

Under these operating conditions, the crew will be faced with a high volume of scientific instrumentation data coupled with the data pertaining to the vehicle and spacesuits. Development efforts are currently underway to prototype and render these instrument data products to both EV and IV crew for consumption during EVA execution to support scientific real-time decision-making. The HR environment affords an unprecedented level of simulation data acquisition regarding operationally relevant metrics (e.g. what the crews see, tool utilization, information transfer and interaction, etc) to objectively measure the execution of scientific operations. Prior work in both portable field instrument utilization [3] and EV and IV support system development [6] are being incorporated to support of this effort. In the coming year, SHyRE will investigate the relationship between crew workload and increased information flow (like that which would come with the addition of high-resolution field portable instruments) for scientifically-driven EVA.

Future Plans: By leveraging the HR setting and developing an environment with high scientific fidelity supported by multiple years of field data, the SHyRE Science Operations research will elevate the resolution and robustness of insights obtained from planetary analog operations research to an unprecedented level of detail. By conducting analog operations in the SHyRE HR environment, we can systematically control and vary relevant features (availability of scientific instrument data, etc.) of the concepts of operations in a repeatable way, something which has never been done before due to the inability to precisely duplicate test conditions in a traditional field environment. This notion of constructing testable, strictly-controlled environments aligns with and leverages experience from a multitude of established research efforts that examine the impact of new technologies and procedures in similarly complex environments (e.g. air traffic operations, maritime traffic management, and military command). Futhermore, SHyRE will be able to serve as a platform to develop, test and integrate the latest standards and process in scientific data management for future planetary exploration missions.

References: [1] W. B. Garry and J. E. Bleacher, (2011) Geological Society of America, vol. 483. [2] K. Young, et al., (2011) *Acta Astronautica*. vol. 90, no. 2. [3] K. E. Young, et al., (2016) *Applied Geochemistry*, vol. 72, no. C, [4] M. J. Miller, et al., (2017) AIAA SciTech #2017-1444, 2017 [5] K. H. Beaton, et al., (2017) IEEE Aerospace Conference [6] M. J. Miller, et al., (2017) *JCEDM*, vol. 11, no. 2.