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Introduction: Testing the technologies and operational concepts that future planetary surface missions will employ in analog field environments on Earth is of great importance in ensuring that we as a community are prepared for future exploration. However, these field deployments are often costly, depend on factors outside of human control (weather, etc.), and are challenging environments to set up repeatable test conditions as ambient conditions are unpredictable. The Scientific Hybrid Reality Environments (SHyRE) project, funded by the NASA Planetary Science Through Analog Research (PSTAR) program, seeks to set up a high fidelity Hybrid Reality (HR) environment where certain procedures, technologies, and operational concepts can be tested in high-fidelity, repeatable test conditions prior to future field operational testing. By designing a series of tests in the SHyRE laboratory environment prior to testing them in larger analog campaigns, we can ensure that the larger missions will test the best possible iterations of each technology or test condition.

Hybrid Reality: HR merges traditional Virtual Reality (VR) with elements of the physical environment. For example, a crewmember operating in a HR environment of the International Space Station (ISS) can visualize what it will be like to be on ISS operating a Pistol Grip Tool (PGT) while also holding a 3D printed realistic version of the PGT in the physical environment (Figure 1).

Figure 1: An example of the HR environment that SHyRE capitalizes on. Here, the user is able to see the ISS environment while also holding a physical copy of the tool he is using in the environment, the PGT. SHyRE will build on this by creating a scientifically relevant environment and making handheld scientific instruments available to the user.

SHyRE Objectives: The SHyRE project seeks to create a high-fidelity, scientifically realistic environment in HR to use as a basis for testing operational concepts and procedures in a laboratory analog environment. The SHyRE testbed can be used by astronauts or other members of the human spaceflight community to develop protocols and procedures for relevant hardware prior to spaceflight or to testing in larger analog campaigns.

The December 1974 Flow Environment: The SHyRE team leverages the multiple years of fieldwork the NASA Goddard Instrument Field Team (GIFT) and the RIS^{4}E (Remote, In Situ and Synchrotron Studies for Science and Exploration) SSERVI (Solar System Exploration Research Virtual Institute) team have completed at the December 1974 lava flow (D1974) at Kilauea, Hawai'i [1,2,3,4] (Figure 2). The GIFT and RIS^{4}E teams have worked for years to collect a robust *in situ* dataset with multiple field portable instruments.

SHyRE Scientific Datasets: The SHyRE D1974 flow environment will incorporate multiple data types. High-resolution Terrestrial LiDAR (Light Detection and Ranging) Scanning (TLS) and kite-based photogrammetry data form the basis of the HR environment. Handheld X-Ray Fluorescence (hXRF) [5] and Laser Induced Breakdown Spectroscopy (LIBS) instruments were also deployed at the D1974 flow, which will be replicated in the SHyRE environment, including replicas of each handheld instrument in HR.

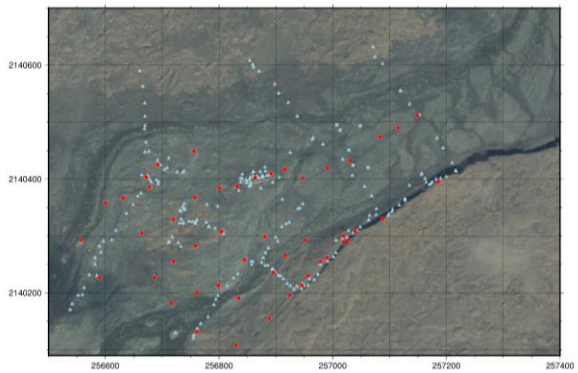

Figure 2: All portable instrument data collected by the SHyRE field team. Blue dots represent data collected with the hXRF and the LIBS. Red dots are locations where a TLS scan was collected. Kite-based aerial data was also collected to provide a high-resolution baseline for the entire test area, shown here [1].

Ongoing SHyRE Development: SHyRE work will be completed in two primary stages. The first major objective of SHyRE is to create the HR environment and the field portable instruments (hXRF and LIBS). The second step will be to conduct simulated extravehicular activities (EVAs) in the SHyRE environment to drive out optimal operational concepts for operating field portable instruments in a planetary analog environment. Significant progress has been made in developing the HR environment and the two field portable instruments (Figures 4 and 5).

The HR Environment. Using the aerial image data as well as the ground-based TLS data, our team has been able to develop the data processing algorithms necessary for ingesting field data to create the high-resolution VR D1974 lava flow (Figure 3). We are now in the process of creating the final D1974 environment from 10,000+ aerial images and 50+ TLS scans.

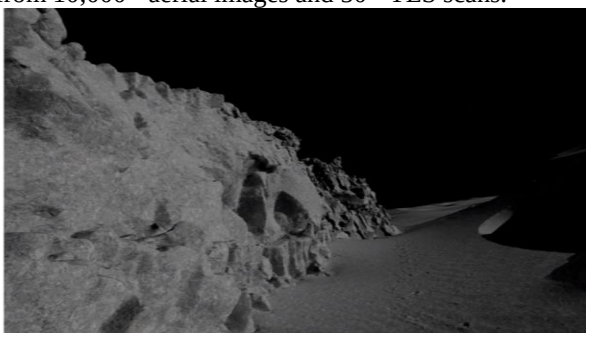

Figure 3: Shown is the initial result from processing TLS data into the HR environment. This is on the southern edge of the field area shown in Figure 2 and we will use this area to train new users in the SHyRE environment.

The Portable Instruments: We are currently working to create HR versions of both the hXRF and LIBS instruments, demonstrated to be valuable additions for future planetary surface missions [1]. We have 3D scanned and 3D printed both instruments and have working models of both (Figure 4). Future work will focus on integrating the 100s of data points from SHyRE fieldwork as layers that HR users can interact with while exploring the SHyRE environment.

Figure 3: (Left) A SHyRE user operating the HR version of the hXRF, collecting data on a 3D printed rock. (Right) What the user is seeing in the HTC Vive headset. Real D1974 flow scan data will be displayed on the instrument screens. We will complete a series of simulated EVAs in the HR environment, giving crewmembers real-time access to both the SHyRE LIBS and hXRF, allowing us to develop optimal instrument deployment procedures for future planetary surface exploration.

Ongoing and Future Work: The SHyRE project consists of a team of scientists, EVA engineers, HR development experts, and instrument specialists. Building off of prior work by the GIFT and RIS^{4}E field teams, this interdisciplinary SHyRE team is uniquely capable of developing a concept of operations for field portable instrument deployment.

While significant progress has been made to date on SHyRE development, we are still working to process all aerial and TLS data to create a robust, high-resolution and high-fidelity testing environment for future EVAs. Additionally, we are working to create a processing workflow for incorporating the hundreds of hXRF and LIBS data points from the D1974 lava flow.

After this development work is complete, we will begin conducting simulated EVAs in the SHyRE environment. Initial EVAs will be conducted in our NASA JSC laboratory, but later EVAs will be conducted in NASA JSC's Active Response Gravity Offload System (ARGOS) facility, allowing us to evaluate how to deploy field portable instruments in lunar, martian, and asteroid gravity conditions. Through setting up repeatable test conditions in HR, we can isolate specific variables of operating with field portable instruments and drive out the optimal concept of operations for conducting science-driven exploration with high resolution instrumentation, something that so far has not been completed on other planetary surfaces.

References: [1] Young K. E. et al. (2018) *Earth and Space Science*, *5, 11,* 697-720. [2] Soule S. A. et al. (2004) *Bull. Volc., 66, 1,* 1-14. [3] Bleacher J. E. et al. (2015) *LPSC 46*, Abstract #2182. [4] Hamilton C. W. et al. (2015) *LPSC 46*, Abstract #1071. [5] Young K. E. et al. (2016) *Applied Geochemistry, 72*, 77-87.