SUPPORTING FUTURE LUNAR SURFACE EXPLORATION THROUGH ONGOING FIELD ACTIVITIES.
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Introduction: The return of humans to both lunar orbit and the lunar surface will greatly enhance the ability of the scientific community to answer some of the highest priority science questions about the history and evolution of the Moon. Understanding how humans will live and work on the lunar surface is of utmost importance in thinking about a return to the Moon and has been identified by LEAG (Lunar Exploration Analysis Group) as one of the three primary SKG (strategic knowledge gap) themes for current investigation [1]. This submission highlights ongoing activities designed to close these SKGs, specifically in the categories of 1) surface trafficability, 2) radiation shielding, and 3) habitat, life support, and mobility.

TubeX - Lava Tube Exploration: Lava tubes have been identified since the 1970's as potential safe havens for humans and life support equipment on the lunar surface [2]. In order to use these features as a resource, we must first understand how a surface mission would find and characterize a tube-rich environment and select one tube for habitation and/or exploration. The TubeX project is working at Lava Beds National Monument, CA, to explore technologies and strategies for mapping and exploring lunar lava tubes. Our team has deployed LiDAR (light detection and ranging), GPR (ground penetrating radar), magnetometry, seismic arrays, and handheld XRF (x-ray fluorescence) to understand which instruments might be used by an exploration mission and how they should be used to select a tube for habitation. Preliminary results indicate that this suite of surface geophysics instruments can indeed identify and quantify lava tube properties at depth. This submission will detail ongoing results of the TubeX project and provide recommendations for exploration of these potential radiation safe havens.

Scientific Hybrid Reality Environments (SHyRE): Several proposed lunar exploration modes place humans in habitats either in cislunar space or on the lunar surface for extended stays. Regardless of which mode is chosen, the presence of humans near or on the Moon presents exploration opportunities including teleoperation of robotic assets, extended periods of scientific observation, and potentially the ability to work with samples collected from the surface of the Moon in a habitat laboratory [3]. All of these capabilities rely on the development of novel visualization concepts, which will bring real-time surface data to the astronaut in the habitat. The SHyRE project explores hybrid reality (HR, i.e. the combination of virtual reality with unique physical characteristics of the environment) as a capability that could be used to train crewmembers, develop operational protocols and a decision-making support system, or allow a crewmember to view and manipulate data collected by a surface asset. SHyRE uses data collected over the past several years by the RIS^{4}E SSERVI (Remote, In Situ and Synchrotron Studies for Science and Exploration) team on the Big Island, HI. We will present initial results and a path forward for developing this capability for future exploration, and discuss how HR can be used to investigate SKGs pertaining to the utility and design of habitats either in cislunar space or on the lunar surface.

NASA Extreme Environments Mission Operations (NEEMO): An important part both of the Apollo missions and any future lunar exploration is the science support team providing input and recommendations on sampling/traverse execution to the crew. Future science support, however, will differ from the Apollo era model of using near real-time science backrooms to direct astronauts on the Moon. With the advancements in technology over the decades since the 1970's come complexities in data assimilation and visualization that benefit from increased science support. Understanding how this support should be structured to maximize utility of habitation on the Moon is critical to mission success and is being explored in the NEEMO analog missions. Also tested during NEEMO was how a crew would transport equipment and samples over long distances away from a habitat, directly addressing the mobility LEAG SKG. This submission will discuss lessons learned from NEEMO that might influence mission design architecture for future lunar exploration.

References: [1] LEAG (2016) *https://www.nasa.gov/sites/default/files/atoms/files/leag-gap-review-sat-2016-v2.pdf.* [2] Horz F. (1975) *Lunar Bases and Space Activities of the 21st Century, LPI*. [3] Evans C. A. et al. (2012) *Acta Astronautica*, doi: 10.1016/j.actaastro.2011.12.008.