MIXED REALITY INTERFACES FOR MOBILE LUNAR SURFACE ROBOTS. M. E. Walker, J. O. Burns, D. J. Szafir. Center for Astrophysics and Space Astronomy, University of Colorado (michael.walker-1@colorado.edu, jack.burns@colorado.edu, daniel.szafir@colorado.edu).

Introduction: For many years, robots have been thought of as instrumental in the continued exploration of space and its planetary bodies. Within our scientific community, great efforts have bene made to improve the physical capabilities and independent decision making of mobile robots to better explore and tame space's hostile environments.

Unfortunately, robot interfaces (e.g., the means in which scientists interact with such robots and take advantage of their full set of state-of-the-art features) have not seen the same level of development and technological advancement as the robots themselves. The high-level design of these interfaces has largely remained the same for decades, forcing scientists to view rich, three-dimensional data returned by their robots on outdated, two-dimensional monitors.

VMR HMD Teleoperation Interfaces: Next generation virtual and mixed reality (VMR) head-mounted-display (HMD) based teleoperation interfaces are currently positioned to reshape robot-mediated space exploration. This new hardware is providing an opportunity for a new design space: remote mobile robot teleoperation enabled by VMR HMD interfaces that merge both real and virtual worlds.

Unlike that of traditional displays, the stereoscopic displays built into these headsets harness the full dimensionality of our world and allow operators to see with depth. This capability has shown to provide a plethora of benefits to human operators that are absent in traditional 2D displays [1 & 2] and will be essential for users when either controlling or supervising remote mobile robots on the lunar surface.

Research has found that the immersion provided by VMR HMD robotic interfaces improves efficiency and situational awareness without increasing the workload of operators, even in the case of multi-agent systems [3]. Additionally, this immersion, and in turn increased situational awareness, can be ascertained by multiple different sensors such as first-person stereo video stream from the robot's head or a 3D point clouds from Lidar scans.

Multi-Perspective Collaborative VMR Interfaces: To fully examine the full capabilities that VMR HMD technologies afford; our research will examine multi-perspective VMR HMD interface designs. Egocentric (1st person) and exocentric (3rd person) designs will be explored to examine overall effectiveness as well as optimal use cases for either design paradigm. By combining the design concepts seen in 1st person virtual control room interfaces (VCRI) and 3rd person cyber-physical interfaces (CPI) [2], we hypothesize interfaces will offer significant operational advantages when a robot operator can simultaneously access both egocentric and exocentric perspectives.

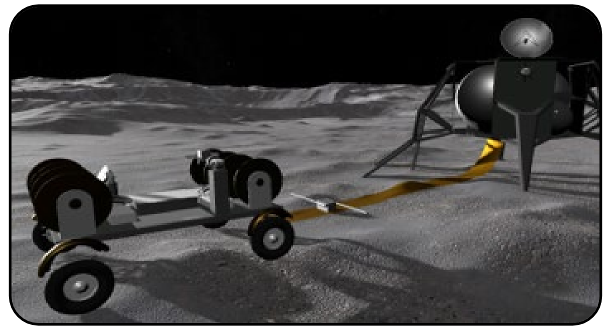

Figure 1: *Use cases for lunar telerobotics include low-frequency radio relay assembly and deployment [4].*

In the CPI portion of our planned interface, users can physically walk within an exocentric 3D representation of a mobile robot in an augmented virtuality space that contains a live RGB point cloud and/or mesh of the robot's current environment. Additionally, we will render an environment-anchored 3D stereo robot video stream within the virtual space to capture the benefits of an VCRI and its egocentric perspective that helps lessen the effects of cyber-sickness. Finally, we will investigate how this type of combined interface can facilitate group collaboration during mobile robot teleoperation/supervision planning and live missions by rendering virtual telepresence user avatars that share the virtual space within the interface.

With the development and utilization of advanced teleoperation VMR interfaces scientists will be better equipped to leverage the full capabilities of their mobile robots and learn more about both the lunar environment and the early universe without the need of a physical human presence (see Figure 1).

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References: *[1] McIntire et al. "What is 3D good for? A review of human performance on stereoscopic 3D displays." 2012. [2] Lipton et al. "Baxter's homunculus: Virtual reality spaces for teleoperation in manufacturing." 2017. [3] Roldán et al. Multi-robot interfaces and operator situational awareness: Study of the impact of immersion and prediction. 2017. [4] Burns et al. FARSIDE: A Low Radio Frequency Interferometric Array on the Lunar Farside. 2019.*