THE EVALUATION OF A MIXED REALITY CYBER-PHYSICAL VIRTUAL CONTROL ROOM FOR LUNAR EXPLORATION. M. E. Walker, J. O. Burns, D. J. Szafir. Center for Astrophysics and Space Astronomy, University of Colorado (michael.e.walker@unc.edu, jack.burns@colorado.edu, daniel.szafir@cs.unc.edu).

Introduction: With the development and utilization of advanced virtual and mixed reality (VAM) head-mounted displays (HMD) teleoperation 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 [1] without the need of a physical human presence.

VAM HMD interfaces allow operators to see from a remote robot’s perspective through live stereo video feeds with depth and enhanced immersion, unlike that of traditional two-dimensional monitors. Research has found that the immersion provided by VAM HMD robotic interfaces improves efficiency and situational awareness [2] without increasing the workload of operators, even in the case of multi-agent systems [3]. Through research in this design space, interface developers can learn how to best leverage the inherent benefits VAM HMDs have to offer.

Cyber-Physical Virtual Control Room: To enhance operator effectiveness and mitigate nausea from direct video streaming to HMD Interfaces, two augmented virtuality (AV) HMD Teleoperation Interface paradigms have arisen from research in the VAM Human-Robot Interaction (HRI) field: Virtual Control Room (robot-egocentric perspective) and Cyber-Physical Interfaces (robot-exocentric perspective) [4].

Both AV interfaces have shown promise in improving traditional teleoperation interfaces; however, they each have their own set of individual strengths and weaknesses. Neither AV paradigm has been unified in a single interface that takes advantage of the unique strengths both methods have to offer (e.g., egocentric vs. exocentric perspectives, etc.). To address this identified research gap, our research will explore unifying these concepts into a single teleoperation interface: a Cyber-Physical Virtual Control Room (CPVCR).

Implementation & Evaluation: To implement the proposed AV interface design, a virtual control room environment will be designed in the Unity game engine. Data collected by our lab’s Boston Dynamics Spot quadruped robot (Figure 1) will be streamed to our CPVCR prototype. Compressed stereo images will be published to the Unity application and projected as a 3D video on the virtual walls. A dense RGB point cloud will be generated from the mounted stereo camera and LiDAR. A compute shader will efficiently render the dense RGB point cloud in the virtual environment which the user can manipulate with hand-held motion controllers. Velocity commands can be sent to robot via the Unity interface to allow for robot navigation through the remote environment. An early prototype of such an interface has already been developed and is undergoing further iterative development (Figure 2).

This CPVCR will be compared against the two baseline AV interfaces listed above in a teleoperation user study. We hypothesize that an interface that provides both ego- and exocentric perspectives will offer significant operational advantages for robot operators, especially in terms of situational awareness.

Figure 1: The CU Boulder NESS Team’s Boston Dynamics Spot quadruped robotic platform used to implement and evaluate our VAM-HRI interface design.

Figure 2: Our prototype VAM-HRI teleoperation interface that unifies concepts from both cyber-physical and virtual control room interfaces by providing mobile space robot operators with egocentric (live 3D video stream) and exocentric (3D environmental construction in the form of a dense point cloud) perspectives.