Construction of Lunar Infrastructure Leveraging Low-Latency VR/AR Teleoperation. M. M. Bell[1], P. S. Curlin[2], M. A. Muniz[3], J. O. Burns[4], [1,2,3,4]Center for Astrophysics and Space Astronomy, University of Colorado-Boulder, Boulder, CO 80309, [1]Mason.Bell@colorado.edu, [2]Phaedra.Curlin@colorado.edu, [3]Madaline.Muniz@colorado.edu, [4]Jack.Burns@colorado.edu

Introduction: NASA is working to achieve the goal of returning humans to the Moon by mid-decade and then create a sustainable human lunar presence by the end of the 2020s. NASA has also begun construction of the Gateway, a lunar orbiting habitation and science laboratory. The Gateway's proximity to the lunar surface will allow for real-time communication with surface assets, therefore enabling the use of low-latency lunar surface telerobotics. Astronauts on the lunar surface can also utilize low-latency telerobotics to perform surface tasks. In addition, high-latency teleoperation from Earth is a viable and inexpensive option. In order for humanity to create a sustainable lunar presence, well-developed collaborations between humans and robots are necessary to perform complex tasks such as surface assembly of radio telescopes and ISRU stations.

Our research team is involved in designing the scientific mission FARSIDE (*Farside Array for Radio Science Investigation of the Dark Ages and Exoplanets*), requiring the use of intricate surface telerobotics [1]. FARSIDE is a NASA-funded concept that would place a low radio frequency interferometric array on the farside of the Moon. The mission design requires four rovers and a large commercial lander. The rover would be teleoperated to deploy antenna nodes from the lander onto the lunar surface.

Sustainable lunar presence creates a platform for low-latency robotic operations on the lunar surface. This enables missions such as FARSIDE, which may require real time human-robot operations. Further, missions using these methods will also require new methods of failure recovery.

Leveraging stereo imaging capabilities, we are generating VR/AR interfaces for both teleoperation and simulated failure recovery. By developing our virtual recovery sandbox, we can create a virtual space representative of the rover's current state and environment. This provides the ability to troubleshoot problems as if the operator were next to the robotic platform itself, in an exocentric perspective (Figure 1). With current imaging capabilities, this sandbox could ideally be created and assessed in real time. If proven to support teleoperated failure recovery, this sandbox method may be leveraged in a variety of robotic applications.

This research also includes an equivalent control interface between the physical and virtual robotic model. By creating a pipeline between the control interface for the physical and virtual platform, we can ensure that the solutions developed by the human operator in the virtual sandbox will be transferable to the physical robotic deployment. This pipeline also includes the use of the same kinematic model for the robotic arm and drive control. Cameras placed on the physical robot used for operator telepresence are also mimicked on the virtual robot for access to the same control viewpoints when developing solutions (Figure 2).

Further developments aim to expand on the VR interfaces supporting operator success in the solution development environment.

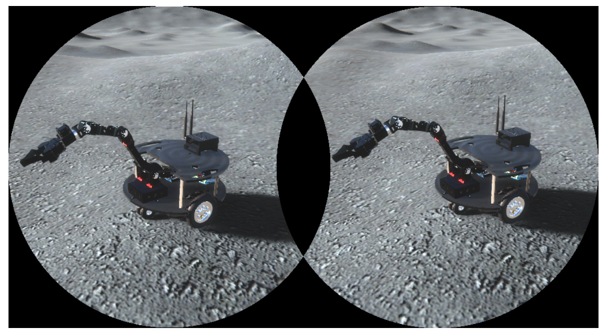

Figure 1: Our rover in the virtual simulation as seen from the ocular view of the operator and exocentric perspective.

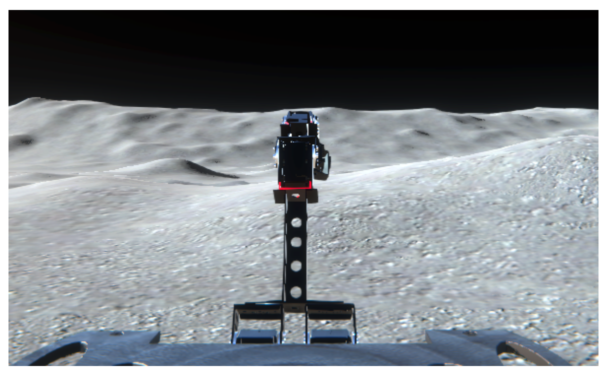

Figure 2: The rover in the virtual sandbox viewed from the egocentric perspective.

Acknowledgments: This work was directly supported by the NASA Solar System Exploration Virtual Institute cooperative agreement 80ARC017M0006.

References: [1] Burns J.O., Hallinan, G., Chang, T-C et al. 2021, *A Lunar Farside Low Radio Frequency Array for Dark Ages 21-cm Cosmology*, arXiv:2103.08623.