Implementing an Augmented Reality User Interface for Future Lunar Telerobotic Assembly Experiments. A. Kumar[1], M. Bell[1], P. Curlin[1], J.O. Burns[1], [1]Center for Astrophysics and Space Astronomy, University of Colorado Boulder, Boulder, CO 80309

NASA is working to achieve the goal of returning humans to the Moon by 2024 and then create a sustainable human lunar presence by 2028. 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 a rover and a lander. The rover would be teleoperated to deploy antenna nodes from the lander onto the lunar surface.

In our previous research, the Telerobotics Laboratory at the University of Colorado Boulder created the Telerobotics Simulation System (TSS) by integrating a commercial off-the-shelf robotic arm and rover along with multiple monocular cameras (Figure 1). The TSS was used in an experiment comparing the effectiveness and efficiency of local assembly to teleoperated assembly. The key takeaways from this work were that local assembly is more efficient than teleoperated assembly, however both methods are effective.

Moving forward, the telerobotics group is researching promising new user interfaces to improve the situation awareness of the operator. By placing a Zed Mini stereo camera on the rover and passing the video stream to an Oculus VR headset, the operator can effectively "see through the eyes of the rover." These headsets provide the operator with depth perception which is crucial when performing complex telerobotic tasks. The transition to a 3D space also opens new avenues to interact with the teleoperator's environment. For example, our lab is currently implementing assistive autonomy controlled by the operator's hand gestures. Rather than controlling every movement that the rover executes, the operator can point to a location and the rover will navigate accordingly.

In our next experiment, we plan to use the updated TSS to compare a 1st person to a 3rd person perspective. In the 1st person view, the stereo camera will be placed on the rover with pan and tilt capabilities. In the 3rd person perspective, the stereo camera will overlook the rover and the assembly task with pan and tilt capabilities. Since our previous experiment favored the 3rd person perspective of local assembly, we are attempting to recreate this perspective with a stereo camera to remove human involvement at the assembly site.

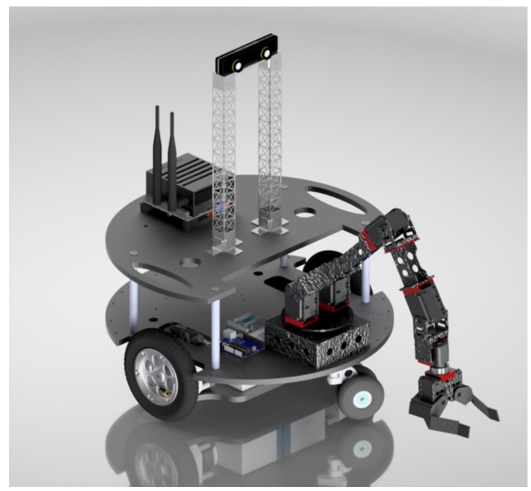

Figure 1. CAD rendering of the TSS rover. An onboard computer controls the rover's movement and arm motion planning. The Zed Mini stereo camera captures video feedback and sends it to the operator via the onboard computer.

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

References: **[1]** Burns, Jack O, G Hallinan, L Teitelbaum, T-C Chang, J Kocz, J Bowman, R MacDowall, J Kasper, R Bradley, M Anderson, D Rapetti, Z Zhen, W. Wu, J Pober, S Furlanetto, J. Mirocha, A Austin 2019 Probe Study Report: FARSIDE (Farside Array for Radio Science Investigations of the Dark ages and Exoplanets), NASA,https://smd-prod.s3.amazonaws.com/science-red/s3fspublic/atoms/files/FARSIDE_FinalRpt-2019-Nov8.pdf