Telerobotic Assembly Research and Artemis Infrastructure to Enable the FARSIDE Mission A. Kumar[1], M. M. Bell[2], and J. O. Burns[3] [1]Center for Astrophysics and Space Astronomy (Arun.Kumar-1@colorado.edu), [2]Center for Astrophysics and Space Astronomy (Mason.Bell@colorado.edu), [3]Center for Astrophysics and Space Astronomy (Jack.Burns@colorado.edu).

Introduction: NASA has proposed the Artemis program that aims to put humans back on the Moon by 2024 for the first time since the Apollo program. Furthermore, NASA plans to create a sustainable human presence on the Moon by 2028 [1]. NASA's first step in creating a sustainable human lunar presence is the construction of a lunar and deep space research and exploration laboratory. Astronauts are limited to 21 days aboard the Orion crew capsule so to enable long duration lunar missions, NASA is currently constructing a space station to orbit the Moon, the Gateway. The Gateway will be launched to Near-Rectilinear Halo Orbit (NHRO) [2]. In NHRO, the gateway will complete an orbit every seven days, on the seventh day drawing closest to the moon's surface. From NHRO, the Gateway can serve as a communication relay between Earth ground stations and the unexplored lunar farside.

The presence of astronauts on the Gateway would enable low-latency teleoperation of lunar rovers. When the orbit of the Gateway is at the equivalent distance of Earth-Moon L2 approximately 60,000 km from the lunar surface, the expected latency between the Gateway and the lunar surface will be 0.4 seconds. This latency is within the human cognitive horizon, meaning operators on the Gateway will notice a slight delay when controlling surface assets, but the delay will not significantly hinder performance [3]. The minimal delay between the Gateway and the lunar surface enables more advanced surface telerobotic tasks than has ever been attempted on an extraterrestrial body.

Our research team is involved with a scientific mission requiring intricate surface telerobotics, FARSIDE (*Farside Array for Radio Science Investigation of the Dark Ages and Exoplanets*). FARSIDE is a concept mission designed to place a low radio frequency interferometric array on the farside of the Moon [4,5]. The lunar farside is the only location in the inner solar system free of human-generated radio frequency interference [6]. A radio interferometer on the lunar farside could probe the Dark Ages and the Cosmic Dawn of the universe. The mission design requires a rover and a lander. The rover would be teleoperated to deploy antenna nodes from the lander on to the lunar surface.

Currently, telerobotic assembly on an extraterrestrial body has never been attempted, and a valid methodology to assess the associated human factors has not been developed. In order to successfully execute the FARSIDE mission our research aims to develop a methodology to assess the situational awareness (SA) and cognitive load (CL) of an operator performing teleoperated assembly tasks. Accurately quantifying these human factors will allow us to determine how changes to a telerobotic system affect the operator’s SA and CL.

The Telerobotics Laboratory at the University of Colorado-Boulder created the Telerobotic Simulation System (TSS) which enables remote operation of a rover and a robotic arm (figures 1 & 2). The TSS was used in a laboratory experiment designed as an analog to a lunar mission. The operator's task was to assemble a radio interferometer (figure 3). Each participant completed this task under two conditions, remote teleoperation (limited SA) and local operation (optimal SA). Data collected during the experiment included performance metrics (time to completion, number of failures, and assembly accuracy) and subjective measurements of SA and CL through surveys (Situational Awareness Rating Technique and NASA Task Load Index).

A successful methodology would yield results showing greater SA and lower CL while operating locally. Performance metrics measured in this experiment showed greater SA and lower CL in the local environment, supported by a 27% increase in the mean time to completion of the assembly task when operating remotely. Subjective measurements of SA and CL did not align with the performance metrics. This brought into question the validity of the subjective assessments used in this experiment when applied to telerobotic assembly tasks. Though this pilot study was intended to determine an effective methodology for assessing human factors associated with telerobotic assembly tasks, the experiment still provided useful insights that could be applied to future lunar missions. For example, our results showed that there is a similar success rate between local and remote operation. However, the task is completed significantly faster when operating locally. This further supports the claim that lunar teleoperated assembly tasks are viable from the Gateway (remote operation), albeit less efficient than if performed from the lunar surface (local operation).

Results from this experiment will guide future work attempting to accurately quantify the human factors associated with telerobotic assembly. Once an accurate methodology has been developed, we will be able to measure how new variables affect an operator's SA and CL in order to optimize the efficiency and effectiveness of telerobotic assembly tasks.

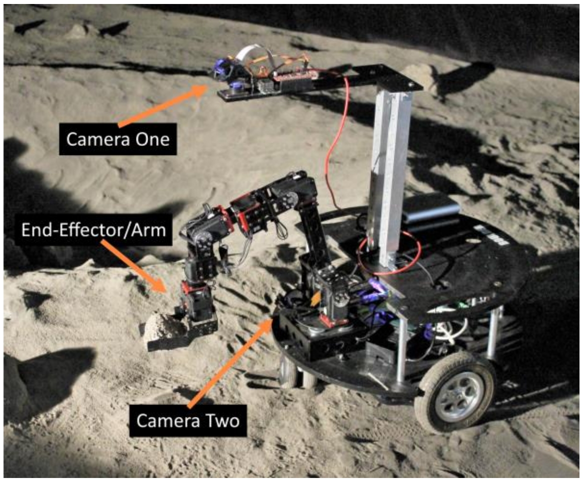

Figure 1. Armstrong Rover: Equipped with two cameras for visual feedback to the operator and robotic arm to perform assembly tasks. This picture was taken at the NASA Ames Research Center in their SSERVI Regolith Testbed / Lunar Lab.

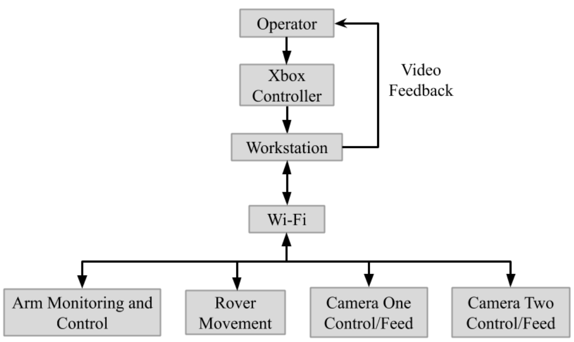

Figure 2. This system flow chart shows the connections between all the individual components of the TSS.

Figure 3. A Mock Lander equipped with the required parts for three antenna array units. Each antenna array unit consists of an antenna module (black) and a USB module (white). Unit 1 has already been deployed, unit 2 is being assembled, and unit 3 remains on the lander. The radio interferometer will be successfully assembled when all 3 antenna units have been deployed.

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