Troubleshooting Lunar Rover Failures: A Virtual Reality Digital Twin and Environment.

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Introduction: NASA is developing assets to create a sustainable presence on the lunar surface by the end of the 2020s. This includes the Lunar Gateway, a space station and science laboratory that will orbit the Moon and enable low-latency communications with the surface. This also comprises missions such as the NASA-funded *Farside Array for Radio Science Investigation of the Dark Ages and Exoplanets* (FARSIDE)[1]. FARSIDE will need autonomous rovers to deploy antennas to create a low radio frequency interferometric array on the farside of the Moon. In the case that a rover enters a state of failure during its autonomous operation, astronauts will be able to teleoperate the rover in real-time into recovery.

Traditional troubleshooting methods for rovers involve using a physical replica in a recreated environment located on Earth, as seen currently with the Mars rovers and Mars Yard. The developed solutions are then applied to the rovers using command sequencing due to the long communication delays. These methods are time consuming, not portable, and have inaccuracies in the emulation of the rover and its environment.

To address these issues, our team proposes a risk-free virtual reality (VR) digital twin in a simulated environment. This is made possible by using novel technologies like VR headsets and stereoscopic cameras for stereo passthrough and 3D scanning that would be placed on the rovers. Teleoperators can interact with a digital twin of the rover with the same kinematic model and control interface as with the real rover. The digital twin's model is based on the computer-aided designs which provide the basis for the collision model which enables the twin to physically interact with the simulated world. The teleoperator can replicate the rover as many times as needed in the environment as well as reset the environment to revert to an earlier stage in their troubleshooting process. Operators can also adopt two points of view from the rover. The egocentric perspective (Fig. 1) imitates stereoscopic passthrough enabled by the rover's stereoscopic cameras. The exocentric perspective (Fig. 2) allows for the teleoperator to walk around the rover in its environment. This simulated environment is based on 3D scans with the appropriate gravitational field values. After developing a solution on the VR platform, operators will be able to apply their solution by teleoperating the rover from the lunar surface.

Future developments of this VR platform will include evaluating the accuracy of the digital twin in representing the physical rover to calibrate the twin to the real rover. We will also create an in-depth comparison between our digital twin with the traditional hardware duplicates used to evaluate the benefits of using the VR platform.

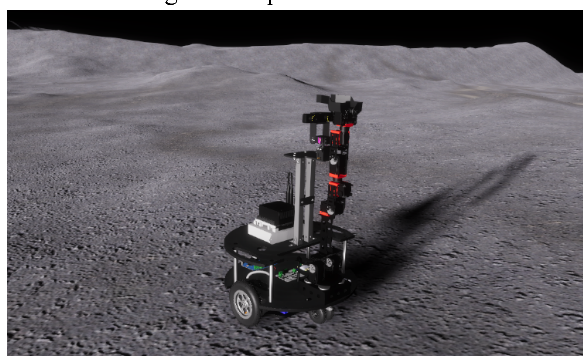

Fig. 1: Exocentric perspective. This unique point of view is made possible by using 3D scans of the environment. Teleoperators can walk around and inspect the rover as needed.

Fig. 2: Egocentric perspective. The operator can see "through" the eyes of the rover with the full impression of depth thanks to the mounted stereoscopic camera.

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References: [1] J. O. Burns et al., "Low Radio Frequency Observations from the Moon Enabled by NASA Landed Payload Missions," *Planetary Science Journal*, vol. 2, no. 44, 16pp, Mar. 2021, doi:10.3847/PSJ/abdfc3.