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

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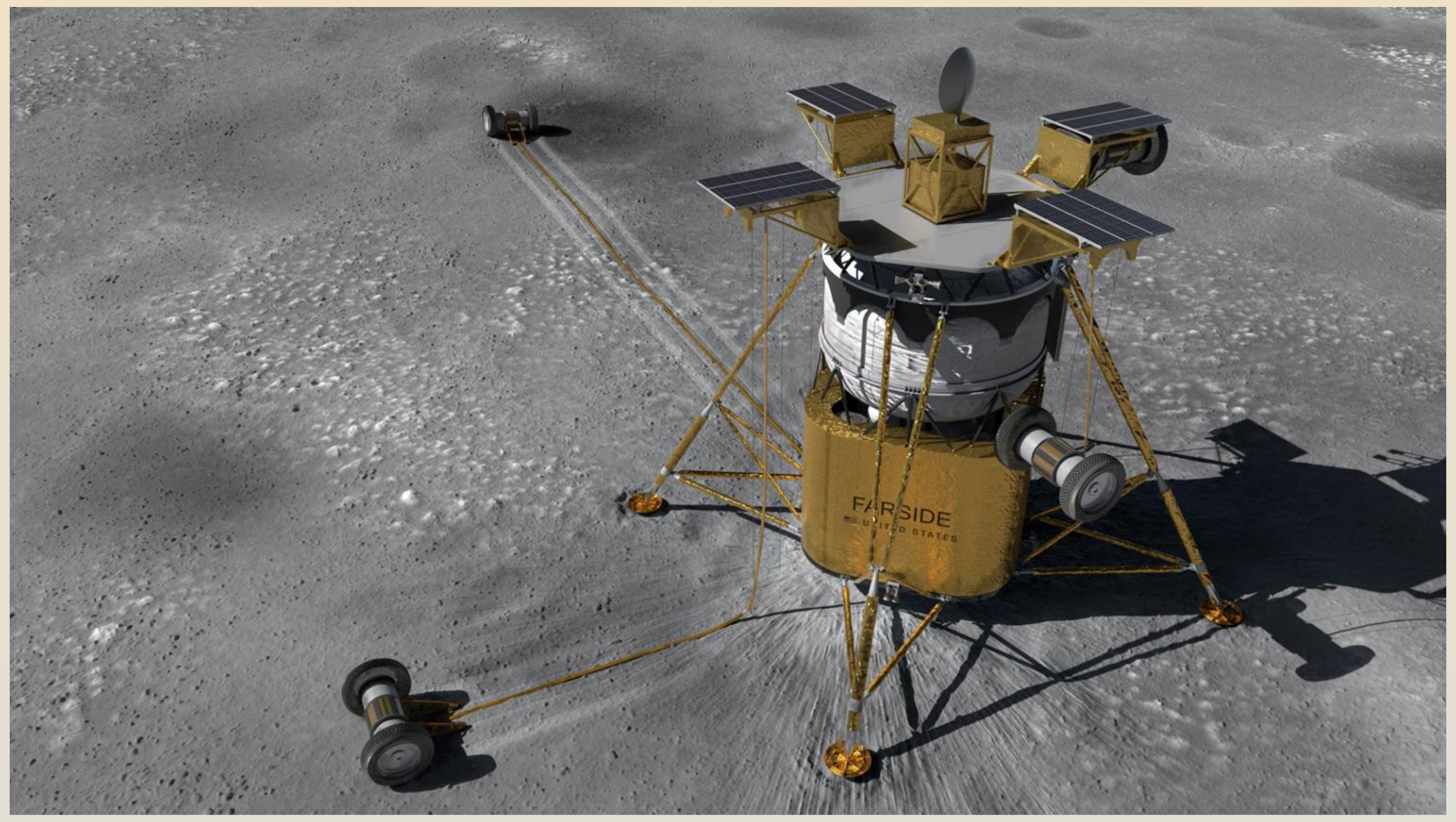
Motivation

NASA is working on creating a sustainable human presence on the lunar surface by the end of the 2020s. This includes the Lunar Gateway, a lab, and station that will orbit the Moon and enable low-latency communications on the lunar surface.

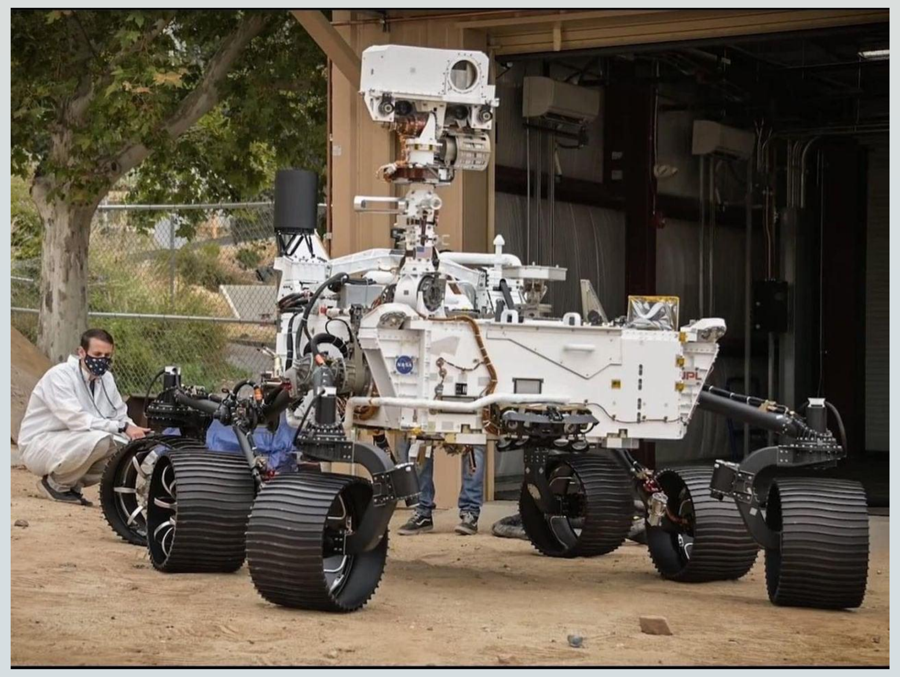
Our team is working with the scientific mission, FARSIDE, which will require rovers to deploy antennas on the farside of the Moon autonomously. In the case of autonomous failure (such as misaligned antennas), humans on the lunar surface will need to intervene to recover the rover. This will be facilitated using novel technologies such as virtual reality (VR) headsets and stereoscopic cameras, enabling telepresence.



"Axel" rovers will deploy antennas autonomously from the lander. Credit: Blue Origin, Inc.

Current Troubleshooting Methods

Current rover troubleshooting methods include the Mars Yard rover, a full-scale engineering model. Rover problems are evaluated in the Yard, which emulates Martian soil characteristics and obstacles.



OPTIMISM, Perseverance's twin, is used to troubleshoot issues from the Mars Yard on Earth. Credit: NASA/JPL

Drawbacks of this include:

- Poor portability - the twin is a full-size replica that is difficult to transport
- Difficulty simulating gravity that is different from Earth
- Cannot rapidly create many replicas due to high costs and development time

Our Solution

Our proposed solution uses a VR digital twin and environment to troubleshoot rovers. This addresses the issues of using a physical twin including:

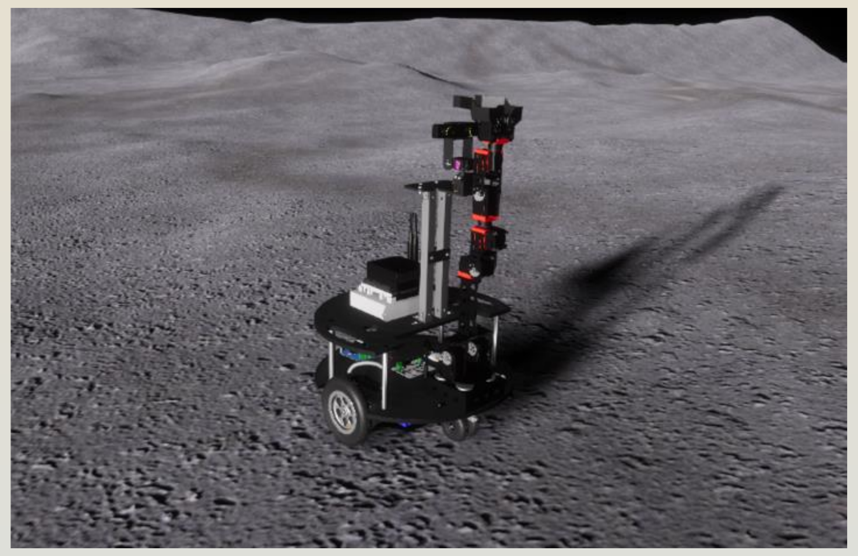
- A software interface that is identical between the virtual and physical rover with an equivalent digital kinematic model
- Access to the egocentric and exocentric views of the rover to develop solutions to failures
- A risk-free free environment where there can be many iterations of the rover
- An environment that can be integrated using 3D scans from the physical environment with simulated gravity

Egocentric Perspective

- 1st-person point-of-view, allowing for the operator to see through the "eyes" of the rover

Exocentric Perspective

- Unique 3rd-person point-of-view
- Operator can walk around rover for inspection
- Made possible using 3D scans of the environment



The Armstrong rover. A complete digital recreation of it has been created to be used on our virtual platform for our experiment.

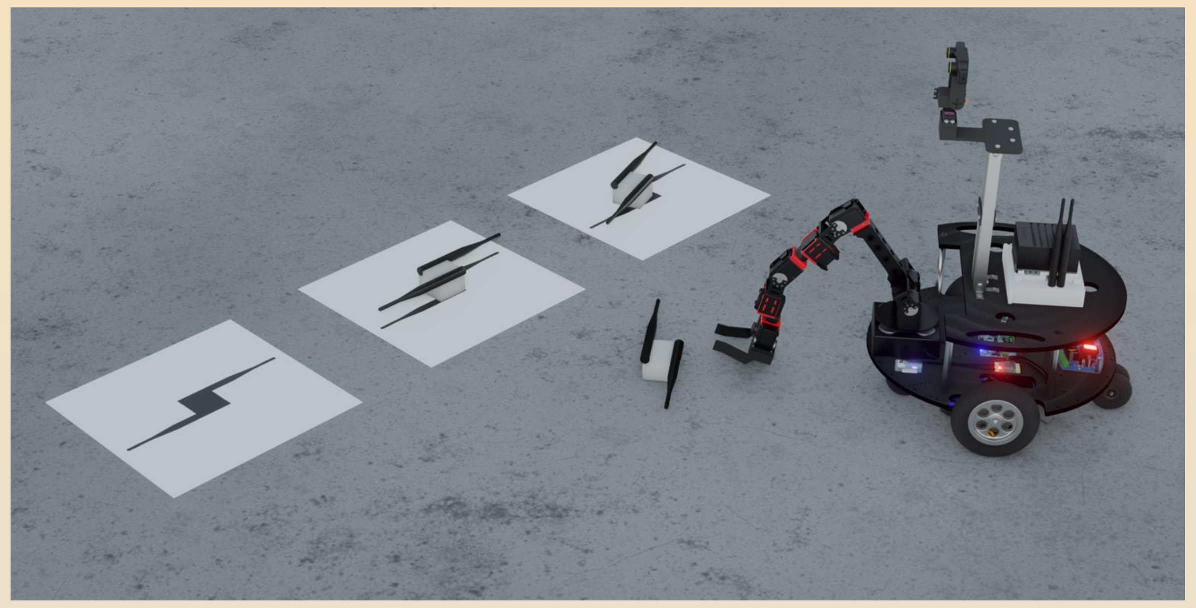
The Armstrong Rover

To test our design, we have created the "Armstrong" rover, a Parallax Arlo Robot with two motorized wheels that we equipped with:

- A 6-degree-of-freedom CrustCrawler Pro-Series arm for grasping items
- A ZED Mini stereoscopic camera for 1st-person stereoscopic passthrough
- A Jetson Xavier with Robot Operating System (ROS) to control the kinematics based on user input with a gamepad

Experimental Design

Our experiment is based on missions like FARSIDE to demonstrate real-world capabilities. The operator will be required to reorient antennas that were misaligned during deployment. The teleoperator will attempt to realign the antennas using the VR platform. They will then apply their solutions to the task on the physical rover.



A graphical render of the experiment. The operator will be required to rotate the antennas into the correct orientation as indicated by the mats.

Evaluating Simulation Accuracy

It is essential to know the limitations of our platform. This includes environmental inaccuracies such as using uniform gravity and friction, which are difficult to implement due to requiring complex scripting to model the behavior. Other limitations include changes to the physical rover after deployment, like component wear.

To address this, the digital twin is being calibrated to match the physical model. We are evaluating four attributes.:

- Message Latency - how long it takes for the rover to be issued a command
- Absolute Joint Error - the error in the arm's movement
- Joint Movement Resolution - the minimum step required to move the arm
- Driving Motion Errors - the deviation that occurs while driving (e.g., due to slip)

Future Work

Our short-term goals include calibrating the digital twin to the physical rover's parameters. We will also develop surveys for measuring teleoperators' situational awareness, cognitive load, and system usability of our VR platform. Lastly, we will run a preliminary test experiment to find flaws overlooked in our platform and methodology.

Our long-term goals include comparing differences using the physical twin instead of the digital twin. The comparisons will give an in-depth look at the proposed model and the current traditional methods. More complex tasks such as tether deployments may also be tested, which would require implementing additional physics.

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