RIDER: A Planetary Terramechanics and Rover Wheel Testbed for Research and Development.
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Introduction: Establishing and maintaining a permanent human presence on planetary surfaces requires vehicles (e.g., rovers, hoppers, walkers) to transport supplies, resources, materials, and personnel for exploration and infrastructure development. Since extraterrestrial permanence relies on efficient locomotion, likely on common paths and roadways, characterization of regolith properties as a function of repeated wheel traffic and rover specifications (mass, geometry, wheel design and materials, motor drive torque and speed) is critical to defining a reliable transport capability for any surface. Save a few restricted-access government laboratories, no facilities are suitable to evaluate long-term rover wheel performance (e.g., traction, slip, sinkage) and longevity. The Regolith Interactions for the Development of Extraterrestrial Rovers (RIDER) testbed (Figure 1) at the University of Central Florida (UCF) Exolith Lab provides these capabilities but adds mineralogically accurate regolith simulants and quantification of traffic-driven changes to regolith surface layers [1] and is expected to be available in Summer 2023.

Figure 1. RIDER with motor box, gravity offload system, dust mitigation systems, illumination, and video recording systems.

RIDER is the first testbed available to the scientific and engineering communities to offer full-scale automated rover wheel testing capabilities in 3.8 m long, 1 m wide, 0.5 m deep regolith simulant bin. The initial testing campaign of RIDER will include a Lunar Roving Vehicle (LRV) replica wheel, a VIPER-like prototype (Resource Prospector) wheel, and an Astrobotic Polaris prototype rover wheel. Data collected using these wheels will serve as baseline comparisons for all future wheels tested in RIDER. The LRV wheel will allow calibration with Apollo data, while the remaining cases will support predictive models to be verified by the associated flights.

Design Considerations and System Overview:

Planetary Environments. RIDER is designed to be an all-purpose planetary rover wheel trafficability testing rig capable of simulating full-scale rover locomotion on the Moon, Mars, and asteroids. RIDER is housed at Exolith Lab, providing access to large-scale simulant manufacturing capabilities allowing standard or custom (mineralogy and/or particle size distribution) regolith simulants suitable for terramechanics simulation of various sites on various planetary bodies. RIDER is equipped with gravity application and offload system suitable for simulation of vehicle wheel loads in reduced or increased gravity depending on the target site. The density and level of compaction of planetary regolith varies from site to site and will affect trafficability, so RIDER has the option to pack regolith simulant capabilities to pack simulant to best mimic the density, stratification, and other site-specific characteristics [3] of target locations to better inform trafficability studies. Initial testing using the LRV, Resource Prospector, and Astrobotic wheel will have regolith beds that replicate mechanical stratigraphy based on Apollo penetrometer logs [3]. Given that moisture content is known to affect the geotechnical properties of regolith simulants [2], RIDER is equipped with a dehumidification unit to manage humidity in the test testing environment.

Electronics and Control Systems. RIDER allows a wheel to be run back and forth across the bin a user-specified number of times while tracking the location of the wheel within the bin to control movement (start, stop, speed) with limit switches at the endpoints for safety; RIDER customers provide wheel size, drive torque and speed limits, and rover mass, and gravity of the target body. The data recording system logs desired quantities (e.g., time elapsed, passes completed, distance travelled, simulated rover mass, motor drive current) to comma-delimited ASCII text files to allow for post-experiment data analysis; during experiments, separate displays show telemetry and plots to evaluate settings and performance in real-time.

Dust mitigation. Planetary regolith has extremely small particle sizes that are susceptible to electrostatic lofting [4, 5] and can cause problems for electronics and mechanical hardware. Exolith Lab simulants are designed to simulate planetary regolith mineralogy and particle size distributions, both of which are key factors in dust mobilization and transport. Due to the high amounts of mobilized dust that are expected during RIDER experiments, RIDER has been designed with dust mitigation features, including air filtering, maintaining a negative pressure in the RIDER bin, developing an airlock to contain any escaped dust and dust while filling the bin, developing a panel and brush system to limit vertical dust travel into rails and sensitive electronics, and electrostatic grounding to avoid dust buildup on metal surfaces.

Rover Wheels. Rover wheel mountings (e.g., size, number of bolts and bolt geometry) are not standardized and rover wheels are designed to bear different masses. Hence, RIDER is equipped with a heavy-duty wheel hub with sealed bearings, an industry interface. Custom adapters are designed and fabricated (typically 3D printed) for each wheel. These allow adaptation to the RIDER motor box and wheel hub (Figure 2). RIDER is able to accommodate wheels from 26 cm to 82+ cm in diameter with arbitrary mounting hole geometry and simulate single-wheel loads up to 200 kg, allowing RIDER to test a variety of rover wheels under various loads to better characterize regolith-wheel systems.

Figure 2. RIDER motor box with wheel hub below the dust mitigation panel and brush system designed to protect the rails above from dust accumulation.

Motors. Rover mobility is, in part, controlled by the characteristics of the motors used to drive the wheels. Motor torque and speed have a direct effect on wheel-regolith interactions, so RIDER is outfitted with brushless DC motors equipped with different reduction levels (10:1, 50:1, 100:1, and 225:1) to allow investigation of travel efficiency and the effects of repeated wheel traffic on regolith physical properties with regards to drive characteristics. These motors are interchangeable within the motor box, allowing efficient swapping of motors based on experiment needs.

Lighting and Video Recording. Rover wheel performance and mission surface interaction assessments rely heavily on video data, so to better support comparison to flight mission video data as well as fully assembled rover testing in laboratory settings, the RIDER lighting system includes moveable, dimmable sources with variable color temperature. Multiple cameras with various resolutions and framerates capture wheel-regolith interactions throughout experiments and record the trajectory and velocity of dust plumes around the wheel. Such data are useful beyond visual inspection, as they can help validate computational models of rover traversals and dust clouds in order to guide safe rover operations [4].

RIDER as a Service: RIDER is a terramechanics and wheel trafficability testbed available to the science and engineering communities that is open to testing wheels and rover-based geotechnical experiments from government (e.g., NASA, ESA), industry (e.g., CLPS providers), and academic institutions worldwide. The RIDER team is ready to partner with customers to fit hardware to RIDER, design experiments, execute those experiments, and address other customer needs. The RIDER team is able to maintain any privacy needs (non-disclosure agreements and physical barriers to limit visibility of experiments and hardware) while leveraging the expertise of Exolith Lab and its collaborators, providing unparalleled terramechanical and geotechnical analysis and modeling. RIDER will provide insights on parameters such as rolling resistance, simulant density and particle shapes as a function of the amount of wheel traffic, relative wheel efficiency, wheel dust lofting as a function of speed and motor torque, and wheel longevity in mineralogically accurate regolith simulants.

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