

Geotechnical Assessment of Trafficability on Regolith (GATOR) Using the RIDER Terramechanics Testbed

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Motivation

Most trafficability studies generally focus on how to design and develop better wheels/rovers. Considering the topic of lunar trafficability from a **geological perspective**, little attention has been dedicated to the topic of how **geomechanical properties of the near-surface regolith evolve due to prolonged interaction with lunar vehicles**. This information is crucial to learn how to most safely and efficiently undertake long duration vehicle excursions between lunar base camp and outlying sites (e.g., scientific assets, power stations, astronomical observatories, mining sites, PSRs), and will also inform future construction (e.g., roadways, LLPs) and ISRU activities. Here, we describe the GATOR project, where we tested three prototype lunar rover wheels on a replicated lunar highlands (e.g., the lunar south pole) regolith stratigraphic column with the goal of measuring the effect that repeated traffic has on the geotechnical properties of the regolith.

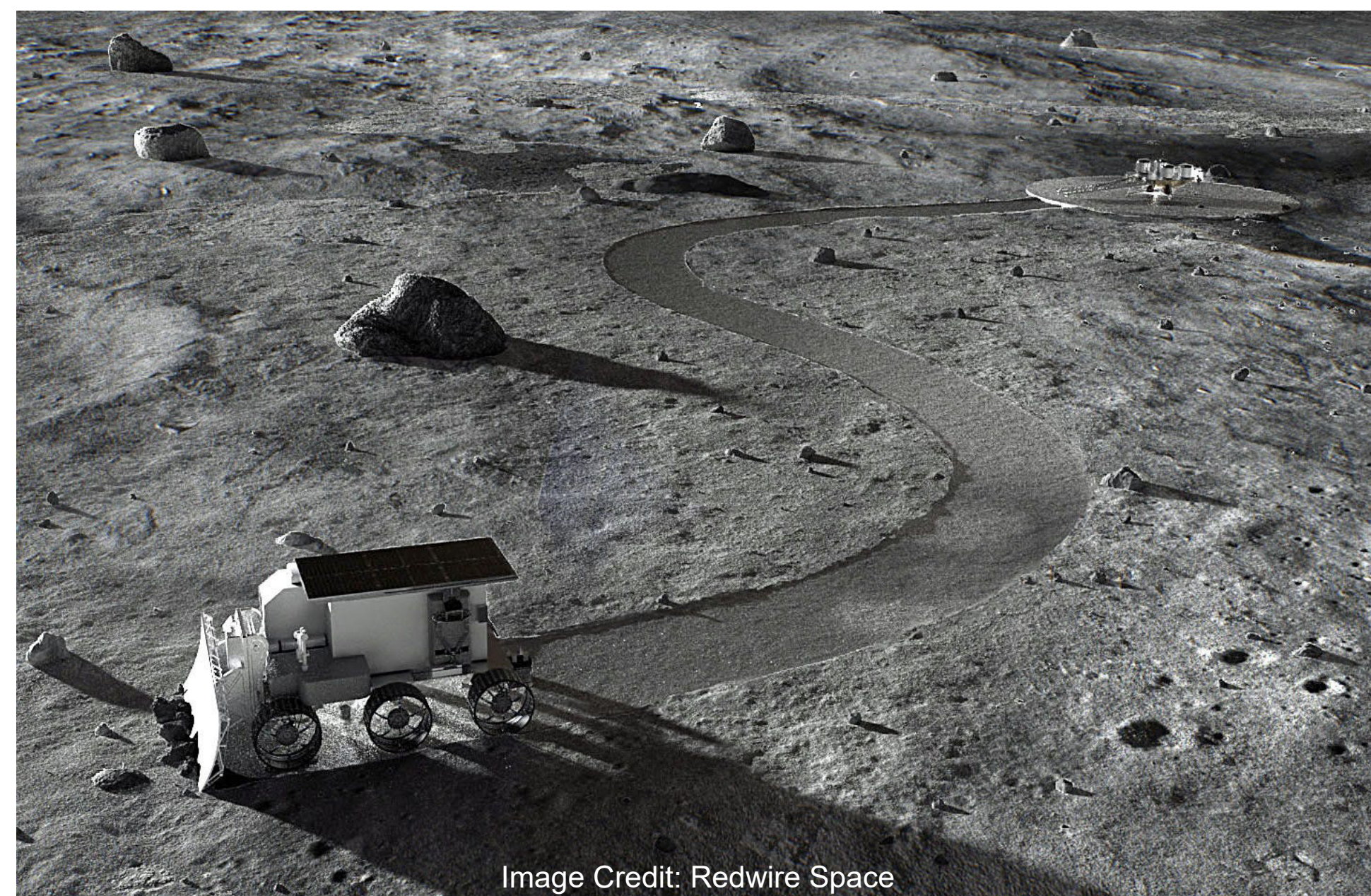


Figure 1. - Long duration stays on the lunar surface will require investigation into the "trafficability" of the lunar surface.

Introduction

- Most terramechanics studies using regolith simulants are undertaken to design and develop a better wheel/rover.
- As geologists, we're interested in how the geomechanical properties of the near-surface regolith evolve due to repeated wheel traffic.
- Unique Application** → To understand how regolith will withstand trafficability and construction activities we need to identify the geotechnical properties **and** density profile of the near-surface.
- Replicate near-surface lunar regolith density stratigraphy in testbed → i.e., pack simulant in layers of specific densities, rather than just dumping it into the testbed
- GATOR Project** → run three actual lunar vehicle wheels on a replicated lunar highlands regolith column to measure the effect that repeated traffic has on the geomechanical properties of the regolith.

Geotechnical Properties of LHS-1

- Candidate Artemis landing sites are within the south polar highlands.
- Characterized by anortositic norite or anorthositic troctolite composition [3].
- LHS-1E: "Engineering Grade" simulant → appropriate analogue material to simulate lunar highlands stratigraphy.

Exolith Lab LHS-1 Simulant



Figure 2. - LHS-1 simulant (Image credit: Exolith Lab).

Table 1. - Geotechnical properties of Exolith Lab's LHS-1 (2σ errors) lunar highlands simulant [see 4] compared to values for lunar highlands regolith.

Property	Undried	Dried	Highland Rego	Reference
Specific G	2.75	2.75	3.05	[5]
Min. ρ (g/cm ³)	1.27±0.01	1.24	1.1 - 1.2	[6,7]
Max. ρ (g/cm ³)	1.86±0.04	1.95	1.7 - 1.8	[6,7]
Bulk ρ (g/cm ³)	1.34±0.03	1.58	1.4-1.8	[8]
Cohesion (kPa)	0.311±0.027	0.299±0.036	0.25 - 0.60	[8]
Ang Int Friction	31.49±3.67°	31.67±4.72°	46.5 - 50°	[8]
Ang of Repose	41.2±8.1°	-	40 - 45°	[8]

Rover Wheels for GATOR Project

Table 2. - Prototype rover wheel parameters for the GATOR project.

Wheel	Diameter (cm)	Rover Mass (kg)	Load per Wheel Lunar (N)	Tested Speeds (cm/s)
Polaris	61.5	240	100	9, 18, 37
VIPER-like	45	430	175	5, 10, 20
Apollo LRV	81.8	800	325	14, 28, 56

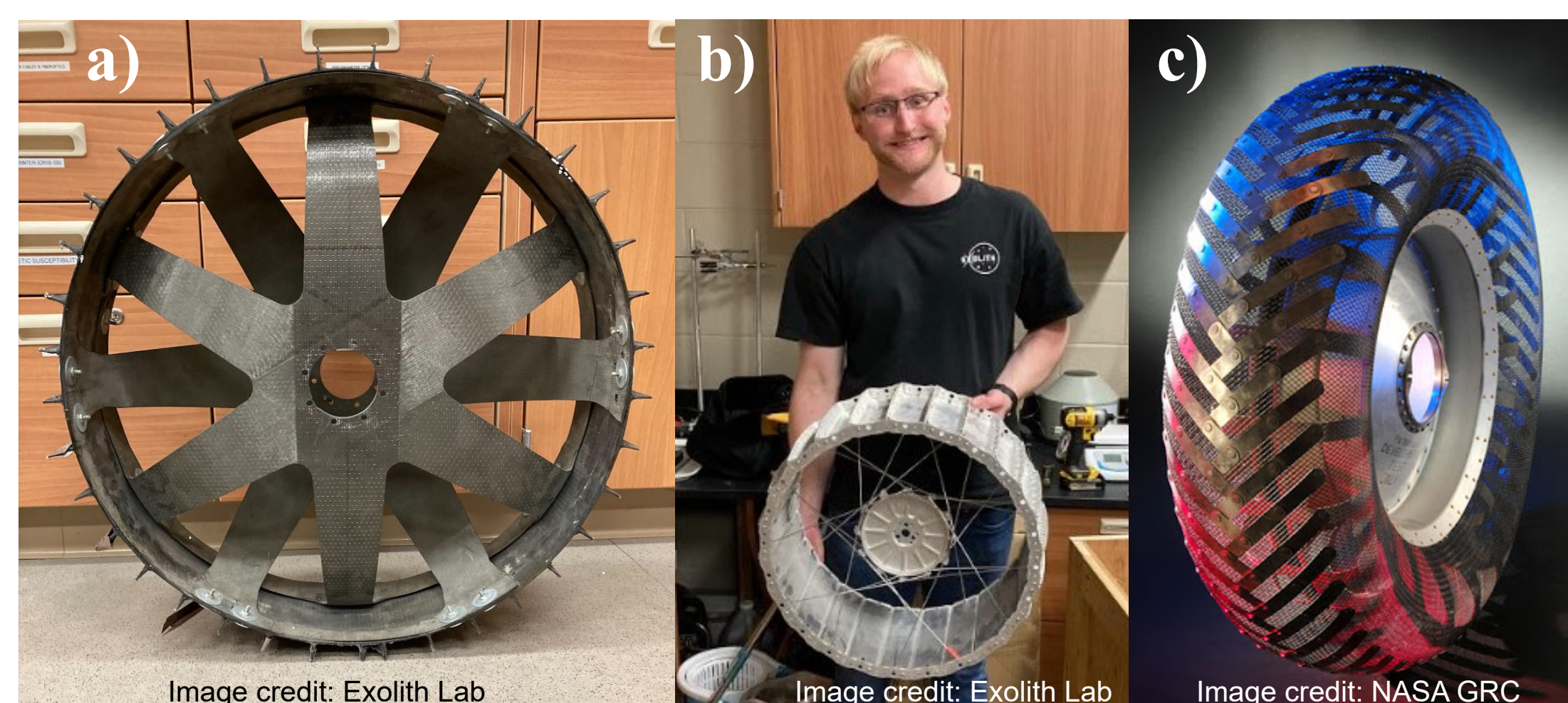


Figure 3. - Prototype lunar rover wheels used for GATOR trafficability experiments. (a) Astrobotic Technology Polaris rover. (b) NASA GRC Resource Prospector (VIPER-like) rover, and (c) **the coolest of all three**, GRC Apollo Lunar Roving Vehicle (LRV) replica tire. We thank Mike Provenzano at Astrobotic for the loan of (a) and Colin Creager at NASA GRC for the loan of (b) and (c).

RIDER Test Facility at Exolith Lab

- RIDER's location at FSI UCF Exolith Lab provides on-site, cost effective access to large quantities of regolith simulants**
→ **no need to ship metric tons of simulant!**



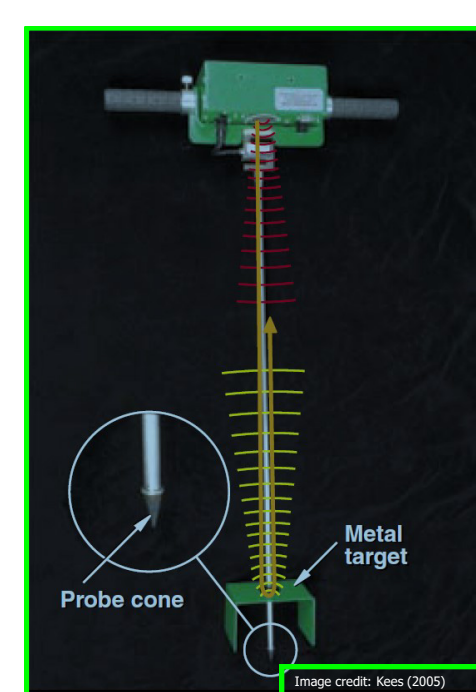
Figure 4. - Regolith Interactions for the Development of Extraterrestrial Rovers (RIDER) is housed at Exolith Lab. RIDER is a state-of-the-art, terramechanics testbed (3.8 m x 0.9 m x 0.5 m deep), designed to test wheel-regolith interactions. **Inset:** (A) 24 V DC brushless motor options for RIDER (10:1, 50:1, 100:1, 225:1), (B) motor-box and wheel hub assembly, attached to a linear actuator that serves as a gravity offloading system.

GATOR Geotechnical Testing

Property	Samples/100 Passes	Total Samples/100 Passes	Std. Method
Particle Size	4	40	ASTM D2487
Particle Shapes	4	40	n/a
Shear (Vane)	16	160	ASTM D8121
Bulk ρ (CPT)	12	120	ASAE S313.3

Table 3. - Geotechnical tests conducted on LHS-1E lunar highlands regolith simulant column in GATOR project.

Figure 5. - RIMIK CP40II cone penetrometer to investigate penetration resistance (stress in kPa) vs. depth for simulated lunar highlands regolith columns (see Figure 6) deposited in RIDER test bin (Image credit: Kees, 2005 [9]).



Replicating Apollo 16 Stratigraphy

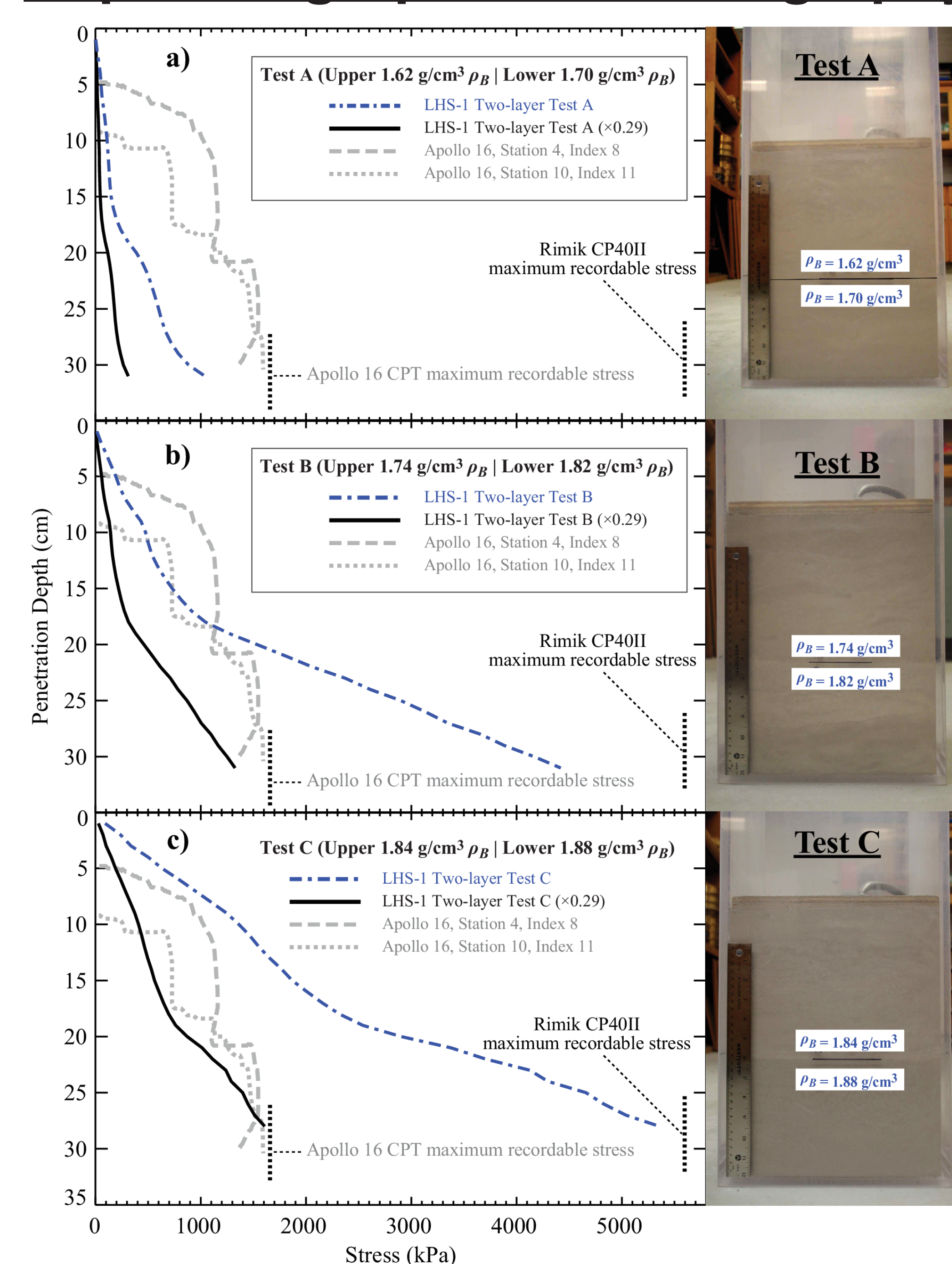


Figure 6. - CPT depth vs. stress for simulated ~35 cm deep two-layer regolith columns using LHS-1. Tests A, B, and C are packed at incrementally higher bulk densities (photos at right). Lab depth-stress curves are shown in blue; curves with a reduction factor of ×0.29 applied (to adjust for lunar conditions) are shown in black. Curves are compared to Apollo 16 CPT measurements from Stations 4 and 10 (gray curves).

Summary

Efficient movement over the lunar surface between base camp and outlying sites (Figure 7) requires a thorough understanding of the effects of repeated traverses on the geotechnical properties of the near-surface regolith column. These effects can be assessed using appropriately-packed regolith simulants that replicate lunar conditions in Earth-based testbeds, such as the RIDER.



Figure 7. - Artist conception of SpaceX Starship launch/landing pads at Artemis Spaceport (Image credit: ICON@humanmars.net).

References and Funding

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