Site Preparation Tooling for Operations on Mobility Platforms (STOMP)

Marco A. Gudino, Benjamin H. Burdess, Evan A. Bell

Introduction

Swamp Work's RASSOR 2[1] is a Technology Readiness Level (TRL) 4 robotic mobility platform (~60kg) with proven capabilities for bulk regolith manipulation. Additionally, Swamp Work's Multipurpose End-Effector for Regolith Construction, Acquisition, and Transfer (MEERCAT)[2][3] is a TRL 5 robotic arm end effector with plate compaction capabilities intended for early small-scale technology demonstration missions.

The STOMP project aims to develop roller vibratory compaction to TRL 4 and demonstrate this capability via a modularly attachable implement to the RASSOR 2 platform. This project will demonstrate excavation, grading, and compaction all from one robotic platform, RASSOR 2.

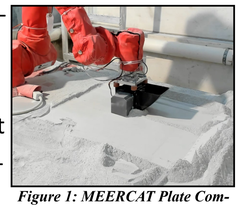

Figure 1: MEERCAT Plate Compaction

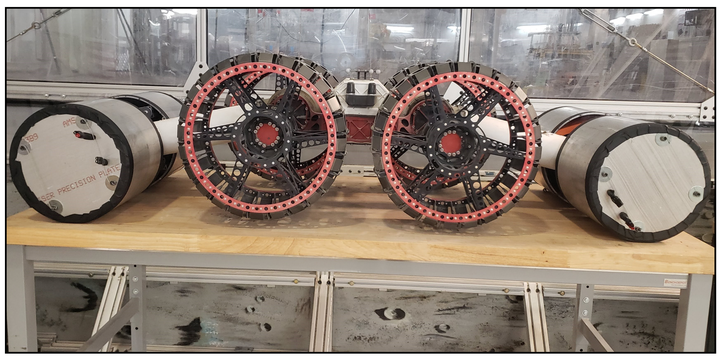

Figure 2: TRL 3 Assembly on RASSOR 2 Rover

Development of STOMP was split into a TRL 3 design and a TRL 4 design. The TRL 3 prototype consists of a COTS 60 Hz vibration motor with an output force of ~222 N (50 lbf) within an aluminum roller housing mounted directly in place of the RASSOR 2 bucket drums. This prototype served to quickly validate RASSOR-scale vibratory roller compaction before moving on to a TRL 4 design.

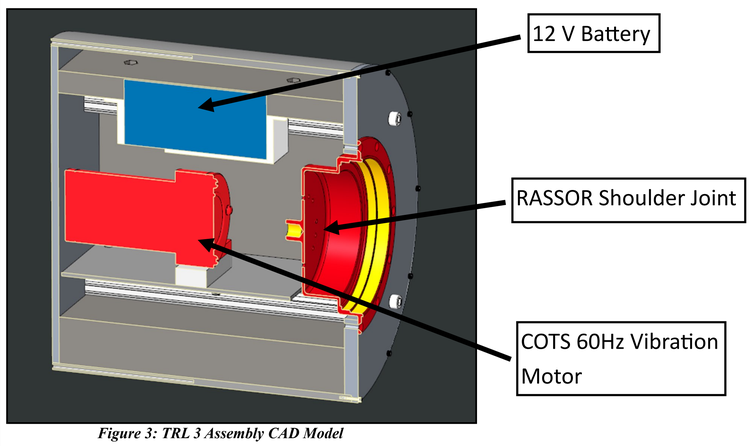

Figure 3: TRL 3 Assembly CAD Model

[1] Gill, T. R., and Mueller, R., "RASSOR - Regolith Advanced Surface Systems Operations Robot," NASA/TM-2015-20150022134, NASA Kennedy Space Center, Cocoa Beach, FL, November 17, 2015. Available: https://ntrs.nasa.gov/citations/20150022134.

[2] Bell, E. A., Bidot, E. J., Gelino, N. J., and Mueller, R. P., "Multifunctional End Effector for Regolith Construction, Acquisition, and Transfer (MEERCAT)," NASA/TM-2024-20240004381, presented at ASCE Earth & Space 2024, Miami, FL, April 15–18, 2024. Available: https://ntrs.nasa.gov/citations/20240004381.

[3] Bell, E. A., et. al. "Vibratory Plate Compaction of BP-1 & LHS-1 Utilizing the Planetary Automated Compaction Tool (PACT)", NASA/TM-20250005172. Available: https://ntrs.nasa.gov/citations/20250005172

TRL 3 Testing

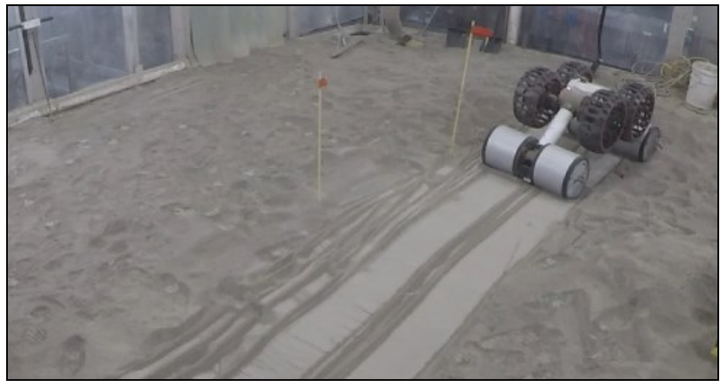

Figure 4: In Progress TRL 3 Testing

Testing was conducted in the Granular Mechanics and Regolith Operations' (GMRO) BP-1 "Big Bin" from March to May 2025. To demonstrate improvement of lunar terrain, RASSOR 2 leveled an area including high and low topology using the existing RASSOR 2 excavator bucket drums, graded the surface using the bucket drums, and then performed compaction of the terrain via driving over it with RASSOR 2's wheels, the bucket drums, and finally the STOMP compactor. A pocket penetrometer was used to estimate surface bulk density and cone penetrometer force measurements were taken at depth. The results of three compaction test runs were averaged and are presented below in Table 1 and Figure 5.

Testing showed the TRL 3 STOMP system is effective at compacting to 80% relative density with 10 passes and provides significantly more surface and at-depth compaction compared to compaction via driving.

Table 1: Pocket Penetrometer Results. Pocket penetrometer pressure readings were converted to a density using the following equation ($y = -0.00004x^2 + 0.0075x + 1.5075$) where y is the density in g/cm^3 and x is pocket penetrometer pressure in kPa. This equation and relative density % range was developed during MEERCAT development under PACT [3]. Results are from three test runs averaged together.

	Uncompacted	Compaction via RASSOR Wheels	Compaction via RASSOR Bucket Drums	STOMP TRL 3 (5 passes)	STOMP TRL 3 (10 Passes)
Surface Bulk Density (g/cm^3)	**1.51**	1.51	1.58	1.70	**1.73**
Relative Density (1.27-1.86 g/cm^3)	**49%**	49%	61%	79%	**84%**

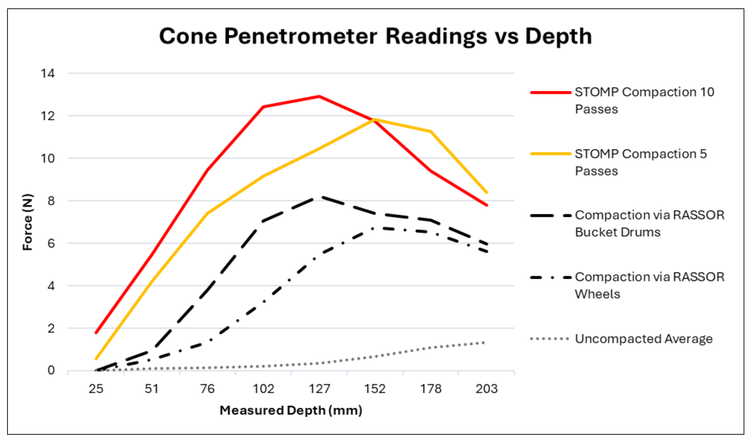

Figure 5: Cone penetrometer measurements of the uncompacted prepared regolith, after RASSOR 2 wheel dive-over compaction, after bucket drum drive-over compaction, and after 10 passes with the STOMP compactor. Results are from three test runs averaged together.

TRL 4 Development

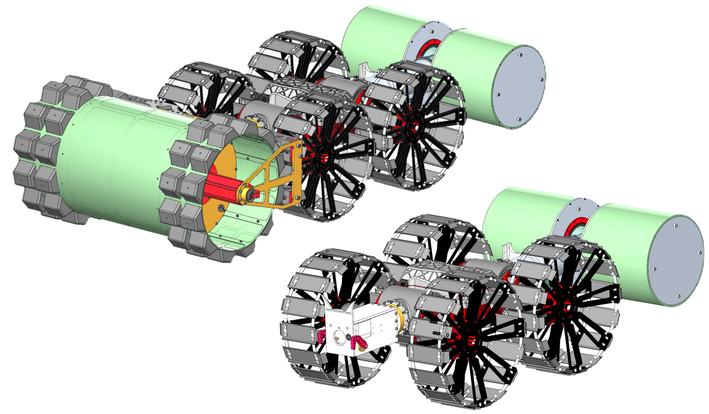

Figure 6: STOMP can be robotically connected and disconnected from RASSOR 2. RASSOR 2 is shown with STOMP TRL 4 connected (upper left) and disconnected (lower right).

The TRL 4 design of STOMP is currently being assembled and features a novel dust tolerant modular disconnect system that allows for robotic in-situ attachment to RASSOR 2. The vibration system uses a dust sealed motor and gearbox outputting 0 to 72 Hz vibratory frequency and has modular excentric masses to vary the amplitude. STOMP TRL 4 will be capable of being equipped with "Sheep's Feet" for increased traction and to tune compaction performance.

Modular Disconnect

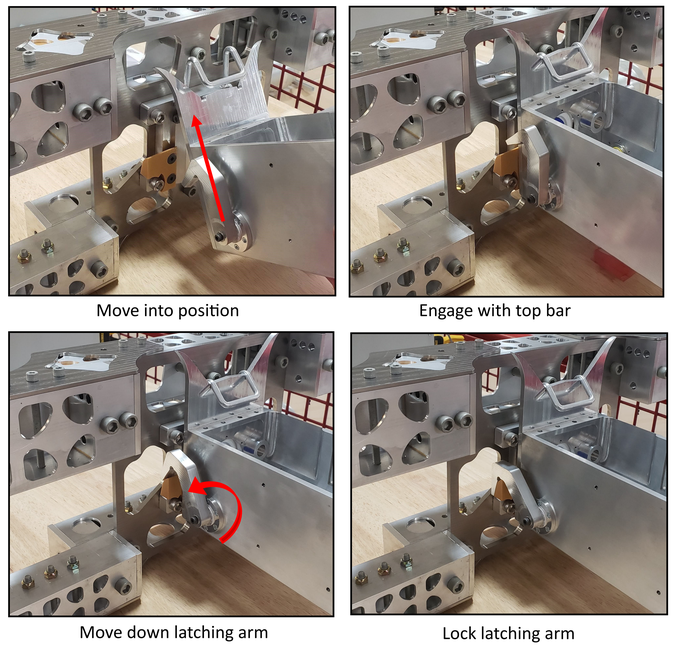

Figure 7: MDS Latching Process

The modular disconnect approximate misalignment capabilities are +50° to -10° Pitch, +/- 40° Roll, +/-20° Yaw. +/- 40mm Left/Right, +/- 15mm Front/Back, +0 to -40mm Up/Down.

Further Development

The TRL 4 STOMP compactor fabrication is complete and testing of the system will occur July 2025 until the end of the fiscal year (October). Swamp Works is looking for means to infuse this technology into industry and advance to a TRL 5.