Test Stand for the Analysis of Excavation Forces in a Simulated Lunar Environment

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Introduction

Excavation of water-ice from lunar permanently shadowed regions is necessary for in-situ resource utilization and building a lunar infrastructure. However, it is currently difficult to compare excavator types due to the inconsistent test procedures and data collection methods of various experimental designs [1].

The Dynamic Response Evaluation for Development of Geotechnical Equipment (DREDGE) provides a mechanism for testing different types of excavators within the same environmental conditions for simplified comparison.

Dynamic Response Evaluation for Development of Geotechnical Equipment

The DREDGE is a 3-DOF, 2.5 axis CNC-like system. S-type load cells are placed throughout the frame and calibrated within the -40˚ to 20˚ C temperature range to collect accurate tensile and compressive data while testing. The material bed supports up to a 15.4 cm cut depth and a 1-meter-long cut path. The DAQ and electrical components are kept in a transportable, insulated container to protect from dust and cold temperatures. An open-source GUI [3] is used for the motion of motors and full functionality of the test stand.

Table 1: DREDGE Specifications

Linear Axis Movement	1.46 m
Max Speed	0.05 m/s
Max Holding Torque [X,Y,Z]	[22,13,22] N/m
Load Cell Capacity	~11200 N
Sample Rate	5 kHz
Temperature Range	-40˚ to 20˚ C
Material Bed Dimensions	102x135x25.4 cm

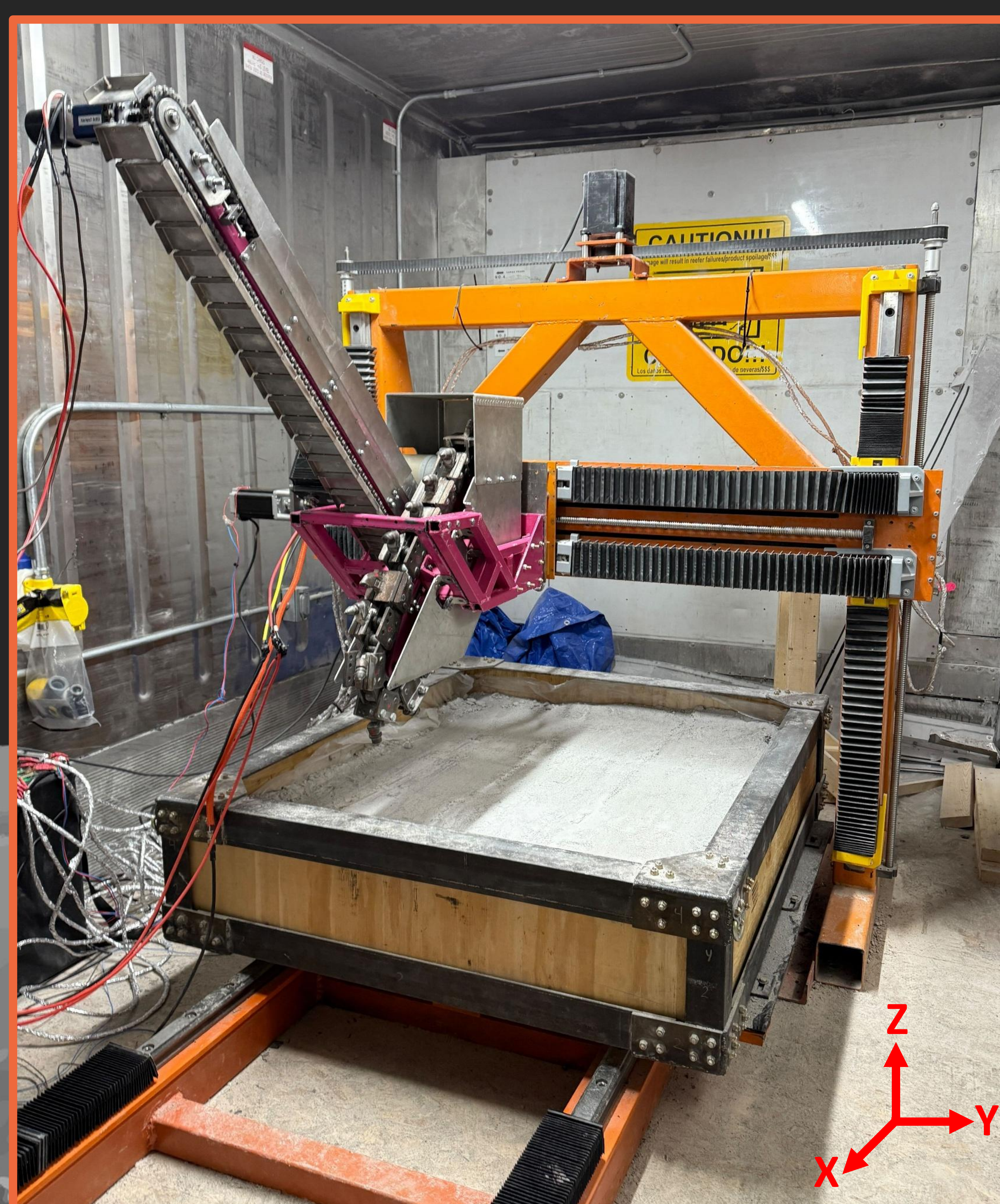

Figure 1: DREDGE with PRIMROSE Excavator [2] and Material Bed filled with Lunar Simulant [4]

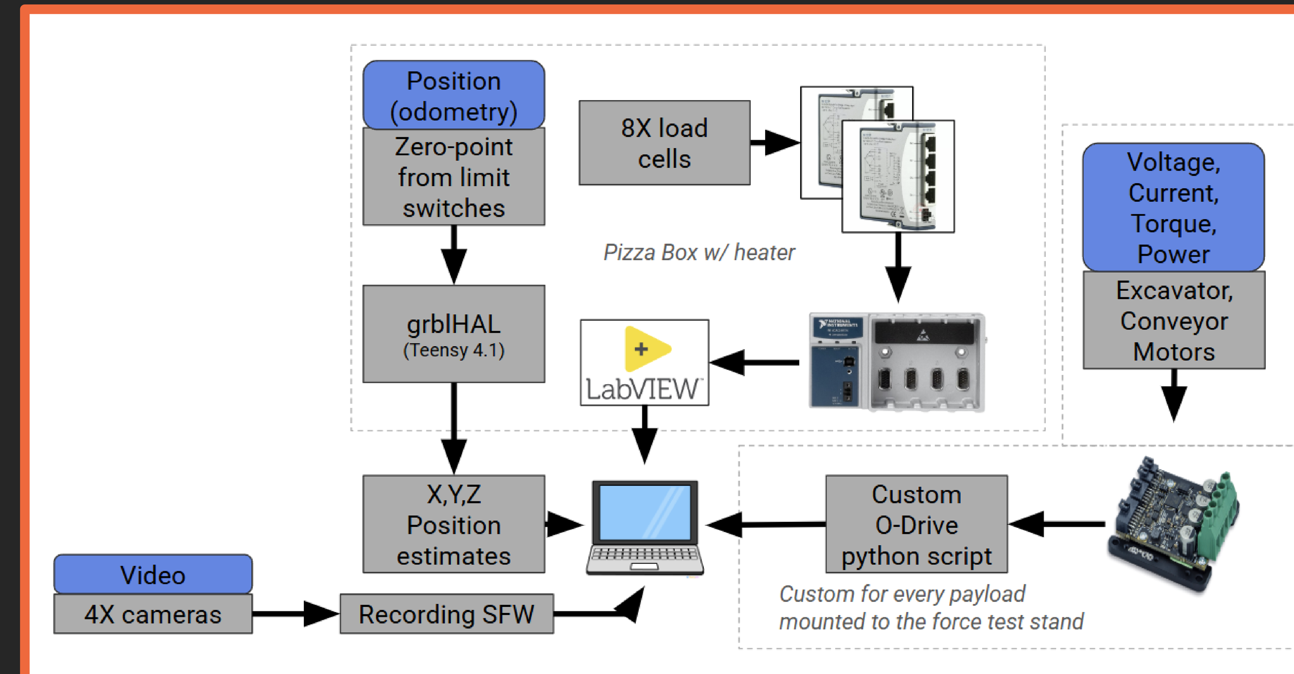

Figure 2: Control flow diagram of the DREDGE, PRIMROSE Excavator [2], and DAQ

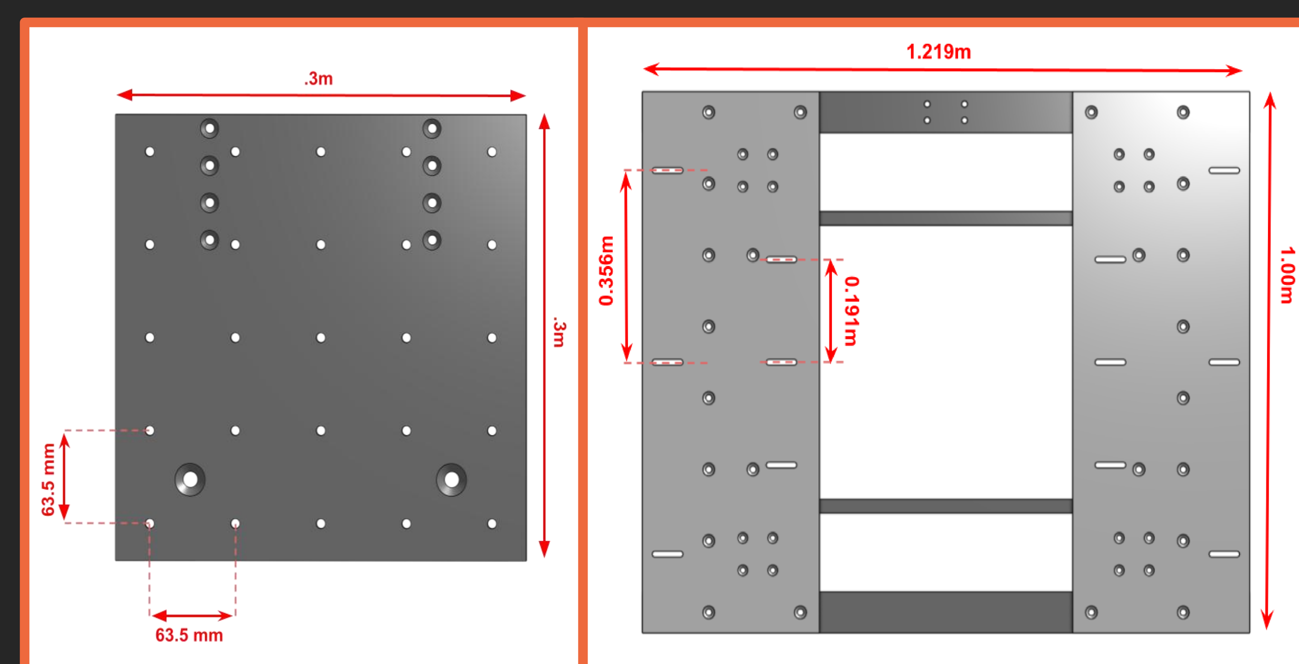

Figure 3: A. Mounting plate dimensions B. Material bed attachment dimensions

Interfacing Capabilities

There are two mounting plates used for interfacing purposes: one to mount the system being tested and another to hold the material bed in place. A modular, battery-powered electrical box and in-house GUI capable of interfacing with two BLDC motors is available for additional electrical and software integration.

Path Forward

Tests using the PRIMROSE excavator assembly [2] to excavate varying ice weight percentages of MTU-LHT-1A [4] are currently being run to capture force and power consumption data. This series of tests will be compared to the theoretical results for pick force calculations per the Goktan and Gunes model [5] and bucket force calculations per the Balovnev model [6].

Other systems can be mounted onto the DREDGE for force data collection and analysis, not limited to excavation systems. Core drills, compaction devices, and additive manufacturing attachments have been discussed as potential use-cases.

References

[1] Just, G. Smith, K. Joy, K. and Roy, M. (2020) Parametric review of existing regolith excavation techniques for lunar In Situ Resource Utilisation (ISRU) and recommendations for future excavation experiments.
[2] Guadagno, M. Bradshaw, P. Primeau J. and van Susante P. (2023) Long Duration Testing of a Rover-Mounted Chain Trencher Excavator in Simulated Lunar Surface Conditions.
[3] Sienci Labs. (2025) Introducing gSender, https://sienci.com/gsender/
[4] van Susante, P. and Carey, C. (2022) Michigan Technological Universities' Lunar Highland Simulant MTU-LHT-1A.
[5] Goktan, R. and Gunes, N. (2005) A semi-empirical approach to cutting force prediction for point-attach picks.
[6] Balovnev, V. (1983) New methods for calculating resistance to cutting of soil.