REGOLITH FLOWABILITY IN LUNAR GRAVITY AND VACUUM. A. Stepanova[1], C. Dreyer[2] and R. Garvey[3]
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Introduction: The renewed global focus on lunar exploration has amplified the demand for effective in-situ resource utilization (ISRU) strategies to enable sustainable lunar operations [1]. The handling and transport of lunar regolith pose significant challenges due to its cohesive, abrasive, and electrostatically charged properties, which are exacerbated under reduced gravity and vacuum conditions.

Purpose: This study investigates the flowability of lunar regolith simulant under simulated lunar gravity and vacuum conditions to improve the design of material-handling systems for future ISRU applications.

Method: Four distinct regolith feed system designs, each incorporating flow-assisting mechanisms, were tested in a vacuum chamber under both terrestrial and simulated lunar gravity conditions using parabolic flight testing. The primary objective was to determine the effectiveness of these designs in mitigating clogging phenomena such as arching, bridging, and compaction, which commonly hinder granular material flow in low-gravity environments [2], [3]. Key parameters, including outlet size, hopper inclination, and external vibration, were systematically varied to identify optimal configurations for ISRU-based regolith conveyance, shown in Figure 1.

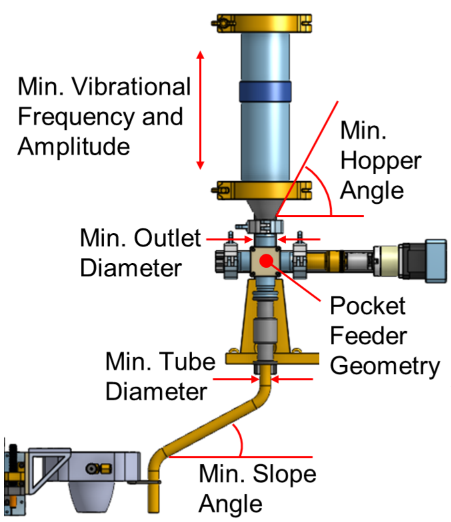

Figure 1. Regolith feed system design overview

Results: Reduced gravity significantly impairs regolith flowability, increasing the likelihood of arch formation and blockages. Larger outlet sizes and steeper hopper inclinations were found to improve flow, while external vibration further enhanced discharge consistency. Additionally, vacuum conditions intensified cohesive forces, necessitating tailored hopper geometries and controlled vibration to sustain steady material movement.

Conclusion: These findings provide critical insights for designing reliable ISRU regolith handling systems, directly benefiting lunar excavation, processing, and transportation infrastructure. The experimental data contribute to the optimization of material-handling techniques essential for constructing lunar habitats, radiation shielding, and resource extraction facilities. This work supports both governmental and commercial entities in developing next-generation ISRU technologies for sustained lunar presence.

Recommendations: While these experiments provide valuable insights, further studies should focus on testing real lunar regolith samples in environments that simulate lunar gravity for extended durations. Parabolic flights offer only short windows of reduced gravity, limiting the ability to fully capture long-term flow behavior. Future research should leverage lunar surface experiments or long-duration microgravity platforms to refine regolith handling system designs under realistic operational conditions.

References:

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