Scaling Relationships for Repose Angles of Lunar Mare Simulants

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Project Goals

➢Measure Repose Angles in Regolith Simulants under Lunar Conditions: Vacuum, 1/6 g

➢Develop Scaling Model for Repose Behavior to Facilitate Robust Predictions of Dynamic Behavior

➢Understand Role of Gravity and Interstitial Gasses in Soil Flow Dynamics

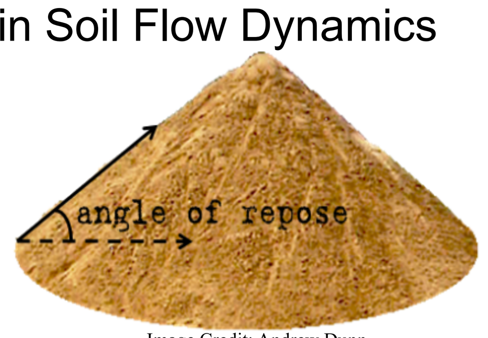
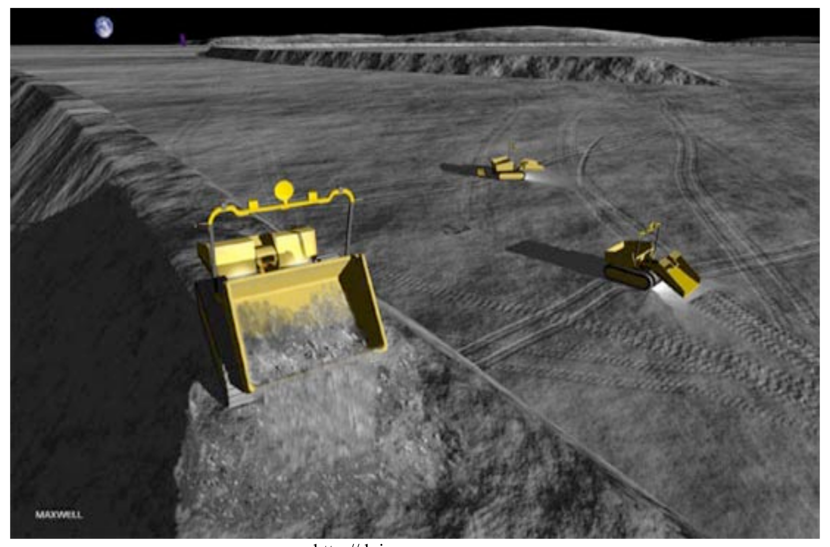


Image Credit: Andrew Dunn

Project Motivation



http://dvice.com

Establish Engineering Constraints on Lunar Soil Processing

Project Context

➢ NASA Systems Engineering Educational Discovery (SEED) program

➢ Undergraduate team designs and builds an experiment in under three months

➢ Parabolic Flights provide ~20 minutes of reduced gravity data

http://nasa.gov

Experimental Rig

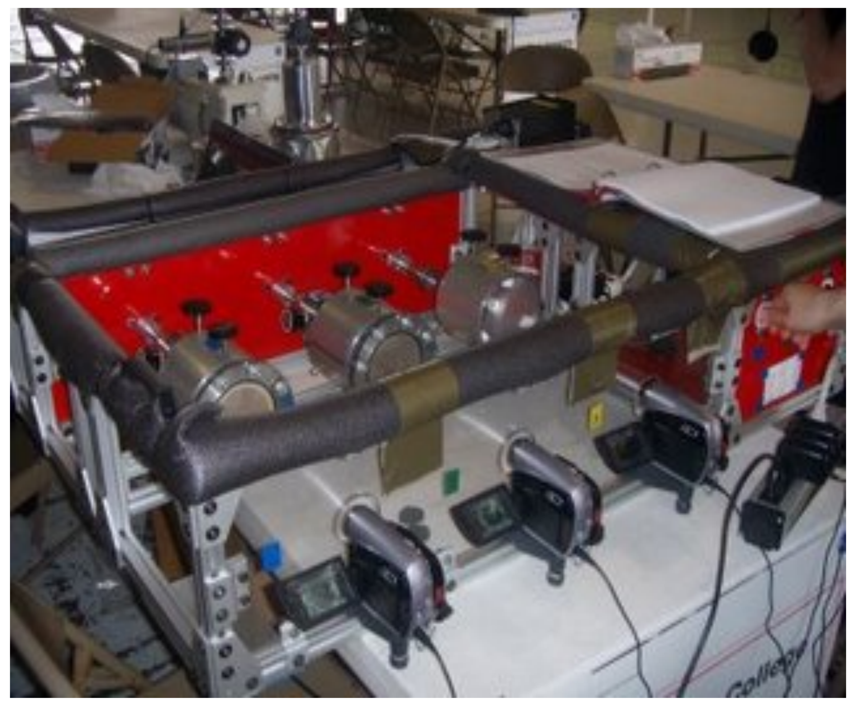
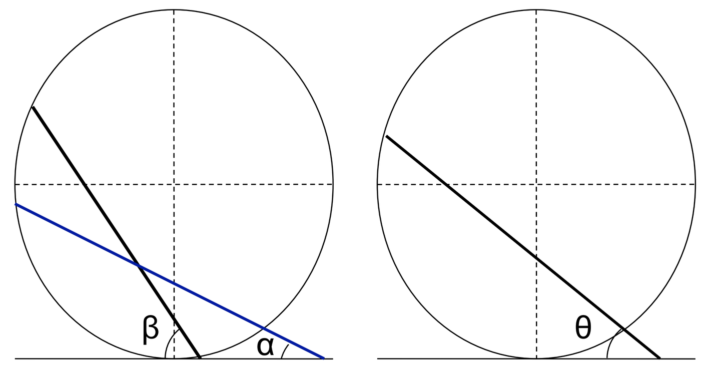


Image Credit: Caitlin Pennington

The rig employs three rotating drums, partially filled with lunar simulant. The drums are under vacuum (mTorr pressures). Rotation rate is varied to explore different flow regimes. Flow behavior is recorded with miniDV cameras.

Granular Behavior Regimes



Slumping Mode *Rolling Mode*

Two Flow Regimes:

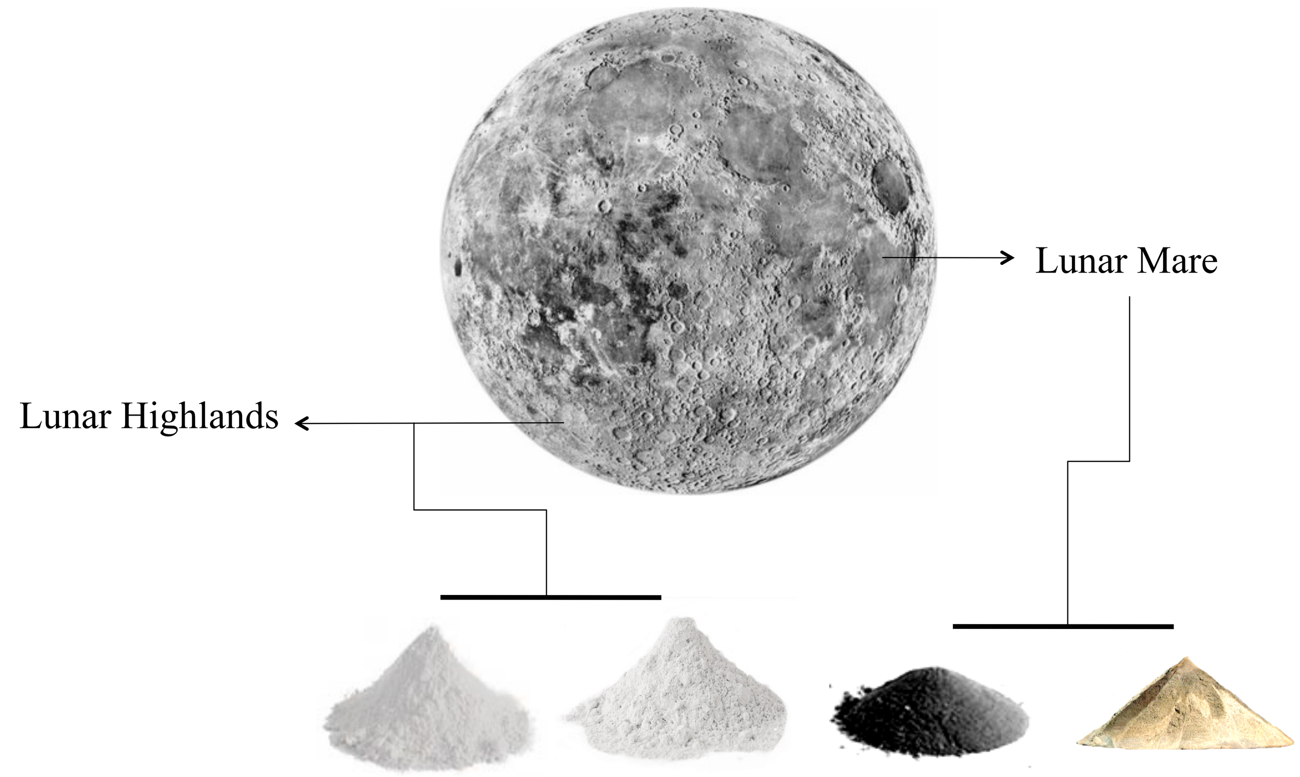
➢Low Speed: *Slumping* – granular material builds up to a steep angle (β) and collapses to a relaxed angle (α).

➢High Speed: *Rolling* - Flow is fluid-like within a narrow surface layer resulting in a constant surface angle, θ.

We find: $\theta \approx (\alpha + \beta)/2$

➢Surface angles in rolling mode are predictive of max. critical surface angles, and are less sensitive to experimental design.

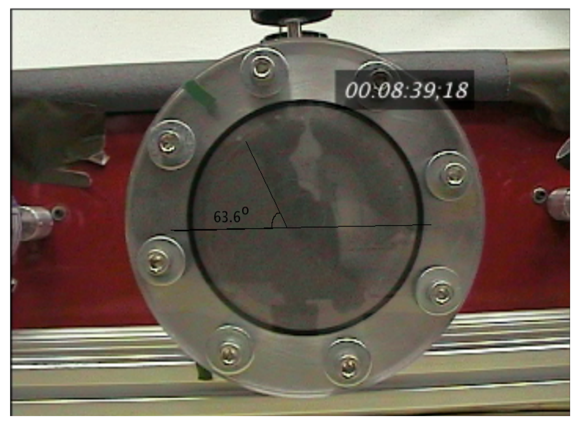
Lunar Simulants

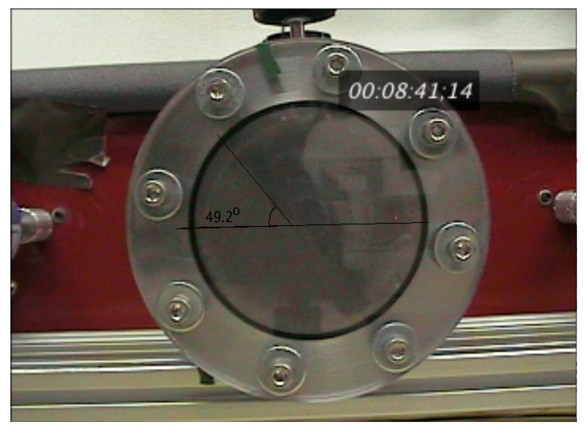


Simulant	OB-1	NU-LHT	JSC-1A	GRC-3
Region Modeled	Highlands	Highlands	Mare	Mare
Cohesiveness	Highly Cohesive	←	→	Low Cohesiveness
Particle Size	75μm – 1.15mm	75 - 150μm	<1mm	0.63mm – 2.0mm

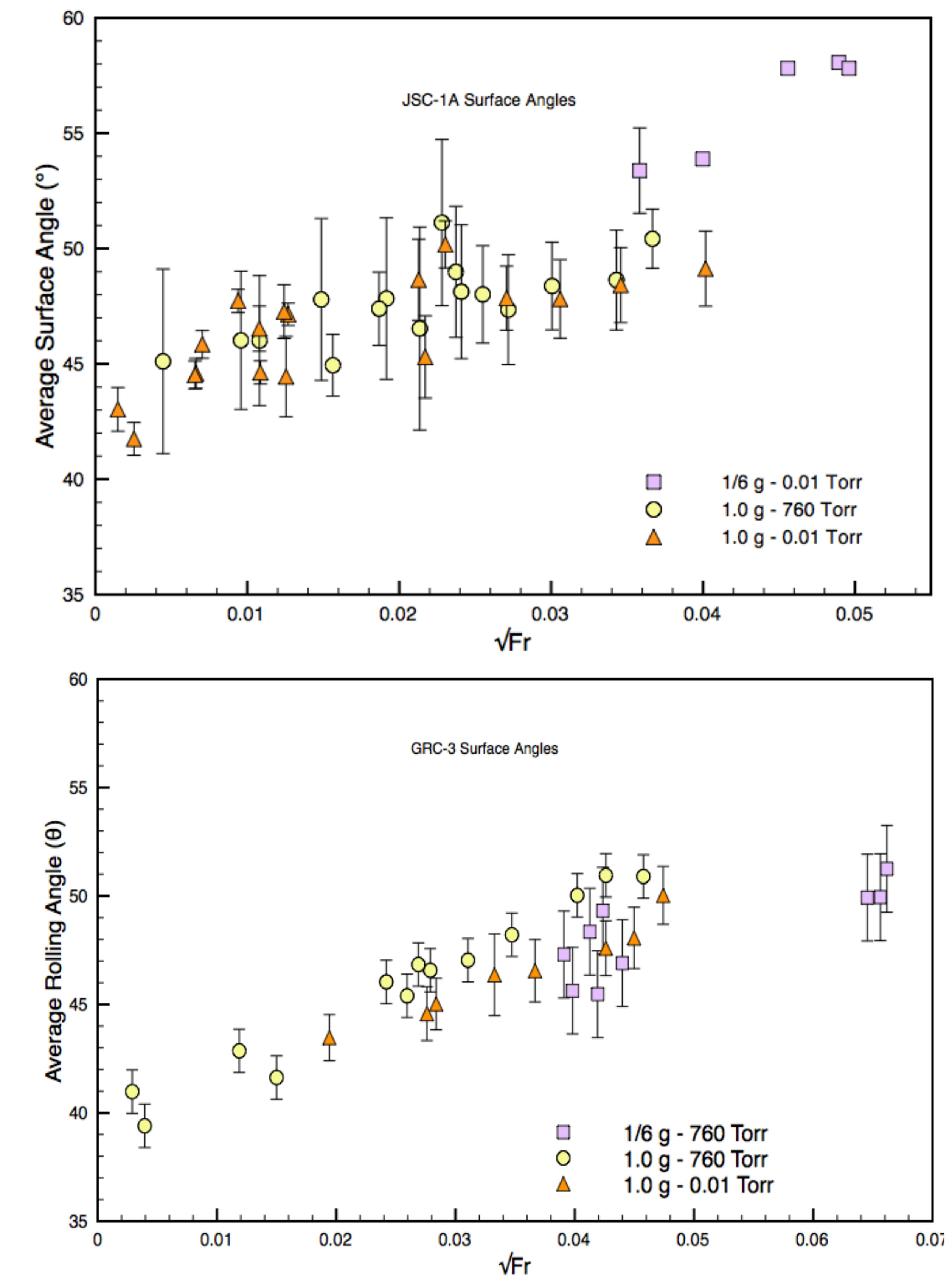
Results:

- Surface flow is characterized by the *Froude Number* $Fr = \omega^2 R/g_{eff}$: the ratio of the centripetal acceleration to the effective gravitational acceleration experienced by a particle in a drum of radius R rotating at angular speed ω.
- Slumping to Rolling Transition at $Fr = 10^{-4}$ (JSC-1A) and 10^{-3} (GRC-3).
- Repose Angles are Independent of Pressure for gas pressures in the range $10^{-5} \leq P \leq 1.0$ Atmospheres.
- Universal Scaling of Repose Angles Plausible with a scaling parameter of $Fr^{1/2}$: $\theta \propto \sqrt{Fr}$.





Surface Angle Scaling: Mare Simulants



Preliminary data suggests that $Fr^{1/2}$ is a useful scaling parameter. Lunar and 1-g data collapse onto the same scaling form. We find no significant pressure dependence of repose angle down to 0.01 Torr.

Note: Data for 1/6-g insufficient to estimate uncertainties.

Implications

➢If scaling holds, we have a predictive model for collapse under lunar gravity.

➢Reduced pressure of lunar environment may have only secondary effect on repose angles

Acknowledgements

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