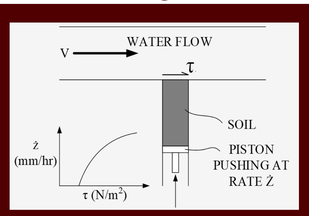
Preliminary Surface Stabilization to Mitigate Lunar Plume Surface Interaction

Maroon Moon Team

TEXAS A&M UNIVERSITY

EFA Testing to Model PSI Mechanics

Background

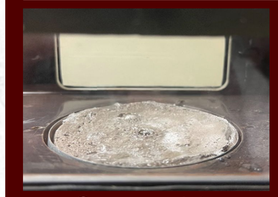


BP-1 Simulant

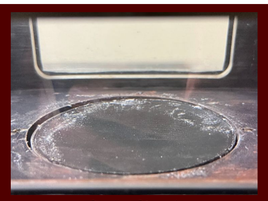
Surface Stabilizers

	Light CA glue	Medium CA glue	PLA Plastic	Sintering
Advantages	Easy Application	Easy Application	Lightweight Solid, Easy to transport	No Additives to Regolith
Disadvantages	Boils at 150 °C Heavy	Boils at 150 °C Heavy	Melts, shrinks	High Energy Input
Cure Time	Seconds	2 minutes	15 minutes	2 hours
Thermoplastic or Thermoset	Thermoplastic	Thermoplastic	Thermoplastic	N/A

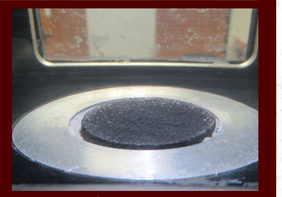
Results



Cyanoacrylate

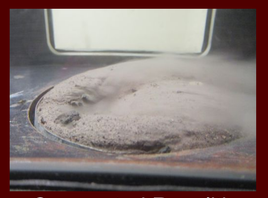


PLA Plastic



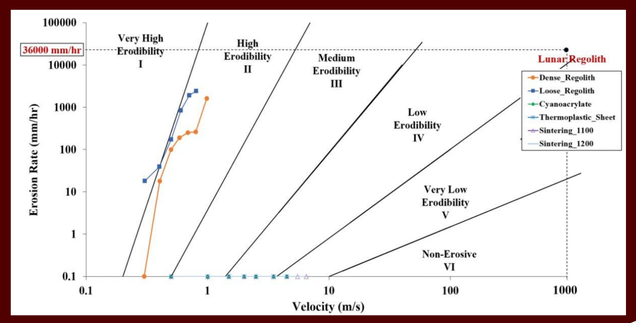
Sintering

Uncompacted Regolith



Compacted Regolith

- All treated samples experienced no erosion
- More testing is needed on the GGEA to find the failure point of the samples



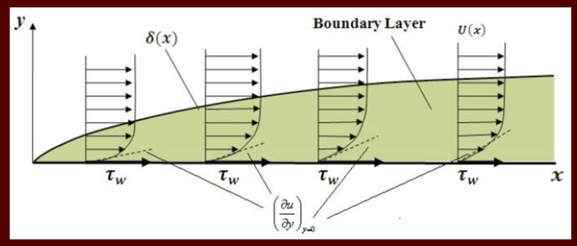
A Coordinated Approach

The Maroon Moon team took a 3-prong approach:

1. Testing/understanding the mechanics of PSI
   - Erosion Function Apparatus
2. Analysis/further understanding the mechanics:
   - Analytical Transformation between Water and Air Mediums
   - Gas flow CFD
   - CFD-DEM Cohesive Effects
3. Zeroing in on solutions:
   - Development of Gas-Granular Erosion Apparatus
   - Proposed CLPS flight experiment

CFD Analysis

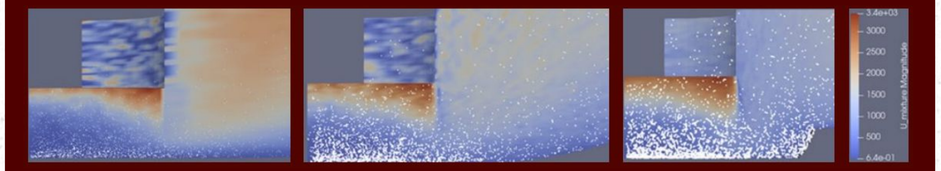
Boundary layer thickness used for erosion comparison to EFA rather than shear stress equivalency



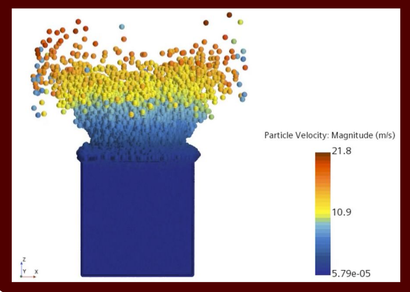
$$Laminar\ Ratio = \left(\frac{\mu_w}{\rho_w u_w} \Big/ \frac{\mu_{eg}}{\rho_{eg} u_{eg}}\right)^{1/2} = 0.302$$

$$Turbulent\ Ratio = \left(\frac{\mu_w}{\rho_w u_w} \Big/ \frac{\mu_{eg}}{\rho_{eg} u_{eg}}\right)^{1/5} = 0.619$$

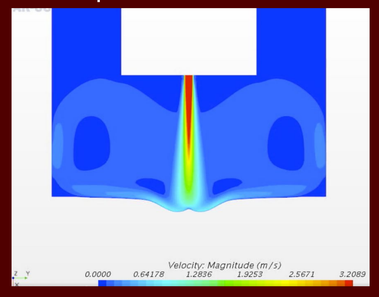
Gas flow velocity results



Low cohesion but effective cohesion effects from angular particle shapes

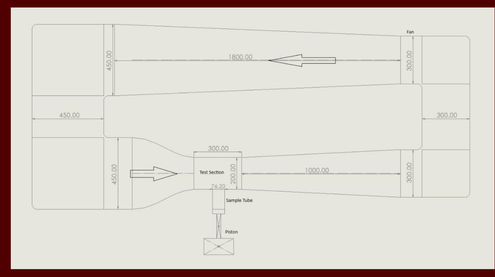


Mesh morphing jet simulation results, continuum assumption



GGEA Design for Future Testing

The GGEA builds on the EFA to solve the issues presented by water as a testing medium, through discrete modelling local flow in a gas apparatus.



GGEA 1.1

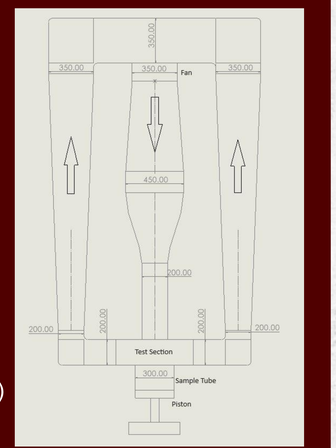
Test Section:
- Area: 200mm x 200mm (0.04 m^2)
- Velocity: 270 m/s (M = ~0.8)

Fan Section:
- Area: 300mm x 300mm (0.09 m^2)
- Velocity: 120 m/s

GGEA 2.1

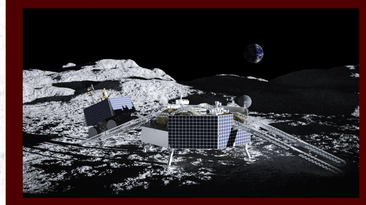
Test Section:
- Area: 200mm x 200mm (0.04 m^2)
- Velocity: 270 m/s (M = ~0.8)

Fan Section:
- Area: 350 mm x 350 mm (0.1225 m^2)
- Velocity: 88.16 m/s



Surface Stabilization Flight Experiment

Thermal Vacuum Testing will be used to test the resilience and viability of chosen stabilizers.



Initially, a small lander such as a Commercial Lunar Payload Service (CLPS) lander will autonomously apply a surface stabilization technology demonstrator.
Our goal is to increase the Technology Readiness Level (TRL) of this technique for use in future human missions.

The following budget was acquired from modeling the solution in NASA's Cost Estimation Toolkit (CET)
- 2024: $981,000
- 2025: $1,009,000
- 2026: $2,373,000
- 2027: $3,095,000

Milestones and Mission Schedule