Lunar Regolith Hopper Design and Testing Under Atmosphere and Vacuum Conditions

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Funding Through NASA GCD

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Michigan Technological University
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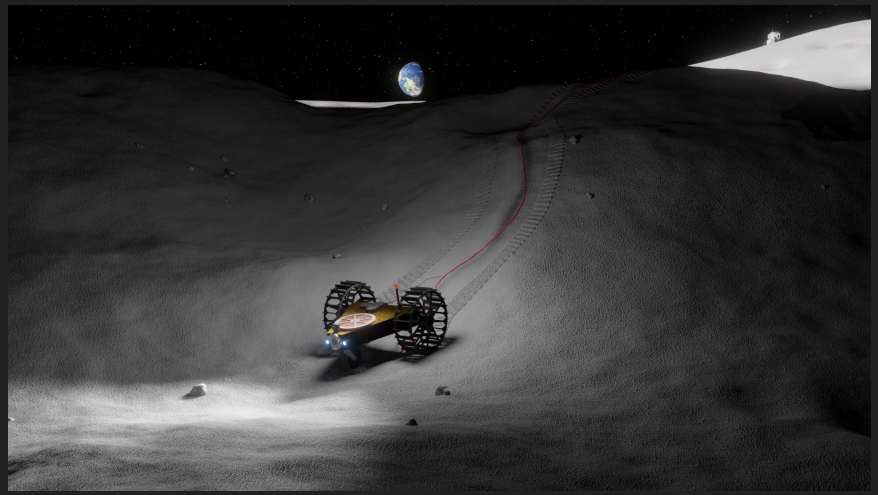
Space Resources Roundtable

ISRU

- In-Situ Resource Utilization (Lunar Regolith)
  - Landing/Launch Pads
  - Roads
  - Berms
  - Foundations
  - Habitats
- As a Feedstock
  - 3D Printing
  - Water Extraction
    - Fuel
  - Molten Regolith Electrolysis
    - Oxygen
    - Metal

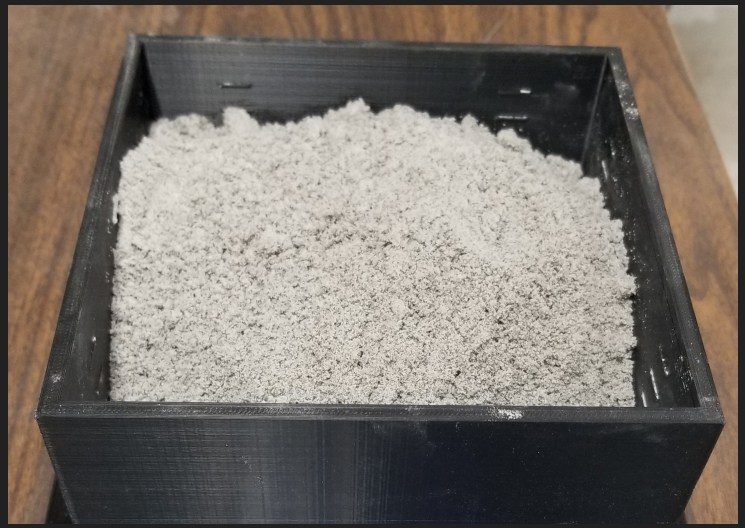


NASA T-REX Big Idea Challenge 2020 (MTU)

Iai et al. (2013), Schreiner et al. (2015), Roman et al. (2020)

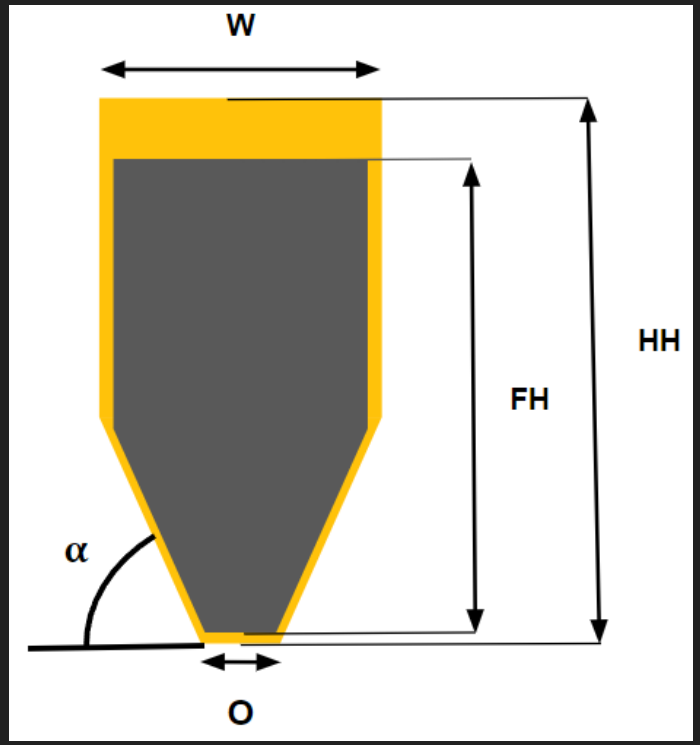
Lunar Regolith Properties

- Varied Particle Size
  - µm to mm
  - Median Particle size of 70 µm
- Angular Particle
- Hard Minerals
  - Olivine
  - Pyroxene
- Charged
  - Statically
  - Triboelectrically



MTU-LHT-1A

Hopper Geometry (2.5 D)



- W – Hopper Width
- FH – Fill Height
- HH – Hopper Height
- O – Hopper Outlet
- α – Inclination Angle

Statistical Analysis

- Experiments 1-3
  - Analysis of Variance – ANOVA
  - Multi-Level Factorial Design
  - Interaction Plots
  - Residuals
  - Experiment 3
    - Fisher Least Significant Difference
- Experiment 4
  - 2 replicates were conducted
- Experiment 5
  - 5 replicates were conducted
- Experiment 6
  - 3 Replicates were conducted

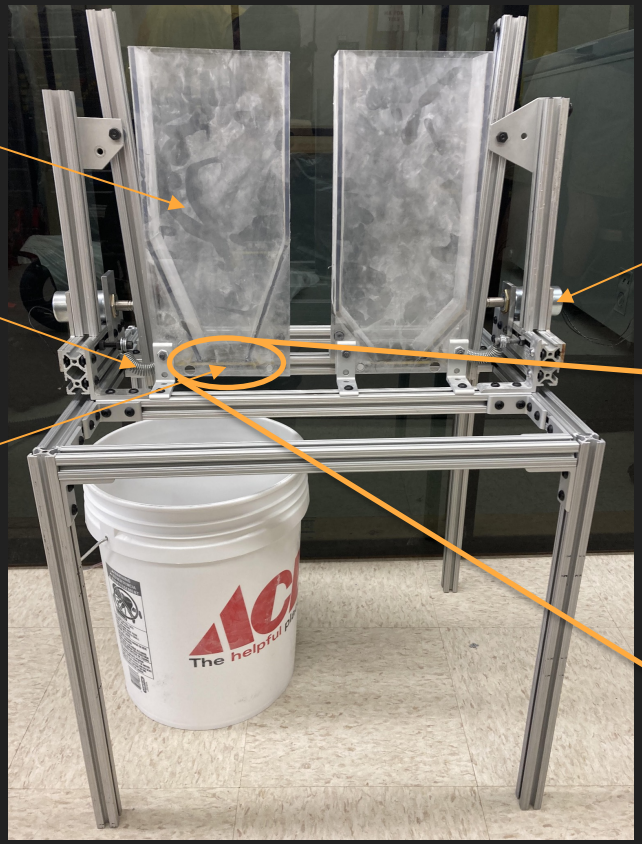
Hopper Testing Rig

Space Resources Roundtable

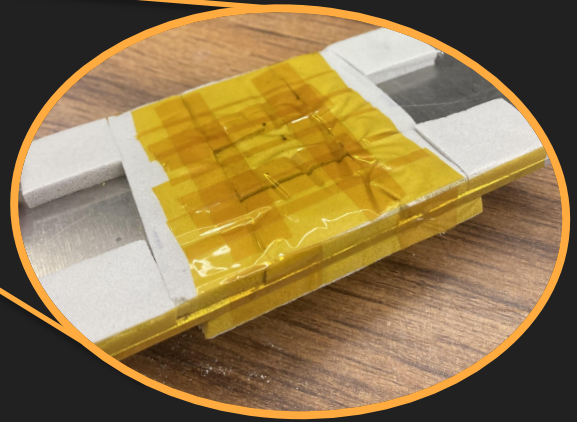
Hopper

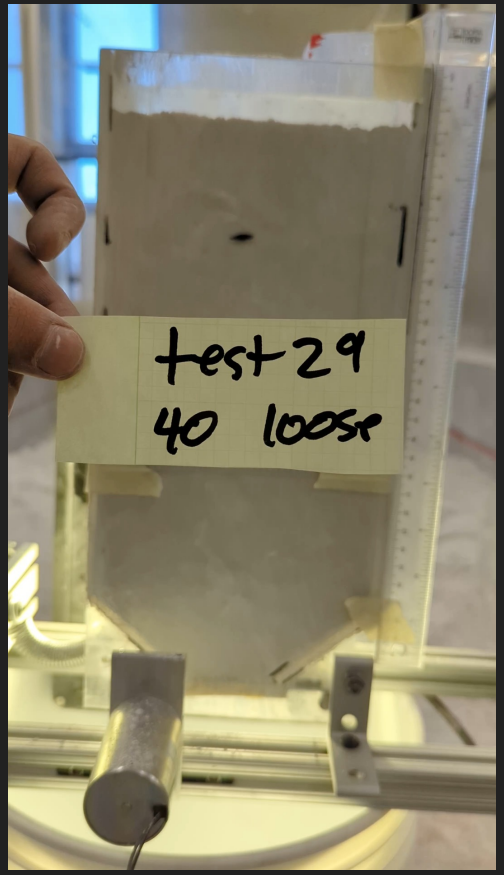
Spring Loaded Latch

Hatch and Seal



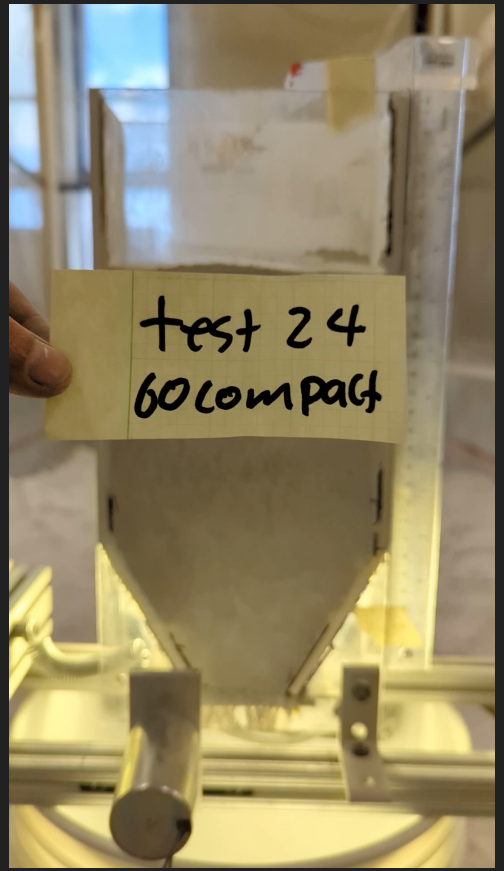
Solenoid Release Mechanism





40 Deg, Loose Simulant, Atmosphere

Uncompacted Video

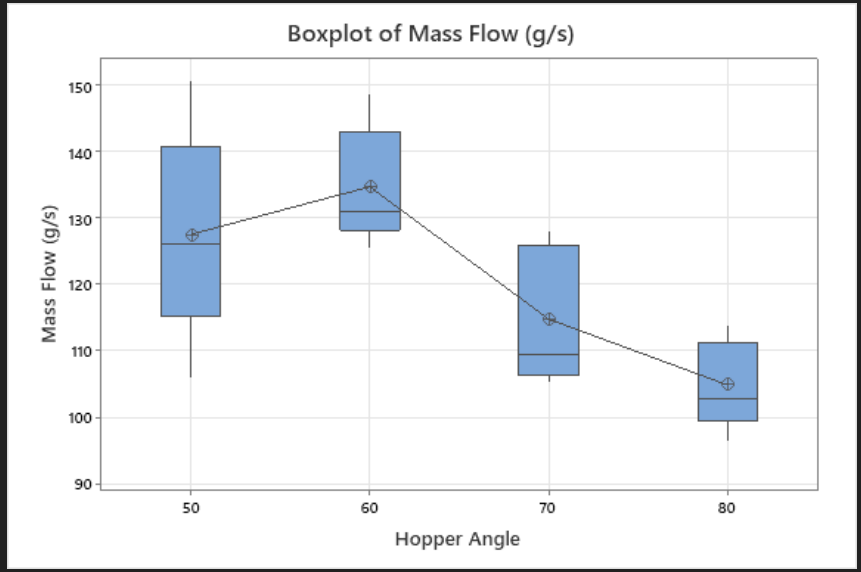


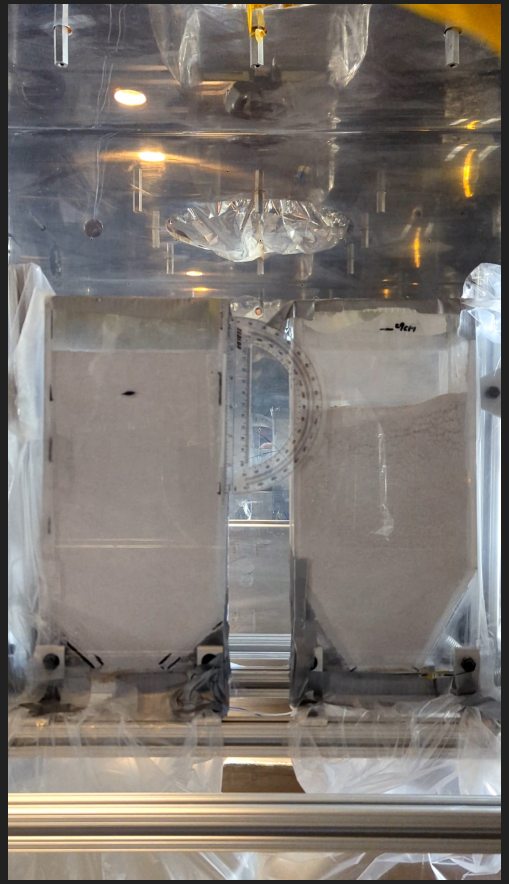
60 Deg, Compacted Simulant, Atmosphere

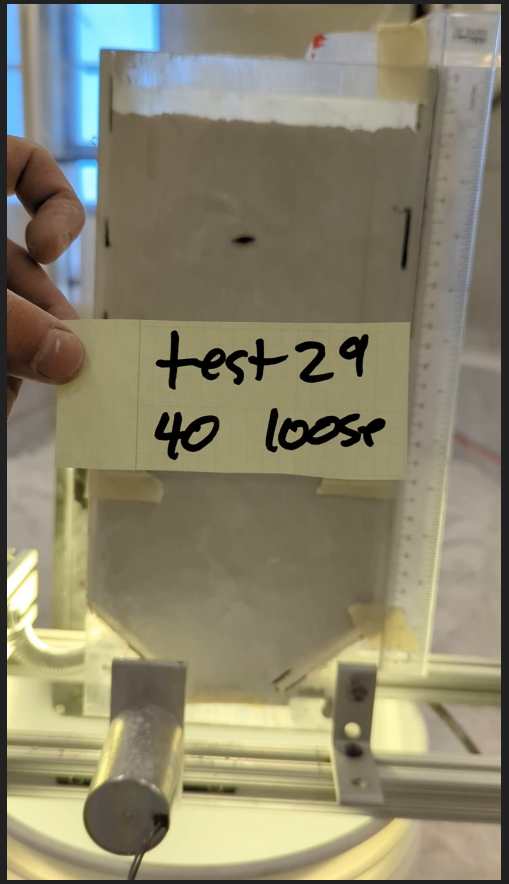
Compacted Video

All Atmospheric Results

- Inclination Angle and Outlet Width are Significant
  - 60 deg has the highest mass flow rate
  - No interaction between the two
- Flow Occurred at all Outlet Widths
  - 2.5 cm, 5 cm, & 7.5 cm
  - 7.5 cm being the highest, & chunkiest flow
- Compaction will Cause Severe Arching, Stopping Flow
  - ~1.3 g/cm^3 – Loose
  - ~1.7 g/cm^3 – Compacted
- Relative Humidity Likely Affects Arching

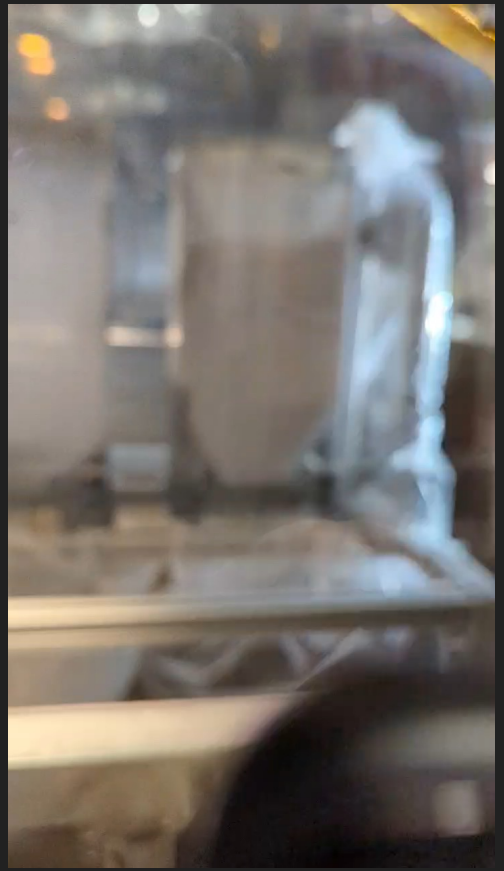


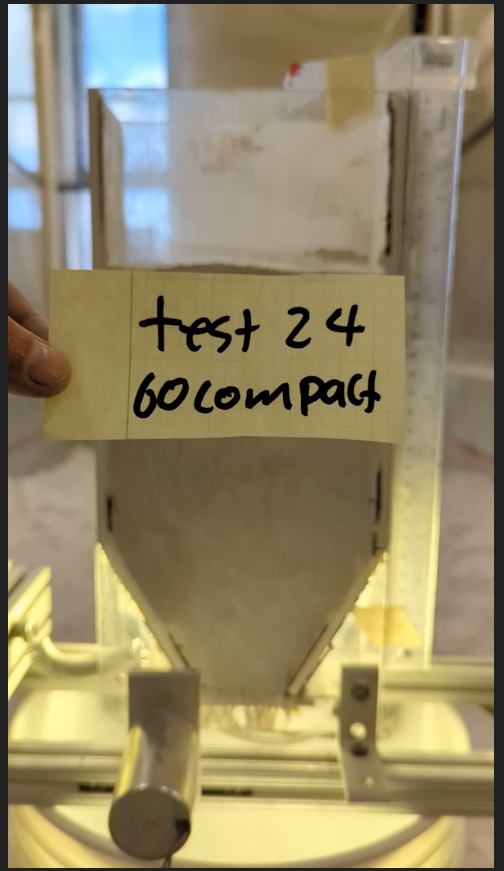




40 Deg, Loose Simulant, Vacuum

Vacuum Testing (Atm Filled)





60 Deg, Compacted Simulant, Vacuum

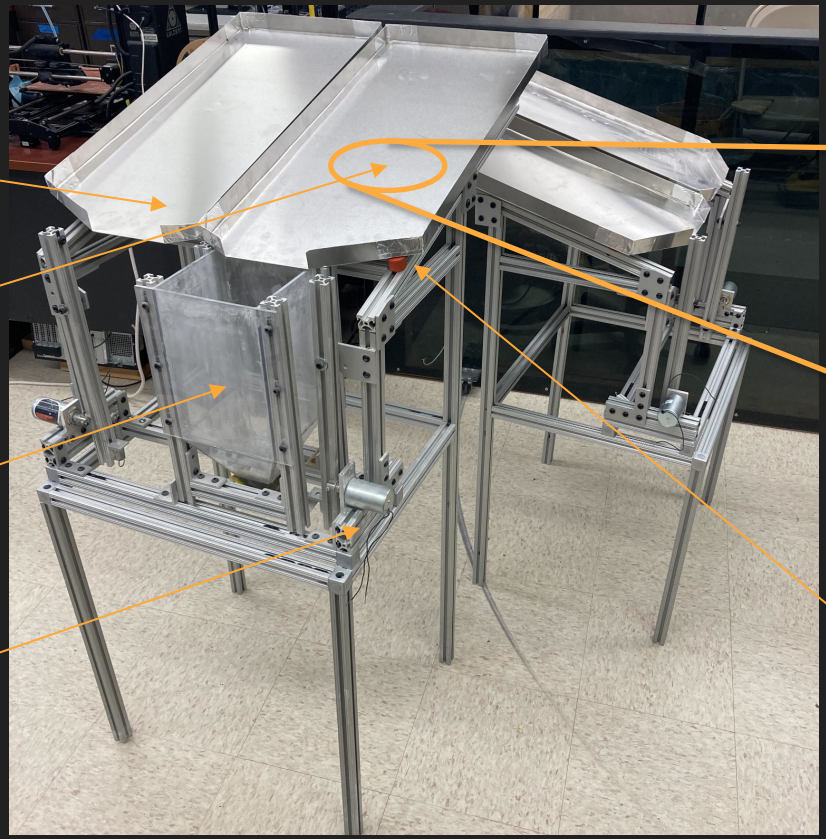
Vacuum Testing (Atm Filled)

Feed Trays

Vibration Motor

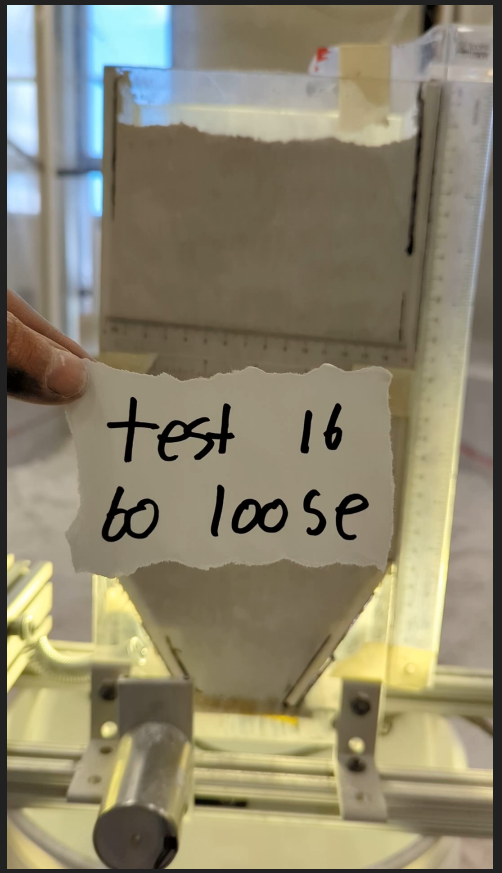
Hopper

Hopper Testing Rig



Vibration Dampers

Hopper Feed Trays



60 Deg, Loose Simulant, Vacuum

Vacuum Testing (Vacuum Filled)

Conclusion

- Inclination Angle of 60 Degrees has Highest Mass Flow Rate in Atm.
- Outlet Width Determines Mass Flow Rate and Type of Flow
- For Vacuum Tests, Lack of Air is Likely Causing Fast Flow

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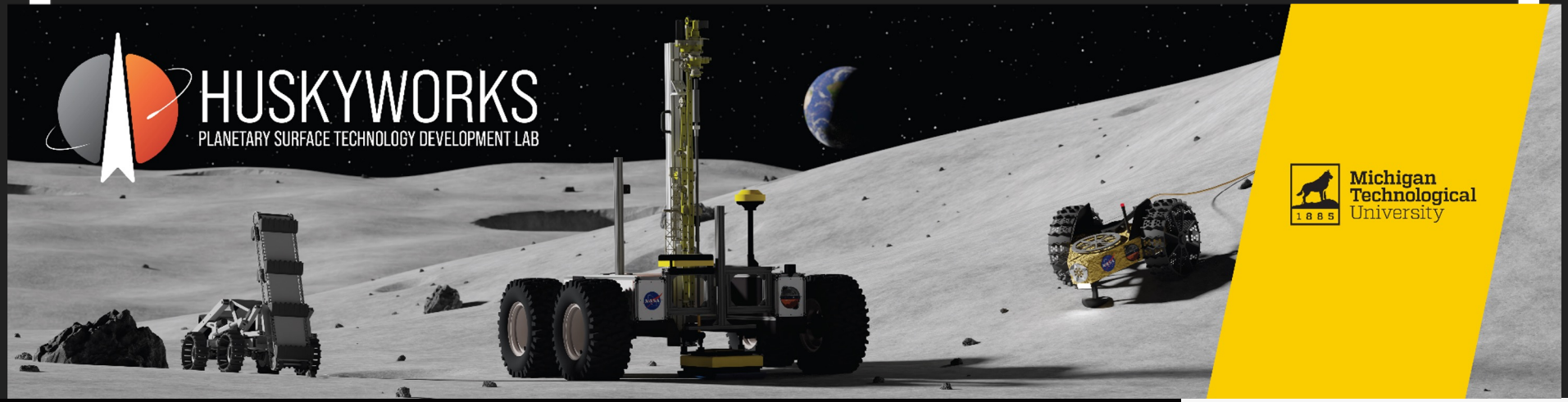
Questions?



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