Three Lunar Regolith Conveying Methods for ISRU

Jason Noe, Paul van Susante, Laurent Sibille, Ben Wiegand, Parker Bradshaw, Eli Sierra

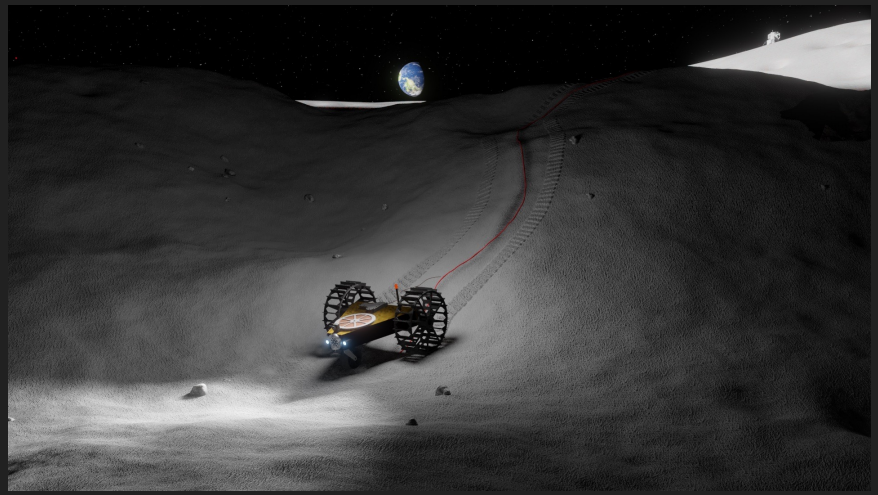
HUSKYWORKS
PLANETARY SURFACE TECHNOLOGY DEVELOPMENT LAB

Michigan Technological University
1885

SPACE RESOURCES ROUNDTABLE

ISRU

- In-Situ Resource Utilization (Lunar Regolith)
  - Landing/Launch Pads
  - Roads
  - Foundations
  - Habitats
  - Refinement
    - Fuel, O2, Water, Metal
- Lunar Regolith Will be a Common Feedstock for ISRU

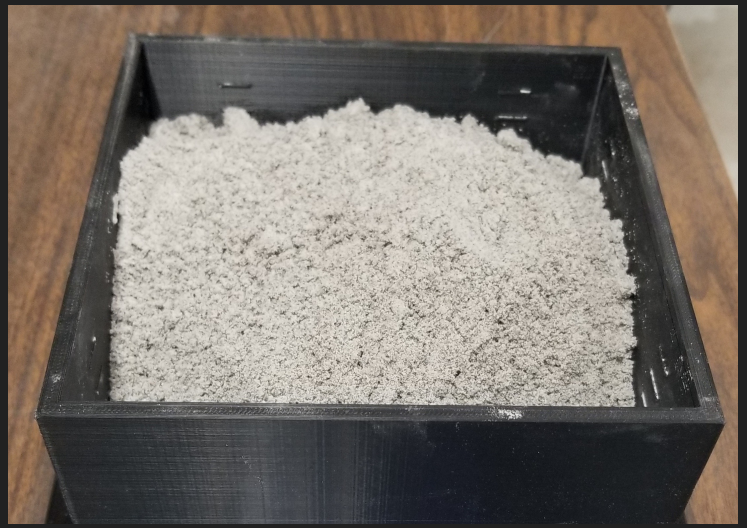


NASA T-REX Big Idea Challenge 2020 (MTU)c

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

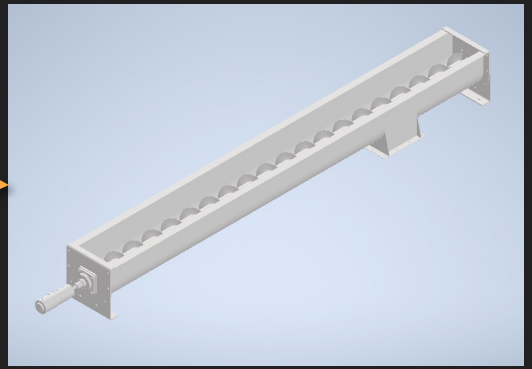


MTU-LHT-1A

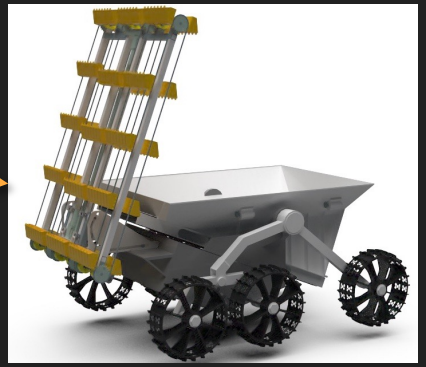
What is the Best Conveyance Method for ISRU (MRE)?

Down Selection

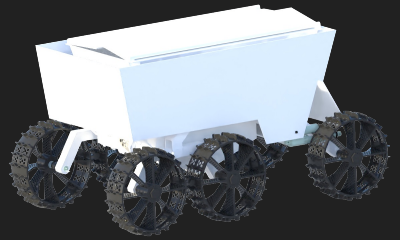
- Conveying System Considered
  - Screw Conveyor
  - Pneumatic
  - Vibratory Conveyor
  - Electro-Magnetic
  - Bucket Ladder/Chain
  - Belt Conveyor
  - Chain Conveyor
  - Loader
  - Piston
  - Skip / Minecart



Proto-MTU Screw Conveyor



NASA Break the Ice, LIQUID, MTU



NASA Break the Ice, LIQUID, MTU

Boles, Walter W., et al. (1997), Güner, M. (2007), Owen, P.J. and P.W. Cleary. (2009), Mueller, Robert P., et al. (2010), Reiss, P., et al. (2014), Walton et al. (2014), Walton et al. (2016), Adachi, M., et al. (2017), Radha Krishnan, B., et al. (2018), Fayed, M. E., and Thomas S. Skocir. (2018), Urukalo, Djordje, and Zeljko V. Despotovic. (2020), Ji, Jianhua, et al. (2020), Kawamoto, Hiroyuki. (2020), Jendrysik, Sebastian, et al. (2021), Kawamoto, Hiroyuki, and Rieko Egawa. (2021), Cannon et al. (2022)

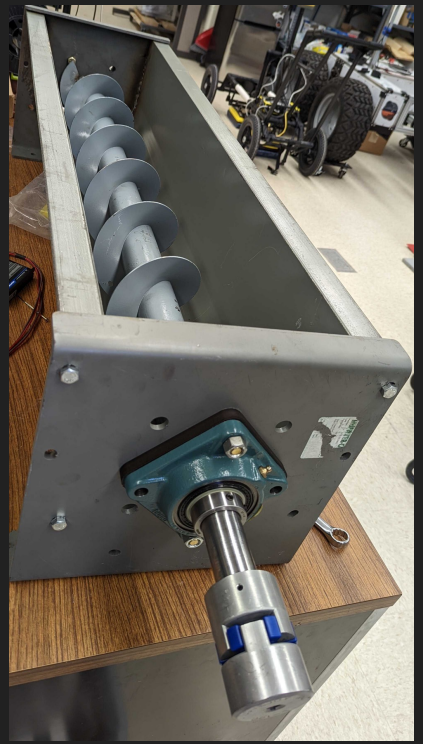
Given Parameters

- MRE Specific Consideration / Constraints
  - +1,700°C Internal Reactor Temperature
  - Initial Fill of 100 kg in 20 min
    - +/- 250 g
  - Incremental Fill of 10 kg in 5 min
    - +/- 50 g
  - Location into Reactor for Deposition
  - Evenness of Deposition
  - Consistency of Deposition
  - Reactor Additions (Volatiles)

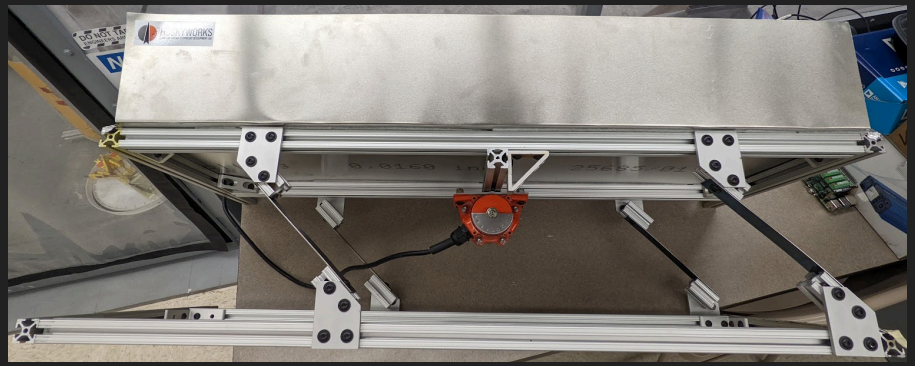
- General Consideration / Constraints
  - Mass of System
  - Size of System
  - Power Consumption
  - Current TRL for Application

1) MTU Screw Conveyor

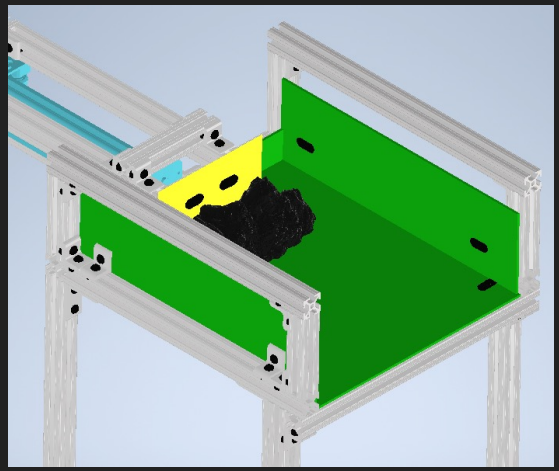
Chosen Three Designs



1) MTU Screw Conveyor



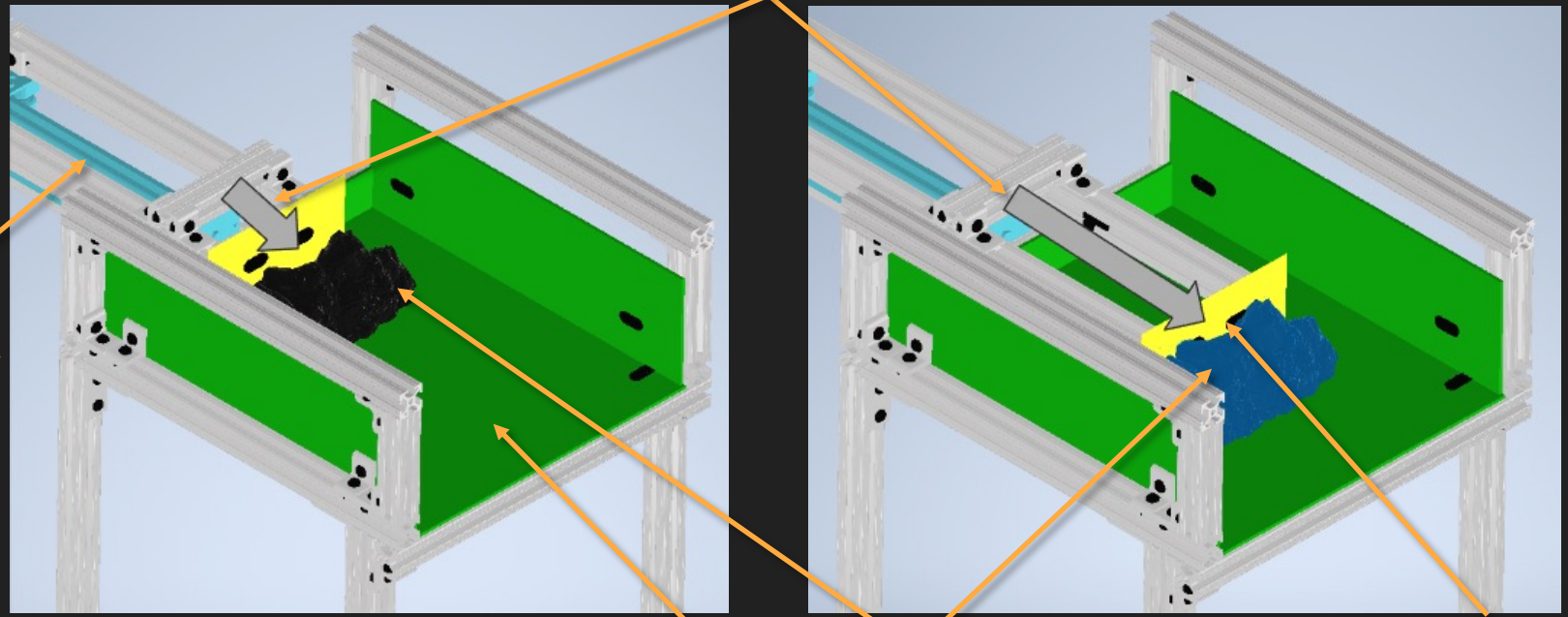
2) MTU Vibratory Conveyor



3) MTU Piston Conveyor

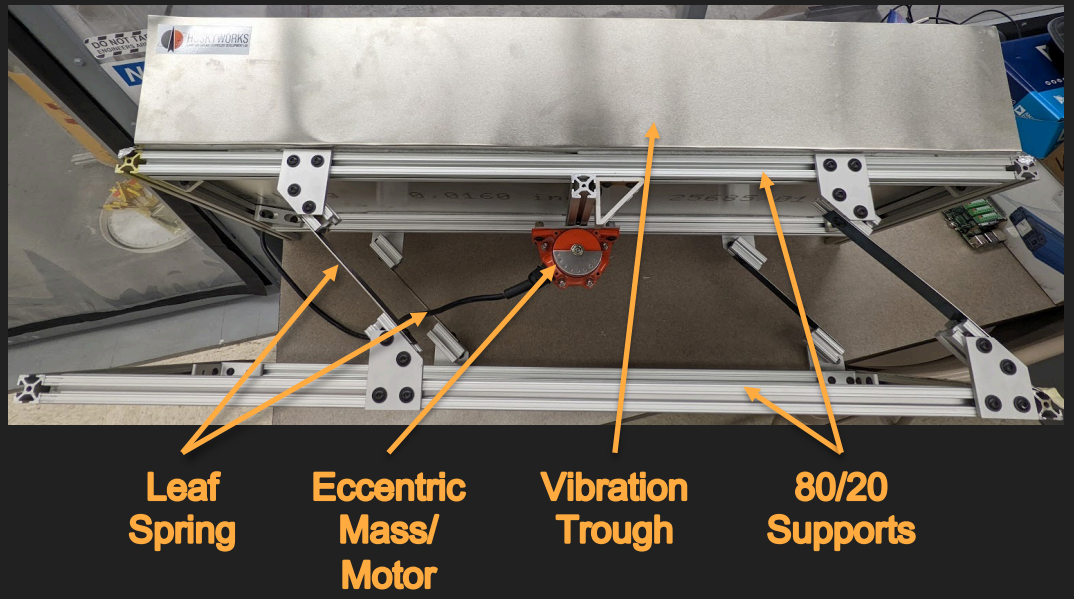
1. Screw Conveyor
2. Vibratory Conveyor
3. Piston Conveyor

Piston Conveyor



Vibratory Conveyor

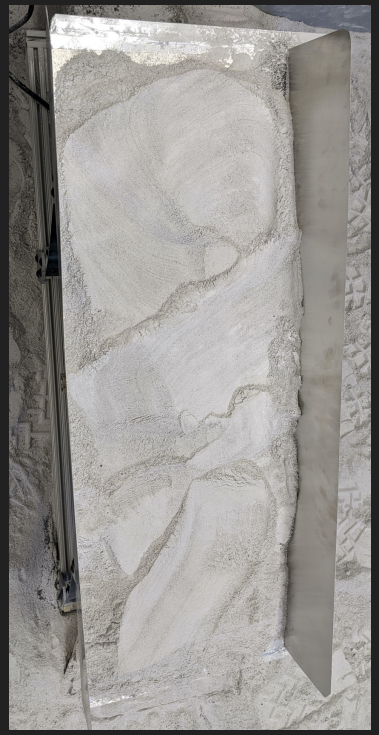
- 4x Leaf Spring
- Eccentric Mass Motor
  - Variable Amplitude
    - Change Vibration Mass
  - Variable Frequency
    - Change Voltage Too System
- Little to No Sizing Literature



Video

Vibratory Conveyor

Vibratory Conveyor



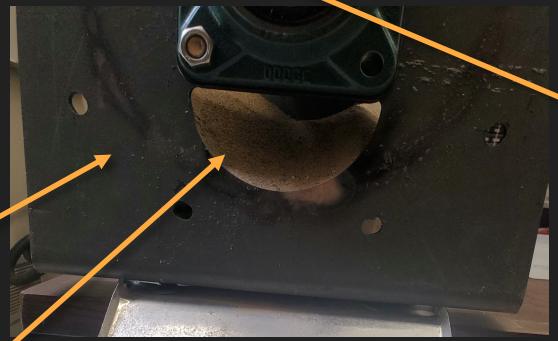
Before

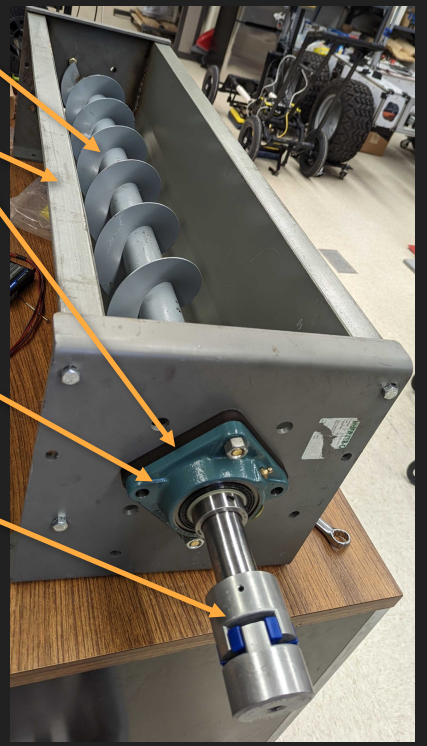
After

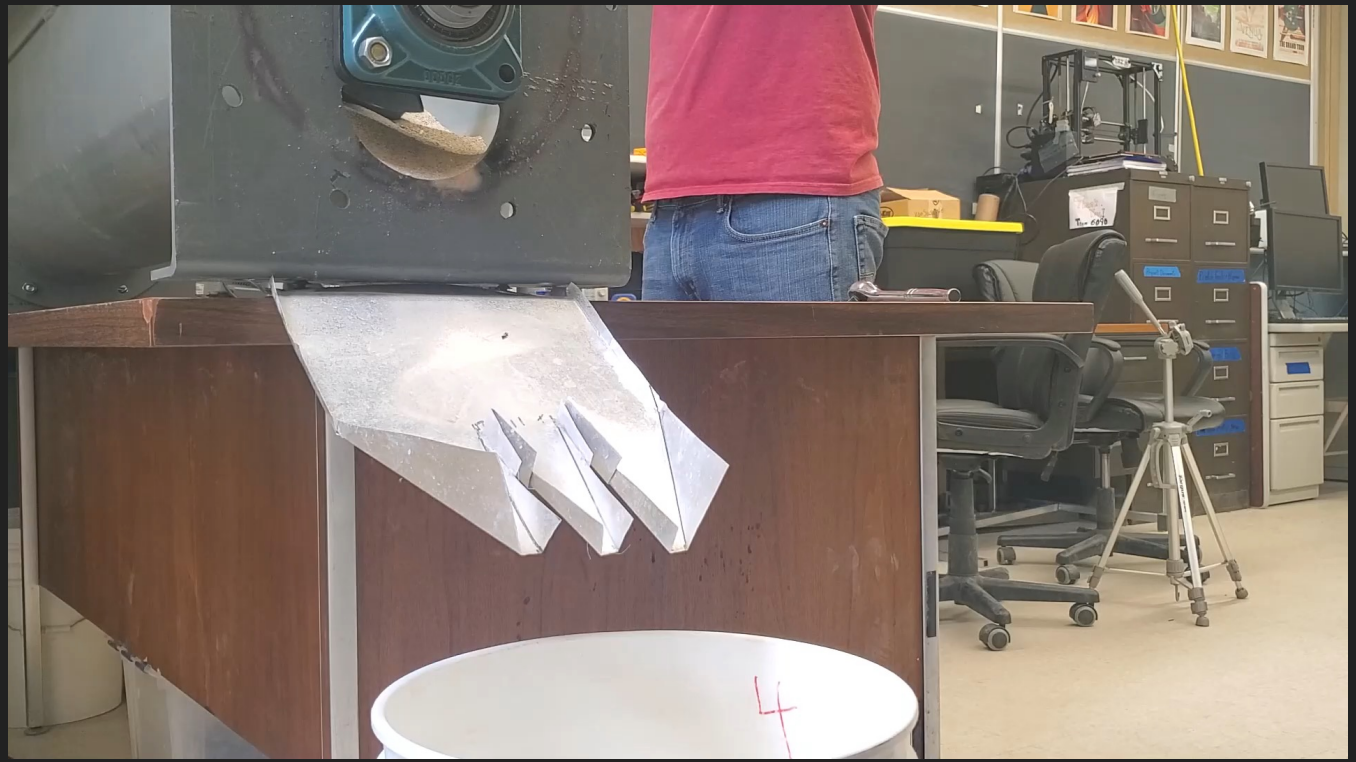
- Initial Results
  - Run Time = 1 min
  - Simulant Mass = 10.3 kg
  - Mass Flow = 0.16 kg/s
    - 159 g/s
    - 2x Target Flow
- Beneficiation Occurs
- Natural Frequency Changes Depending on Mass on System
- 10 deg of Inclination

Screw Conveyor

- 6” Diameter Screw (Cut to ~4’)
- 9” Diameter Trough (~Cut to 4’)
- Motor (80-90 nm)
  - Variable RPM
  - 5-20 RPM
  - Sized for 10 RPM
- Different Screws
  - Different flow Properties







Video

Screw Conveyor

Screw Conveyor

Before

After

- Initial Results
  - RPM = 32
  - Run Time = 26 seconds
  - Sand Mass = 6.4 kg
  - Mass Flow = 0.24 kg/s
    - 243 g/s
    - 3x Target Flow
- Sand = 1.6 g/cm^3
- Lunar Regolith = 1.5 g/cm^3

Future Work

- Quantify Performance for all 3 Systems
  - Mass Flow
  - Power Consumption
  - Deposition Accuracy
  - Consistency of Flow
- Compare Atmospheric Performance to Vacuum Performance
- Look at the Wear of the Systems Over Time
  - Change in Roughness
  - Scratching
- Compare Systems and Down Select to One

Questions?

HUSKYWORKS
PLANETARY SURFACE TECHNOLOGY DEVELOPMENT LAB

Michigan Technological University

SPACE RESOURCES ROUNDTABLE