# EXPERIMENTAL ANALYSIS OF MODULAR DRUM CONVEYOR AND SCREW CONVEYOR FOR HORIZONTAL, INCLINED AND VERTICAL REGOLITH TRANSPORT

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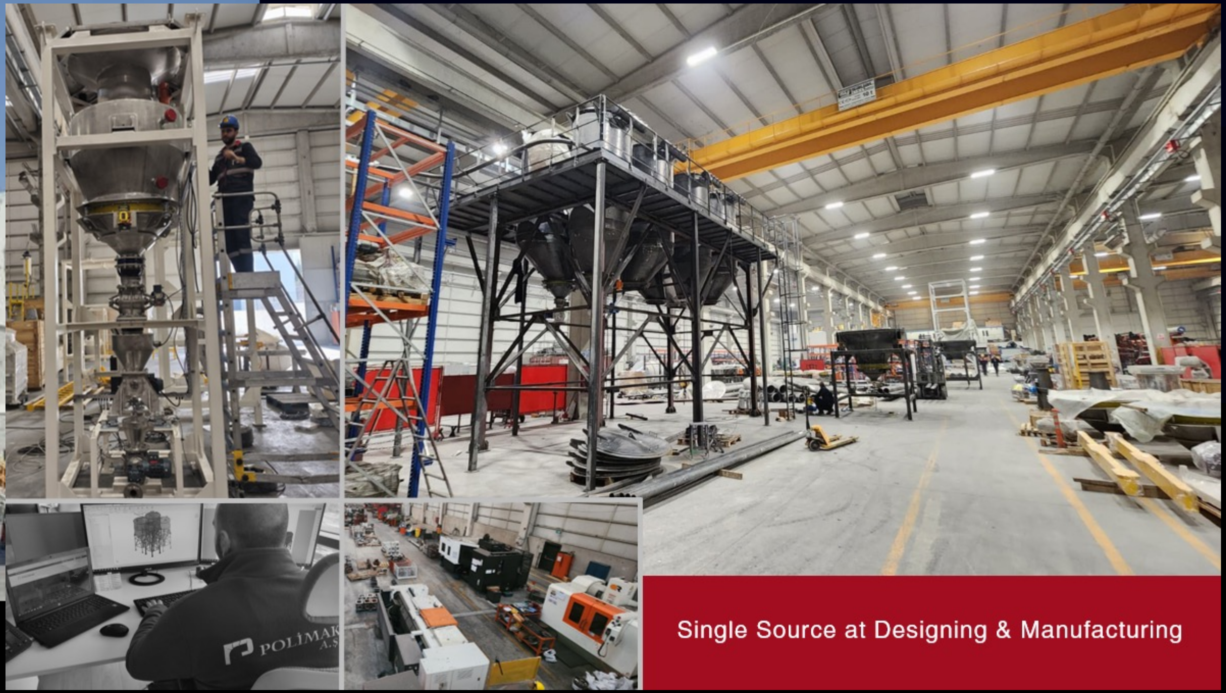
# 50 Years of Bulk Solid Heritage

Excavate & Collect → Haul & Transport → Convey & Feed → Beneficiate & Stockpile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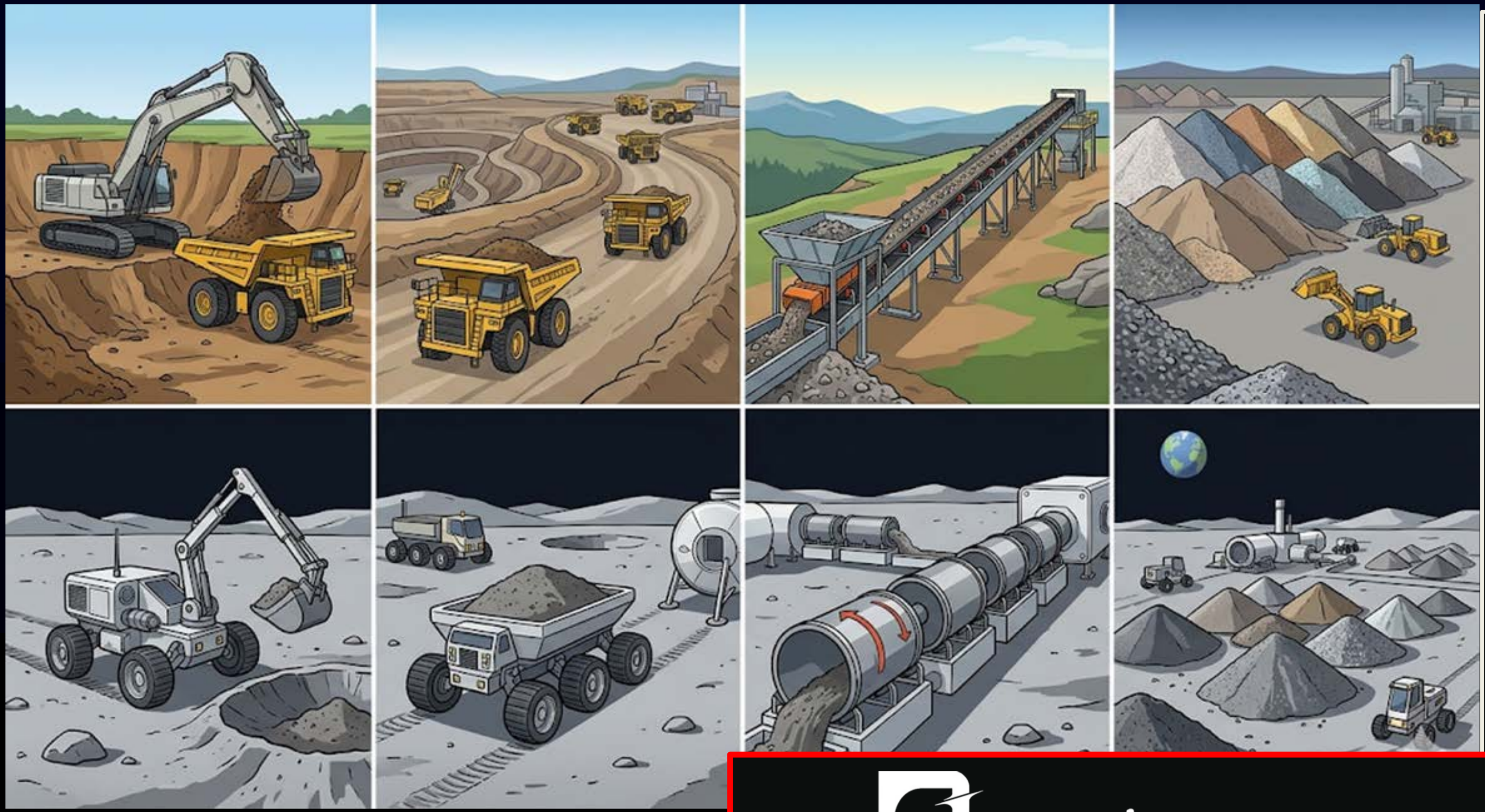
SPACE POLİMAK®

# Key activities required for an emergent ISRU sector

Excavate & Collect → Haul & Transport → Convey & Feed → Beneficiate & Stockpile



**ISRU Specific Challenges:**

- **Regolith:**
    - Abrasive Nature of Regolith
    - Temperature Extremes
    - Dust Emission
    - Static Electricity
- **Lunar Environment:**
    - Distance
    - Vacuum
    - Access to Energy

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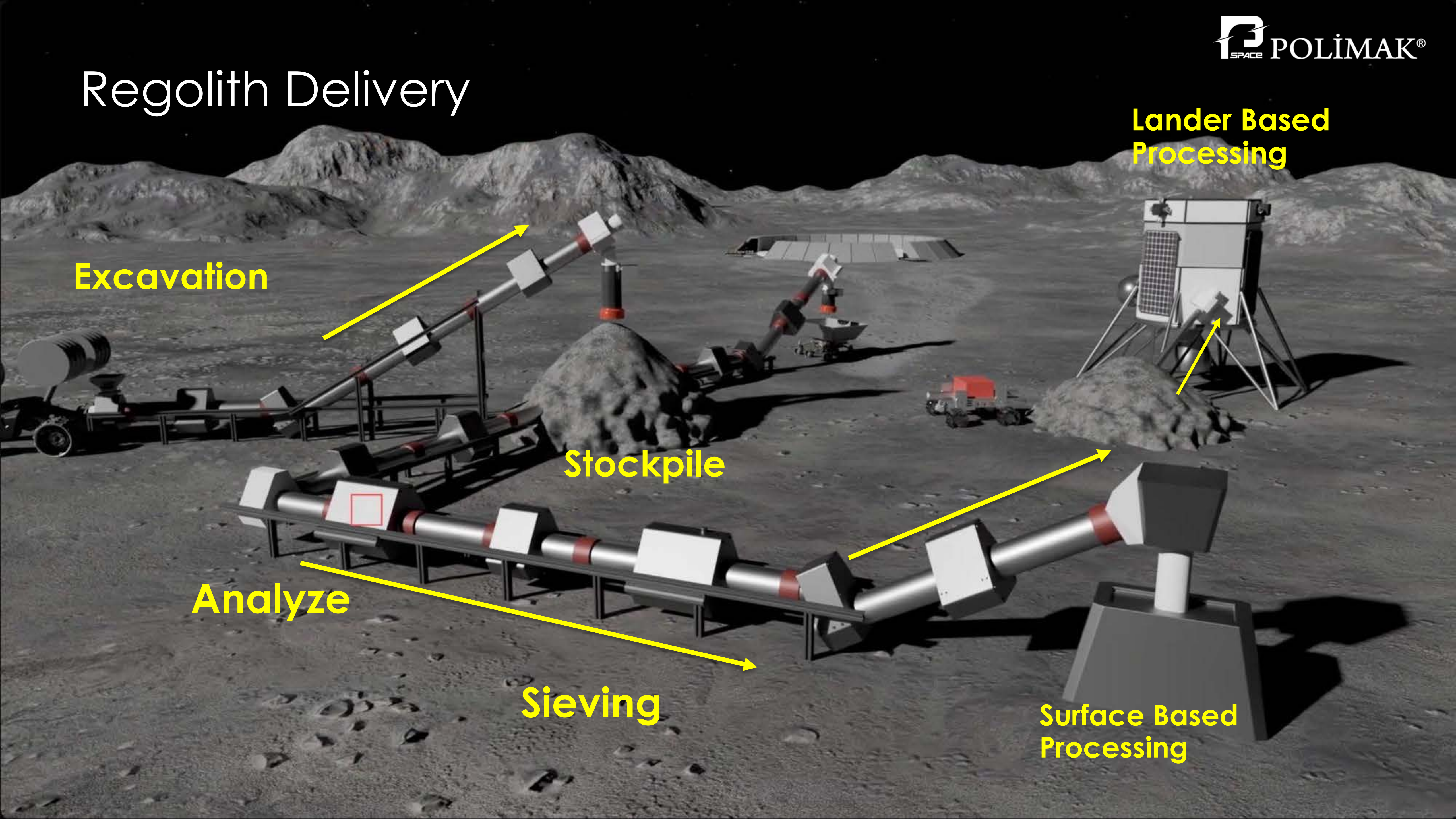
Regolith Delivery
POLİMAK®
SPACE
Lander Based
Processing
Excavation
Stockpile
Analyze
Sieving
Surface Based
Processing

# Enabling Infrastructure for the ISRU Value Chain

We enable ISRU operations and bring the whole ecosystem together by **providing the regolith handling infrastructure**

Providing essential infrastructure for ISRU through the **patented Modular Drum Conveyor (MDC) system, a** modular approach that supports the full ISRU chain.

- **Excavation**
- **Conveying and Transport**
- **Sieving and Particle Size Separation**
- **Preheating and Thermal Conditioning**
- **Stockpiling and Storage**
- **Multi-Sensor Feeding and Analysis**
- **Thermal Energy Storage for Lunar Night Survival**
- **Processing and Material Preparation**

# Existing Conveyors

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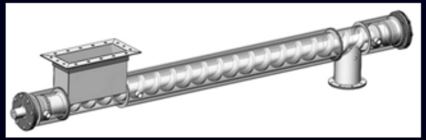
**Belt Conveyor**
Pros: Suitable for Long Distance
Cons: Open to environment, lots of moving parts, static electricity

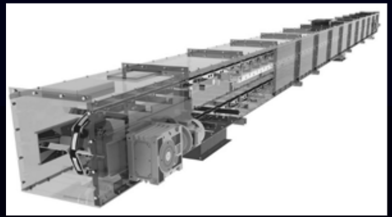
**Bucket Elevator**
Pros: Suitable for vertical conveying
Cons: Not for horizontal conveying, lots of moving parts

**Pneumatic Transport**
Pros: Contained conveying
Cons: Needs air/gas for conveying, abrasion in pipeline

**Vibrating Feeder**
Pros: Simple design, for short distances
Cons: Abrasion, open to environment



**Auger/Screw Conveyor**
Pros: Suitable for short distances
Cons: Abrasion and flexibility problems



**Chain Conveyor**
Pros: Contained conveying
Cons: Heavy contruction, static electricity, abrasion

**Pipe Conveyor**
Pros: Contained conveying
Cons: Heavy contruction, static electricity

| Challenge | Auger | Robot Trucks | Belt Conveyor | Pipe Conveyor | Vibrating Feeder | Bucket Elevator | Chain Conveyor | Pneumatic Transport |
|---|---|---|---|---|---|---|---|---|
| Low Gravity | ●●● | ●●● | ●●○ | ●●● | ●●○ | ●●○ | ●●● | ●●● |
| Changing Route Direction | ●●○ | ●●● | ●●○ | ●●● | ●●○ | ○○○ | ●○○ | ●●● |
| Vacuum Environment | ●●● | ●●● | ●●● | ●●● | ●●● | ●●● | ●●● | ●○○* |
| Extreme Temperatures | ●●○ | ●●○ | ●○○ | ●○○ | ●●○ | ●●○ | ●●○ | ●●○ |
| Abrasion | ○○○ | ●●● | ●●○ | ●●○ | ●○○ | ●○○ | ○○○ | ○○○ |
| Efficiency (kW/kg) | ○○○ | ●○○ | ●○○ | ●○○ | ●●○ | ●○○ | ○○○ | ○○○ |
| Launch Weight Limitations | ●●○ | ●●○ | ○○○ | ○○○ | ●●○ | ○○○ | ○○○ | ●●○ |
| Dust Containment | ●●● | ●○○ | ○○○ | ●●● | ●●○ | ●○○ | ●●○ | ●●● |
| Static Electricity | ●●○ | ●●○ | ○○○ | ○○○ | ●●○ | ●●○ | ●○○ | ●○○ |
| Reliability | ●○○ | ●●● | ●○○ | ●○○ | ●●● | ●○○ | ○○○ | ●●● |
| Reconfiguration for New Routes | ●○○ | ●●● | ●○○ | ○○○ | ●○○ | ○○○ | ○○○ | ●●○ |
| InSitu Production of Parts | ●○○ | ○○○ | ○○○ | ○○○ | ○○○ | ○○○ | ○○○ | ●○○ |
| Multiple Inlets/Outlets | ●●○ | ●●● | ●○○ | ○○○ | ●○○ | ○○○ | ●○○ | ●●○ |

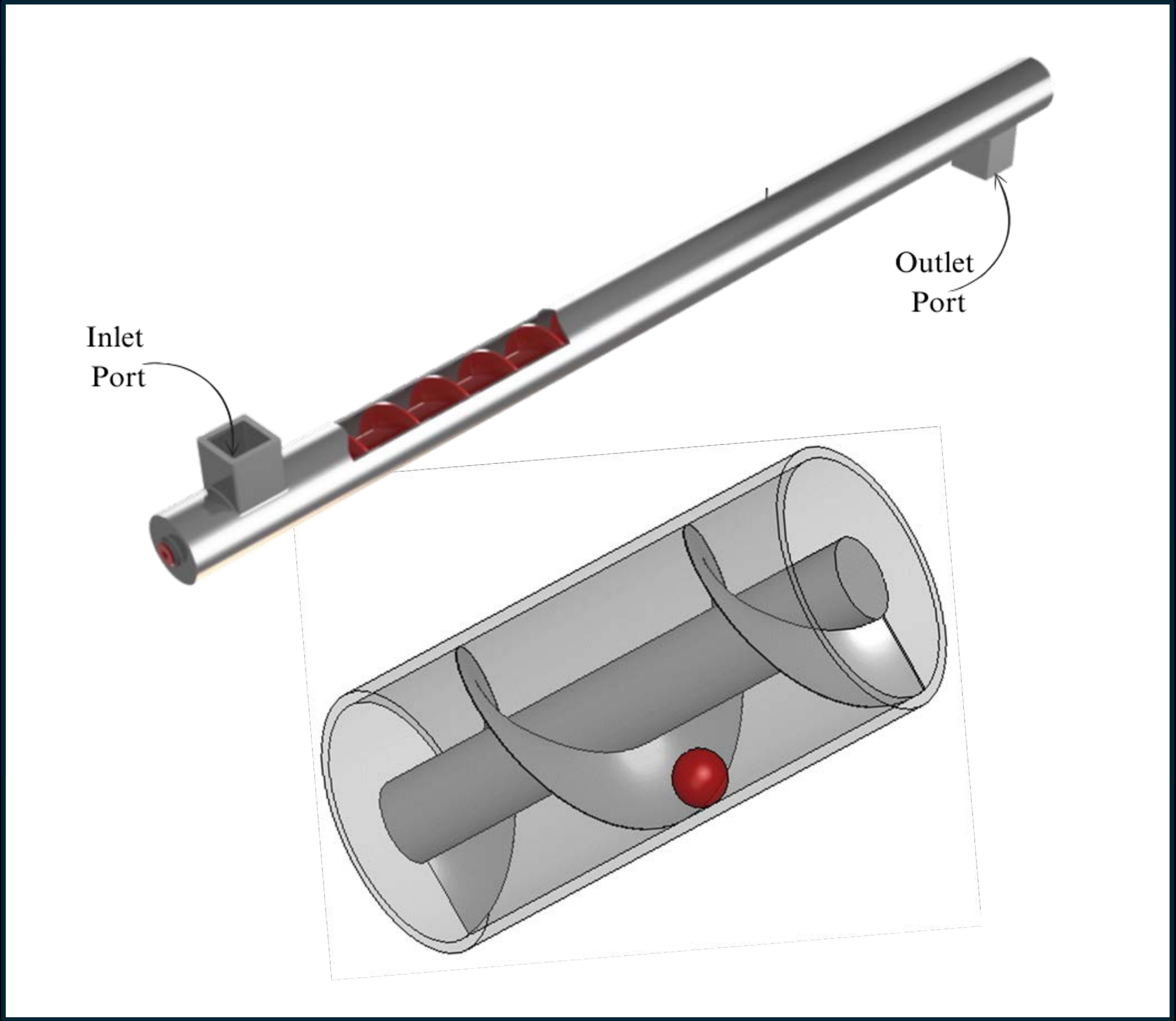
# Screw Conveyors - not designed for Regolith

**Lunar Regolith Transport: Conveyor Types:**

- **Required Properties**
  - **simple mechanics, few parts**
  - **resistance to abrasive regolith**
  - **low-maintenance**
  - **dust mitigation**

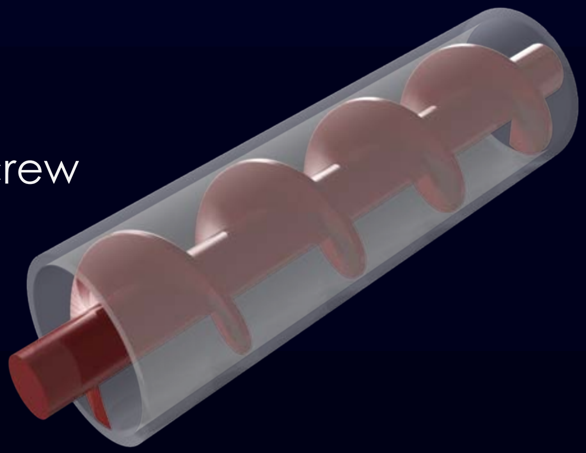
- **Screw Conveyors**
  - Simple but problematic:
    - Tube-screw gap = jamming risk
    - Regolith abrasion causes wear

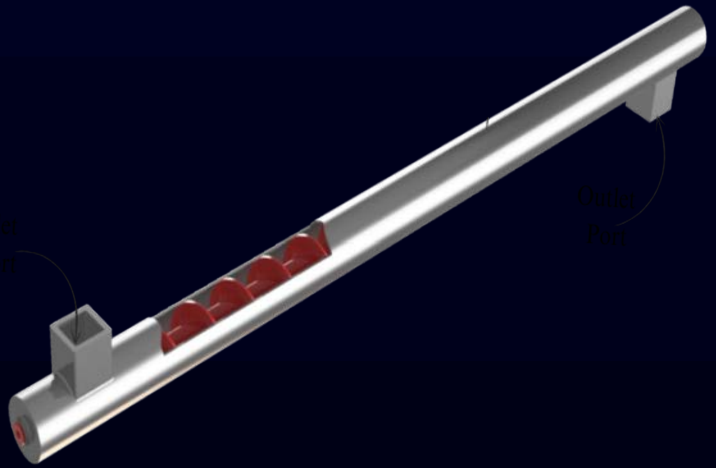
- **What's Needed**
  - Clogging free auger design
  - Fully enclosed, dust-tight
  - Modular and lunar-ready

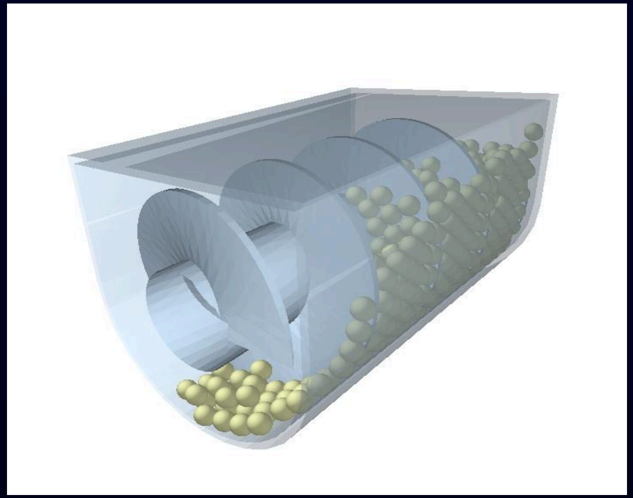


# The Solution - Modular Drum Conveyor

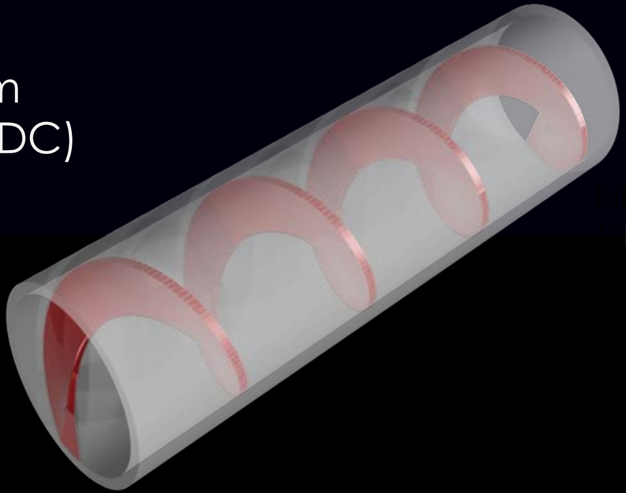
Auger / Screw Conveyor

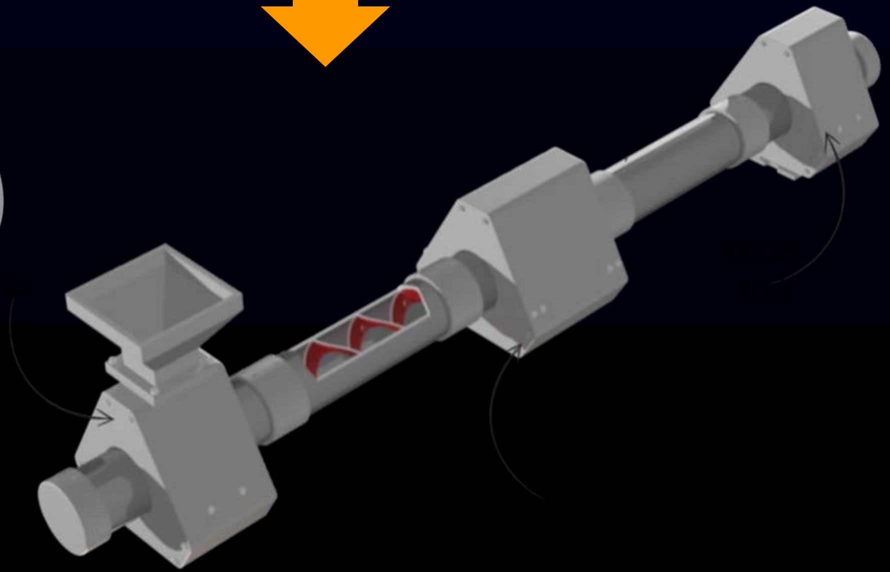


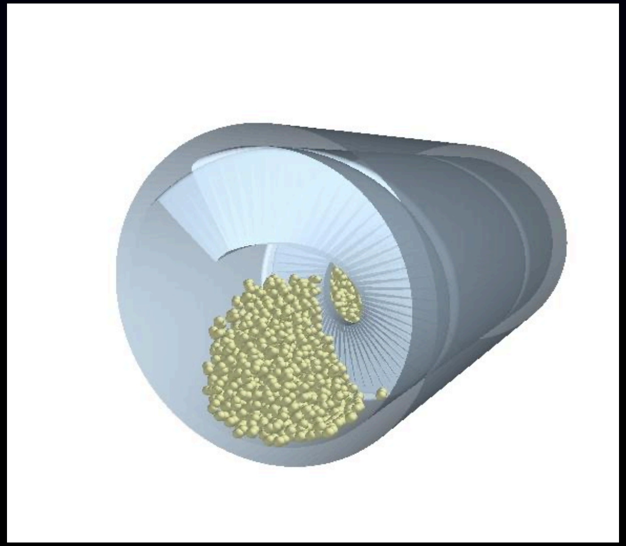




Modular Drum Conveyor (MDC)



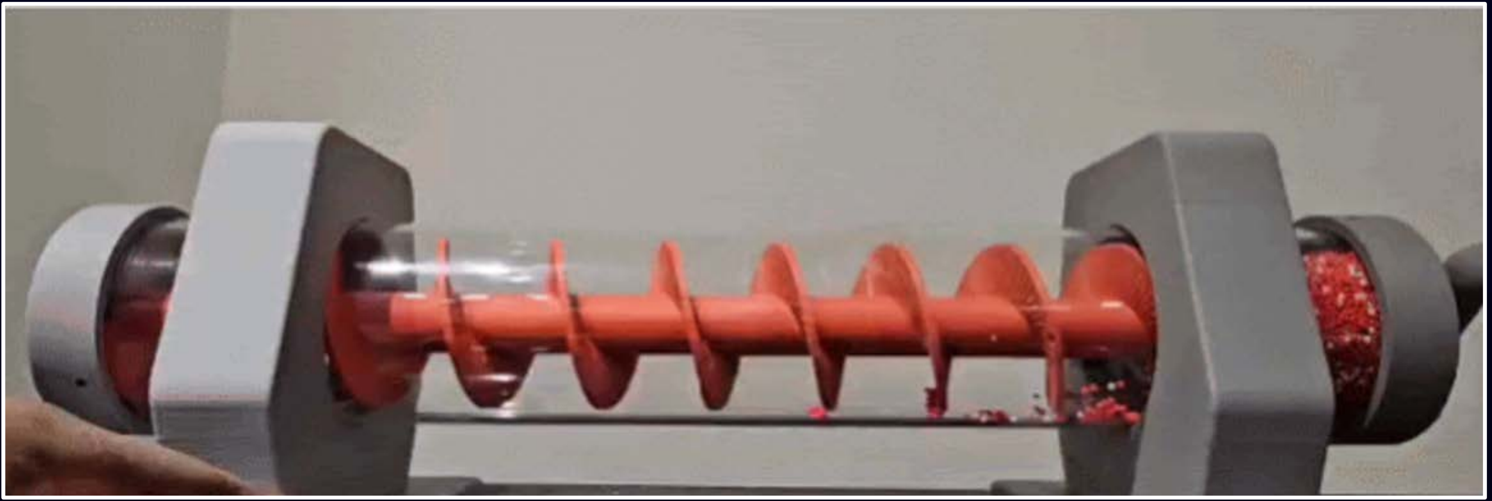




# MDC versus conventional Screw Conveyor

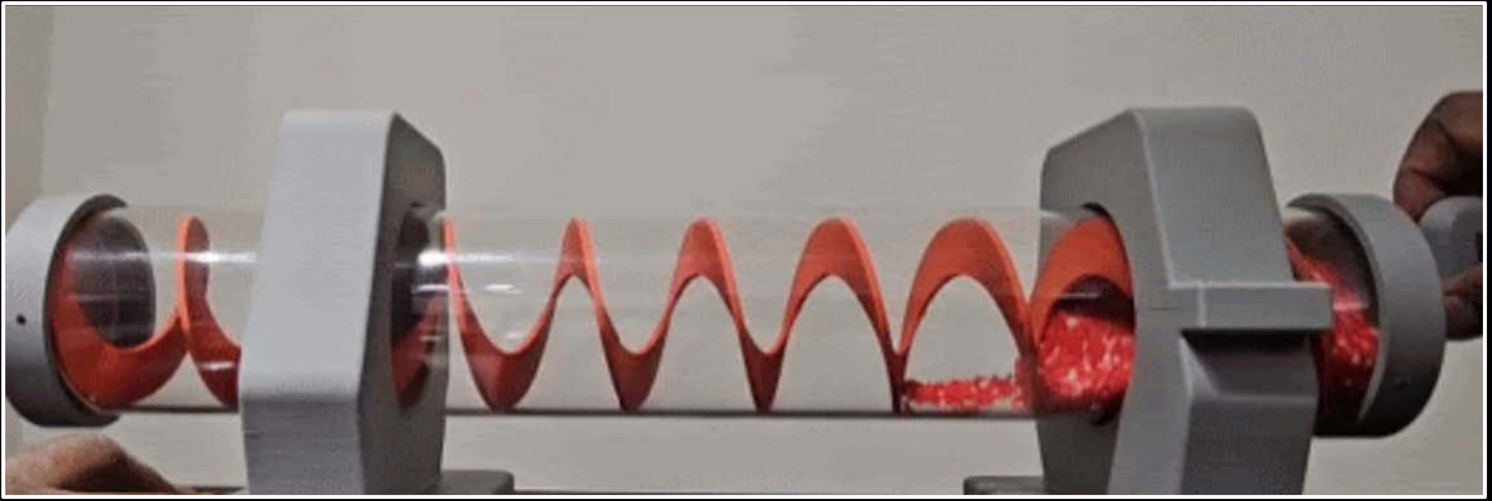
## AUGER / SCREW CONVEYORS:

- **Mass Transport**: High-friction linear drag.
- **Wear Profile**: Severe abrasive degradation of flights.
- **Failure Modes**: High risk of "dead-zone" clogging.
- **Maintenance**: Complex bearing & seal requirements.
- **Operational Fit**: Non-optimized for abrasive regolith.



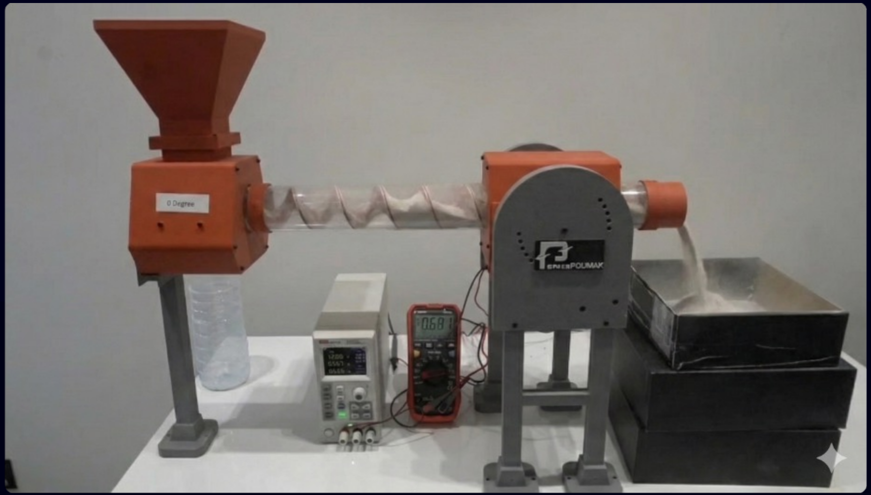
## MODULAR DRUM CONVEYOR (MDC):

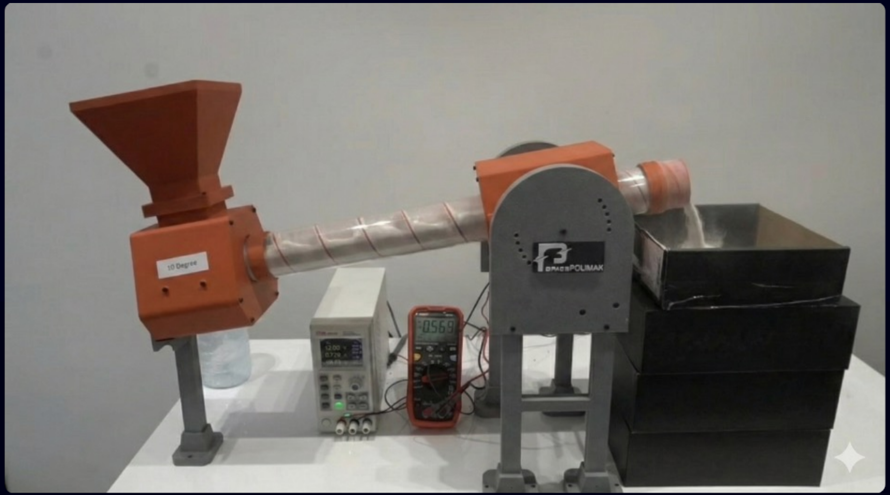
- **Mass Transport**: Low-friction material "rolling".
- **Wear Profile**: Fused design , no internal abrasion.
- **Failure Modes**: Gapless; prevents jamming & buildup.
- **Process Efficiency**: Concurrent conveying & mixing.
- **Operational Fit**: Purpose-built for lunar ISRU.



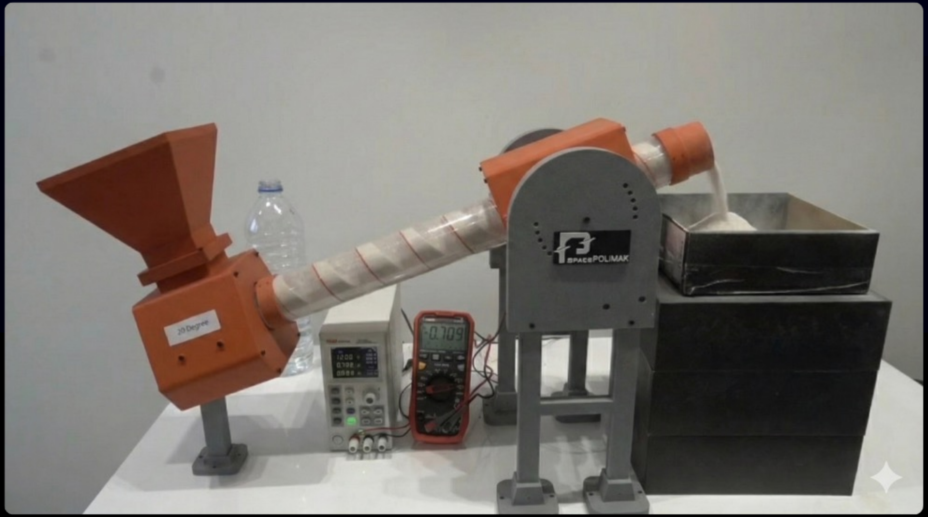
# Performance Comparison

Operational metrics of the MDC were evaluated directly against the Auger screw conveyor system using a low density material to simulate low gravity environments and quantify transport efficiency.





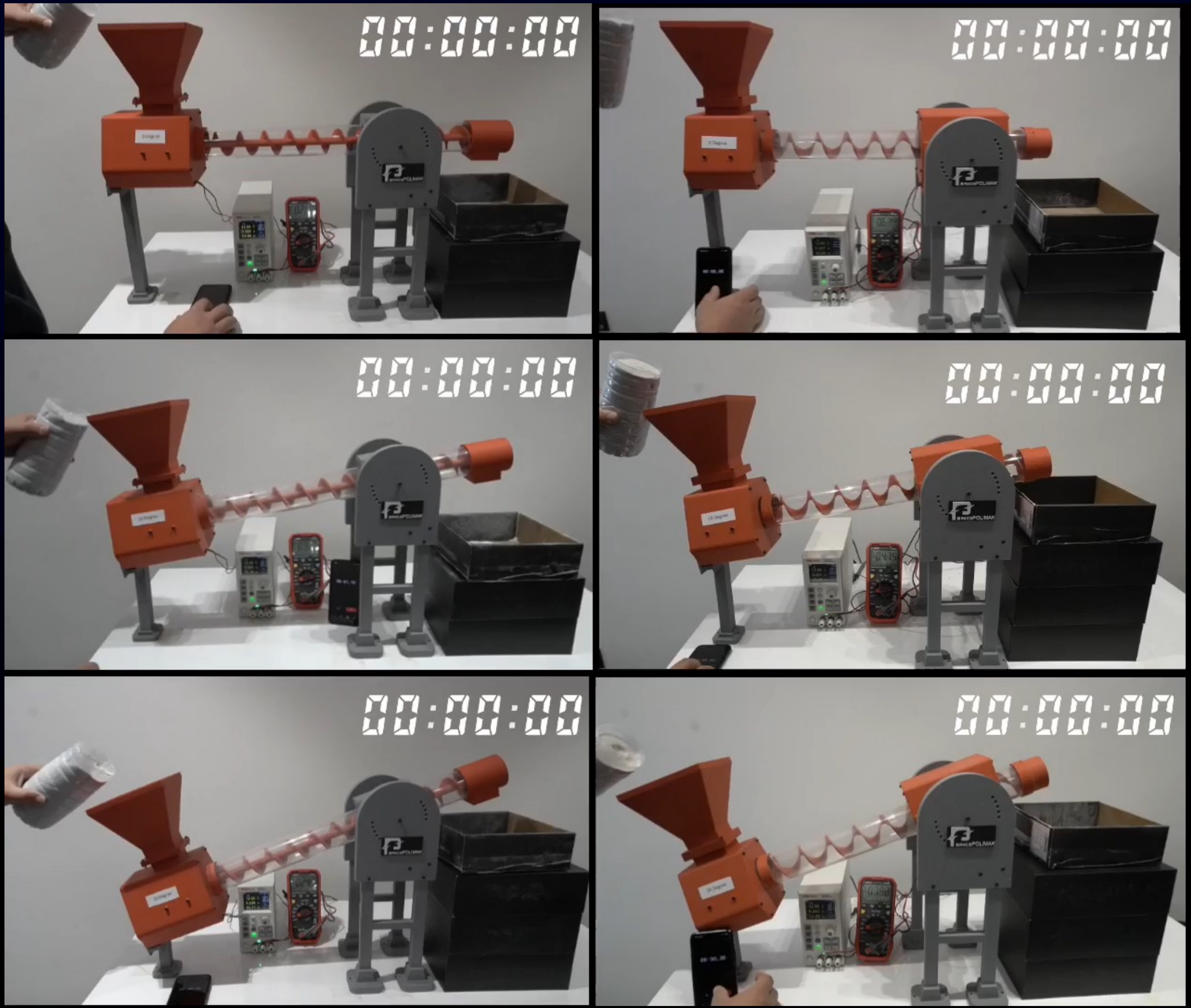
Handled Material: 123 g of Perlite
Rotational Speed: 100 RPM
Diameter: 50mm
Angles: 0°, 10°, 20°



# Performance Comparison

Auger Screw Conveyor (ASC)

Modular Drum Conveyor (MDC)



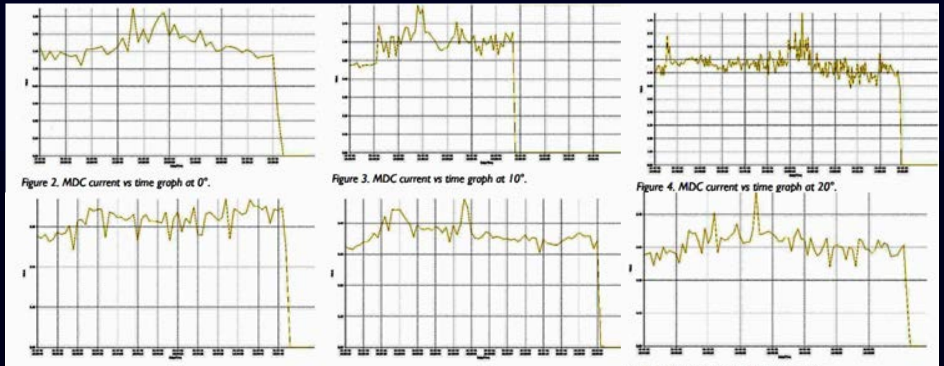



Figure 2. MDC current vs time graph at 0°.

Figure 3. MDC current vs time graph at 10°.

Figure 4. MDC current vs time graph at 20°.

Figure 5. ASC current vs time graph at 0°.

Figure 6. ASC current vs time graph at 10°.

Figure 7. ASC current vs time graph at 20°.

| Angle (°) | ASC Time (s) | ASC Throughput (g/s) | MDC Time (s) | MDC Throughput (g/s) |
|---|---|---|---|---|
| 0 | 58 | 2.12 | 28 | 4.39 |
| 10 | 65 | 1.89 | 47 | 2.62 |
| 20 | 77 | 1.60 | 177 | 0.70 |

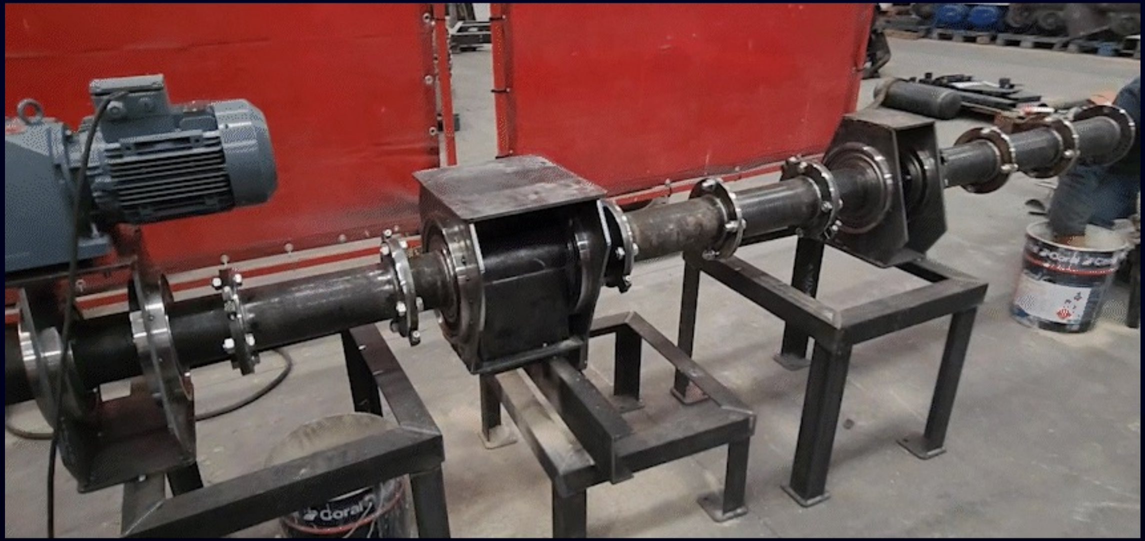
| Angle (°) | ASC Current (A) | ASC Power (W) | MDC Current (A) | MDC Power (W) |
|---|---|---|---|---|
| 0 | 0.30 | 3.60 | 0.63 | 7.56 |
| 10 | 0.38 | 4.56 | 0.62 | 7.44 |
| 20 | 0.32 | 3.84 | 0.78 | 9.36 |

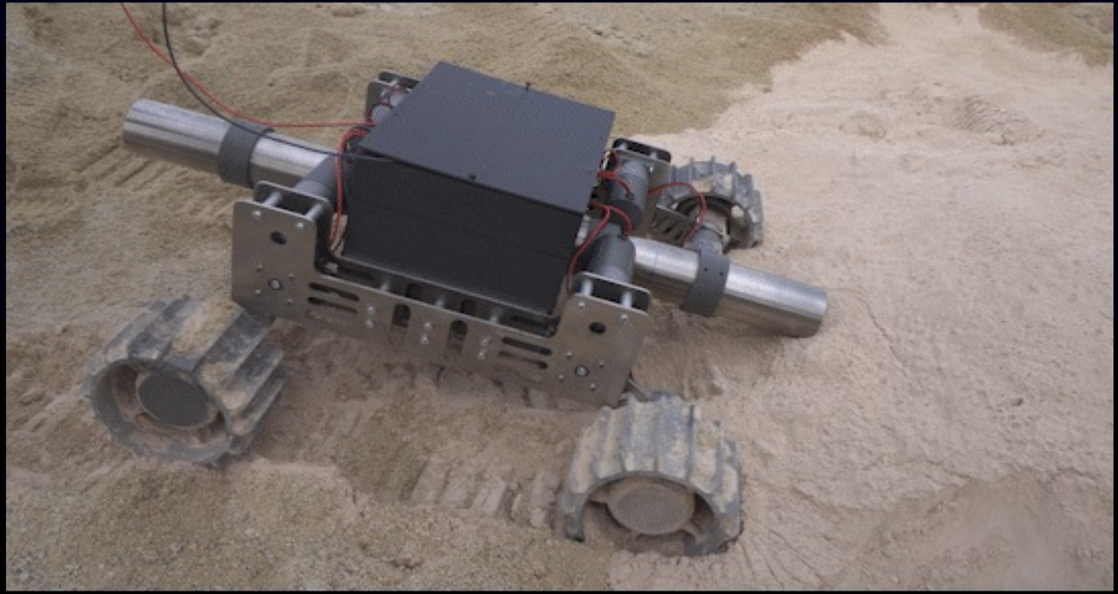
- The MDC achieved superior horizontal throughput but suffered a steep non-linear decline at higher inclinations.

- The ASC sustained consistent mass flow and minimized energy expenditure across all tested angles.

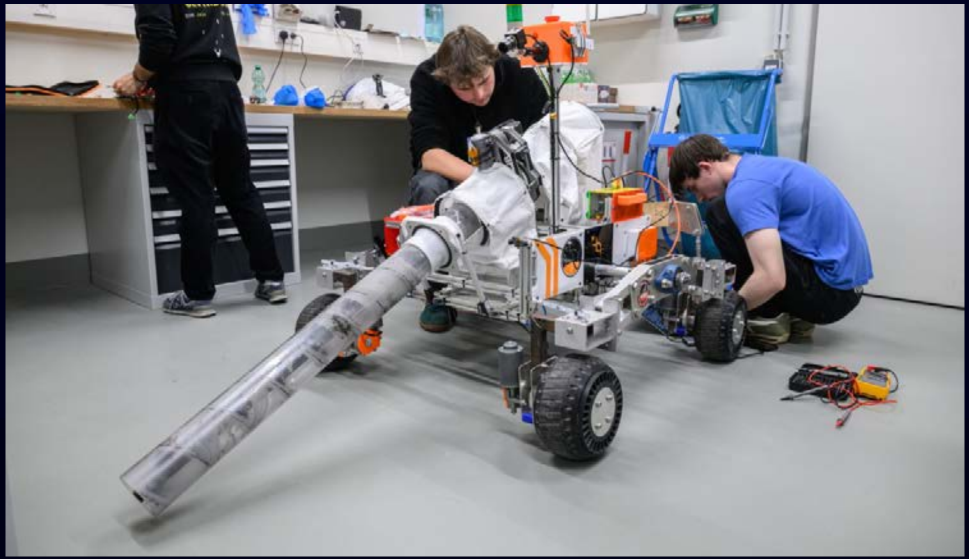
- Power demands varied by under 15% between loaded and empty states showing that mechanical friction dominates the load.

# Other Tests





## MDC in ESA & ESRIC Space Resources Challenge



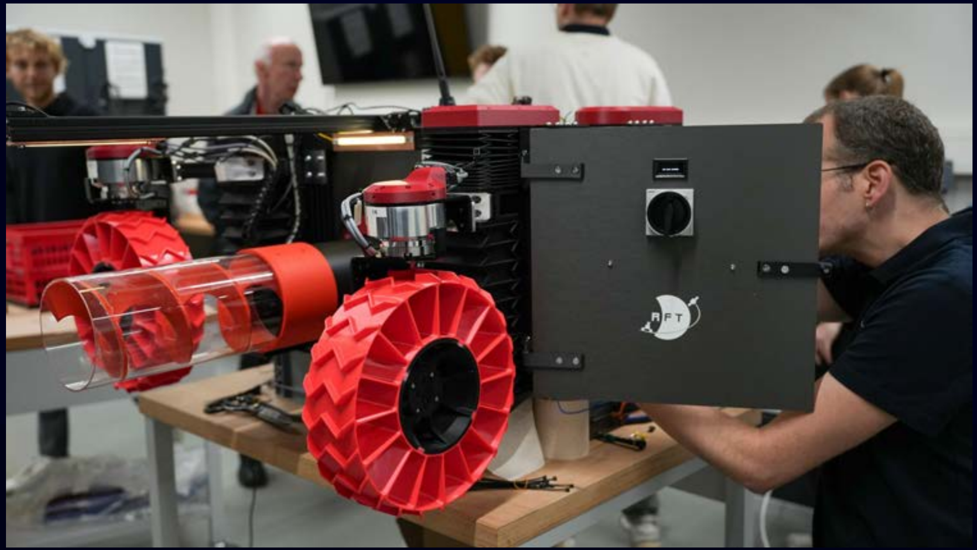


*Image Credits: ESA & ESRIC*

# Vertical MDC

- The Vertical MDC ascends regolith by spinning the outer casing around a fixed screw based on Olds Elevator principles
- Lower scoops guide particles into the rotating tube where centrifugal forces establish a wall boundary layer
- Spinning material meets stationary screw flights to climb upward while forming a dynamic seal against leakage
- Advantages include stable vertical lifting and a continuous feeding capability achieved through a relatively simple mechanism
- Disadvantages involve increased energy draw because the full vertical column must be packed to lift material
- Additional challenges encompass mechanical wear risk alongside potential clogging and low inlet hopper collection efficiency

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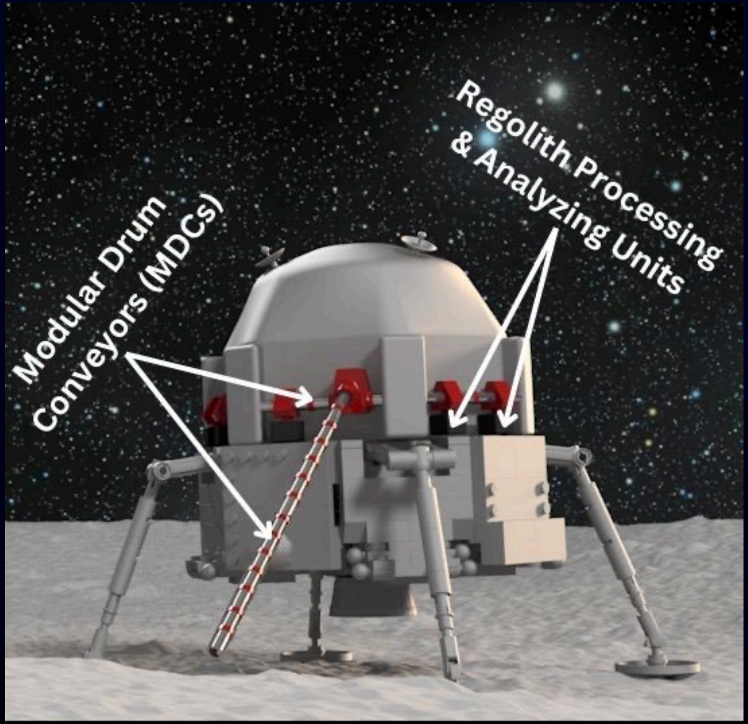
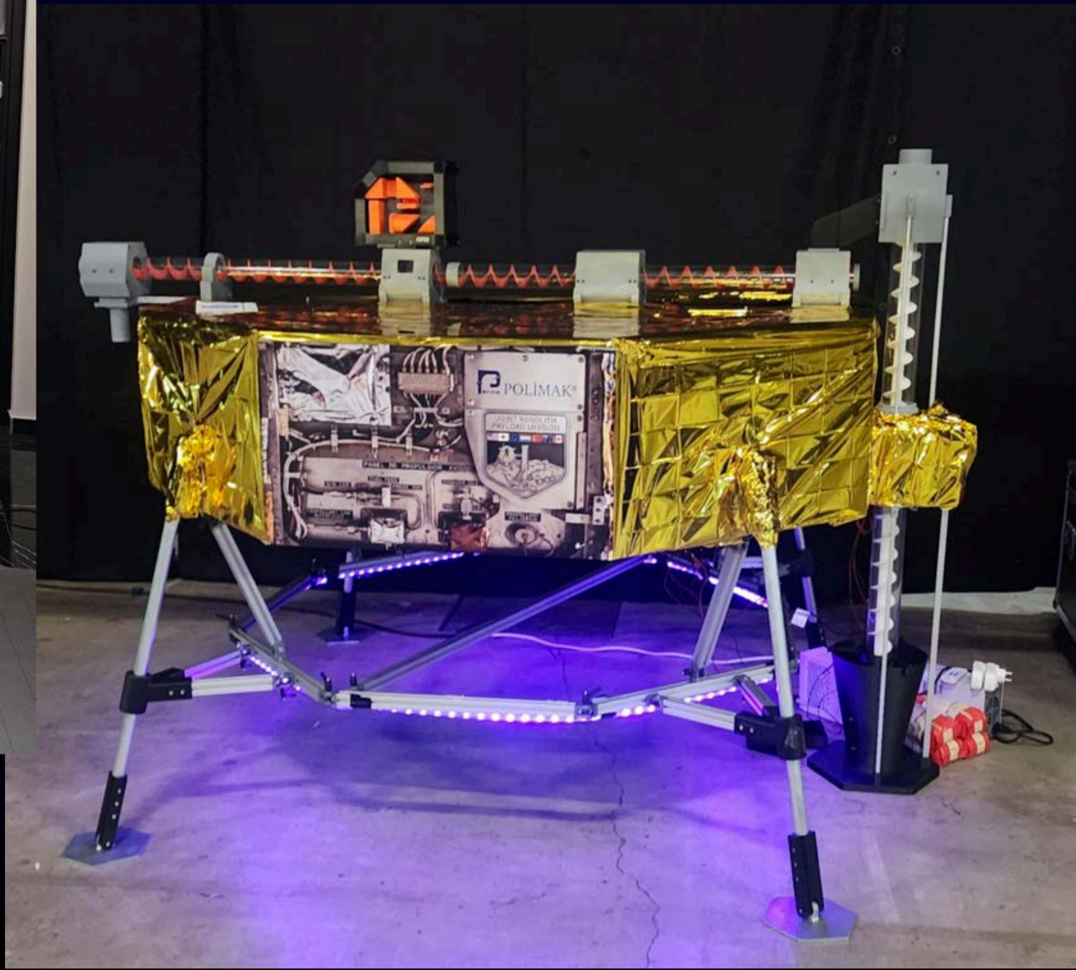
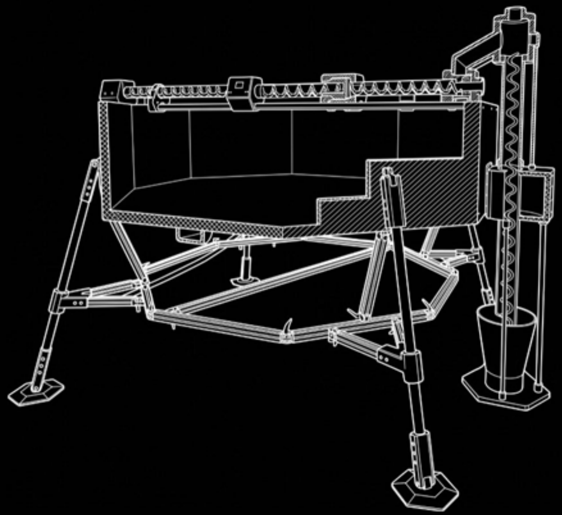
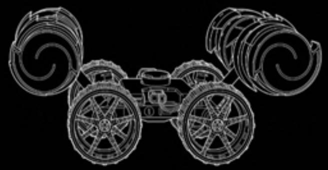
# Regolith Delivery System For Lunar Landers





# Regolith Delivery System For Lunar Landers

## Casting

# MDCs made from lunar regolith

**Partnership:** POLİMAK® SPACE, Fraunhofer IPK, Technische Universität Berlin, Hochschule Aalen University of Applied Sciences

**Lunar Manufacturing: Casting the MDC from Regolith**

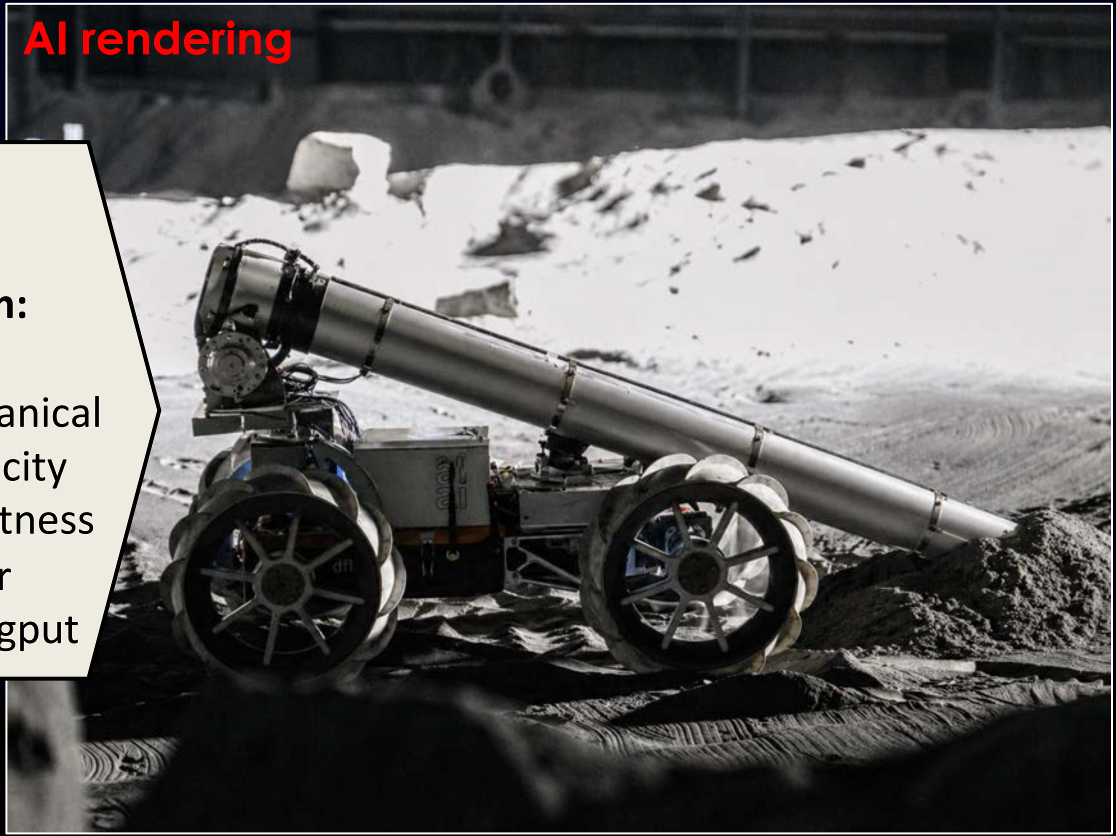
- **The Challenge:** Scaling lunar infrastructure requires more hardware than can be economically launched from Earth.
- **The Process:** Regolith simulants are melted at 1350°C–1450°C under vacuum.
    a. Molten material is cast into reusable graphite molds to form helical segments.
    b. Thermal stress is relieved via a controlled furnace cooling cycle.
- **The Result:** Successful demonstration of MDC-like geometries, validating regolith casting as a viable path for large-scale, on-site infrastructure.

## Rover integration

# Excavating, fetching & conveying loose regolith


**Compare Conveying Mechanism:**

- mechanical simplicity
- robustness
- power
- througput



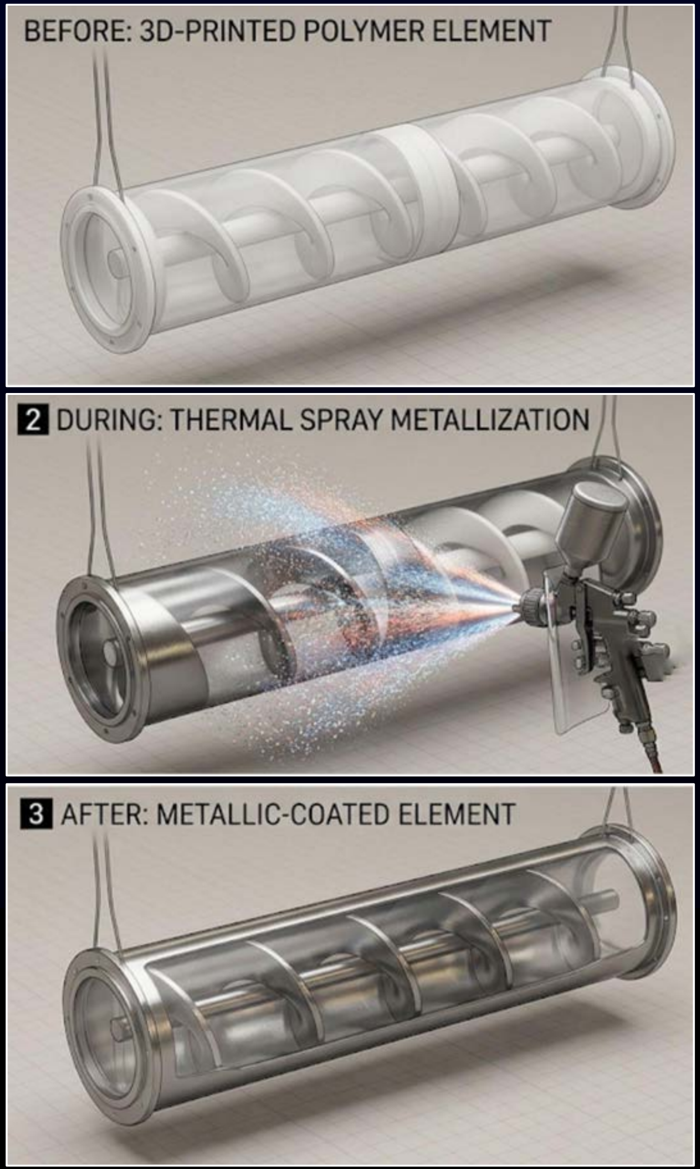
## Coating

# Increase Abrasion Resistance

**Partnership:** POLİMAK® Fraunhofer IGP

**High-Performance Metallization for Lunar ISRU**

- **The Problem:** Abrasive regolith and UV radiation aggressively degrade 3D-printed components, creating a gap between rapid prototyping and mission-ready durability.
- **The Solution:** Applying **"Thermal Spray" coating technology** to facilitate surface metallization of non-metal parts.
- **The Impact:** Integrates metallic properties (high thermal/electrical conductivity, extreme wear resistance) onto lightweight MDC modules, enabling the Modular Drum Conveyor to transition from transport to **active digging and extraction.**



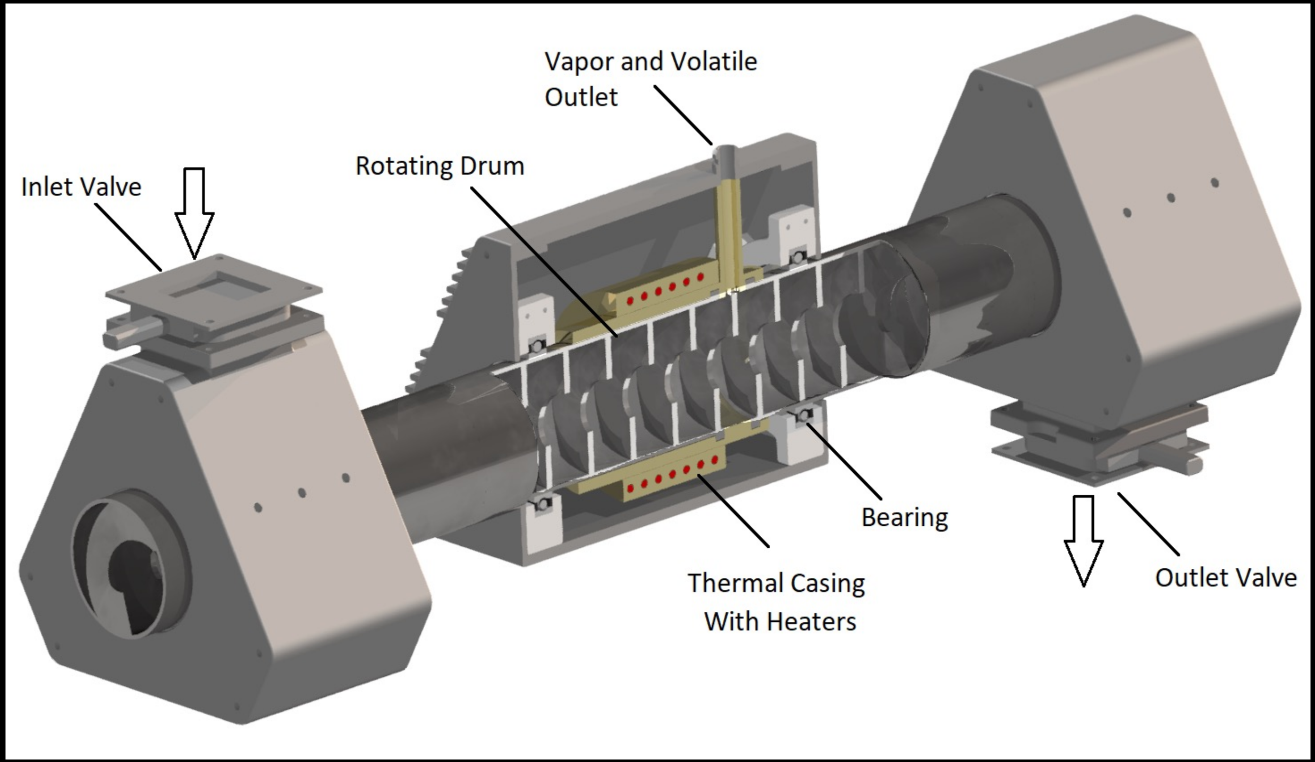
# Volatile Extraction & Sieving

**MDC Based Regolith Preconditioning and Volatile Extraction**

Preconditioning of regolith by sufficient heating to remove deleterious contaminants such as sulfur in preparation for subsequent O2 and metal extraction processing or other uses, based upon discussions with LSII (pers. Comm. with C. A. Hibbitts).

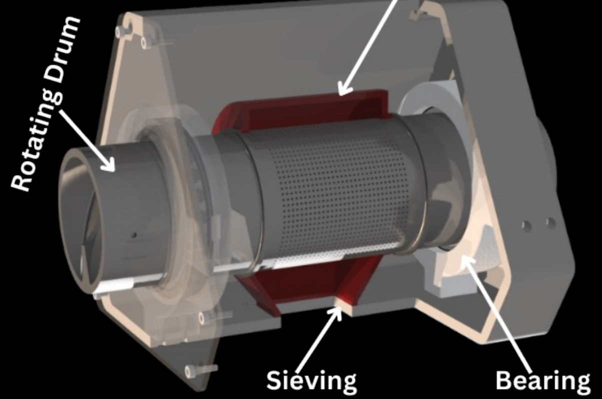
The preconditioning system design, analogous to but independently developed from NASA's Auger Dryer system [1],focuses primarily on preconditioning for O2 extraction rather than water ice removal.

[1] Collins et al., 2021. https://ntrs.nasa.gov/api/citations/20210013233/downloads/PTMSS-SRR_LADI%20Abstract.doc.pdf

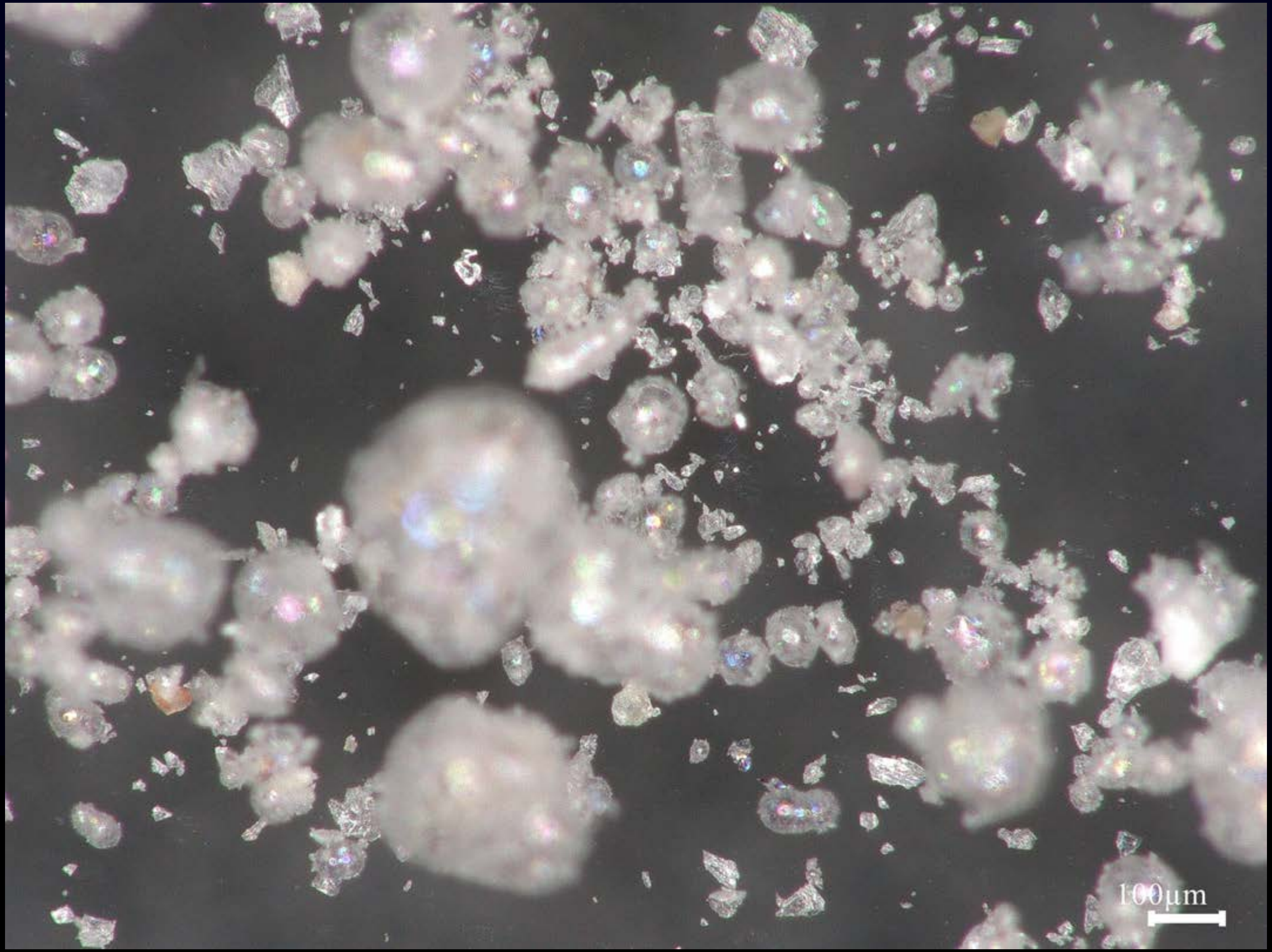


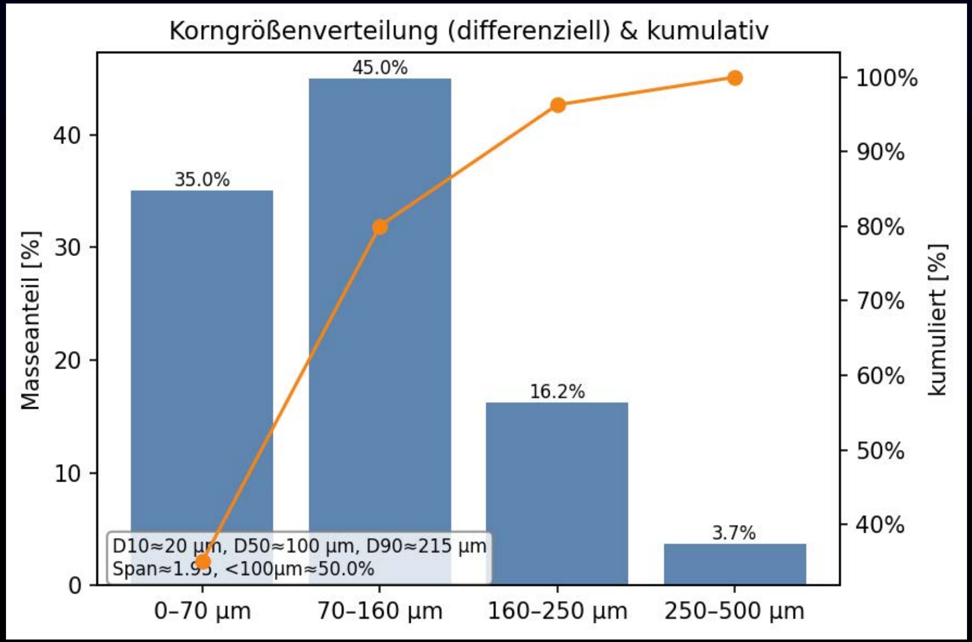

**MDC Based Regolith Sieving Module**

- Adjustable particle size
- Self cleaning
- Suitable for Low Gravity



# Regolite: Same properties as simulant - ⅙ the weight



# Lunar Testbed Services #TheMoon

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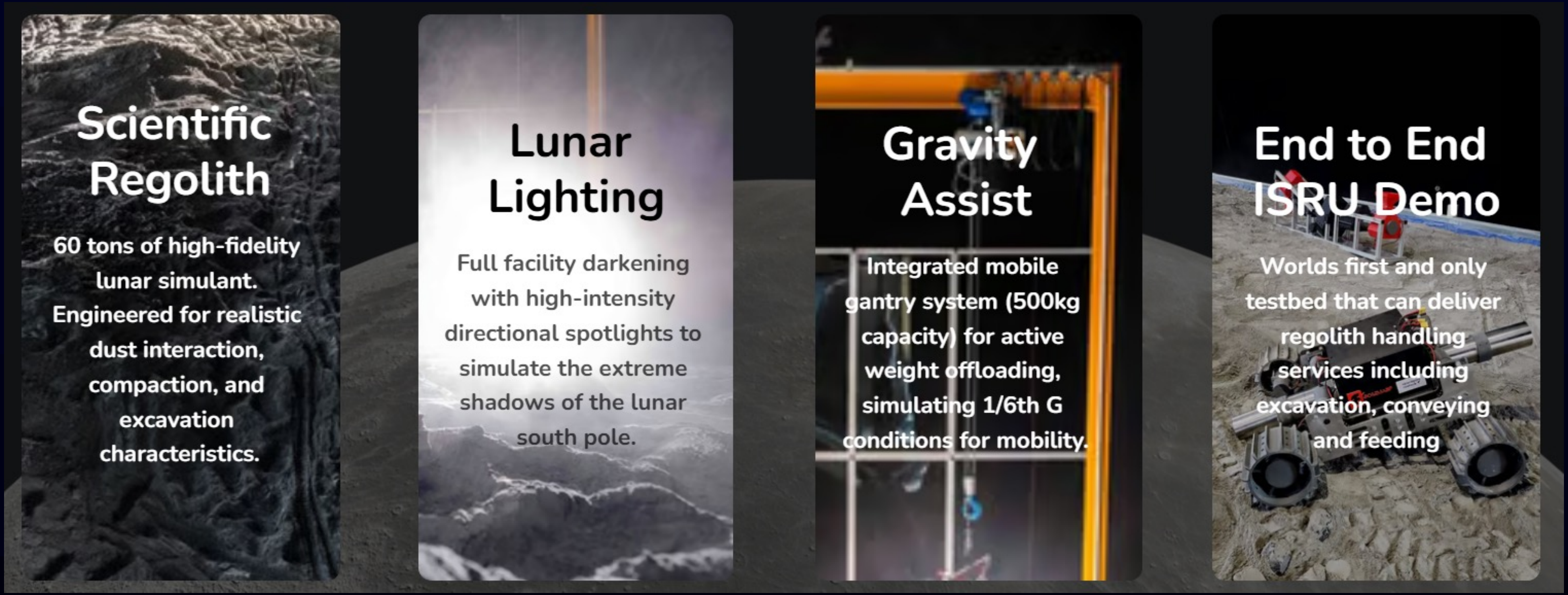


OPEN FOR BUSINESS

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# Recent Progress

- ESRIC: Established Polimak Space SARL in Luxembourg with the support from ESRIC

- TU Berlin: storage, feeding and fine dosing of regolith into melting chamber

- DLR: Analysis and modelling of Modular Drum Conveyor

- TUMI Robotics: MDC mounted rovers for mining applications

- CEITEC: sensor module and LIBS sensor integration

- University of Hannover: Einstein drop tower testing

- Fraunhofer Rostock: Experimental program to compare the performance of coated versus uncoated extractors

- OHB: Regolith compaction and sieving units for internal melting units at OHB

- Solsys Mining: Partnership for integrated hardware offerings and establishment of university laboratories

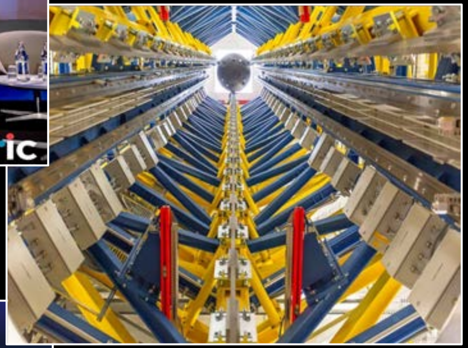
- Astroport: NASA Lunar Landing Pad Site Prep. Project

- Vulcanis (USA) (Norway): Development of multi-sensor modules for regolith analysing

- Instrict Space (UK & USA): Lunar lander mission focused on regolith analysis and processing on the surface

- TOM (USA): Applied NASA SBIR project on regolith sampling

- University of Greenwich, UK : Mechanical Surface Energy Tester (MSET) for Regolith Characterisation



# Lab Equipment

Regolith Box for enclosed testing of regolith simulant in lab environment.

Fully sealed volume with glovebox.

Customazible for different needs.

Optional Features:

- Dust collection unit
- 0.2 bar (gauge) vacuum
- Waste bag compaction
- 2 linear + 1 rotational axis motion for wheel tests
- Internal vacuum cleaner
- Vacuum loading from Bigbags


Regolith feeding system for high temperature vacuum chambers


Rover mounted MDC for testbed terrain manipulation works

# Polimak & Instinct Space Lunar Payload Campaign Dedicated to Regolith Access

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INSTINCT

LUNAR SURFACE ACCESS CHALLENGES
- Instruments performing material analysis volatile extraction or melting require direct regolith contact on landers
- Payloads must implement expensive robotic arms or custom inlet conveyors to capture surface material
- Budget constraints and long integration wait times restrict institutional access to standard lunar missions

STRATEGIC MISSION SOLUTION
- Polimak partnered with Instinct Space to deliver a low cost mission focused exclusively on regolith access
- The shared lander platform accommodates a total payload mass of  20kg
- Target flight deployment is scheduled for a launch window between 2029 and 2030

POLIMAK INTEGRATION ADVANTAGE
- Engineering support elevates TRLs to ensure rapid flight qualification
- Client instruments integrate directly into the onboard Polimak MDC regolith delivery system

INSTINCT SPACE ADVANTAGE
- Lunar lander is designed as a rideshare vehicle, it can launch from any launcher to any orbit, decreasing cost and enabling higher mission cadence.
- Flies to the Moon from any orbit, no staging and refueling required. Simple and efficient.

Instinct Space Supported By:

Y Combinator

NVIDIA Inception Program

REBEL FUND

Calm Ventures

a16z Scout Fund

MAIORA VENTURES


Join us and register
your payload

POLİMAK®

INSTINCT

Join the workshop at the ESA Space for Inspiration Conference in Copenhagen on September 1 & 2

* The workshop achieved formal approval from ESA