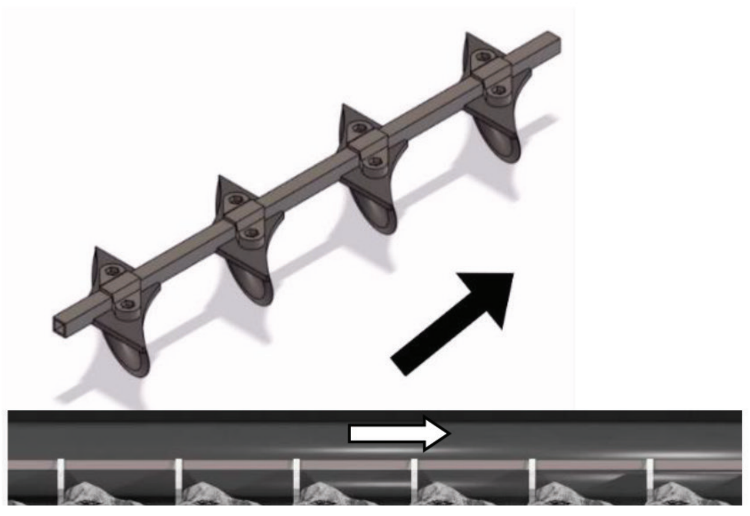
Design and Construction of a Lunar Regolith Transport Device Prototype: A Scraper Conveyor with a Rotating Rod

Project duration: 2023
Project manager: Dr hab. Eng. Piotr Kulinowski
Space Technology Centre

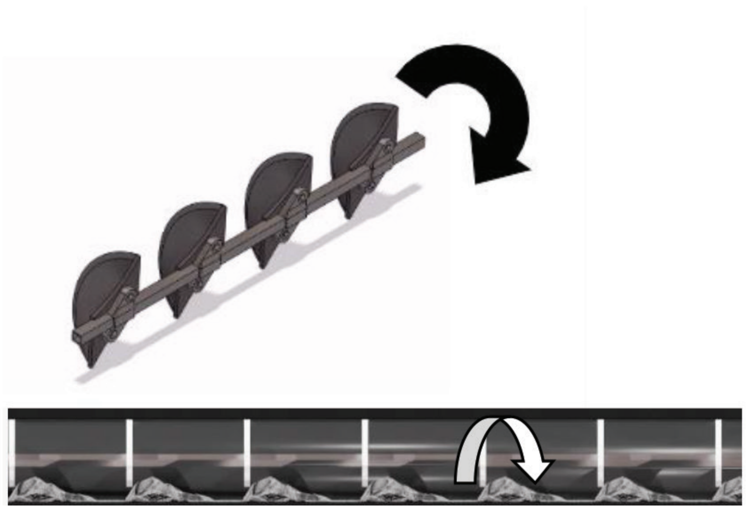
INTRODUCTION:

Horizontal regolith transportation in the TOLRECON 2.0 system is done by our unique rod-scraper conveyor. The conveyor pushes the lunar regolith along using a set of scrapers, spaced evenly and attached to the rod. The conveyor consists of a set of tubes connected end-to-end, supported by legs. Inside the tube is a rod with scrapers mounted to it. The reciprocating motion of the rod is what causes the regolith to move inside the tubes. The motion of the rod can be divided into four distinct phases:

1. Push phase: the functional phase of the conveyor; in that phase the rod is moving in the direction of resource transport with the scrapers facing downwards, pushing the regolith along.
2. Left-handed move phase: in that phase, the scrapers rotate with the rod, along its axis, until they face upwards, away from the transported material. The unique shape of our scrapers allows them to "unscrew" from the regolith without disturbing it too much.

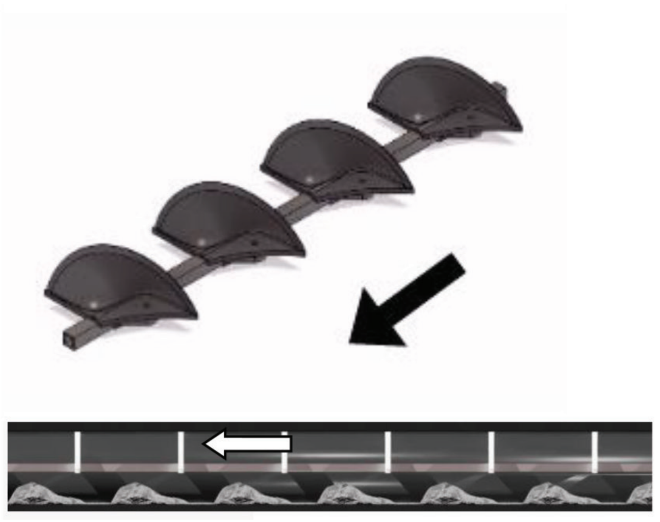


1. Push phase.

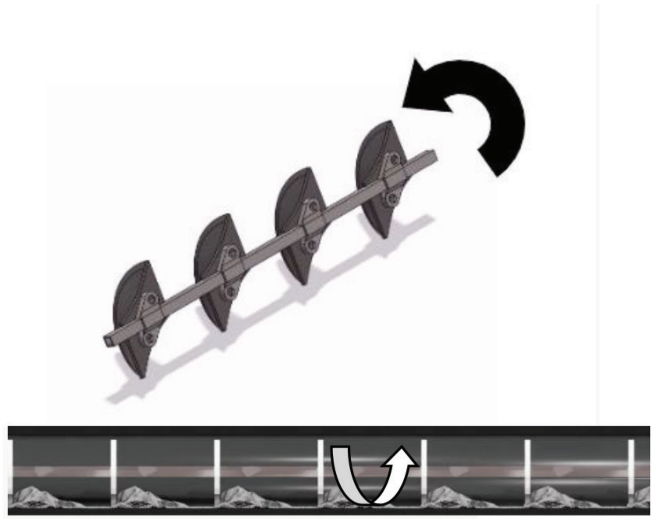


2. Left-handed move phase.

3. Return phase: in that phase, the rod moves back to its original position with the scrapers still facing upward. No resource transport happens, as there is no interface with the regolith.
4. Right-handed move phase: the last phase of the move of the mechanism; then, the rod rotates back to its original position, inserting the scrapers into the regolith. After this phase, the conveyor is ready to push the regolith again and the cycle repeats from phase 1.



3. Return phase.



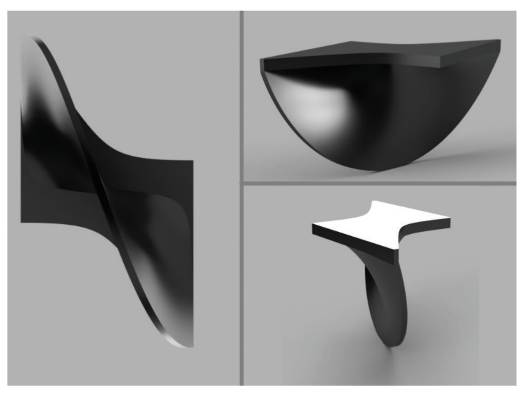
4. Right-handed move phase.

METODOLOGY:

To enhance the rod conveyor's regolith transportation process, the research focused on designing an optimized blade geometry for the scrapers. The new scraper geometry follows a helical line along half the circumference of the trough cross-section. This modification retains the core concept of the rod-scraper conveyor while optimizing the shape of the scrapers to align with this new idea.

The research was conducted on a 1-meter-long conveyor model with a special transparent polycarbonate tube. This allowed researchers to observe the movement of the material and the scrapers. Two types of rods were prepared, one with conventional straight scrapers and the other with helical scrapers. Comparative studies were performed to determine the impact of scraper type on the amount of material transported. Due to the unique characteristics of the mechanism used for rod movement, a combination of linear and rotational motion was employed. This combination can lead to an unfavorable phenomenon known as regolith rollback, which needs to be eliminated or minimized without altering the fundamental mechanics of the system.

Additionally, the scraper pitch, i.e. the distance between individual scrapers, was investigated. Three different scraper pitches were selected: 8 cm, 12 cm, and 16 cm. These distances were adjusted and tested to determine their influence on the transportation process.

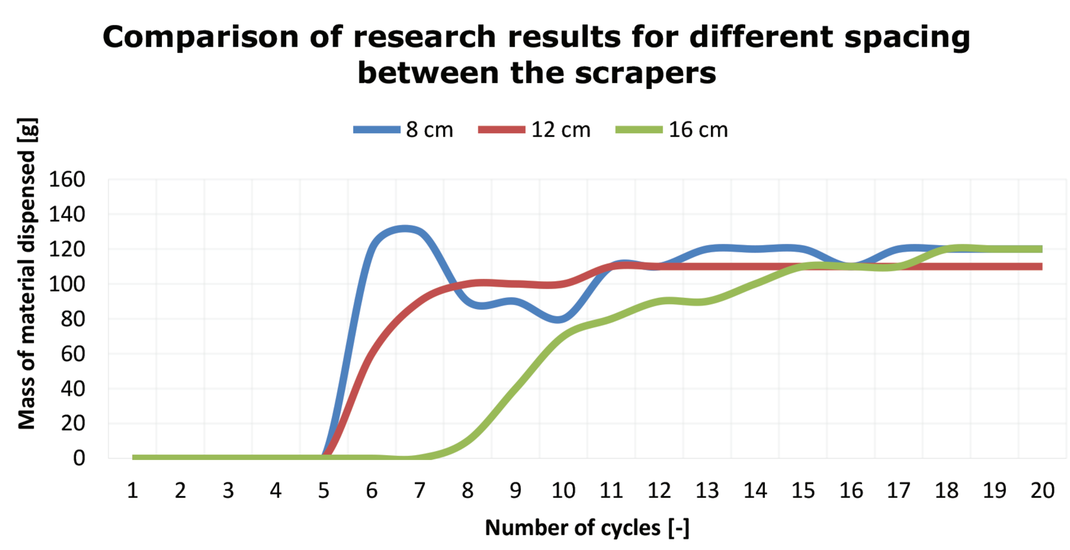


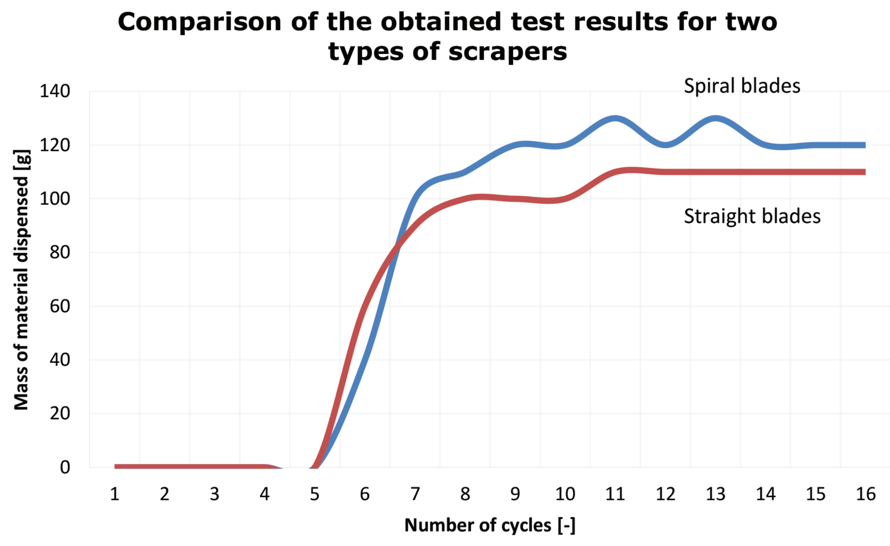
Concept of scraper shape.

This blade's geometry is adapted to the characteristics of the movement with which the rod moves.

RESULTS:

The research results were analyzed using Microsoft Excel, and graphs were generated to present the trends of different scraper pitches and scraper types in the rod-scraper conveyor system. These graphs provided visual insights into the impact of varying scraper pitch and type on the efficiency of regolith transportation.





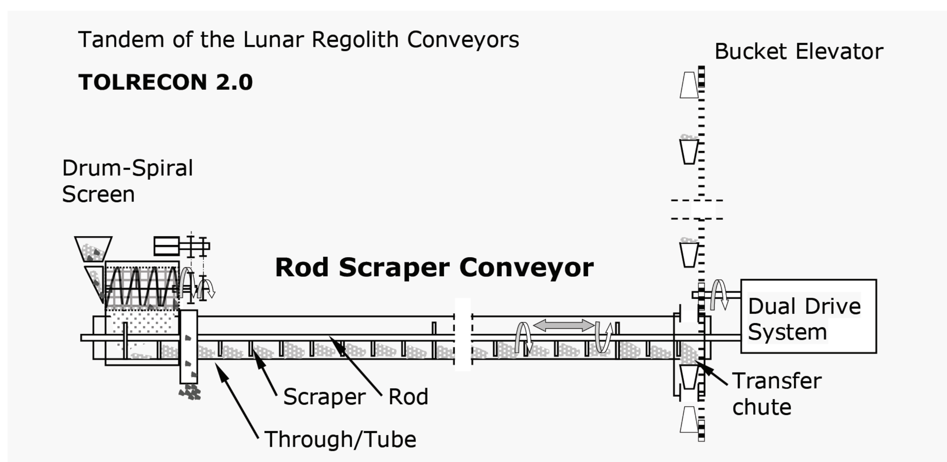
DISCUSSION:

The obtained results clearly demonstrate the significant impact of the type of scraper on the amount of transported material. The helical shape of the scrapers allows for smoother penetration into the material, minimizing regolith rollback during the working cycle. On the other hand, flat scrapers tend to initiate material discharge more rapidly, potentially causing instability during the transportation process. Further studies should consider exploring the influence of the helix angle on scraper performance to optimize this aspect.

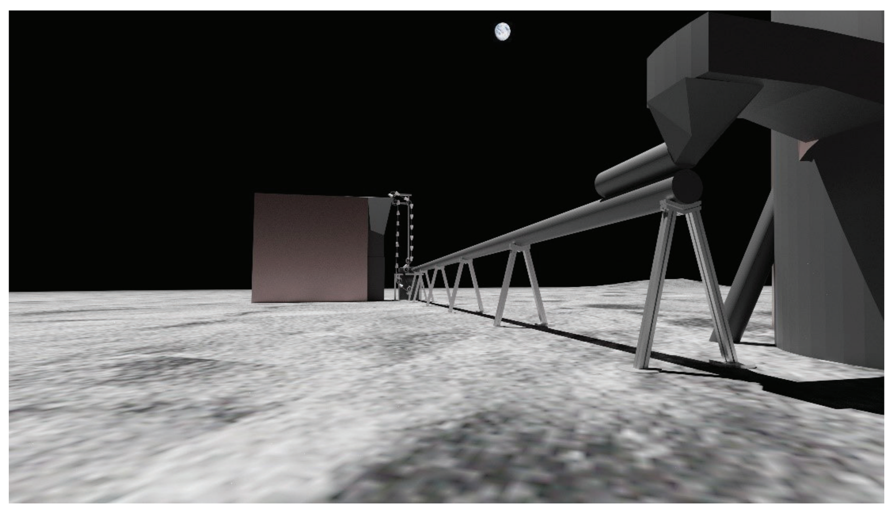
Investigating scraper pitch also yielded interesting results. Among the three tested distances, 12 cm proved to be the most suitable. A scraper pitch of 8 cm led to rapid initiation of material discharge with subsequent fluctuations and instability. On the other hand, with a 16 cm scraper pitch, material discharge slowly increased and only became significant around the tenth cycle, nearly twice as late as the other distances. The 12 cm pitch demonstrated gradual material discharge followed by stabilization, making it crucial for the efficient collaboration of this conveyor with other systems, such as bucket conveyors.

SUMMARY:

The research conducted provides an essential foundation for optimizing the rod conveyor system, which represents a novel solution for horizontal regolith transportation. Understanding the characteristic parameters of this design is crucial for its further development. Continuing this exploration will pave the way for implementing this innovative conveyor system in industrial applications. The conveyor system was presented during the international Over the Dusty Moon Challenge that was held in June 2023 in Colorado. It was organized by Colorado School of Mines and the Lockheed Martin. The AGH University team won 1st place in this competition. The unique design was spotted by the jury consisted of specialists from the space technologies.



Concept of tandem of the lunar regolith conveyors with a drum-spiral screen.



Visualizations of the TOLRECON 2.0 on the Moon.

Tolrecon 2.0 during Over the Dusty Moon Challenge.

The wining team after the competition with the Tolrecon 2.0 conveyor system.