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

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Introduction: Sustained lunar exploration requires reliable In-Situ Resource Utilization (ISRU) systems capable of processing and distributing large volumes of regolith. While excavation and processing technologies continue to advance, regolith transport between excavation, processing, storage, and construction systems remains a critical logistical challenge. These operations require material conveyance across horizontal, inclined, and vertical orientations.

Polimak Space addresses this gap through its Regolith as a Service (RaaS) concept, which envisions a fully integrated and modular regolith handling ecosystem supporting end-to-end ISRU operations. Within this framework, Polimak Space contributes to the development of regolith handling and distribution technologies, supporting the infrastructure required for efficient material logistics on the lunar surface.

At the core of this regolith logistics architecture is the patented MDC, complemented by the emerging VMDC. Together, these systems represent a major step toward operationally viable lunar material handling. To advance these technologies beyond conceptual design, Polimak Space has developed working prototypes and conducted a series of experimental evaluations. These tests involve conveying various material samples to assess transport efficiency, power consumption, and operational stability under different orientations.

Modular Drum Conveyor (MDC): The MDC is a patented material transport technology designed for conveying granular materials in horizontal and inclined orientations. The system consists of a rotating cylindrical drum with helical flights attached to its inner surface, which guide and move the material during conveyance as the drum rotates. This configuration promotes rolling motion of the particles during transport, enabling efficient material movement. Unlike conventional auger screw conveyors, where a rotating screw moves material inside a stationary trough primarily through sliding friction, the MDC integrates the flights with the rotating drum itself. As a result, the material moves with the rotating surface rather than sliding along it. This design allows the system to operate with minimal residual material remaining inside the drum while conveying as seen in the figure.

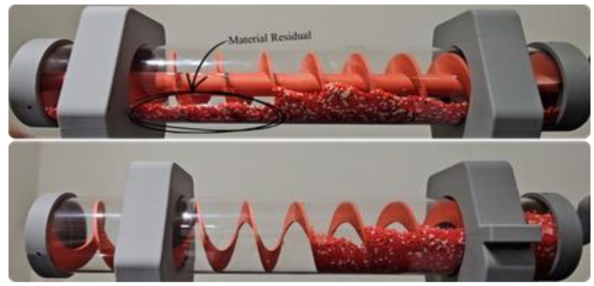

Figure 1: *MDC vs Auger screw material transport pattern.*

Experimental Validation of the Scaled MDC Prototype: To evaluate operational feasibility and quantify performance metrics, a scaled MDC prototype was designed and fabricated. The objective of the experimental campaign was to assess, material conveyance capacity, influence of inclination angle on system efficiency, and energy consumption.

Material conveyance tests were conducted using 1 kg perlite powder as the conveying medium. Perlite was selected due to its low density to simulate 16 gravit on lunar surface. The conveyor was evaluated at three distinct inclination angles: 0°, 10°, and 20°, representing horizontal transport and progressively steeper inclined configurations. During testing, the system was operated at constant supply voltage and fixed rotational speed, allowing the influence of inclination angle on conveying performance to be isolated from other operational parameters. The material throughput was determined by measuring the time required for the conveyor to transport the test material from the inlet to the outlet under each inclination configuration. In parallel, electrical current measurements were recorded throughout operation.

Figure 2: *Experimental setup of the MDC prototype demonstrating material conveyance tests conducted at distinct orientations 0° (top left), 10° (top right), and 20° (bottom center).*

Discussion: The experimental results indicate a clear inverse relationship between conveyor inclination angle and material throughput when the system operates at constant voltage and rotational speed. As the inclination angle increases, the gravitational component acting opposite to the conveying direction increases, thereby reducing the net axial transport rate of the material within the rotating drum.

The observed trend is consistent with the expected behavior of bulk materials moving under rotational motion on inclined surfaces. At higher inclination angles, a larger portion of the material weight contributes to backward gravitational resistance, which reduces the forward displacement achieved during each rotational cycle of the drum. In some cases, localized particle tumbling or partial backflow can occur when the gravitational force acting downslope becomes comparable to the forward conveying force generated by the internal flights. Nevertheless, the system maintained substantial throughput at all three tested angles, demonstrating that the conveyor is capable of effectively transporting material even under inclined operating conditions. In addition, energy consumption was observed to increase with higher inclination angles, as the system requires greater power to overcome the increased gravitational resistance acting against the direction of material conveyance.

Inclination angle *(°)*	Avg. Current *(A)*	Avg. Power *(W)*	Operational Time *(s)*	Energy *(Wh)*
0	*~0.63*	*7.68*	*~31*	*0.098*
10	*~0.62*	*7.44*	*~60*	*0.141*
20	*~0.82*	*9.84*	*~176*	*0.601*

Figure 3: *Operational performance parameters of the MDC prototype under varying inclination angles.*

Experimental Validation of the Scaled VMDC Prototype: While the MDC addresses horizontal and inclined transport, lunar infrastructure requires efficient vertical material transfer to elevated processing units, storage silos, or lander platforms.

The VMDC utilizes a conveying mechanism in which the outer tubular casing rotates while the internal screw remains stationary. The material is introduced into the rotating tube by intake scoops located at the lower section of the casing. As the casing rotates, friction between the inner wall of the tube and the material causes the material to rotate, generating a moving layer of particles along the casing wall. This rotating material layer interacts with the stationary screw flights, forcing the material to move upward along the inclined screw surface. At the same time, the rotating layer of particles acts as a dynamic seal within the clearance between the casing and the screw, limiting downward leakage. The material is progressively lifted to the discharge region, where it exits the system in a continuous flow. This design is based on a type of vertical conveyor named “OLD’s Elevator”.

To evaluate the operational feasibility and quantify the performance metrics of the Vertical Modular Drum Conveyor (VMDC), a scaled VMDC prototype was designed and fabricated. The objective of the experimental campaign was to assess the continuous vertical lift of material and overall conveyor performance.

Figure 4: *Experimental demonstration of the VMDC, showing vertical conveyance.*

Discussion: The VMDC prototype demonstrated stable and continuous vertical material conveyance throughout the test campaign. Material was consistently transported upward without significant spillage, blockage, or flow interruption. The internal flight geometry effectively retained the material during rotation, enabling sustained upward transport.

Conclusion: The experimental tests conducted on the patented Modular Drum Conveyor (MDC) and the Vertical Modular Drum Conveyor (VMDC) prototypes yielded promising outcomes, demonstrating the capability of both systems to effectively convey bulk materials under different operating conditions. The results confirm that the conveying concepts are suitable for material transport and show strong potential for applications involving regolith handling.

While the tests validated the operational feasibility of the conveyance systems, further optimization can enhance overall performance and efficiency. In particular, improving the MDC’s performance at steeper inclination angles will require targeted design refinements, such as modifications to the internal geometry to improve material flow and maintain higher throughput. Continued development and testing will support the advancement of both systems as reliable solutions for regolith conveyance in future space resource utilization operations.