REGOLITH AS A SERVICE: ENABLING END-TO-END ISRU OPERATIONS

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Introduction: Polimak Space introduces the "Regolith as a Service" (RaaS) concept, a groundbreaking approach to support ISRU systems by delivering regolith in the right amount, composition, temperature, and condition for various lunar applications, properly prepared for their specific needs. Moreover, it supports critical functions such as thermal energy storage, enabling lunar night survival by retaining and utilizing heat stored in regolith.

The RaaS approach includes a range of modular regolith handling units, each designed for different tasks or processes. These modules can operate independently or be interconnected, depending on the specific application. This flexibility makes RaaS a powerful enabler for ISRU operations, streamlining resource management and supporting a wide array of lunar missions.

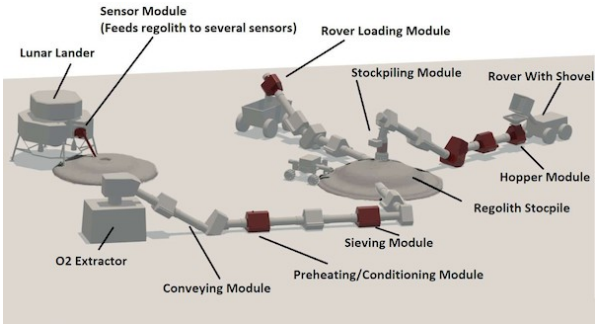

Figure 1: RaaS Concept showing wide range of ISRU operations

The key modules include:

Modular Drum Conveyor (MDC): The backbone of the system, MDC is an innovative, patented regolith transport system featuring a pipe with an integrated screw that efficiently moves regolith by allowing material to roll rather than slide. It is capable of transporting regolith efficiently in lunar conditions. Unlike traditional conveyor systems, MDC operates in low gravity and high-vacuum environments, handling the abrasive, electrostatically charged lunar dust while maintaining reliability. Its enclosed design minimizes dust dispersion, making it ideal for integration into lunar infrastructure. MDC is adaptable to various ISRU applications and can be customized for different flow rates and material properties.

Excavation Module: This module can be installed on rovers for excavating loose regolith efficiently. Its wear-tolerant design ensures continued operation even when the tip experiences wear, as its uniform shape along the axis allows for sustained excavation. The system stores collected regolith internally and discharges it as needed, enabling precise material handling. Utilizing the same MDC concept, this module seamlessly integrates with other ISRU processes.

Figure 2: Excavation module attached on a rover collecting loose regolith and feeding another MDC

Stockpiling and Storage Module: The Stockpiling and Storage Module is a crucial system for efficient regolith management, designed to receive, store, and discharge regolith for various ISRU applications. It ensures controlled deposition and retrieval, minimizing dust dispersion and optimizing storage efficiency on the lunar surface. The module features a flexible bellow system that extends and retracts to allow for controlled and dust-free deposition of regolith. As the MDC delivers material, regolith flows into the bellow, which directs it onto the lunar surface, forming a structured stockpile. As the pile grows in height, the bellow retracts, ensuring a uniform and stable formation.

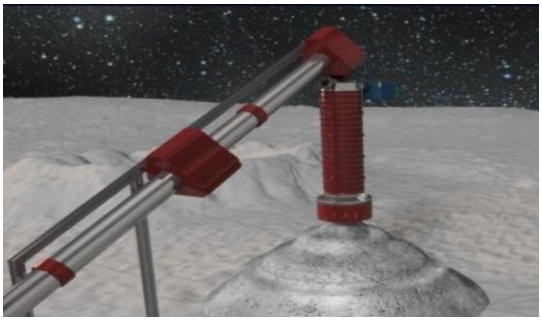

Figure 3: Stockpiling Module, receiving regolith from MDC and preparing a regolith stockpile

Sieving Module: This module is essential for particle size separation, ensuring that regolith fractions meet specific application requirements. Fine particles

are suitable for 3D printing, oxygen extraction, and other processing needs, while coarser particles are ideal for lunar construction and thermal energy storage. The patent-pending variable mesh design allows for adjustable output sizes, reducing the need for multiple sieving systems and improving processing efficiency. Its self-cleaning mechanism prevents clogging, ensuring continuous operation in dusty lunar environments.

Preheating Module: This module preconditions regolith for downstream processes by applying thermal treatment. It can utilize electric heating or concentrated sunlight via Fresnel lenses, making it an energy-efficient solution for heating regolith for oxygen extraction, volatile collection, and thermal energy storage. The preheating process helps remove contaminants such as sulfur and prepares the regolith for chemical and industrial applications.

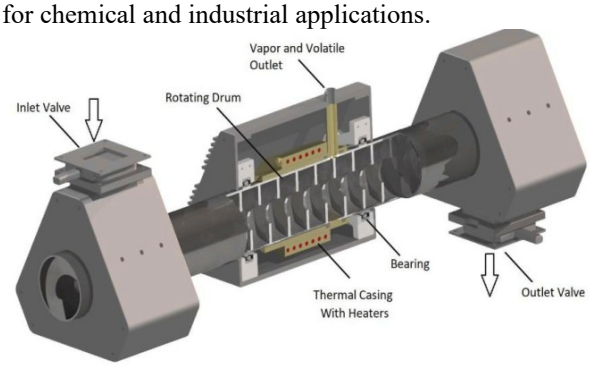

Figure 4: Preheating Module, receiving regolith from inlet valve, heating in the middle and discharging

Multi-Sensor Feeding Module: This module features several slots that accommodate various types of sensors, such as XRF analyzers, water content detectors, and particle characterization devices. It efficiently receives regolith from the MDC and transports it to the sensors in a controlled manner, ensuring even delivery while maintaining the required flow rates. Installed on lunar landers or rovers, the module eliminates costly operations related to transporting sensors to the lunar surface and feeds regolith from ground level to elevated heights. This solution offers a cost-effective approach for lunar prospecting by reducing payload costs for both academic and commercial sensor manufacturers, allowing multiple producers to share flight and lunar landing expenses. Additionally, it reduces payload weight by minimizing the number of mechanical components needed for sensor attachment, optimizing the overall design of lunar landers and rovers.

Sandbag/Flexible Structure Filling Module: This module efficiently fills sandbags or expandable fabric structures with regolith for radiation shielding, structural reinforcement, and habitat protection. The MDC delivers regolith to the filling unit, which then pushes the material inside the structures, ensuring uniform distribution and compaction for enhanced stability and protection.

Thermal Energy Storage Module: The Thermal Energy Storage Module harnesses and retains heat from high-temperature regolith, ensuring a reliable energy source during lunar nights when solar power is unavailable. By integrating with the MDC and Preheating Module, it utilizes regolith's natural thermal insulation properties to store and gradually release heat for long-duration lunar missions. During lunar daylight, the Preheating Module with Fresnel lenses heats regolith, which is then stored by the Stockpiling Module, where the outer layers act as a thermal insulator, preserving the heat. This stored energy remains available for heating systems, power generation, and other ISRU processes. When needed, the MDC transfers the heated regolith, enabling efficient heat utilization through thermal conduction or fluid-based heat exchange.

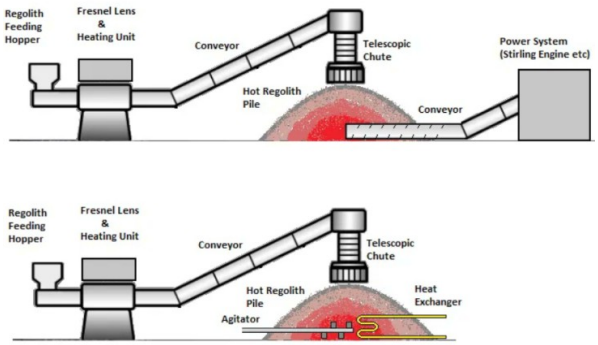

Figure 5: Two configurations of thermal energy storage system

Processing Module: This system consists of interconnected MDC-type components designed for end-to-end processing of both liquid and powdered materials. The sequence and configuration of each component can be customized for various applications. It supports functions such as sieving, mixing, coating, thermal treatment, and gas extraction, enabling ISRU applications like mixing regolith with additives for construction, sintering, phase changes, chemical reactions for resource extraction, and biomining to extract valuable minerals and metals from regolith. Its scalable design is essential for sustainable lunar resource processing and space-based applications, including pharmaceutical, medicine, and drug production in microgravity environments like the ISS.