Sintering of Lunar Regolith for Roads

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Introduction

- Lunar regolith is highly abrasive and poses significant risks to astronauts and equipment, tending to stick to materials, cause severe abrasion, or wear down and puncture materials.
- There is a need for hardened infrastructure to support lunar habitation, such as roads and landing pads.

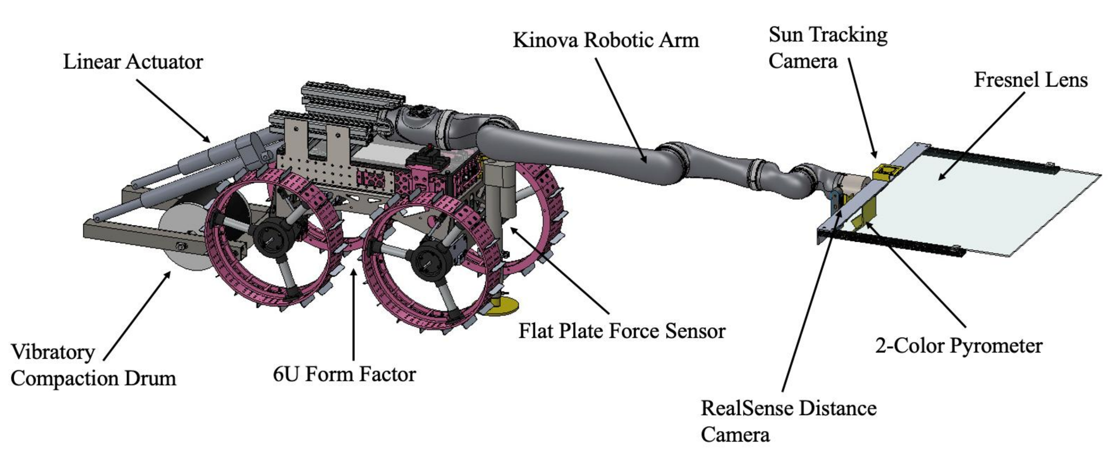

Fig. 1: System-wide CAD rendering.

Scope of Work

- **Project Goal:** Design, develop, and validate a rover-based prototype to create durable, sintered road surfaces from lunar regolith.
- **Method:** Utilized concentrated solar energy for in-situ resource utilization (ISRU) infrastructure to mitigate abrasive regolith hazards.
- **Limitations:** As a prototype focused on end-to-end system validation, full flight operations were not considered.

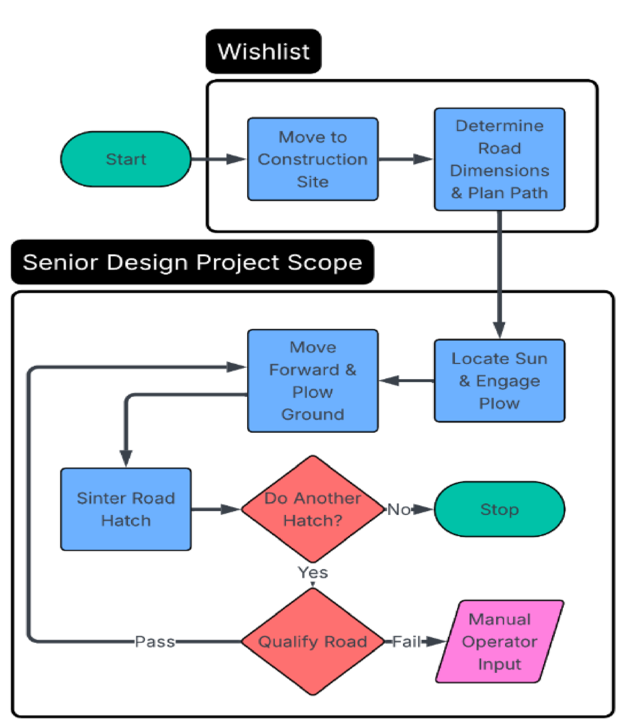

Fig. 2: Project scope.

Prepare

- **Excavator Subsystem:** Utilized a rake and roller combination to compact and level the regolith in a single pass.
- **Rake:** Mounted at the front of the rover to distribute regolith and improve material workability.
- **Roller:** Followed the rake and is attached via a frame and two linear actuators.
- **Vibratory Motor:** Located inside the roller to increase regolith packing density.

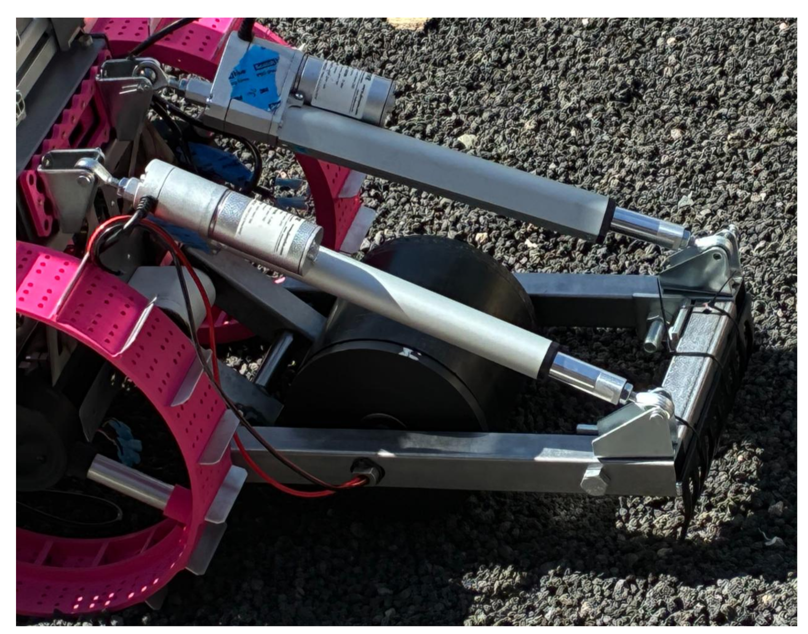

Fig. 3: Final excavator blade hardware on rover.

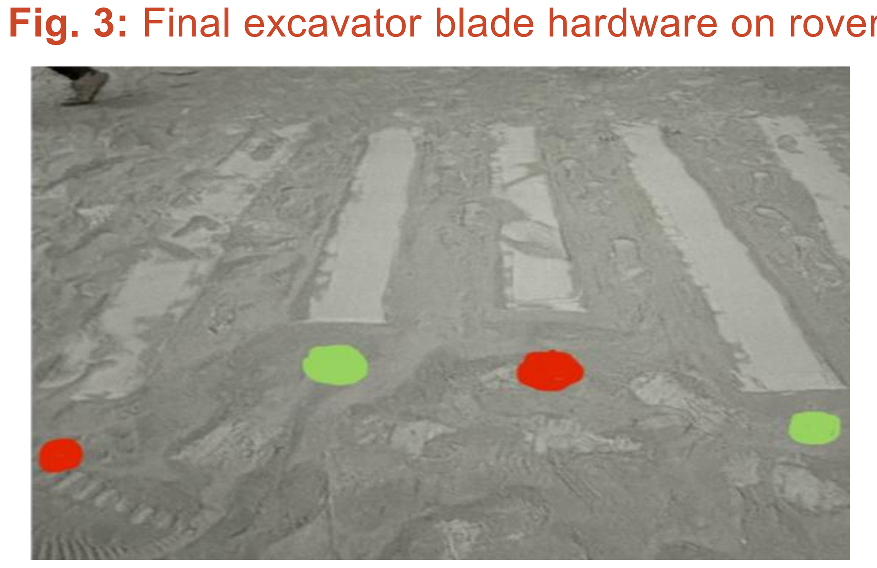

Fig. 4: Alpha excavator flattening test results.

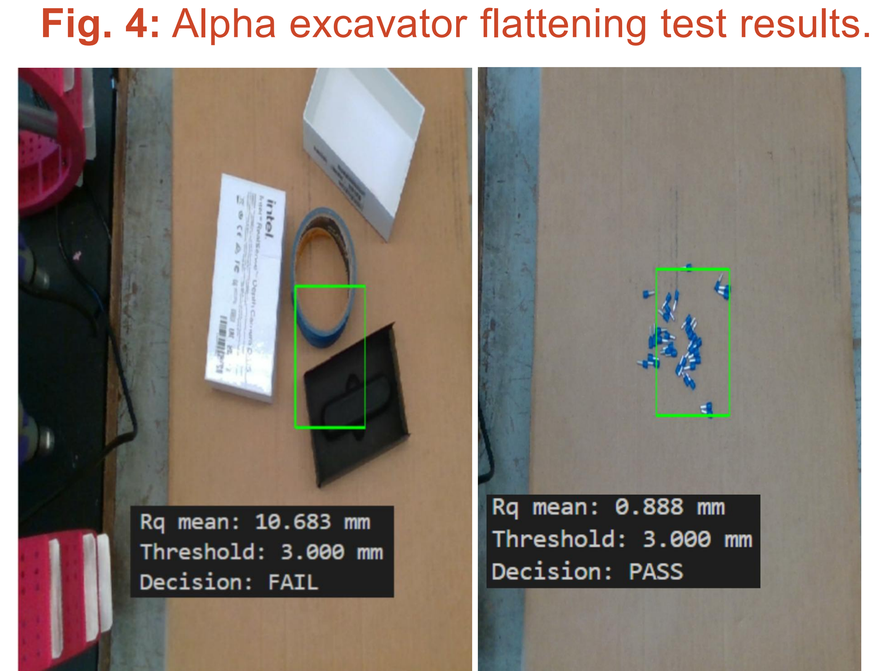

Fig. 5: 3D-depth image taken from the arm during a test.

Sinter

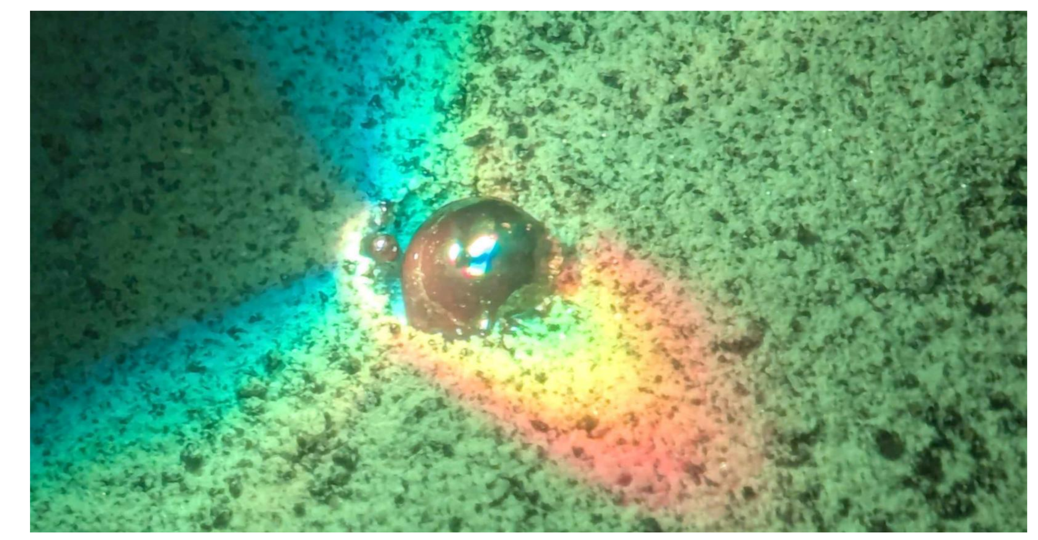

Fig. 6: Sinter melt test of lunar regolith.

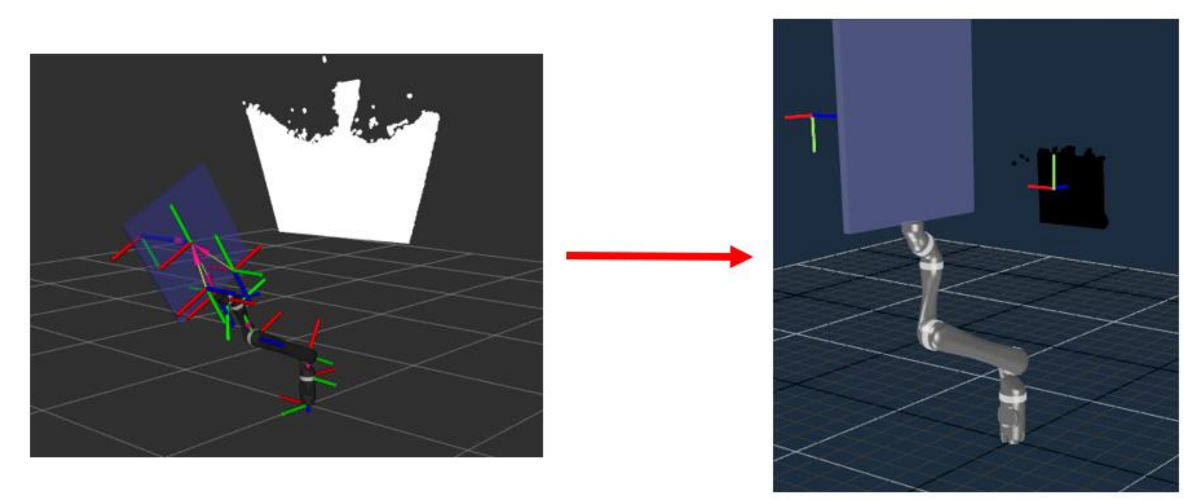

Fig. 7: Control interface that commands the system. Demonstrates point cloud sensing.

- **Arm and Sinter Subsystem:** Features a 6-Degree-of-Freedom robotic arm mounted on the rover chassis.
- **End-Effector:** Maneuvers a custom mechanism holding a Fresnel lens to concentrate solar flux onto the prepared surface.
- **Control System:** Operated via ROS2 MoveIt Pro.
- **Sensors:** Utilizes a sun tracking camera and a RealSense depth camera to guide pathing.

Fig. 8: Straight line sintered sample.

Evaluate

- **Temperature:** A two-color pyrometer takes melt-pool temperature readings.
- **Surface Roughness:** A stereo camera evaluates the sintered surface.
- **Soil Testing:** Uses a flat plate for testing prepared soil.
- **Qualification:** Conducts a compressive test to qualify the sintered road segments.

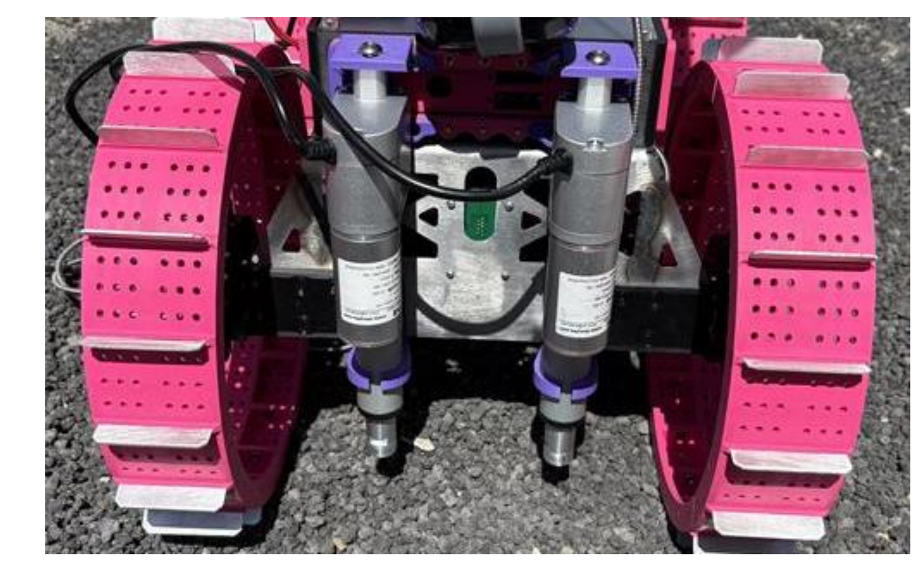

Fig. 9: Monitor suite testing suite.

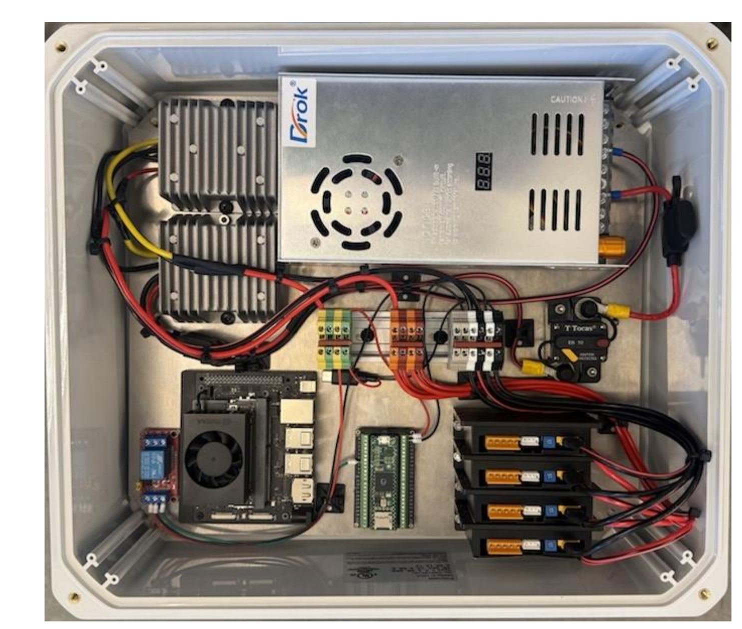

Fig. 10: Auxiliary avionics system to support subsystems

Conclusion

- **Feasibility:** The SOLAR prototype validates the mechanical, thermal, and control feasibility of a mobile solar sintering platform on a small-form-factor rover.
- **Scalability:** The small package allows for lower launch and maintenance costs. The system can be scaled into swarms to build expansive infrastructure for lunar habitation.

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