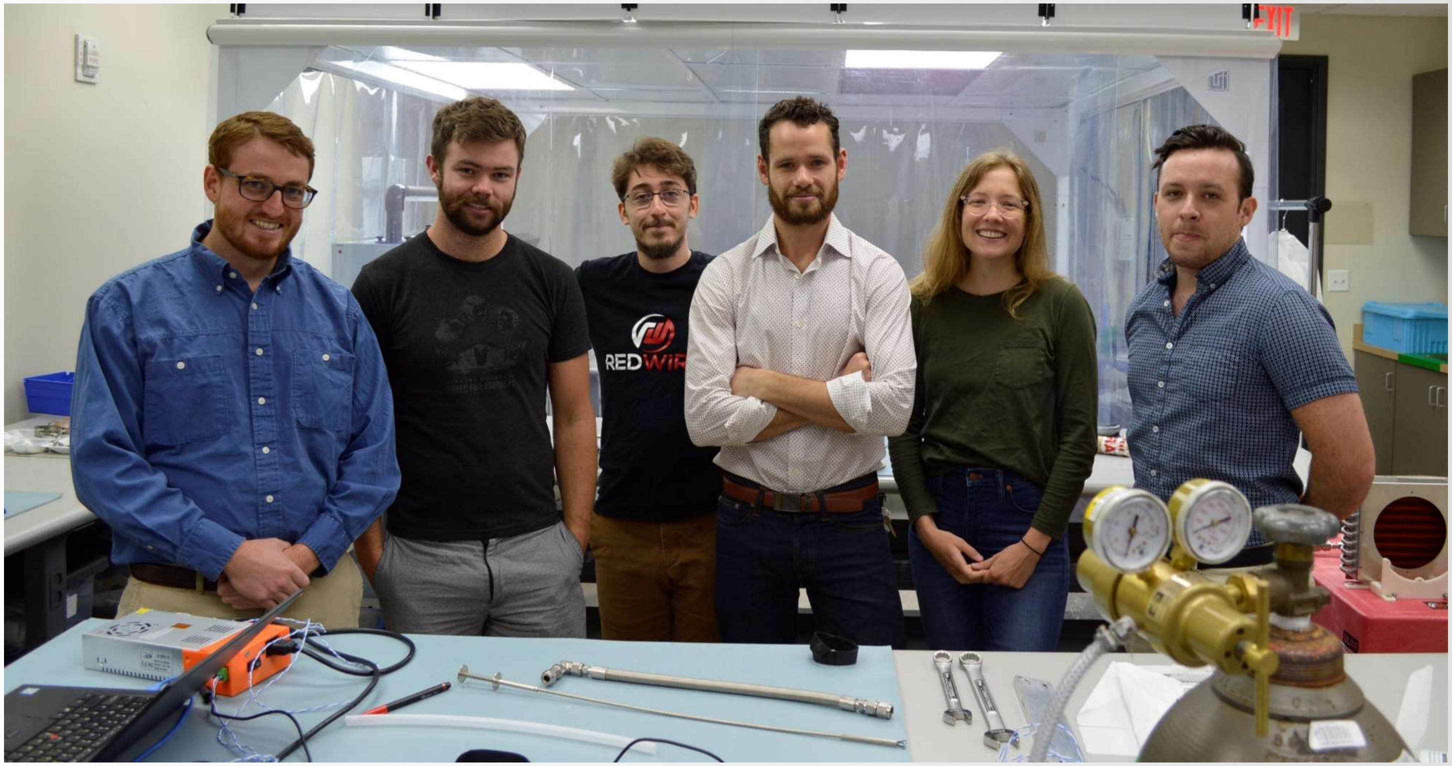
REDWIRE

POC: Elon Gordon

NASA Break the Ice Challenge: Redwire Submission

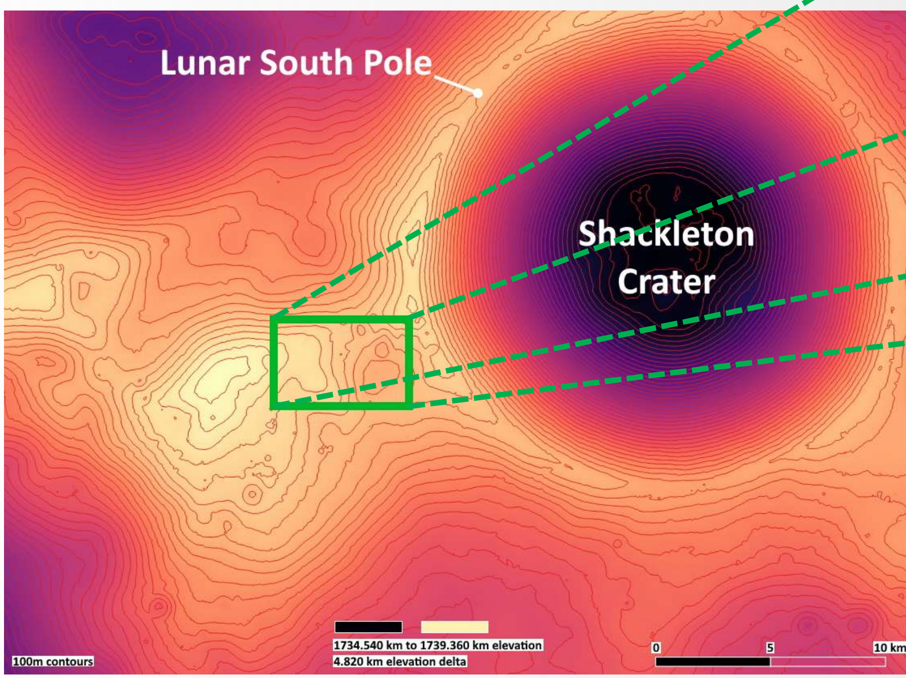
Redwire Team

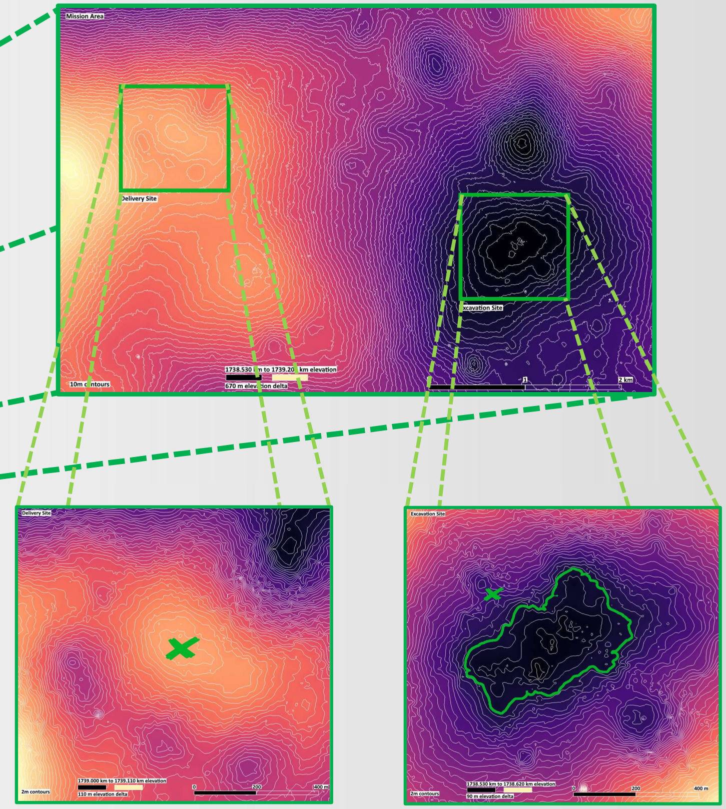


From L → R: Kevin French (Robotics & GNC), Dash Kieler (Animation), David Evinshteyn (Power), Elon Gordon (Team Co-Lead & Mechanical Design), Kari Abromitis (Team Co-Lead & ConOps), Dylan Pendlebury (Mechanical Design)

Introduction – Mission Site & Problem Statement

Goal: Extract at least 10,000 kg of water from the PSR at Artemis Site 001, while minimizing landed mass and power consumption

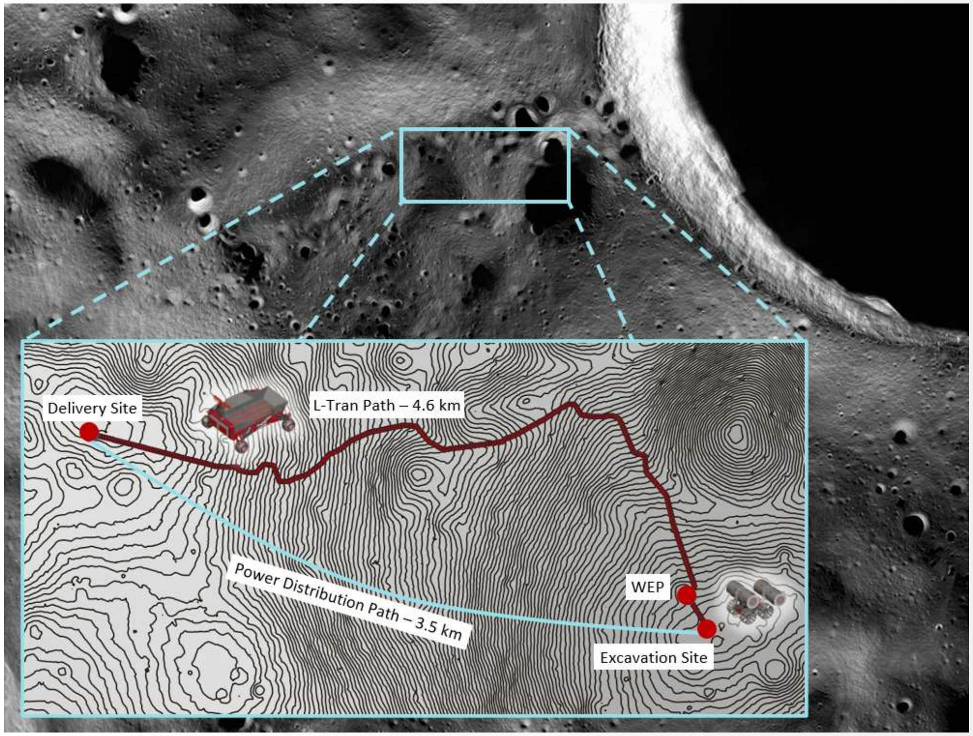




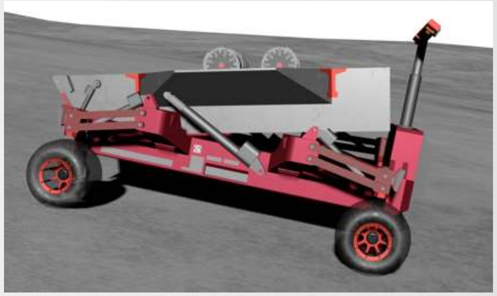
Architecture Overview

We utilized NASA's water extraction architecture and focused on specialized tools for regolith excavation and multi-material transport

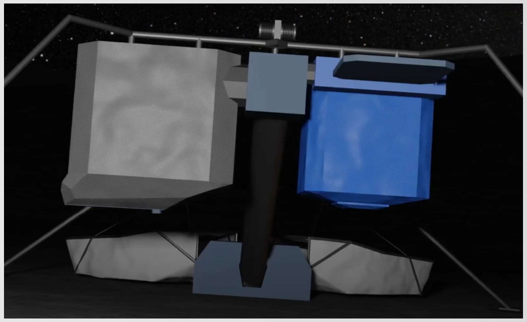
Approached the architecture with simplicity & robustness in mind



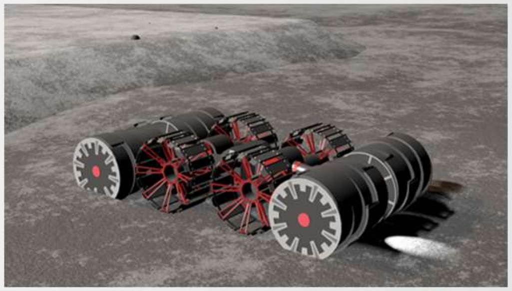
L-Tran (Lunar Transporter)



WEP (Water Extraction Plant)



L-REx (Lunar Regolith Excavator)



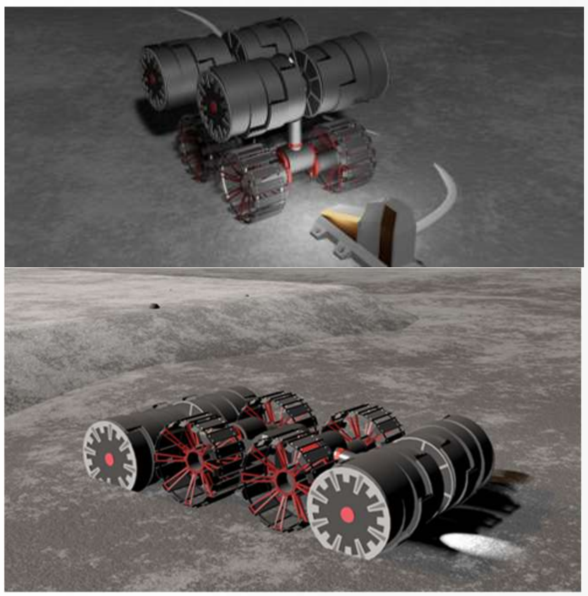
Architecture Elements

L-REx (Lunar Regolith Excavator)

Dual Bucket Drum Excavator (Based on NASA's Rassor)

Optimized for short trips into and out of the excavation site.

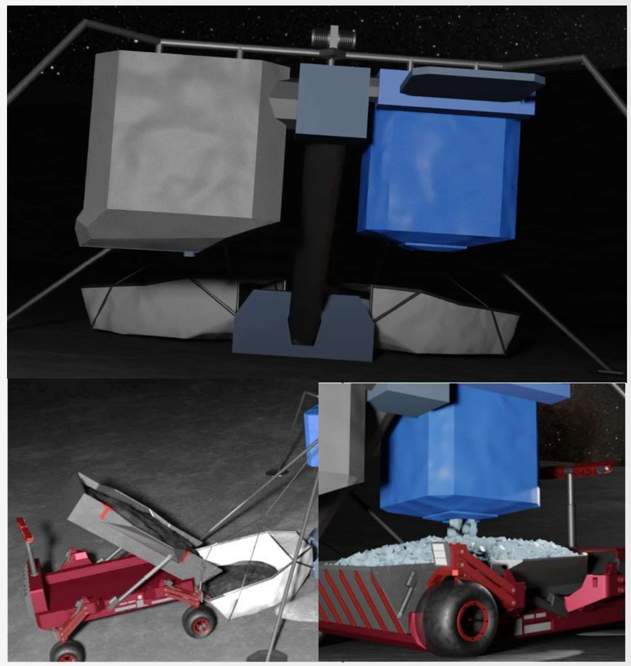
Conceptual modifications for higher wear-resistance, cold temperature survivability, and launch survivability were considered.



WEP (Water Extraction Plant)

To be developed by NASA

The image below is Redwire's depiction of what that would look like, with requested interfaces.

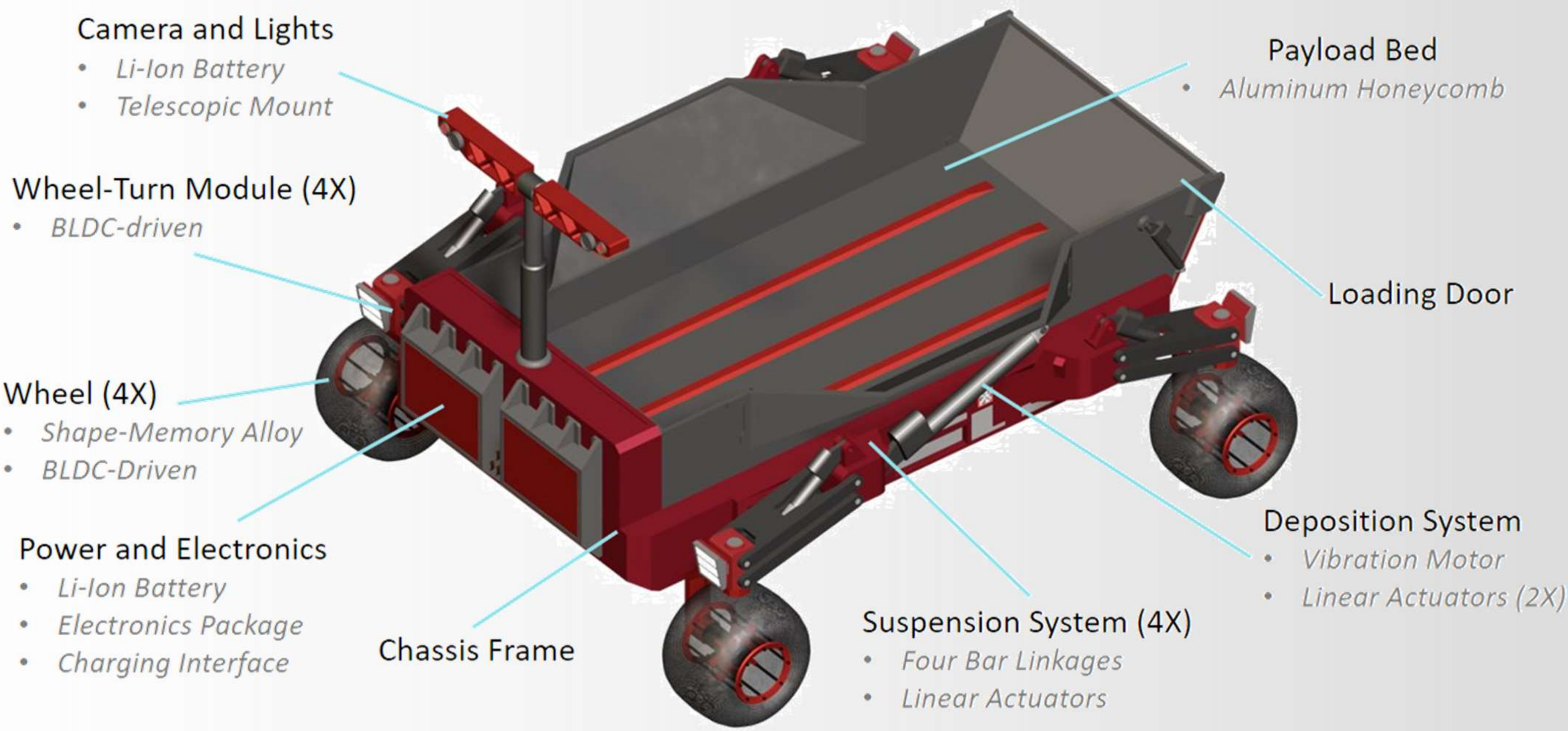


L-Tran (Lunar Transporter)

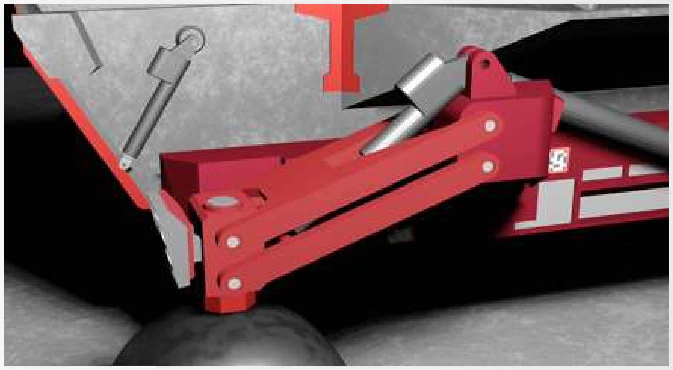
Long-distance transporter

Optimized for long-distance high-load transport over rocky surfaces and steep inclines

L-Tran Overview



L-Tran Actuation Systems



Four-Bar Linkage Suspension

L-Tran's four bar linkage system enables

- *Cross-slope roll compensation up to 16 degrees*
- *Up-Slope pitch compensation up to 17 degrees*
- *Bed leveling over rough terrain*

Deposition System

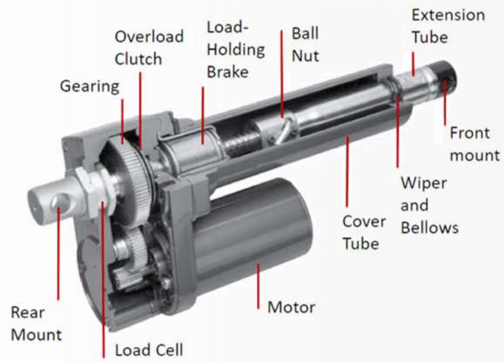
L-Tran's four deposition system enables

- *Up-Slope Pitch compensation up to 50 degrees*
- *Regolith and Ice Dumping capabilities*
- *A hopper door for regolith loading and unloading*

L-Tran – Deposition System

Linear Actuators

- *Encoders that track position are modified to be more robust for the space environment*
- *Load holding brakes are utilized to mitigate the continuous torque requirements, and thus power requirements on the motors*
- *Multi-layer seals are used to ensure that actuators are dust-proof*
- *Solid film lubricants are used to improve subsystem durability at low temperatures*
- *Standard interfaces and components for modularity*



Linear Actuators

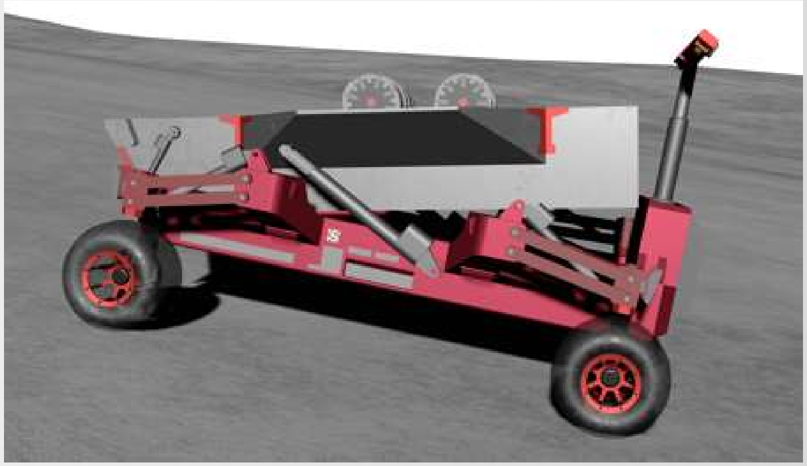
Wheels

Wheels

- *Nitinol Shape Memory Alloy based from NASA Glenn research prototype*
- *Extremely high load capacity (5.8kN +)*
- *Low Load requirement (1.3 kN per wheel)*
- *Tested to 10 km with no damage*

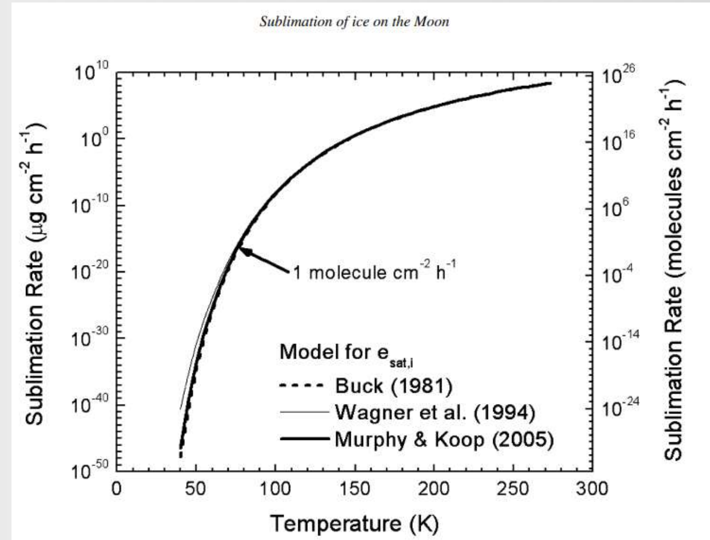
Guidance, Navigation, and Control (GNC)

- *Utilizes a "hammerhead" deployable visual system to provide 3D mapping of environment.*
- *Includes LIDAR and visual hybrid navigation system*
- *Range of 20-30 m*
- *Utilizes Simultaneous Localization and Mapping algorithm (SLAM)*

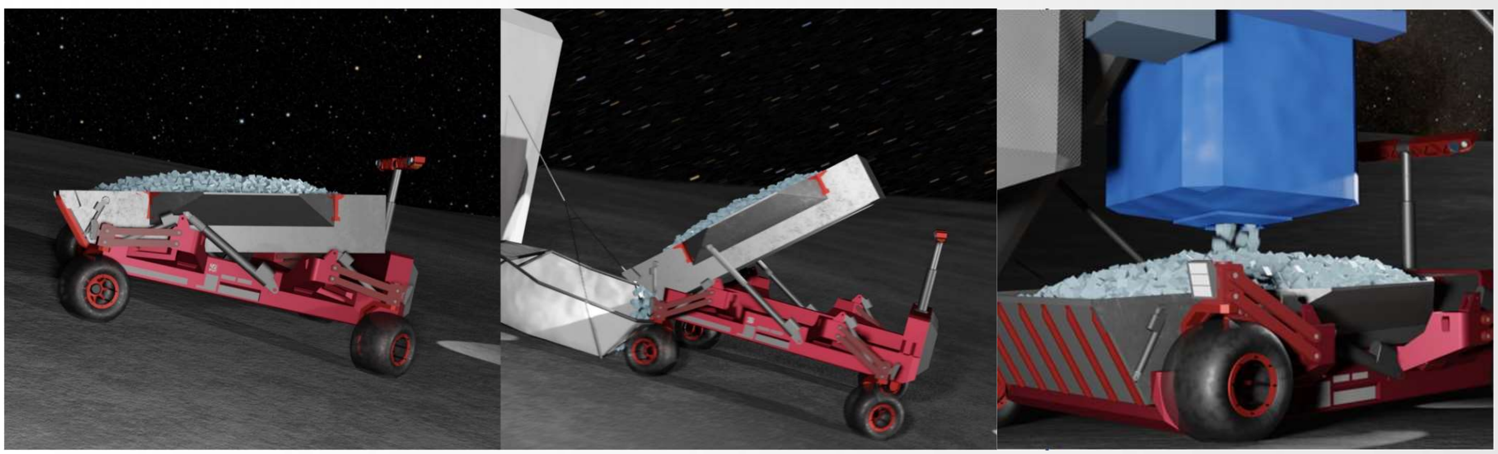


Ice Transport & Sublimation Risk

- *The Redwire team built a model to show that sublimation was negligible with the open-bed design.*
- *Sublimation only resulted in ~2 grams of water loss per trip*
- *Time in sunlight = 3.44 hours | Water loss in shade is negligible*
- *Sublimation was highly dependent on ice chunk size*
- *Low incidence angle of the sun at the poles reduces amount of energy absorbed by ice*

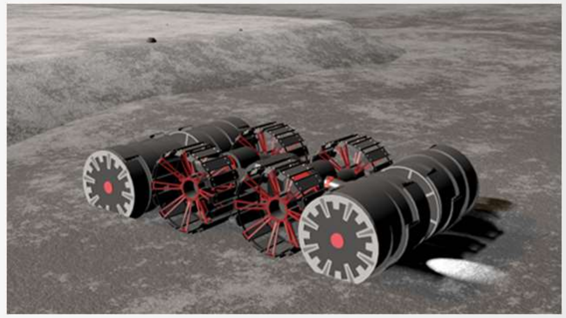


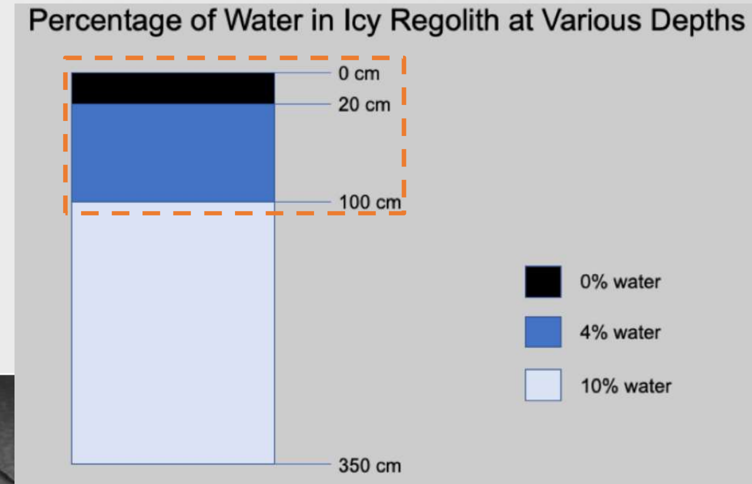
Model Based on Andreas, Edgar L. "New Estimates for the Sublimation Rate for Ice on the Moon."

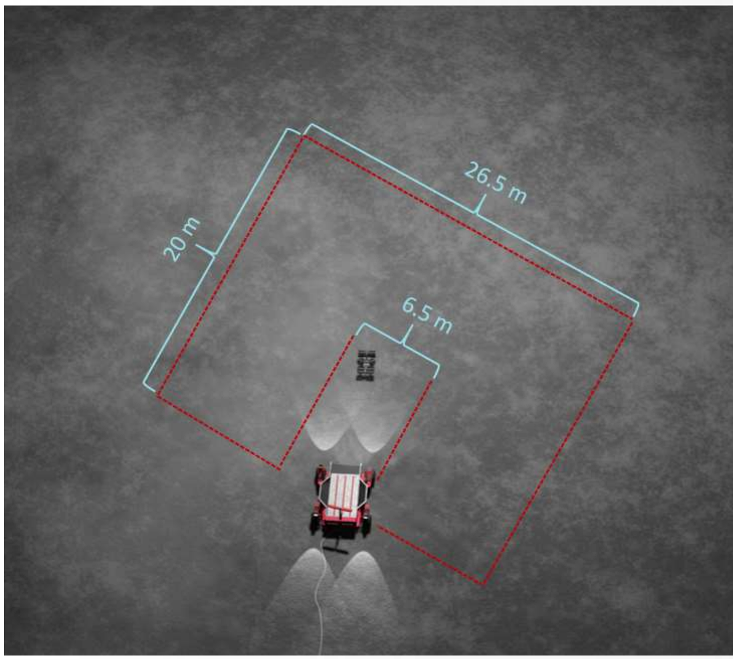


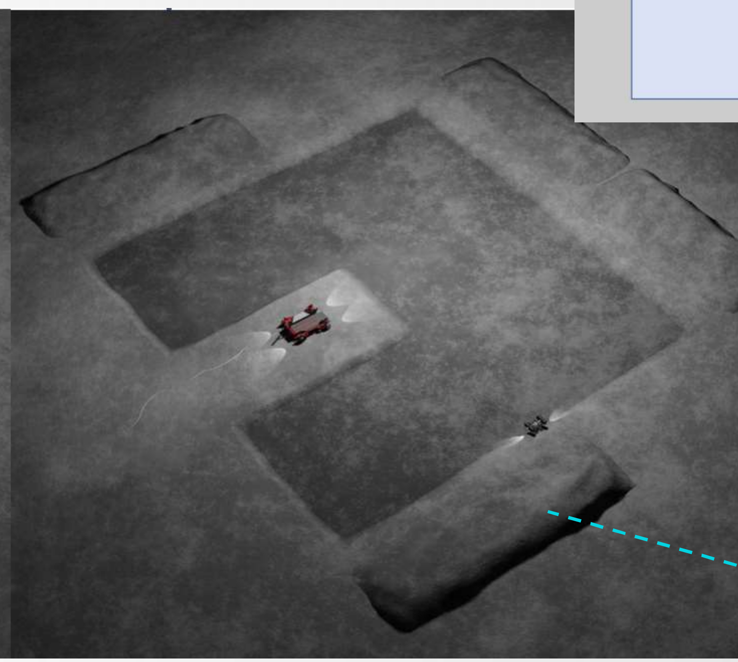
Excavation Site

We decided to target regolith with 4% water content due to the increased energy, complexity, and/or infrastructure required to extract an equal amount of water from the regolith with 10% water content.









4. Compressive Strength:

- For regolith with 4% H_2O: 1.5-2 MPa
- For regolith with 10% H_2O: 20-35 MPa

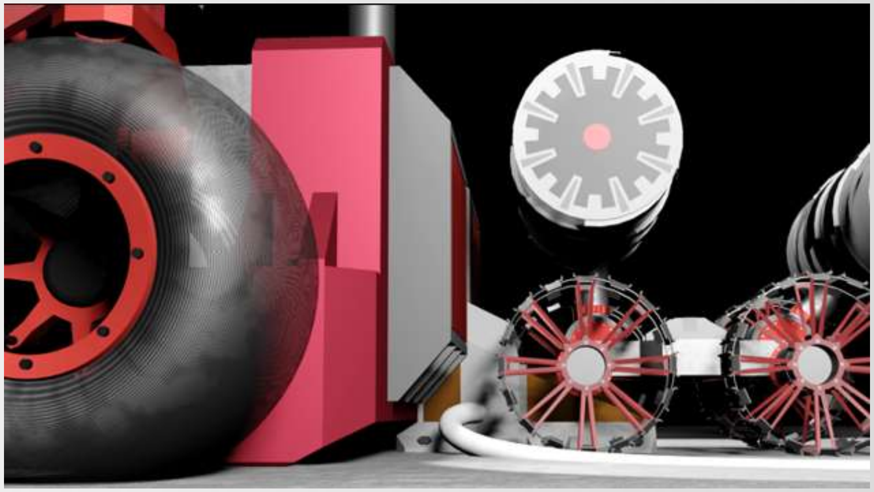
5. Tensile Strength:

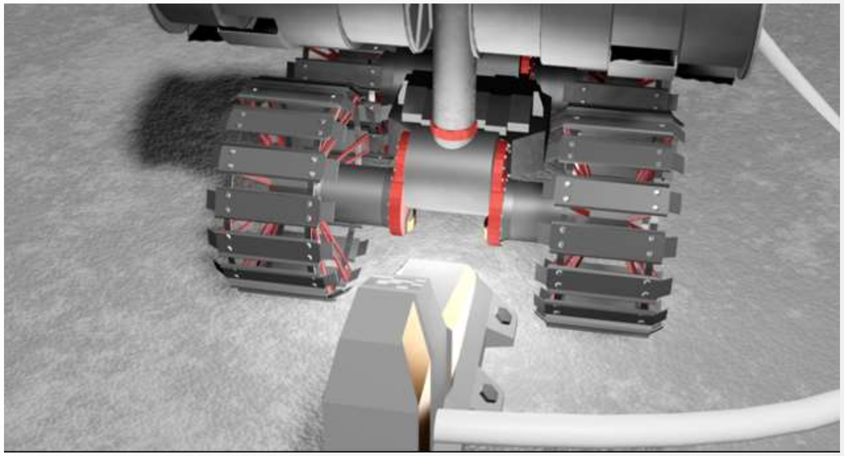
- For regolith with 4% H_2O: 0.40-0.55 MPa
- For regolith with 10% H_2O: 10-12 MPa

Mounds of 0% Regolith from upper 20 cm

Charging Architecture

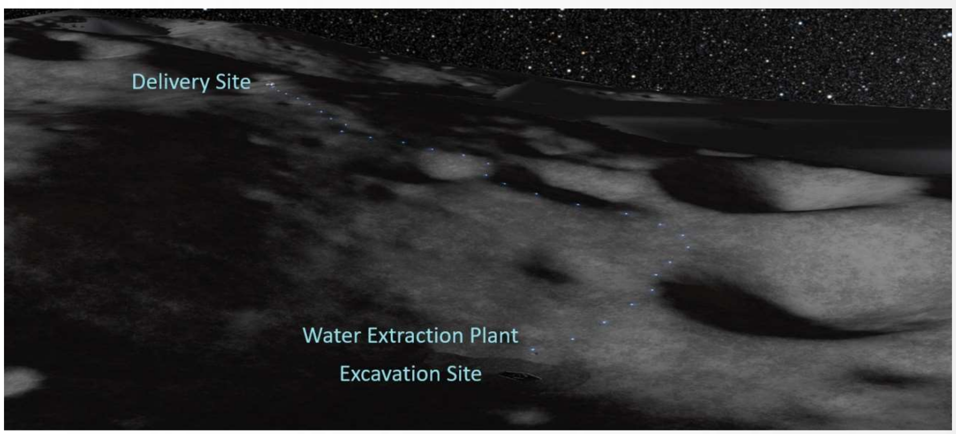
- *Operational charging occurs at excavation site, due to amount of downtime for both rovers in the CONOPS*
- *Conductive pads selected over WPT (Wireless Power Transfer) due to increased efficiency and tolerance to misalignment*
- *Vertical orientation, electrostatic charging, and high-lubricity coatings to minimize dust buildup*
- *Rover Batteries: Li-Ion Batteries (11.8 kWh for L-Tran and 1.5 kWh for L-REx)*





Route

Maximum Slope Requirement	13°
Maximum Flat Bed Slope Capability	50°
Water Transport time (hours)	6.7
Total Transport distance	780 km



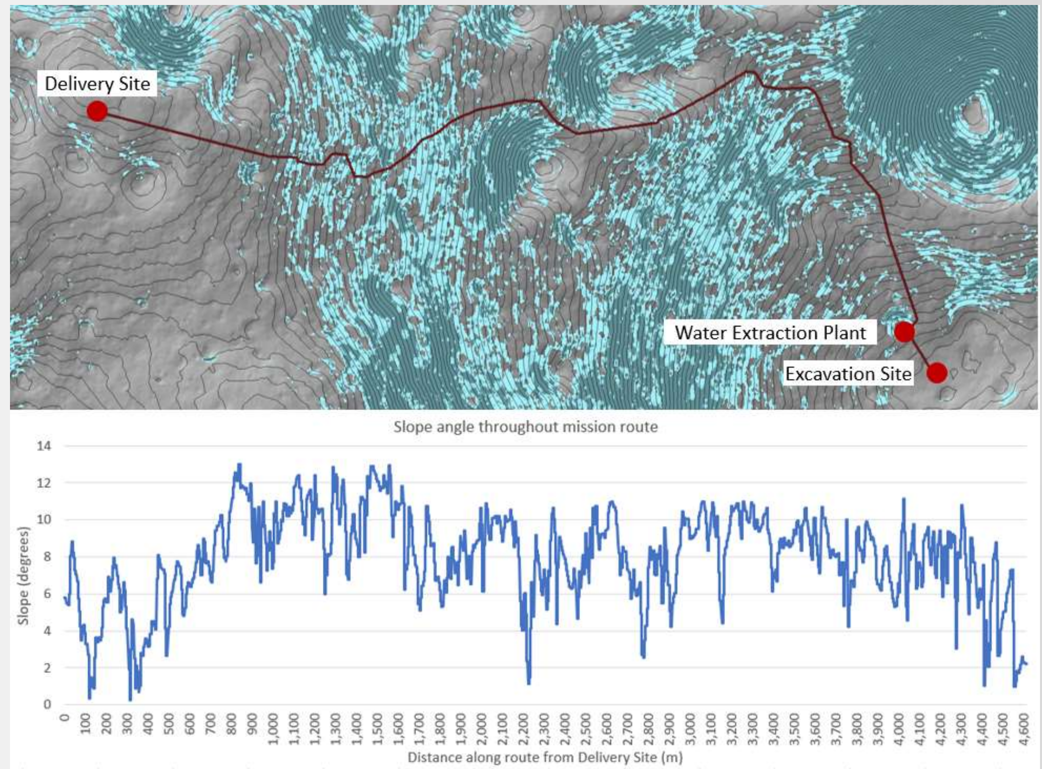
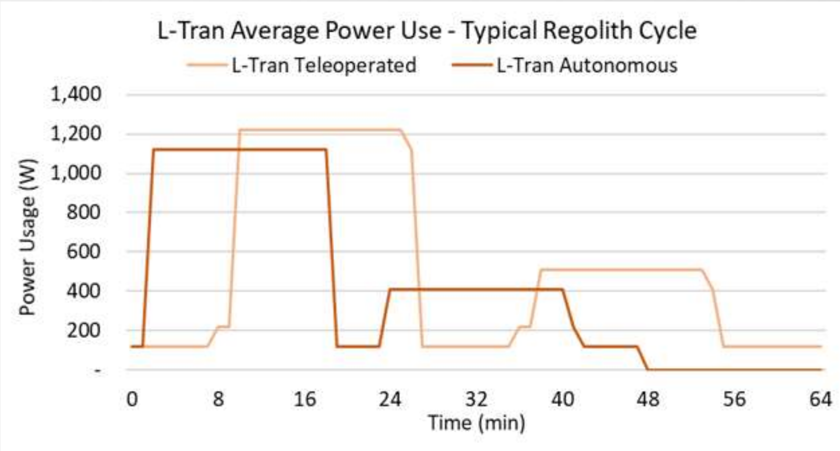
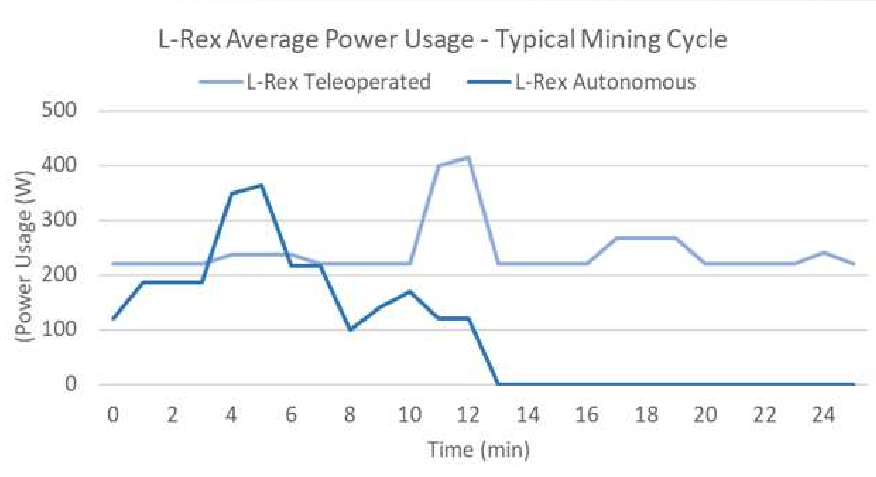


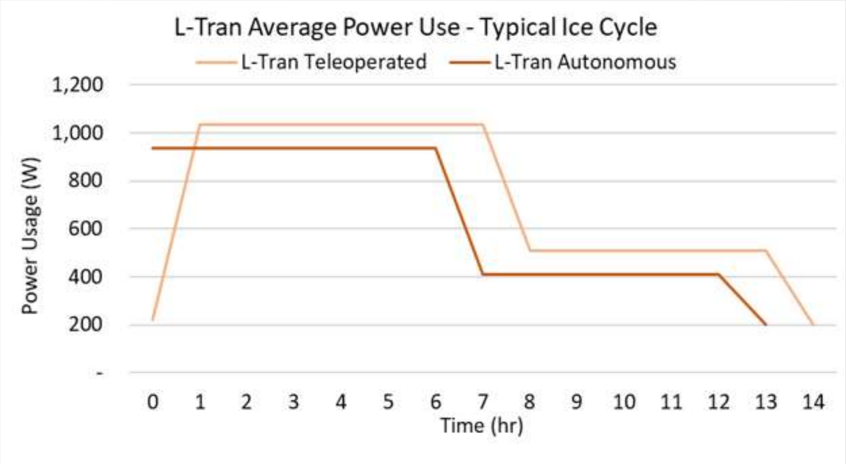
Figure 13: Mission path between DS, WEP, and ES over 4,617 m (top) and slope throughout mission path (bottom).

Energy Consumption

Energy consumption depends, significantly, on whether the mission is run autonomously or is teleoperated, due to the amount of power required by the downlink from a high-gain antenna. Redwire's architecture can be teleoperated or run autonomously.

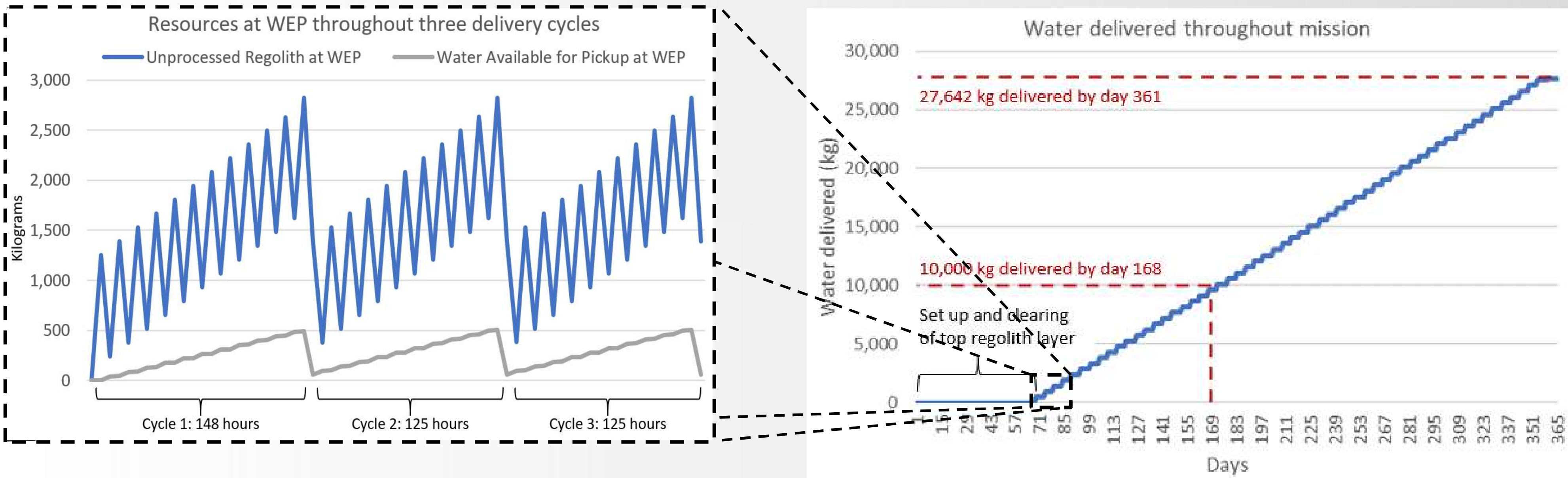






Performance Metrics

Summary Statistics	
Water Delivered (kg)	27,642
Landed Mass (kg)	1,303
Energy Consumed (kWh)	1,743
Ratio of Water Delivered to Landed Mass	21.2
Ratio of Water Delivered to Energy Consumed (kg/kWh)	15.9



Architecture Trade Study

Architecture	Systems Examined	Trades Performed
Excavation	Bucket drum, bucket ladder, percussive scoop, percussive plow, dragline, auger drill, roadheader, explosives, hydraulic wedge, and jackhammer	Excavation rate, depth of excavation, mass, power consumption, CONOPS complexity, regolith handling, dust interaction, mining forces, mechanical risks, thermal risks, and maintenance
Transport	Rover-based, duaxel cable climber, ISRU rail/road climber, coil car, cable car, ballistic launch, and pipeline	Throughput, mass, power, CONOPS complexity, dust tolerance, mechanical risk, thermal risk, maintenance, and reliability