DEPARTMENT OF AEROSPACE ENGINEERING

SCORPION

Servicing Crane Outfitted Rover for Payloads, Inspection, Operations, N'stuff

A. JAMES CLARK SCHOOL OF ENGINEERING

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Problem Definition

Assist in base development and sustainment on the lunar surface by designing a small rover for the purpose of performing autonomous and controlled servicing missions.

Preparation is Completed	Launch and Elliptical Orbit	Transfer Orbit Insertion	Circular Lunar Orbit	Landing and Primary Mission
10/18/2029	5/3/2030	5/3/2030	5/21/2030	6/5/2030-2035

Design Calculations & Analysis

System Details

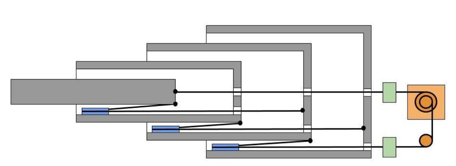
Cost Estimate	R&D/Testing: $456.1 M	First Unit Cost: $371.3M	Flight Cost: $458.4M	Break Even: 1.25B-2.5 Years

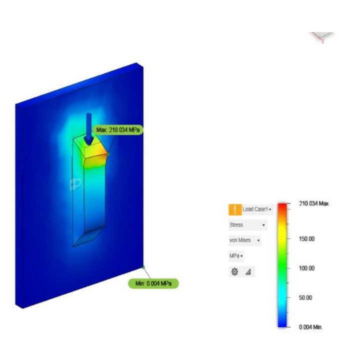
Mass Budget	Total: 375 kg		Power Budget			Absolute Mass Limit: 500 kg	Travel speed: 0.5 m/s
Structures and Mechanisms: 120 kg	Power, Propulsion, and Thermal: 220 kg	Avionics: 35 kg	Actuators: 300 W	Power, Propulsion, and Thermal: 800 W	Avionics: 200 W	Op Temps: -250C to 120C	Min Comm Range: 2 km

Chassis and Manipulators

Crane

- Payload capacity of 300kg at maximum reach
- Cable drive for crane extension minimizes weight, outer baffle for lunar dust mitigation improves lifespan
- Beam structure formed from carbon fiber composite, ω_n=1.12Hz, loaded tip sag=3cm
- Beam segments slide on MoS2 coated plates for increased reliability over roller bearings

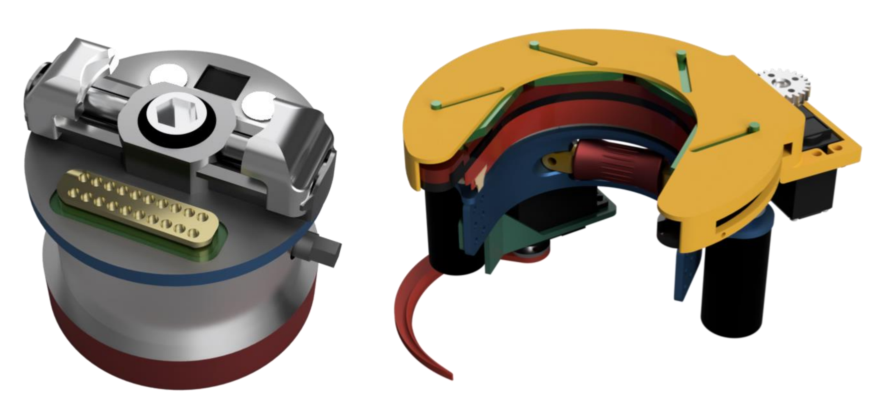




Contact Plate Loading

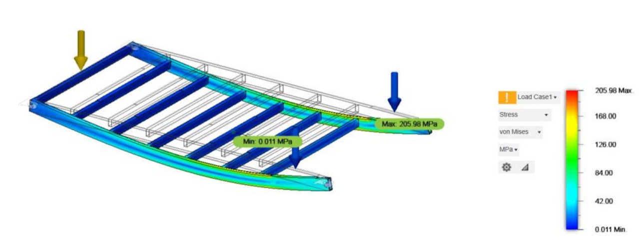
Manipulator Arms

- Dual 7-DoF Arms: The UMD Dymaflight
- Interchangeable tool-tip mechanism
- Dedicated tools for screwing, plugging in cables, cleaning, welding, inspecting, brushing



Chassis

- 2x1.3m platform
- Extendable jacks isolate suspension when lifting
- Payloads connected to the bed via 2.756"x2.756" ExPA bolt pattern



Chassis Under Launch Loads

Power, Propulsion, and Thermal

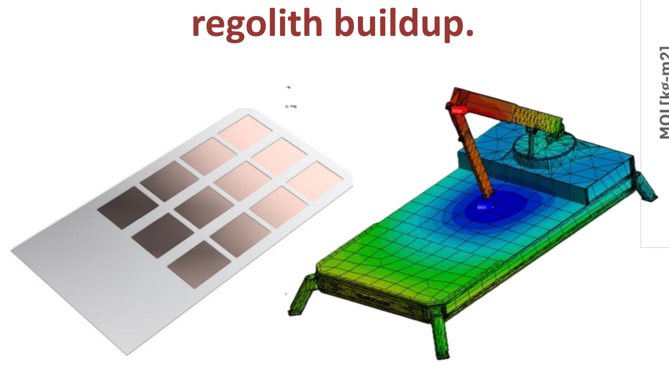
Battery and Electrical Systems

Two custom batteries based off space-rated SAFT MP176065 XTD INT cells.

- Nominal Voltage: 47.5 V
- Nameplate Capacity: 55.3 Ah
- Nameplate Energy: 5300 Wh
- Continuous Power: 2630 W
- Cell Configuration: 13S10P
- Mass: 17.6 kg

Lunar Regolith and Thermal Analysis

High Voltage Electrostatic plates helps to reduce undercarriage regolith buildup.

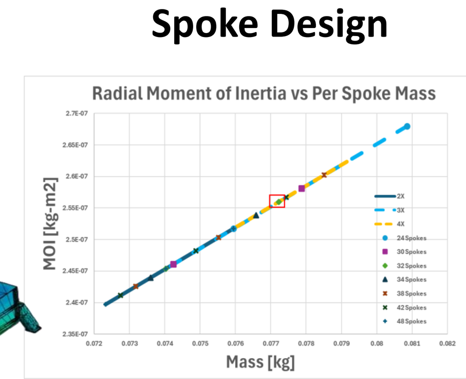


- 12 capacitor blankets, paired with a brush tooltip, reduce regolith buildup by 98%
  - Ensures optimal thermal performance
- Smart heater and MLI use, as well as variable emissivity coatings helps keep maximum heater power under 300 W

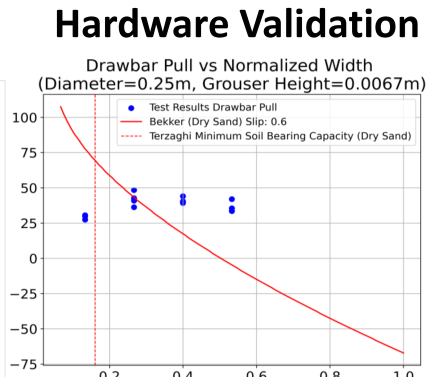
Wheel Design

Novel method to minimize mass pairing Bekker's equations and battery weight

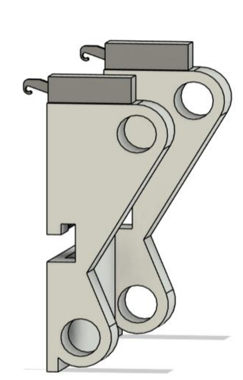
Spoke Design



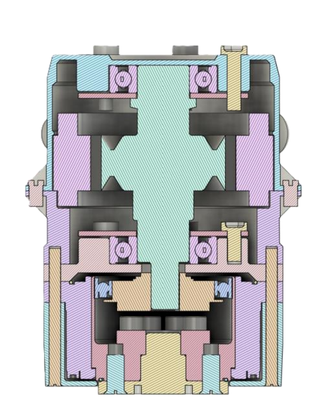
Hardware Validation



Final Wheel



Suspension Mount Bracket



Drive Motor Cross-Section

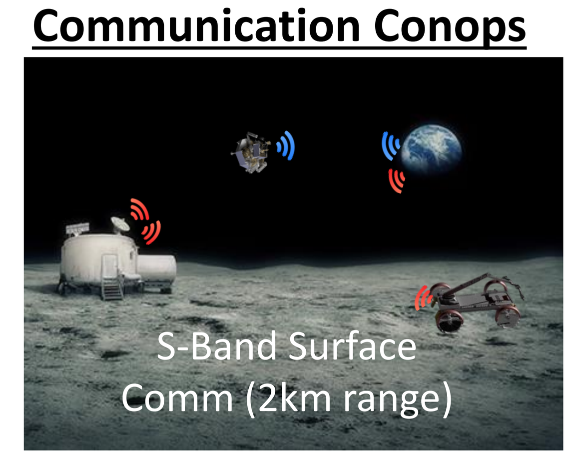
Motors and Suspension

- Custom designed 48V motor with integrated strain-wave drive.
- Astronaut and rover serviceable two-fault tolerant double-wishbone suspension.
  - Spring Constant: 1800-2000 N/m - Damping Constant: 700-800 kg/s
  - Custom 85 N-m steering actuators integrated into assembly.

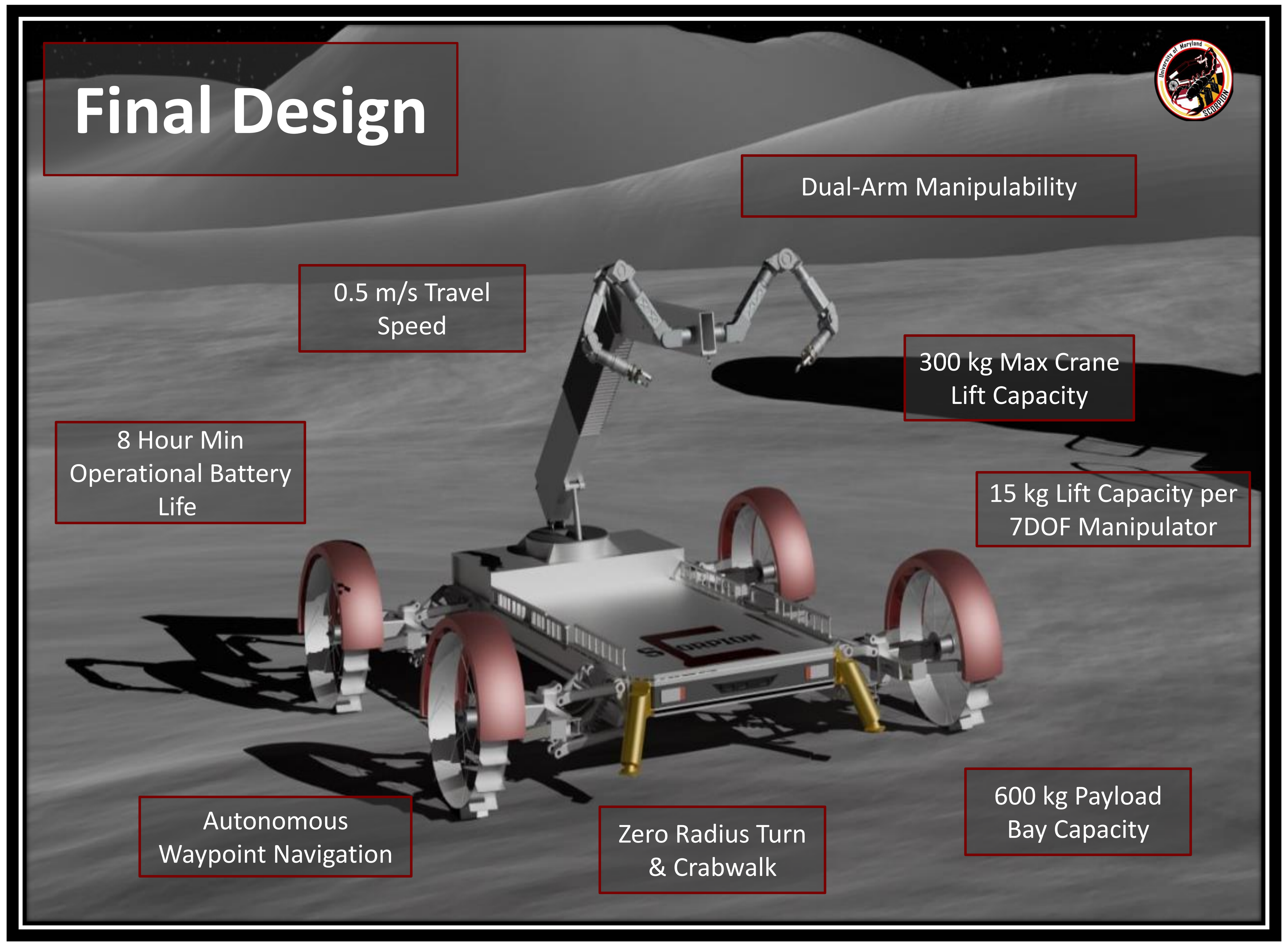
Avionics

- FPGAs motor control in an SPI interface receiving directions from a CPU
  - Optimized performance and clock time
- Rover simulated in Gazebo
- LiDAR based SLAM for position estimation and mapping with inconsistent lighting
  - NASA's Space Qualified Rover LiDAR (SQRLi) mounted on front face of chassis
- Obstacle detection done using LiDAR and cameras

Communication Conops



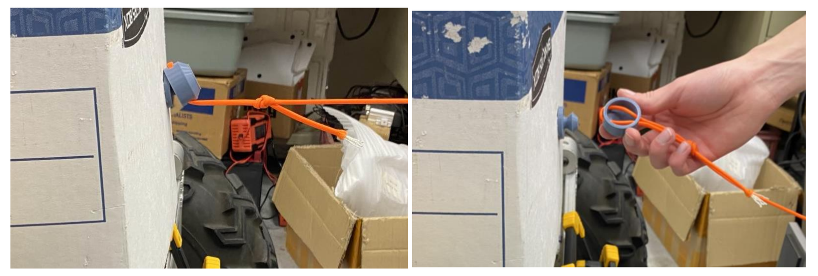
Final Design



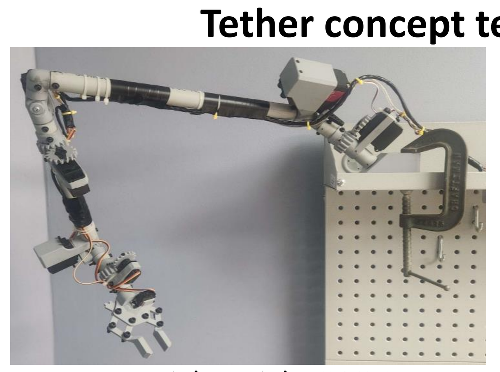
Prototype & Test Results

RAVEN

- UMD SSL testbed for lunar rover testing
- **Payload/umbilical manipulation**
  - SAWYER arm mounted on rover bed
  - Payload tether system tested and proven infeasible
  - Umbilical connector analyzed
- **Crane mockup testing**
  - 50% scale telescopic crane and full scale, low capacity 6DOF arm constructed for workspace analysis
  - Human factors analysis for operations with astronauts



Tether concept testing

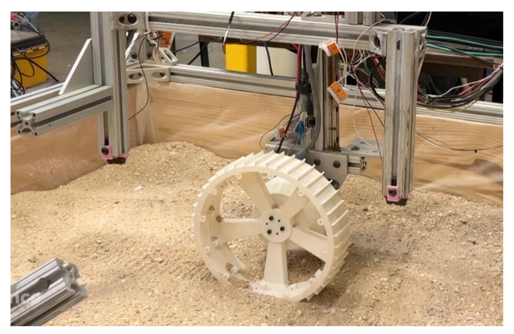


Lightweight 6DOF arm

RAVEN with attached crane

Wheel testing

- 1/3 scale wheel testing in the UMD SSL wheel rig
- Modular width design allowing for various test samples
- Setup with realistic slip conditions in mind, drawbar pull results were verified according to theoretical model



Wheel Hardware Testing

SAWYER arm on RAVEN

Motor mockup

- 1-to-1 scale 3D-printed drive motor paired with metal hardware to show ease of assembly/disassembly for maintenance, real life geometric reference

Left: Deconstructed model
Right: Assembled model