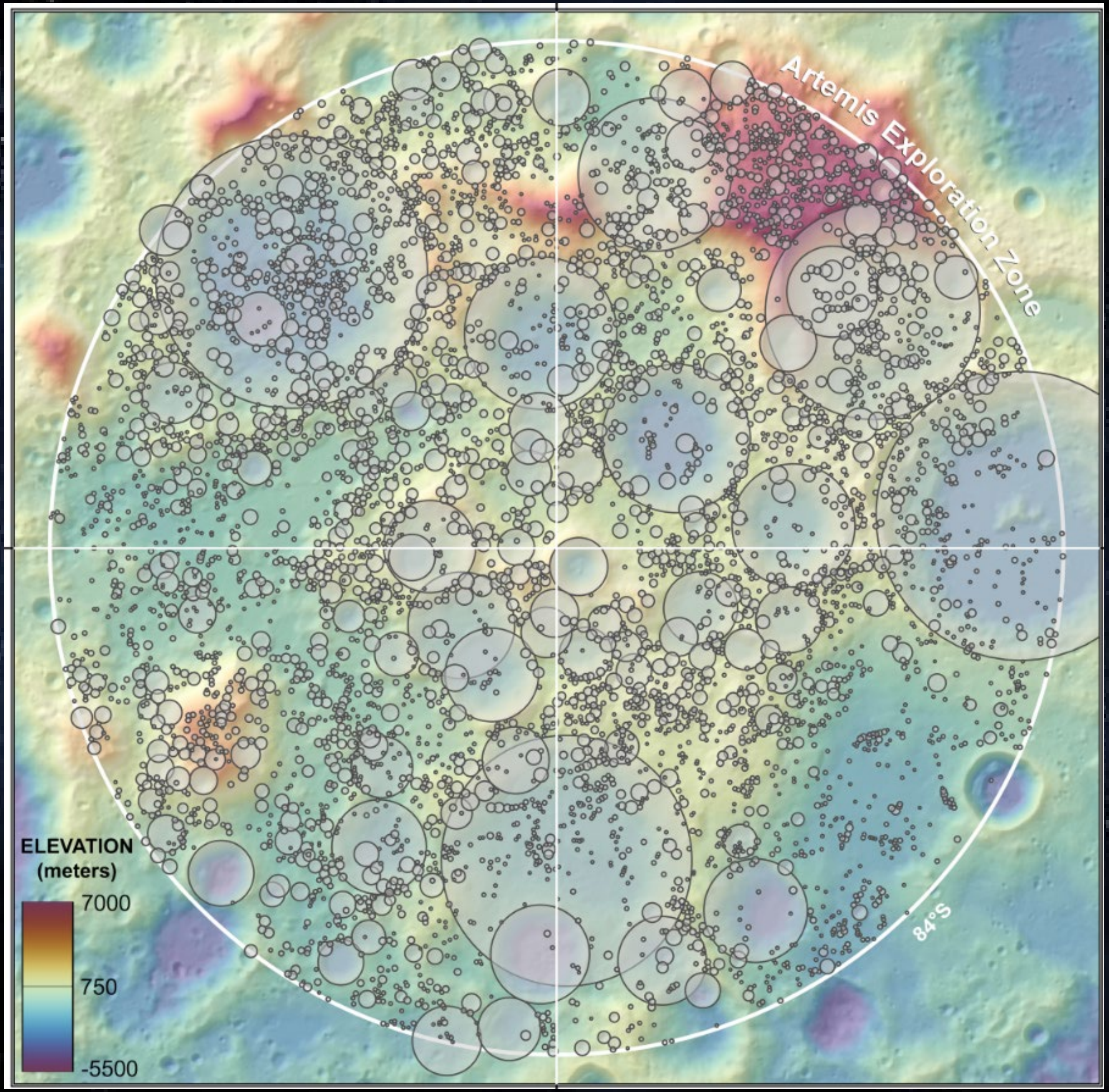
THE PROBLEM

The Moon has varied Topography. How do we move a dozer to solve that?

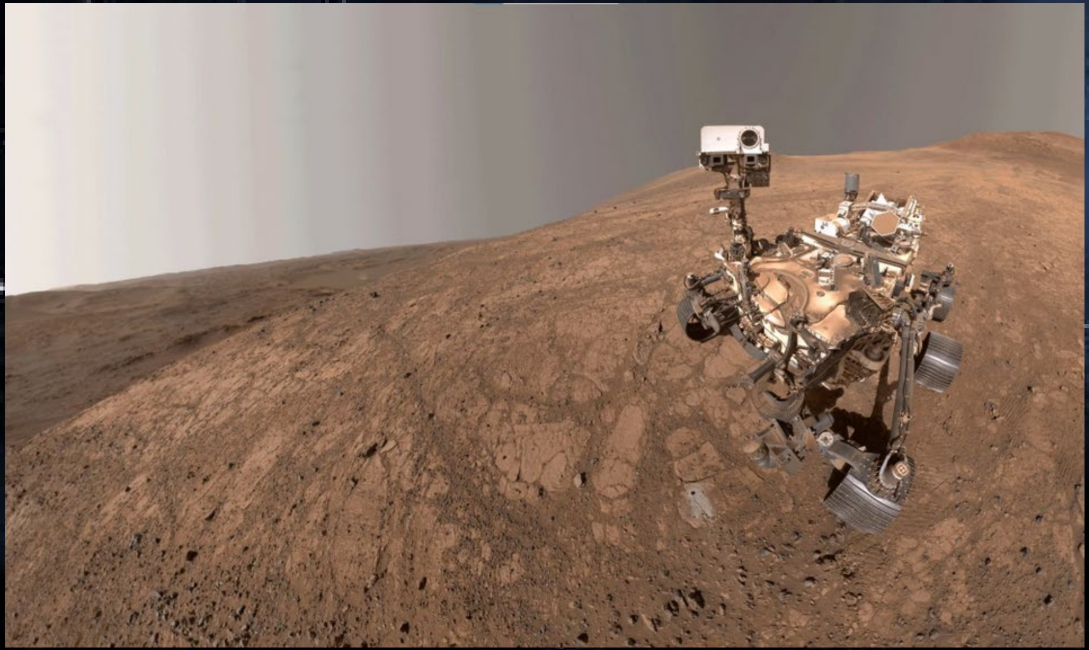


KAI REID

4/13/2026

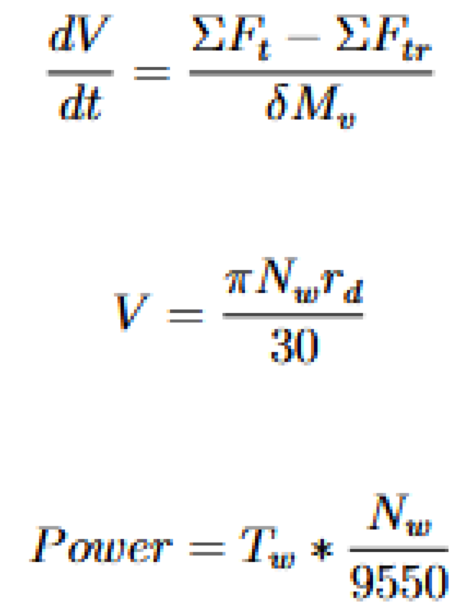
SIMILAR SYSTEMS, BACKGROUND AND REQUIREMENTS

Perseverance Rover



Lunar Environment

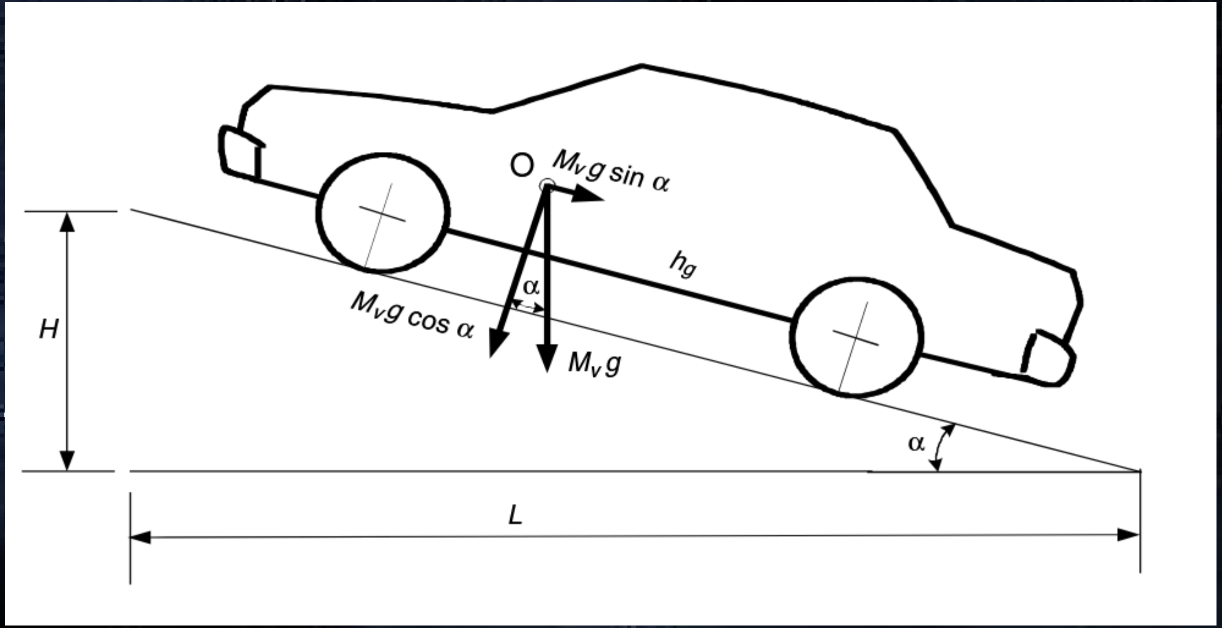
ENGINEERING MODEL



$$\frac{dV}{dt} = \frac{\Sigma F_t - \Sigma F_{tr}}{\delta M_v}$$

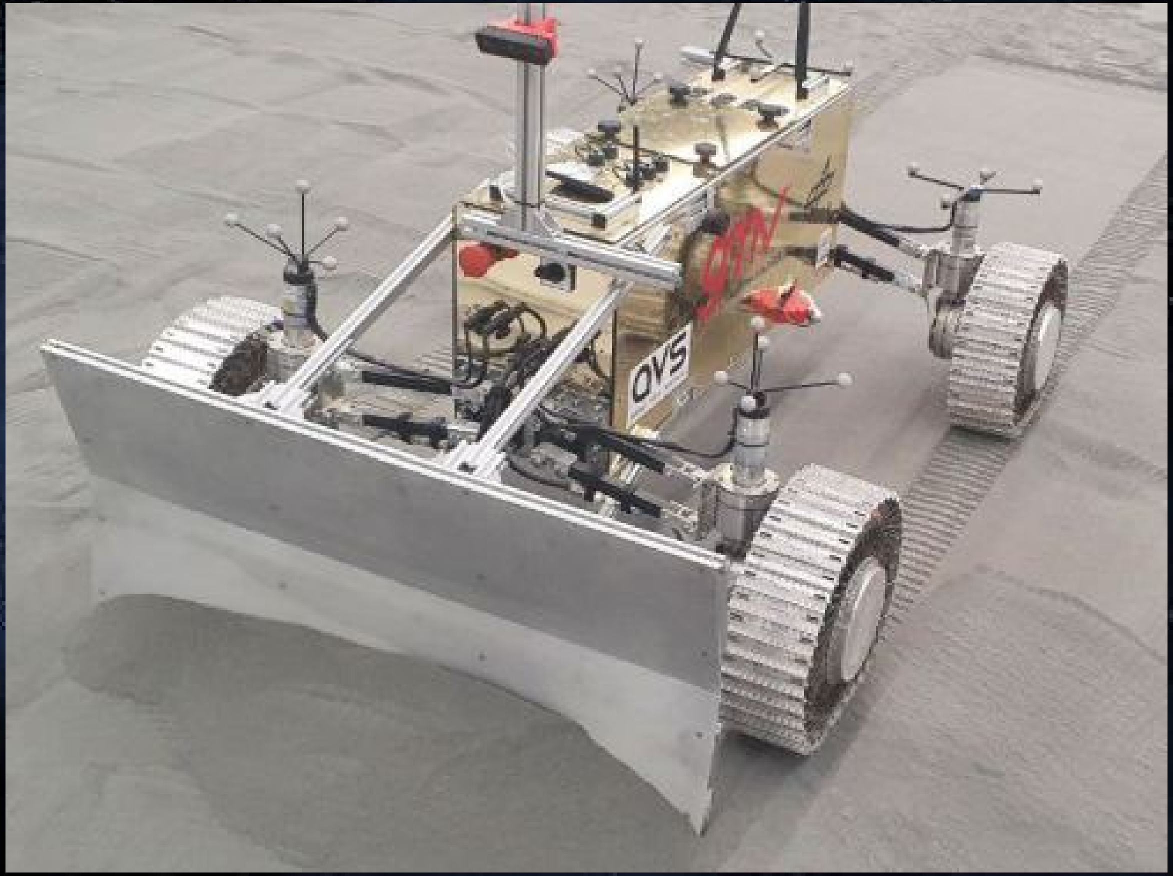
$$V = \frac{\pi N_w r_d}{30}$$

$$Power = T_w * \frac{N_w}{9550}$$



SIMILAR SYSTEMS

- FAU R.O.V.E.R
  - **Dozer Blade**
  - **Box Frame**
- Auburn Lunar Regolith Excavator
  - **Report Structure**
  - **Individual Subsystems Guidance**



SYSTEM CONFIGURATION

- Total size of 1.5 x 2.3 x 1 m
- Total weight of 182.9 kg
- Top layer of Shell made of Solar Array
- All electronics contained within shell.
- Dozer Blade attached to front with 2DOF
- Four Wheels
- Estimated total cost of: $140,972 (Material only, not including assembly and delivery)

CRITICAL REQUIREMENTS

- FR01 The System must be capable of Grading Lunar Regolith ahead of other Lunar Infrastructure systems.
- FR02 The System must be capable of maneuvering through Lunar South Pole Terrain.
- FR03 The System must have an operational range that protects the Griffin Lander from potential Plume Damage.
- FR04 The System must be able to communicate progress to Mission Command.
- FR05 The System must be able to determine it has completed grading of a designated area
- FR06 The System must be able to manage heat as to prevent damage to its components.

FRAME MATERIALS

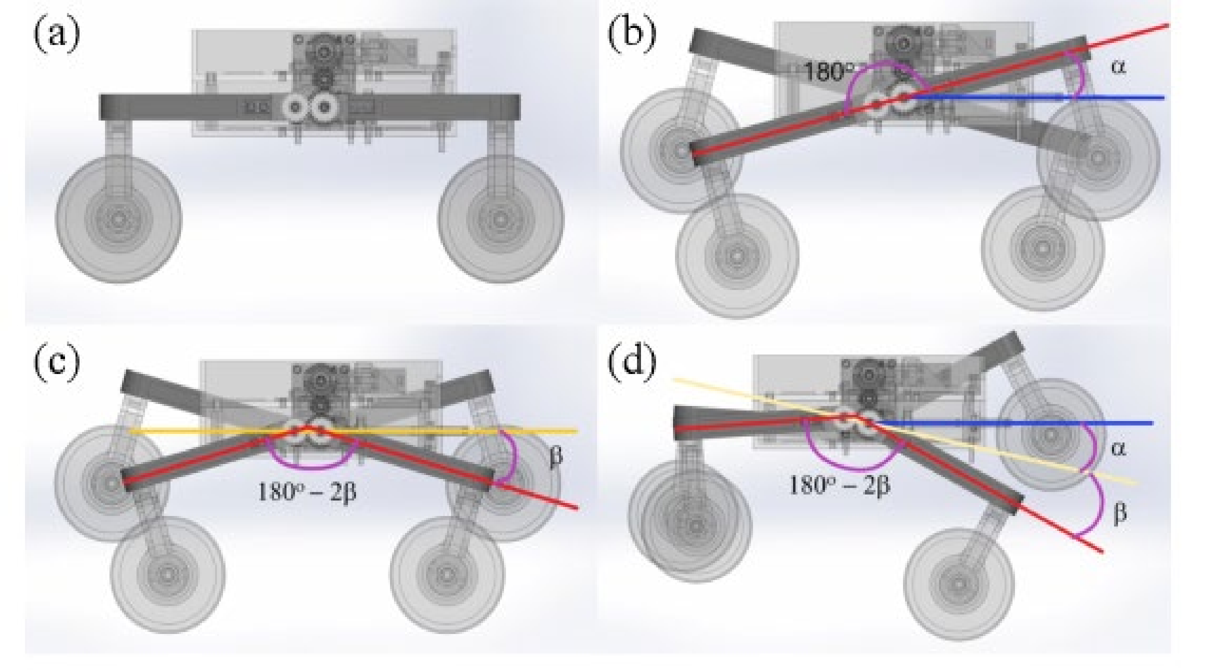
- Frame will be made of 6061-T6 aluminum alloy
  - **Due to its high strength to mass ratio**
- High load attachment regions
  - **Will be made of 7075-T6 aluminum for reinforced strength at these points**
- Bolted Frame Construction
  - **Over welding to preserve material strength**

FRAME ARCHITECTURE

- Box Frame Chassis
  - **Two longitudinal rails connected by transverse crossmembers**
- High torsional rigidity
  - **Resist Chassis twist during uneven terrain traversal**

FRAME SIZING

- 2.13 m x 1.52 m footprint
  - **Accommodates** blade, battery, and avionics
- Strong Stability Margin
  - **Tip angle exceeds 50°**



IMPLEMENT DESIGN & STRUCTURE

- attached to front of C.L.E.A.R. rover
- considered three types of implements: the front bucket, the dozer blade, and the roller

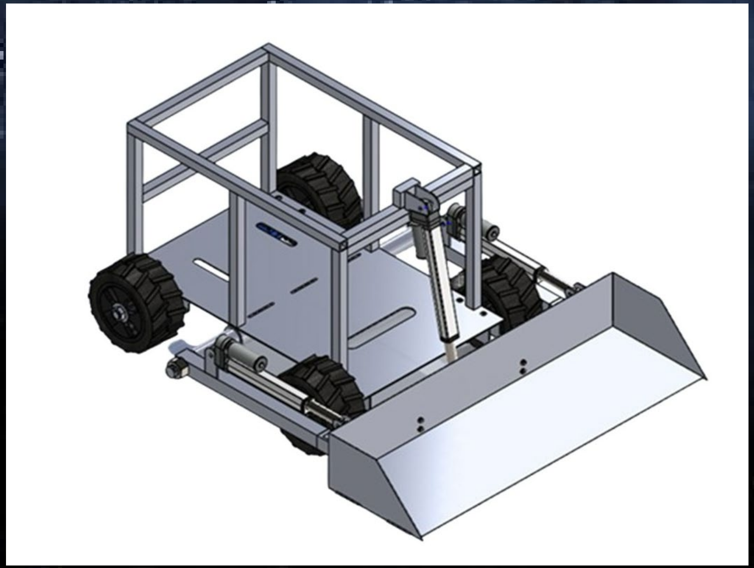
  dozer blade was ultimately chosen – provided the highest excavating and control capabilities
- selected the semi-universal (SU-type) blade

  combined flat center with slightly angled side wings to hold material more easily during excavation
- specific dimensions determined based on previously concluded frame dimensions

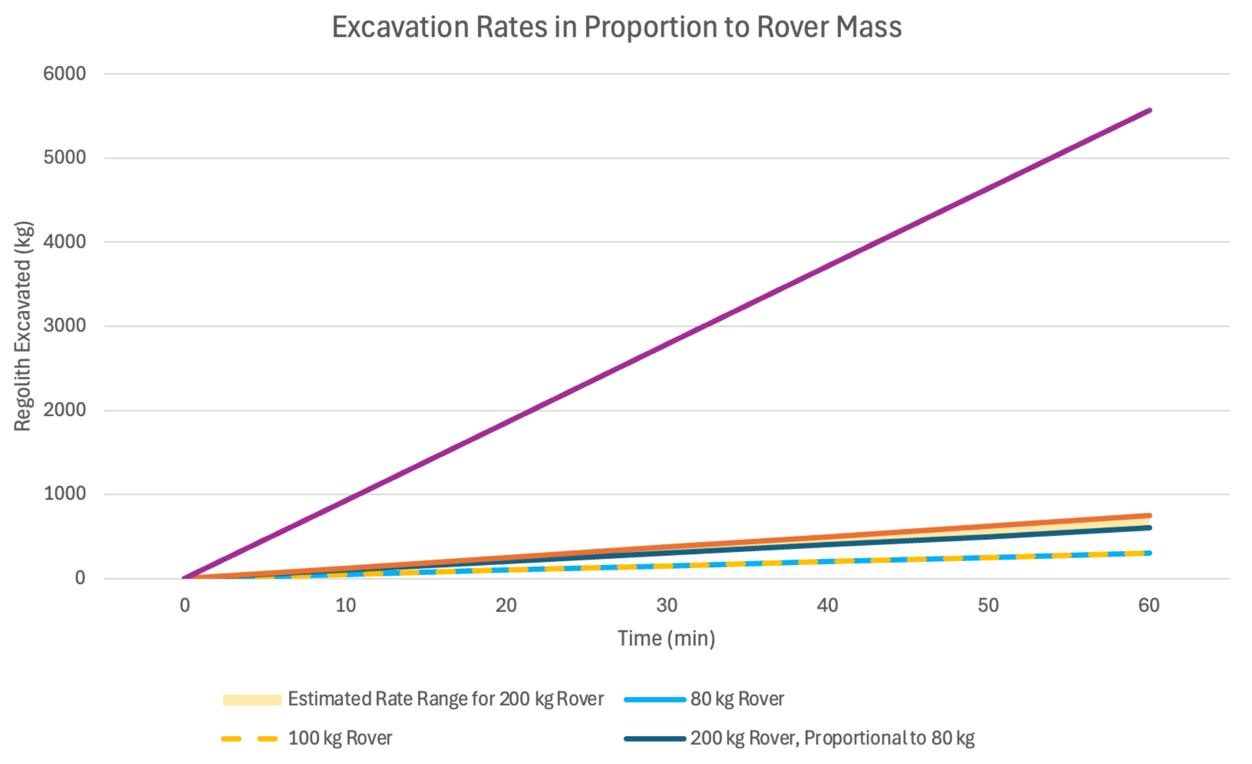
  blade width: 4.59 ft (1.4 m)

  blade height: 1.64 ft (0.5 m)
- determined to have an overall mass of around 30 kg

  well below 200 kg mass limit of entire rover



EXCAVATING CAPABILITIES



- proportionalized excavation rates for 200-kg rover based on rates of rovers from previous experiments

  previous experiment rovers were about 1/6th the size of our full 200-kg rover

- took average of rate results from MATLAB simulation to compare with proportionalized rates

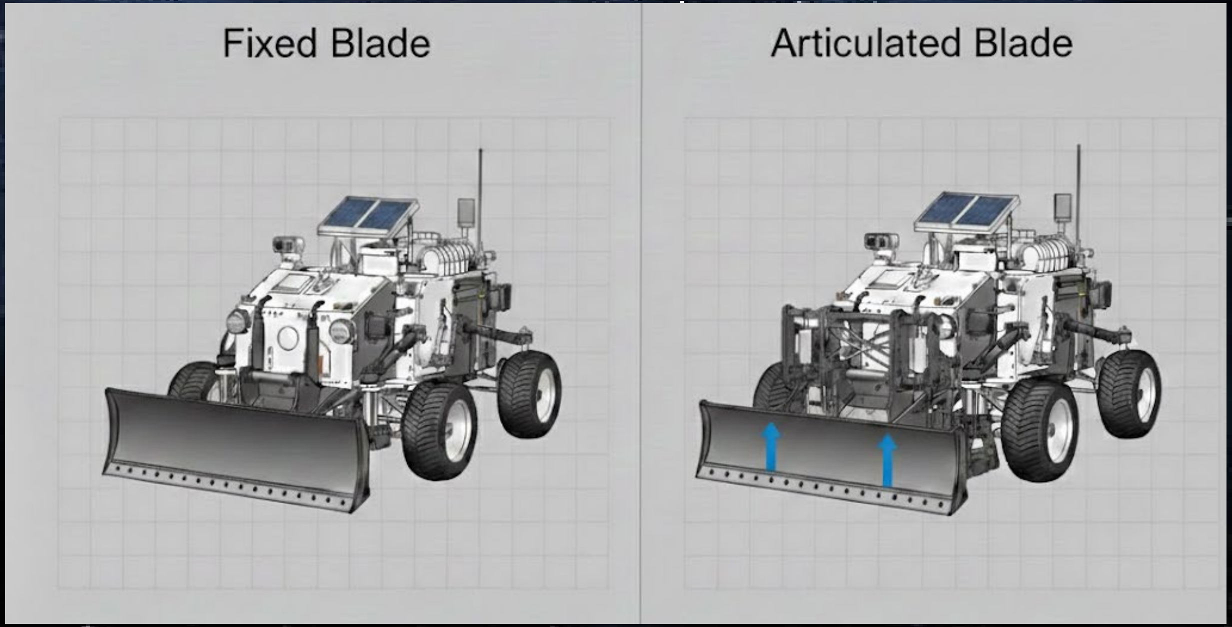
  average excavation rate: 5570.758 kg/hr

IMPLEMENT MATERIALS

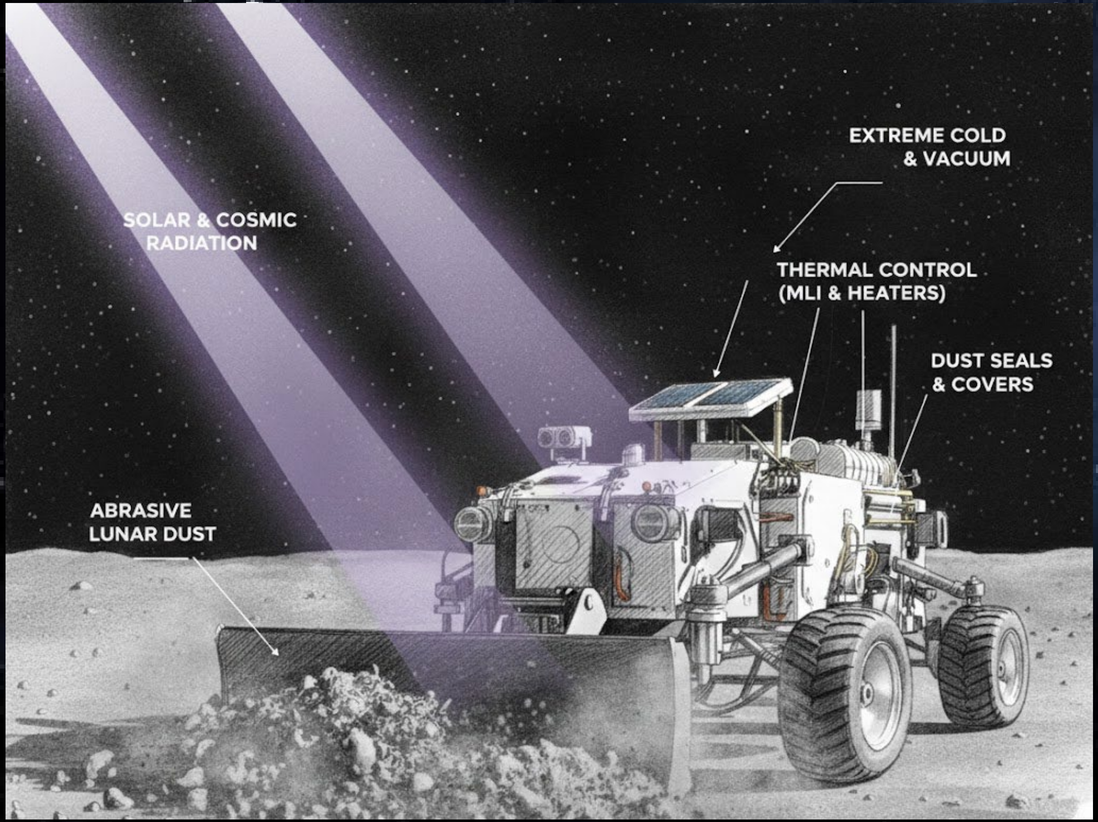
- considered both having the implement fixed to rover or allowing movement capabilities
- for both considerations, blade body and side wings would be composed of 6065-T6-Al

cutting edge (wear strip) composed of carbide-coated steel

- mounting bracket (whether fixed or articulated) composed of aerospace aluminum
- structural reinforcements composed of aerospace aluminum alloy
- fasteners composed of either stainless steel or titanium



IMPLEMENT MATERIALS



- any force/torque actuation and motor control – only apply of blade has degrees of freedom

  all components (high-force actuators, motor drivers, position encoders, harnessing and connectors) must be composed of space-rated, radiation-tolerant materials

- sensors must also be composed of proper space-rated materials
- custom dust seals and covers implemented as needed
- must include thermal control elements (heaters, multi-layer insulation)

WHEEL DESIGN

- Weight
  - Every kilogram sent to space is costly; lighter wheels will help us stay under 200kg requirement
  - Skeletal frame will mitigate dust and regolith from getting stuck and causing unnecessary wear
- Traction
  - By using a mix of straight and chevron shaped grousers we can maximize our traction and regolith dispersion
- Flexibility and Durability
  - Metal outer wheel and grousers will ensure strength when going over sharp rocks
  - Must be strong enough to travel ~50 km without substantial deterioration

WHEEL DESIGN – MATERIALS

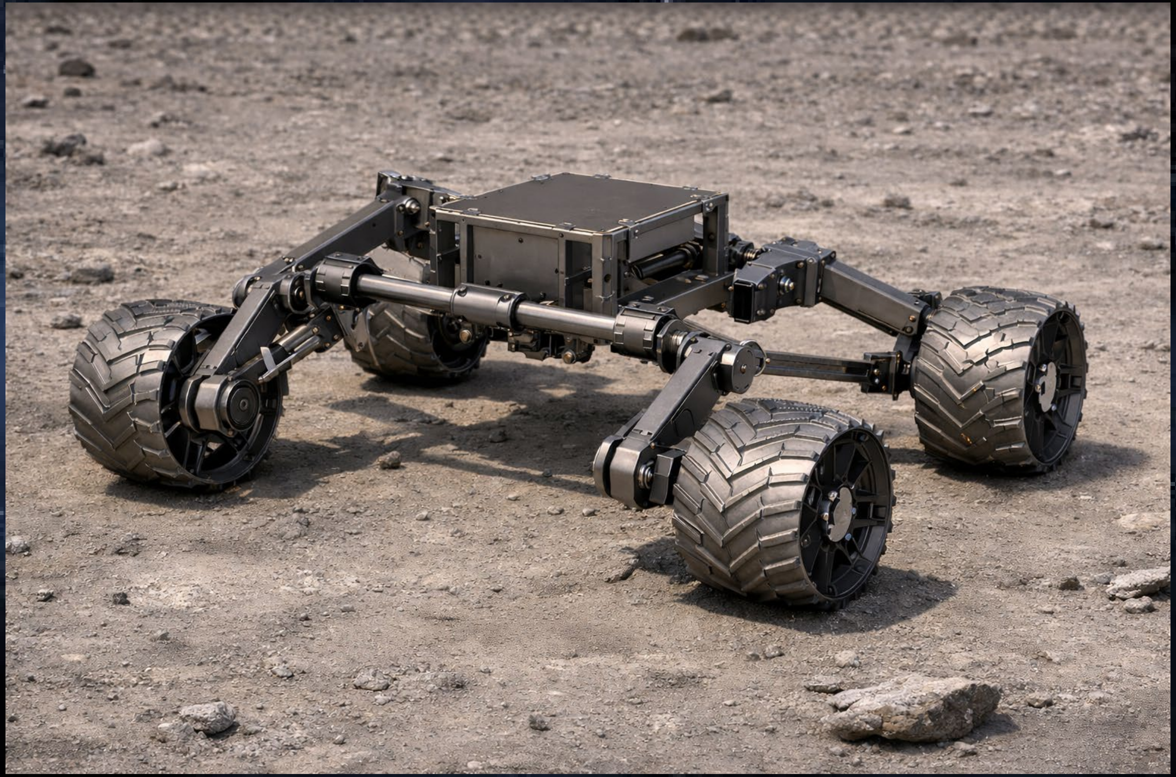
- Primary wheel material is flight-grade aluminum (e.g., 6061-T6 or 7075-T6) for low mass and established spaceflight heritage.
- Titanium (e.g., Ti-6Al-4V) or hardened stainless wear strips considered for the leading edges of grousers to mitigate abrasive wear.

SUSPENSION

- Designed to support continuous wheel-ground contact, distribute loads evenly across all four wheels, and enable stable traversal on grades up to 15%
- Four-wheel suspension similar to that of a jeep
- Each side of the rover incorporates a longitudinal rocker arm allowing vertical articulation as terrain height changes.
- The left and right rocker arms are connected through a Central differential linkage that averages chassis roll and maintains uniform normal force across all wheels.

SUSPENSION - MATERIALS

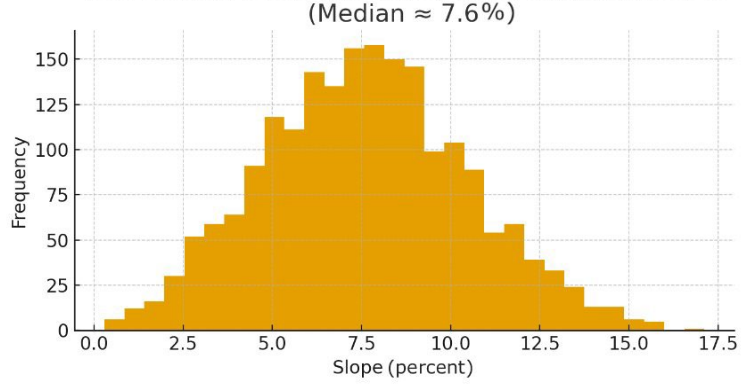
- Primary structural members of the suspension, including rocker arms and trailing links, are manufactured from 6061-T6 aluminum box sections to achieve high stiffness with minimal mass.
- High-load attachment points and pivot interfaces utilize 7075-T6 aluminum or titanium hardpoints to reduce bearing stresses and prevent deformation under repeated excavation loads.
- Pivot joints employ stainless steel or titanium shafts supported by sealed bearings and dry-film lubrication to ensure reliable operation in dusty, vacuum environments.
- Labyrinth-style dust seals are incorporated at rotating interfaces to mitigate regolith intrusion and extend functional life.

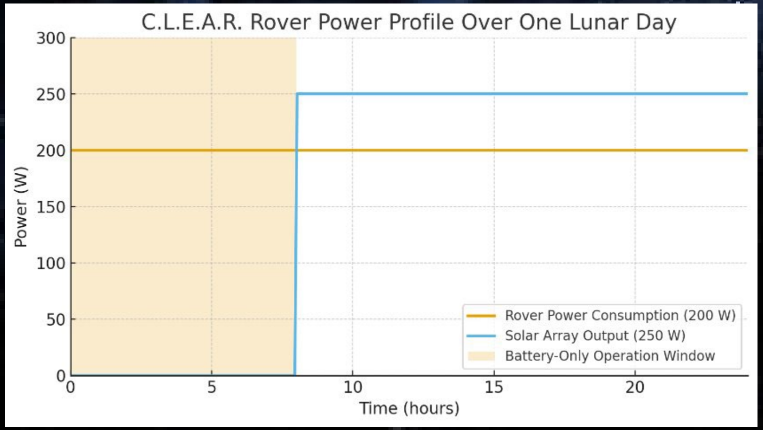


CONTROLS

- Controls affected by almost all critical requirements.
- So, what kind of Control Schema did we select? Downslope Grading.

POWER DESIGN

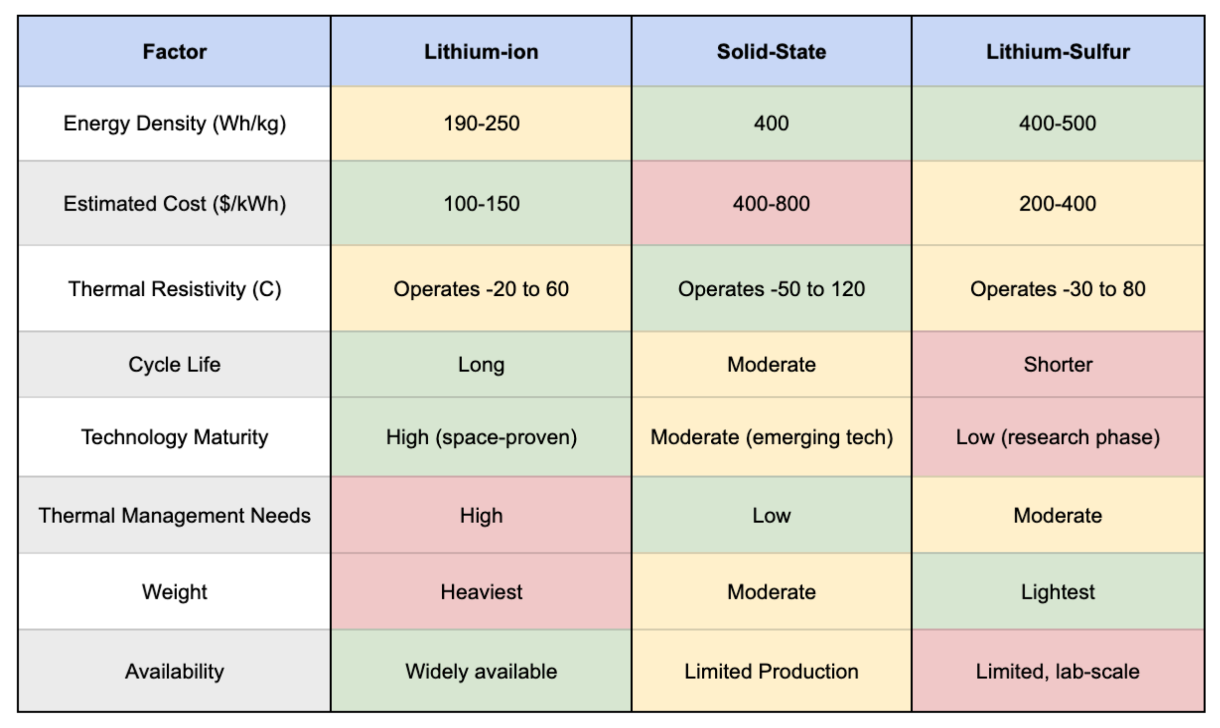




- Grading 600-750 kg/hr
- Slopes up to 15%
- System runs 8 hours on battery power
- 200 kg mass limit
- 75-80% Depth of discharge
- Lunar temperature -163° C to 54° C

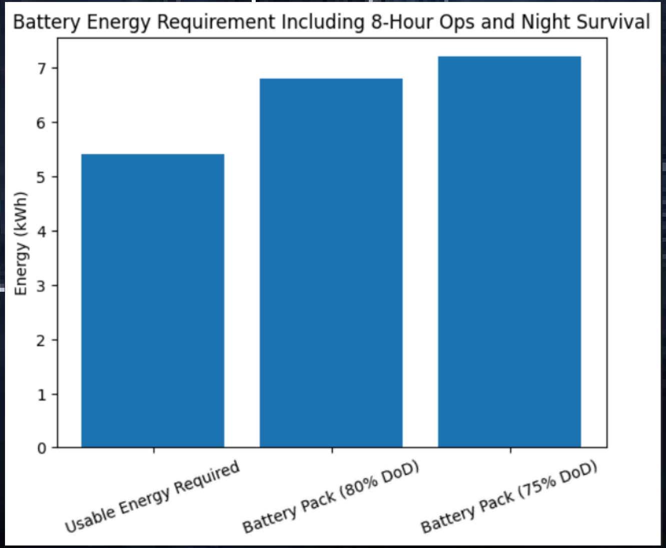
Assessing solar array necessity

POWER DESIGN



Factor	Lithium-ion	Solid-State	Lithium-Sulfur
Energy Density (Wh/kg)	190-250	400	400-500
Estimated Cost ($/kWh)	100-150	400-800	200-400
Thermal Resistivity (C)	Operates -20 to 60	Operates -50 to 120	Operates -30 to 80
Cycle Life	Long	Moderate	Shorter
Technology Maturity	High (space-proven)	Moderate (emerging tech)	Low (research phase)
Thermal Management Needs	High	Low	Moderate
Weight	Heaviest	Moderate	Lightest
Availability	Widely available	Limited Production	Limited, lab-scale

- 6.8-7.2 kWh battery capacity
- Depth of discharge limited to 75-80%
- 8hr battery-only operation


Battery Energy Requirement Including 8-Hour Ops and Night Survival

RISK ASSESSMENT

Risk	Before	Mitigation	After
Mobility Failure	Wheels slip on material	Testing with Regolith simulant	Reassess design, wheels have enough traction
Thermal Management Failure	Insulation fails	Testing insulation performance	Reassess design, insulation meets requirements
Disturbing Potential Samples	Pristine regolith compromised	Operational zones, limiting excavation depth, proper documentation	Future samples preserved
Structural Failure of Blade	Blade and actuator fail before meeting requirements	Limiting maximum depth of engagement, selecting fatigue resistant materials, validation testing	Blade and actuator perform as necessary

CONCLUSION - DESIGN

- Aluminum Frame
- SU-Type Blade
- Flight-Grade ALuminum Wheels
- Classical Four-Wheel.
- Exceeds previous experimental results.

CONCLUSION – LESSONS, INNOVATION AND TECH GAP

- New Wheel Designs to help further mitigate regolith damage.
- Improved electric motors for scalability.

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LUNAR TEAM

CONCLUSION – LESSONS, CHALLENGES

- Descoping to improve overall system performance and make goals more achievable
- Translating requirements into forms that can apply to prototype testing
- Importance of good documentation when undertaking a long-term project.

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THANK YOU

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FORMAT

- • System Overview
- o Purpose/Benefits (definitely do this first and don’t forget!) Objectives Concept of Operations (graphical) Similar systems used as inspiration for your design
- • System Description
- Describe the overall system configuration Describe the critical requirements which drove your design Give an overview of how you chose particular design options. State if you met (supported by analysis/evidence) or failed a requirement. If you failed, explain how you plan to meet the requirement. o Mass/Power/Cost budgets if pertinent to presentation (at least mention total budget)
- Subsystem XYZ (dedicate a section to each subsystem)
- Describe the subsystem’s role in achieving the mission objectives Describe critical requirements which drove your design. Give an overview of how you chose particular design options. State if you met (supported by analysis/evidence) or failed a requirement. If you failed, explain how you plan to meet the requirement.
- • Risk Assessment
- Discuss critical risks associated with your project Describe how you plan to mitigate those risks Show before and after mitigation risk table
- • Conclusion
- Summarize your design and your major design choices. Briefly discuss how your design satisfies the requirements and objectives. Discuss important lessons that have been learned this semester and plans for future work.
- • Back-up slides as needed

ATLAS AND PRESENTATION

- https://www.lpi.usra.edu/lunar/lunar-south-pole-atlas/

- https://docs.google.com/spreadsheets/d/1I3VvDSGnDzT5KcNWMbr3IzUX_H5w0TWgv3bfnxQpCXw/edit?usp=sharing