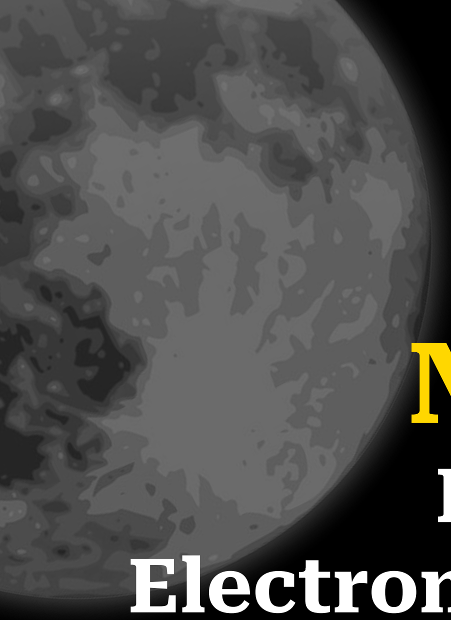
Lunar ROADSTER

(Robotic Operator for Autonomous Development of Surface Trails and Exploration Routes)

"Starting with a foothold on the Moon, we pave the way to the cosmos"



NASA-STD-8739.10

Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard

NASA-STD-8739.10: What is it about?

- Establish a consistent, Agency-wide set of requirements for managing EEE parts in space flight hardware
- Manages the selection, acquisition, traceability, testing, handling, packaging, storage, and application of EEE parts as required by NASA Policy Directive (NPD) 8730.2, NASA Parts Policy

Summary: To control risk and enhance reliability in NASA space flight hardware and critical ground support equipment

NASA-STD-8739.10: Where does it apply?

Target Market: For *"scientific and engineering organizations engaged in space and ground testing technology development"*

Government labs

Internal NASA use

Academic institutions

Contractors

Private space companies

NASA-STD-8739.10: Where does it apply?

Products: Electrical, Electronic, and Electromechanical parts used for space applications

Different EEE Parts

NASA-STD-8739.10: Main prescriptions

Guideline 1: Parts Selection and Grading

- Parts must be selected to meet performance and reliability requirements in the worst-case predicted mission environment (e.g., thermal, vibration, radiation)

Part Types	Federal Stock Classes	Part Types	Federal Stock Classes
Capacitors	5910		
Circuit Breakers	5925	Hybrid microcircuits (including dc/dc converters, opto-electronics, RF, and microwave devices)	5962
Connectors	5935	Magnetics, Inductors & Transformers	5950
Crystal & Crystal Oscillators	5955	Monolithic Microcircuits	5962
Diodes	5961	Relays	5945
Fiber Optic Accessories	6070	Resistors	5905
Fiber Optic Cables	6015	Switches	5930
Fiber Optic Conductors	6010	Thermistors	5905
Fiber Optic Devices	6030		
Fiber Optic Interconnects	6060	Transistors	5961
Filters	5915	Wire and Cable	6145
Fuses	5920		

NASA-STD-8739.10: Main prescriptions

Guideline 2: Derating Analysis

- Programs shall document the derating criteria for all EEE parts
- To operate parts below their manufacturer-specified maximum stress levels (voltage, current, power) to increase reliability and mission life

5.3.1 Derating

5.3.1.1 Derating is the reduction of electrical, mechanical and thermal stresses applied to a part during normal operation with respect to the part's design limits in order to decrease the degradation rate and prolong the part's expected life.

5.3.1.2 Project documentation shall specify derating requirements for all EEE part types in the design of the hardware.

5.3.1.3 A derating analysis shall be conducted by the design organization and submitted for project/Center review and approval (see section 8.3.1).

5.3.1.4 A part that does not meet the derating requirements shall require additional review and approval before use in space flight hardware.

5.3.1.5 The use of parts where the predicted worst case parameters exceed the part manufacturer's absolute design limits shall be prohibited.

NASA-STD-8739.10: Main prescriptions

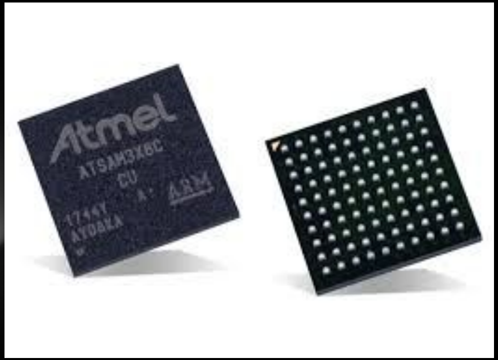
Guideline 3:

1. Counterfeit Part Avoidance
   - Projects shall have a plan to prevent, detect, and mitigate the use of counterfeit EEE parts, typically by procuring only from trusted sources
2. Parts Lists (Traceability)
   - Projects shall generate and maintain three lists: **As Designed Parts List (ADPL)**, **Approved Parts List (APL)**, and **As Built Parts List (ABPL)**
3. Documentation: EEE Parts Management & Control Plan (EPMCP)
   - Every project shall develop and implement an integrated EPMCP outlining the program's approach to meeting the standards' requirements
4. Non-Standard Parts (NSP) Justification
   - If a part is used that does not meet the prescribed reliability grade, it must be documented as an NSP and receive formal approval (waiver) from the relevant Parts Control Board (PCB)

NASA-STD-8739.10: Application to project

We are using multiple EEE parts across our system!

We made sure our EEE parts are properly rated, reliable, and tested



For example, the IMU we used is specifically designed to operate in a wider range of temperatures seen on the moon

NASA-STD-8739.10:: Application to project

Counterfeit Avoidance: We strictly controlled our supply chain, ensuring all computers, microprocessors, and motor drivers were procured from reputable distributors to guarantee quality and avoid system failure

NASA-STD-8739.10: Application to project

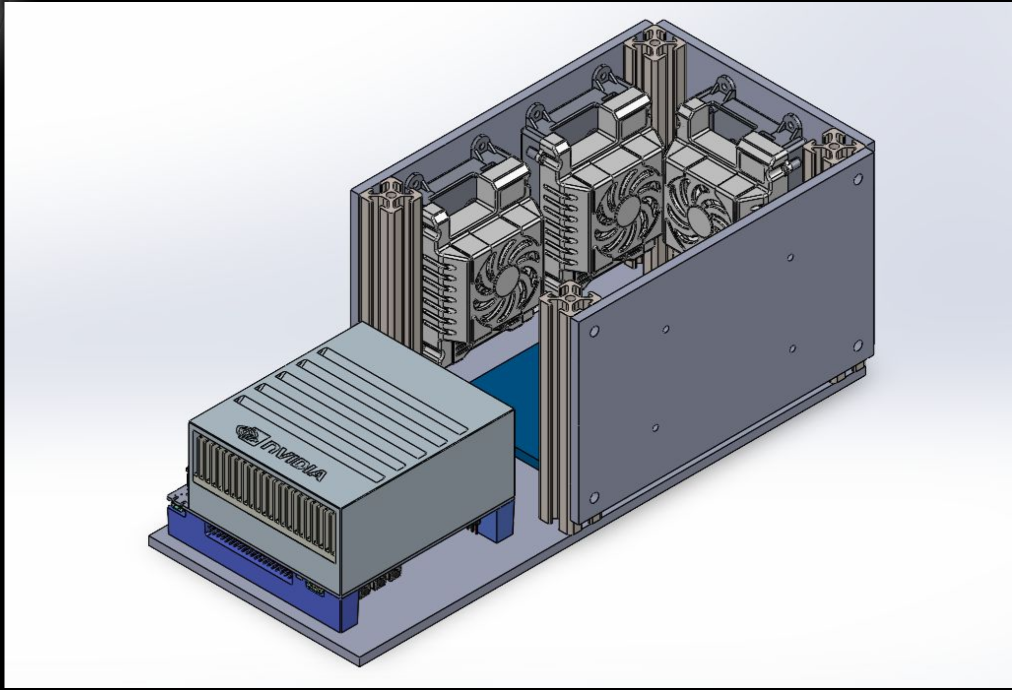
- **Derating:** We applied this by ensuring our motor controllers and power electronics are oversized for the maximum continuous loads expected, extending their operational life on the lunar surface

- **Documentation:** We applied the principle of the **As Built Parts List (ABPL)** by meticulously recording the manufacturer, part number, and purchase date for every electronic component used in the final rover build for future reference and failure analysis

Part ID	Part Name
P37	16T, 0.125″ (1/8) Bore 32P Shaft Mount Pinion Gear (Steel)
P33	18-8 Stainless Steel SAE Washer
P16	32 RPM Planetary Gear Motor
P15	60 RPM Planetary Gear Motor
P03	118 RPM Planetary Gear Motor
P39	8020, 14162, 10 25 Series Steel 10-32 Standard Drop in T Nuts

NASA-STD-8739.10: Application to project

- **Environment Control:** We ensured critical parts (motor drivers, GPU, etc.) are temperature controlled by providing adequate cooling

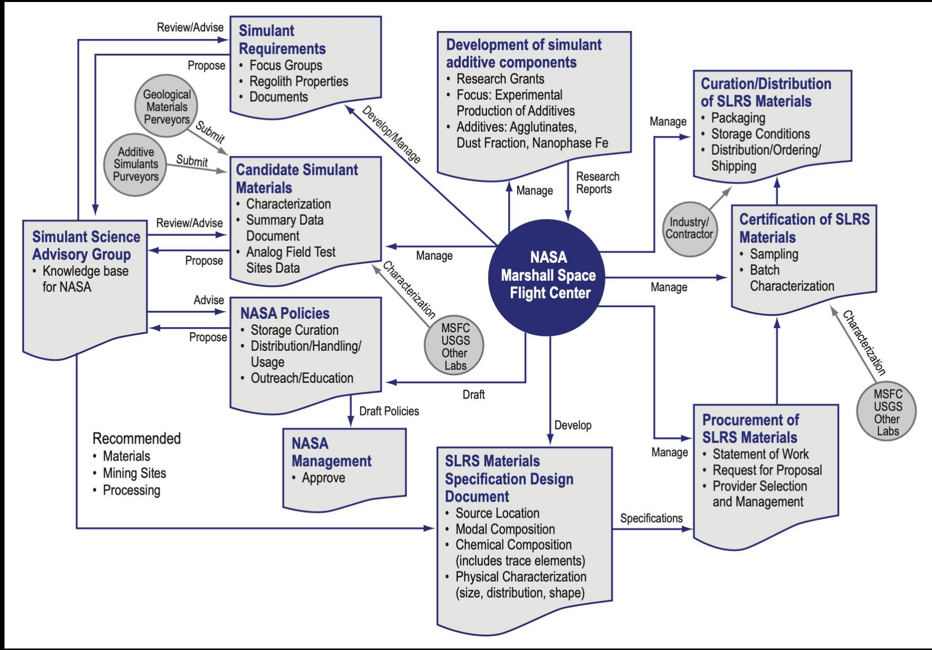


NASA/TP—2006–214605

Lunar Regolith Simulant Materials: Recommendations for Standardization, Production, and Usage

NASA/TP—2006–214605: What is it about?

- Standardizing lunar regolith simulants (SLRS) for NASA missions and consistent lunar surface technology testing
- Defines regolith families such as mare, highland, and polar soils
- Creates process for simulant selection, characterization, and certification
- Establishes Simulant Science Advisory Group (SSAG) to guide requirements and policy



Summary: A very complicated and bureaucratic way to source and produce lunar accurate sand

NASA/TP—2006–214605: Where does it apply?

Target Market: For *"scientific and engineering organizations engaged in lunar and planetary technology development"*

Government labs

Internal NASA use

Academic institutions

DoD space research

Private space companies

NASA/TP—2006–214605: Where does it apply?

Products: Standard lunar regolith simulant (SLRS) materials

Different lunar regolith simulants

NASA/TP—2006–214605: Main prescriptions

Guideline 1: Regolith geotechnical properties

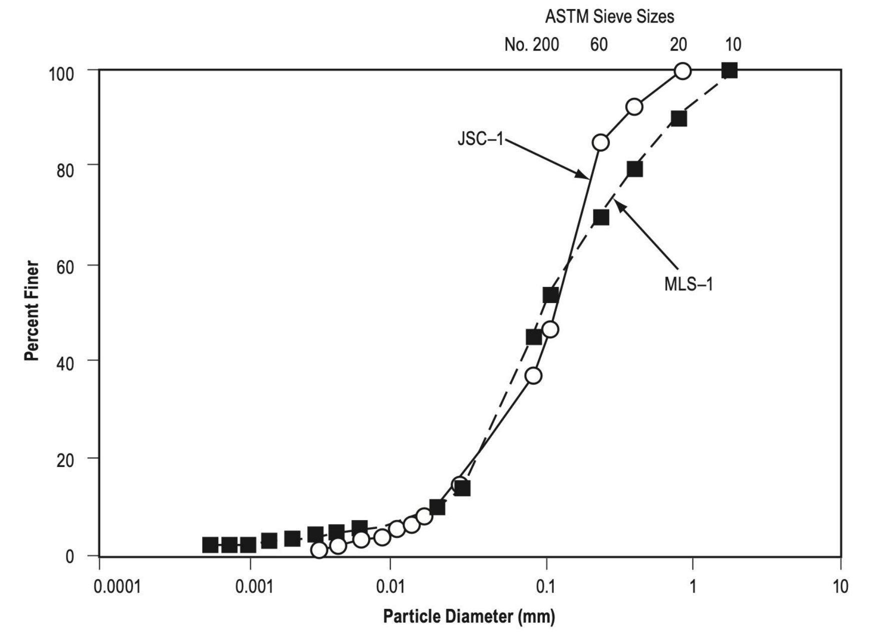
- For "standard" regolith intended to represent average soil encountered on the lunar surface

	Lunar Regolith	Terrestrial Soils (Dry, Cohesionless)
Geotechnical Index Property		
Relative soil density	65% in top 15-cm depth (medium to dense) 90% below 30-cm depth (very dense)	65% to 75% is practical limit for field compacted terrestrial soils
Bulk density, ρ	1.4–2.2 g/cm^3	1.4–1.9 g/cm^3
Specific mass of solids, ρ_s	> 3.32 g/cm^3, Basalt particles 1 to > 3.32 g/cm^3, Agglutinate/glass 2.9 to 3.1 g/cm^3, Breccia	2.7 g/cm^3 for most terrestrial soils
Engineering Property		
Unit weight, γ	2.9–3.6 kN/m^3 (at 1/6g)	14–19 kN/m^3 (at 1 g)
Cohesion, c	0.1 to 1 kPa	0 kPa for dune sand
Friction angle, ϕ	30° to 50°	30° to 35° for dune sand
Ultimate bearing capacity, q_{ul}	25–55 kPa, intercrater areas < 25 kPa, crater rims;* 6–419 kPa, calculated range for 0.1 m footing width on level ground 6,000 kPa for 1 m footing width	30–60 kPa, stiff to hard clays; 20–60 kPa, compact sand and gravel; < 20 kPa, loose gravel and sand, 10–31 kPa, calculated for 0.1-m (footing width on level ground in dune sand)
Allowable bearing capacity, q_{all}	8 kPa (1-cm acceptable settlement depth) 0.2 psi recommended	100–300 kPa, compact sand < 75 kPa, soft clays and silts (1-cm acceptable settlement depth); Dune buggies: 15-psi tires
Permeability, K	1–7 $\times$ 10^{-12} m^2 (1.65x10^{-3} cm/s)	10^{-13}–10^{-16} m^2, very fine sands; 10^{-4}–10^{-7} cm/s, silts

NASA/TP—2006–214605: Main prescriptions

Guideline 2: Particle diameter distribution

- Similar to "standard" simulants JSC-1 (Johnson Space Center) and MLS-1 (Minnesota Lunar Regolith)
- How to measure similarity left undefined, up to SSAG board to decide



NASA/TP—2006–214605: Main prescriptions

Guideline 3: Particle chemical composition

- Oxide weight percentage composition for each representative particle

Oxide	Anorthosite	Gabbroic Anorthosite	Anorthositic Gabbro	Troctolite	Low-K Fra Mauro Basalt	Medium-K Fra Mauro Basalt
SiO_2	44.3	44.5	44.5	43.7	46.6	48.0
TiO_2	0.06	0.35	0.39	0.17	1.25	2.1
Al_2O_3	35.1	31.0	26.0	22.7	18.8	17.6
FeO	0.67	3.46	5.77	4.9	9.7	10.9
MgO	0.8	3.38	8.05	14.7	11.0	8.7
CaO	18.7	17.3	14.9	13.1	11.6	10.7
Na_2O	0.8	0.12	0.25	0.39	0.37	0.7
K_2O	–	–	–	–	0.12	0.54
MnO	–	–	–	0.07	–	–
Cr_2O_3	0.02	0.04	0.06	0.09	0.26	0.18
Σ	100.5	100.2	99.9	99.9	99.6	99.4

NASA/TP—2006–214605: Main prescriptions

Recommendation 1: Standard Lunar Regolith Simulant Materials

- Goal: Establish traceable, standardized lunar soil simulants
- Prescription 1: 3 root simulants – baseline materials for each major lunar terrain
  a. Mare Simulant: Low-Titanium Mare Basalt
  b. Highland Simulant: High-Calcium Highland Anorthosite
  c. Polar Simulant: Mixture of Low-Titanium Mare Basalt and High-Calcium Highland Anorthosite

Oxide	Olivine Fo_{92}	Anorthite	Quartz	Root Mix	Apollo 16*	Diff[2]
SiO_2	41.23	43.19	100	46.29	45	1.65
Al_2O_3	–	36.65	–	28.59	27.3	1.66
FeO	7.89	–	–	1.26	5.1	14.73
MgO	50.89	–	–	8.14	5.7	5.97
CaO	–	20.16	–	15.72	15.7	0
Total	100	100	100	100	(100.78)	–

Material mix for mare simulant root mix

NASA/TP—2006–214605: Main prescriptions

Recommendation 1: Standard Lunar Regolith Simulant Materials

- Prescription 2: 7 derivative simulants – derivative of root simulant for specific site or system tests
  a. Glass Fraction: Percentage of impact-glass per sample
  b. Agglutinates: Stickiness of the regolith
  c. Nanophase Iron: Percentage of iron per sample
  d. Shocked Grains: Percentage of particles crushed by meteorite impact
  e. Solar-Wind Volatiles: Percentage of particles exposed to solar wind
  f. Dust Fraction: Percentage of particles below 50 µm
  g. Minerals: Adjustments to the chemistry and mineralogy of simulant as required

NASA/TP—2006–214605: Main prescriptions

Recommendation 2: Process for Development, Production, and Certification of Standard Lunar Regolith Simulant Materials

- Goal: Create a formal, repeatable pipeline for the production of SLRS to ensure all lunar simulants are high-quality, traceable, and reproducible.

Prescriptions:

1. **Estimate Quantities Needed**
   - Plan production capacity
2. **Define Requirements & Specifications**
   - Set targets for chemistry, mineralogy, grain size, and physical properties
3. **Select Source Materials**
   - Choose terrestrial basalts/anorthosites or synthetic mixes
4. **Initial Batch Screening**
   - Screen candidate materials (composition, mineralogy, particle size) before large-scale production

NASA/TP—2006–214605: Main prescriptions

Prescriptions:

5. **Production & Characterization**
   - Use controlled crushing, blending, and sieving
6. **Packaging**
   - Package under clean, dry conditions
7. **Quality Control**
   - Maintain batch sampling, verification, and traceability records
8. **Curation, Storage & Monitoring**
   - Store under stable environmental conditions
9. **Distribution Management**
   - Central NASA hub to handle logistics, safety, and control
10. **Safety Protocols**
    - Evaluate inhalation and abrasion hazards
11. **Characterization Techniques**
    - Apply standardized methods to characterize the produced material
12. **Simulant Grade Options**
    - Bulk Grade, Technical Grade, and Research Grade

NASA/TP—2006–214605: Main prescriptions

Recommendation 3: Long-Term Simulant Acquisition Strategy

- Goal: Establish a sustainable framework for governance, policy, and coordination of all lunar simulant activities

Prescriptions:

1. **Advisory Group on Simulant Materials**
    - Establish the Simulant Science Advisory Group (SSAG)
    - Expert panelists from planetary science, materials science, geochemistry, and standards
    - Define technical requirements and review simulant proposals
    - Recommend certification criteria and quality control methods
    - Make recommendations on the improvement of existing SLRS materials
    - Assist in the organization of workshops on lunar simulant materials

NASA/TP—2006–214605: Main prescriptions

Prescriptions:

2. **Policies and Governance for the Development of Standard Simulant Materials**
   a. Requirements for Standard Lunar Regolith Simulant Materials
   b. Developmental Research on Selected Simulant Materials
   c. Standard Lunar Regolith Simulant Materials Certification Process
   d. Quality Control of Standard Lunar Regolith Simulant Materials
   e. Storage, Distribution, and Reuse of Standard Lunar Regolith Simulant Materials
   f. Use of Standard Lunar Regolith Simulant Materials by NASA-Sponsored Projects
   g. Use of Standard Lunar Regolith Simulant Materials by Non-NASA-Sponsored Projects
   h. Tracking Standard Lunar Regolith Simulant Material Usage
   i. Procurement of Standard Lunar Regolith Simulant Materials

Caveat: Report intentionally leaves policies and governance structure vague as they relate to future developments and have not been implemented yet

NASA/TP—2006–214605: Application to project

We are using the lunar regolith simulant everyday!

We need to make sure our rover's capabilities are up to standard in its intended lunar deployment environment

Planetary Robotics Laboratory Moon Yard

NASA/TP—2006–214605: Application to project

The allowable bearing capacity of the regolith guided the development of our performance requirements

M.P.3: The rover shall have a contact pressure of less than 1.5 kPa

	Lunar Regolith	Terrestrial Soils (Dry, Cohesionless)
Geotechnical Index Property		
Relative soil density	65% in top 15-cm depth (medium to dense) 90% below 30-cm depth (very dense)	65% to 75% is practical limit for field compacted terrestrial soils
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Unit weight, γ	2.9–3.6 kN/m^3 (at 1/6g)	14–19 kN/m^3 (at 1 g)
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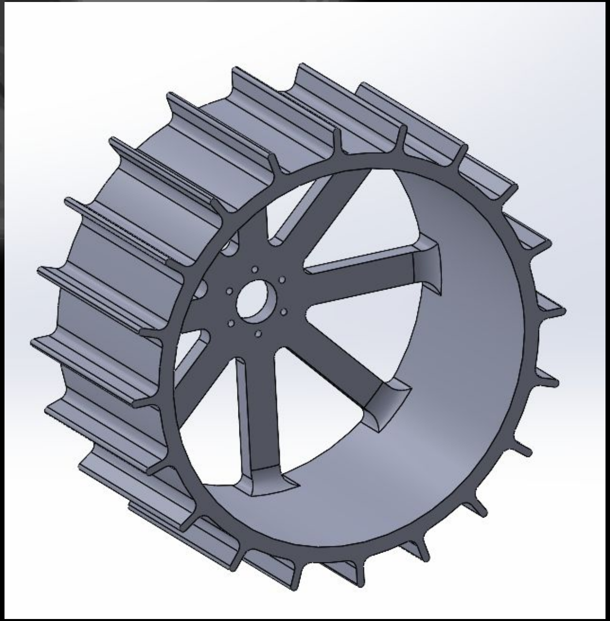
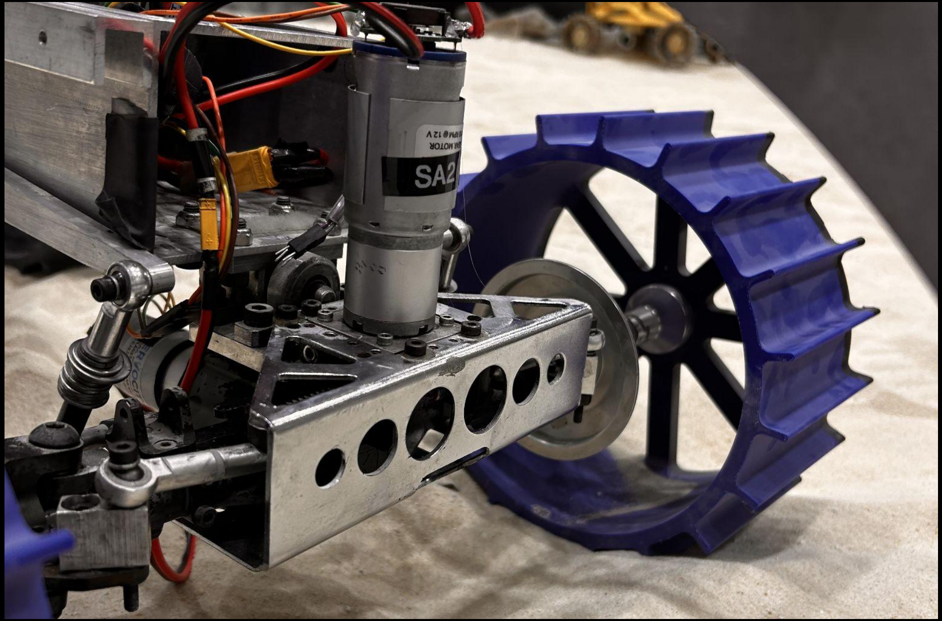
Permeability, K	1–7 x 10^{-12} m^2 (1.65x10^{-3} cm/s)	10^{-13}–10^{-16} m^2, very fine sands; 10^{-4}–10^{-7} cm/s, silts

NASA/TP—2006–214605: Application to project

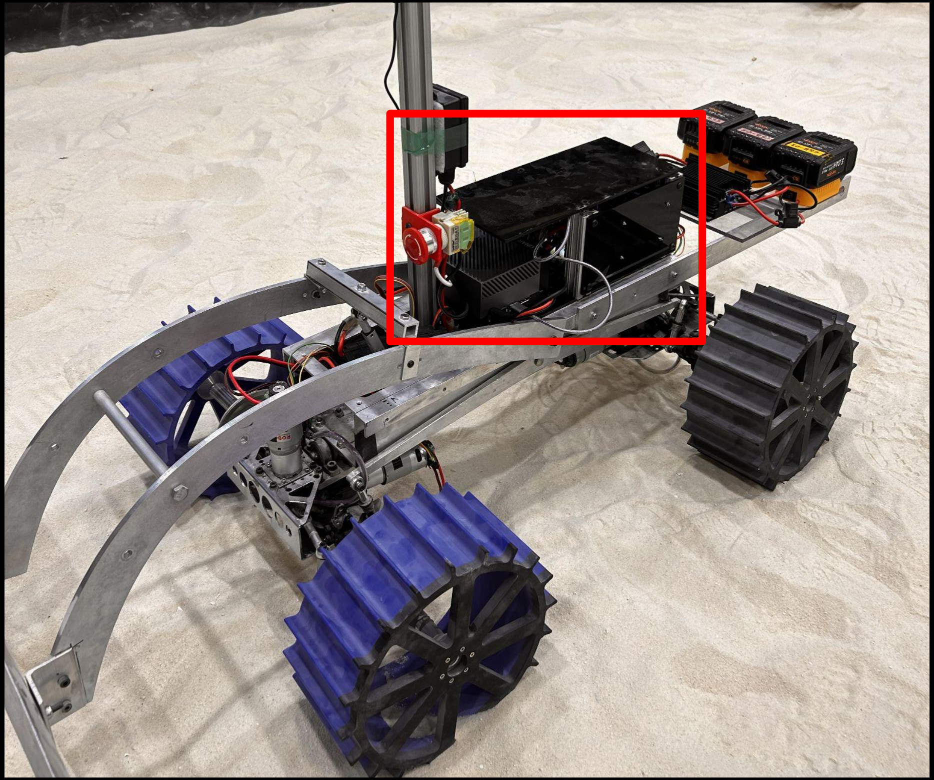
The low agglutinate (stickiness) and friction of the fine powdery regolith led to the development of our customized wheel with high grousers. This is designed for maximizing traction, minimizing slip, and allowing for efficient steering





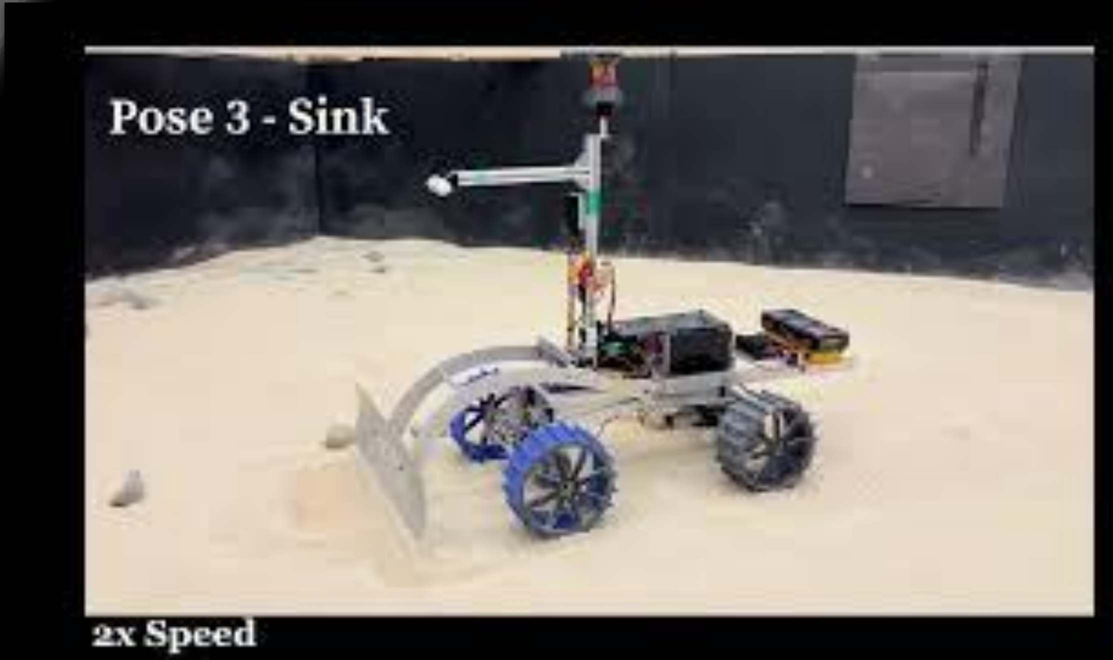
NASA/TP—2006–214605: Application to project

The fine particulate nature of the regolith necessitated the development of our dust resistant electronics box

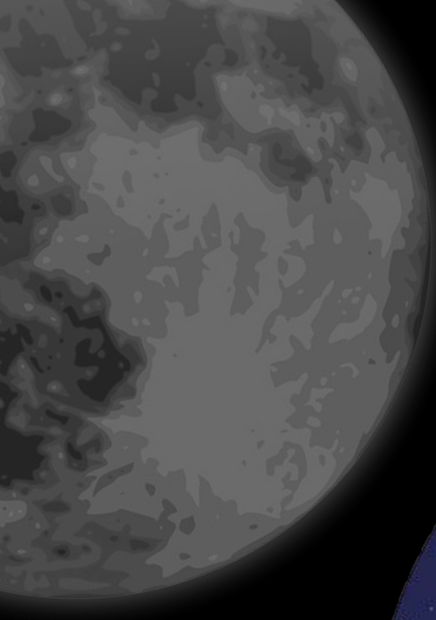


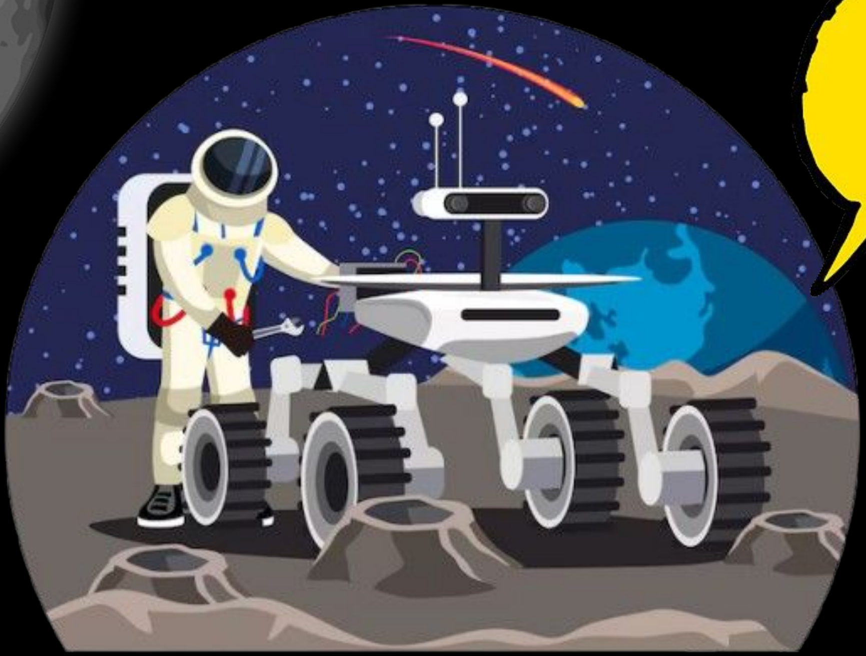
NASA/TP—2006–214605: Application to project

Our back-blading methodology for grading craters comes from the fact that lunar regolith has very low cohesion. It can be easily pushed to the sides if enough linear force is applied (such is the case when the entire weight of the rover is dragging the blade backwards)



Colonize the Moon!
- *Team Lunar ROADSTER*

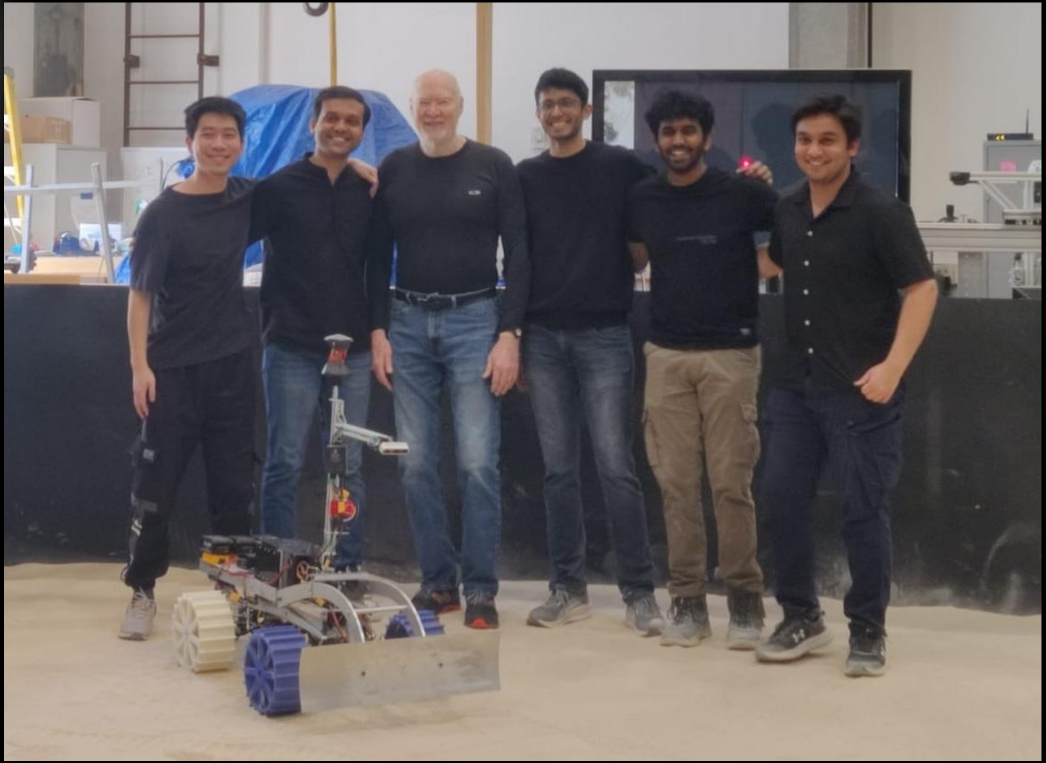




Any Questions? 🤖🦾🚀

“Starting with a foothold on the Moon, we pave the way to the cosmos”

Thank You!



https://mrsdprojects.ri.cmu.edu/2025teami/

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