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The 9th
Mission Idea Contest:
to the Moon

VISTA-PIPR: Virtual Immersive Sensing & Terrain Analysis for Polar Ice Prospecting Rover

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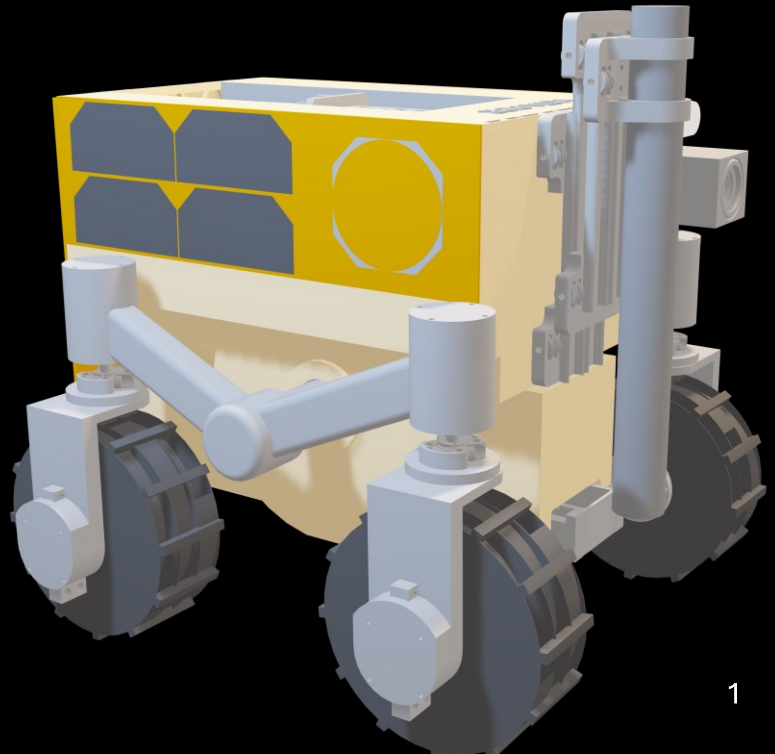

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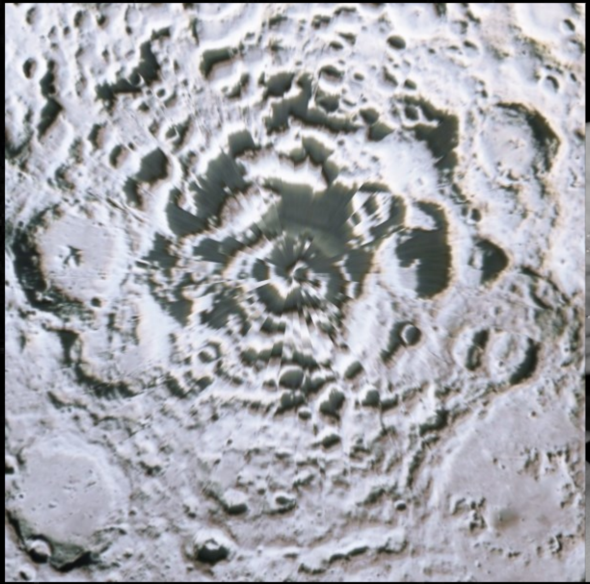
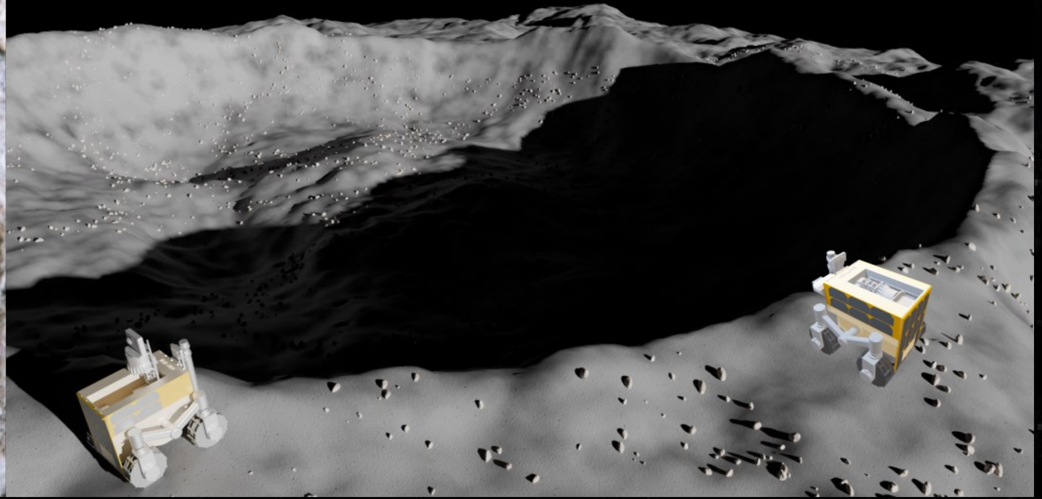
The Quest for Lunar Water

- Access to lunar water ice is the key to sustainable space exploration (life support, propellant).
- Current orbital data lacks the resolution for mission planning;
- We need meter-scale ground truth that ties H-content to terrain safety and mechanical properties.





Mission Objective

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Map Subsurface Ice

Detect & map ≥1 wt% H to ~30 cm across ~500 m^2

Impact

Ground truth for Artemis-class ISRU planning

Immersive VR models

120 MP panoramas + ~1.5M pts/s LiDAR.

Impact

Digital twin with ≤10 cm horizontal / ≤5 cm vertical errors.

Validate Extraction

Drill ≤30 cm; heat samples to release H_2O vapor

Impact

Proof-of-concept extraction (grams scale).

Multi-Site Survey

≥500 m traverse; ≥5 distinct sites (rims, PSR edges, slopes, plains)

Impact

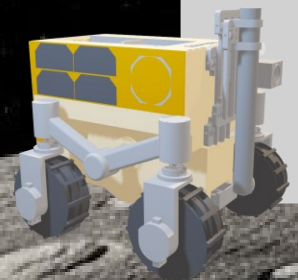
Build statistics across terrains for safety & feasibility

Autonomy Demo

Meta-Reinforcement Learning for hazard avoidance and re-planning

Impact

Execute 1 autonomous excavation + analysis cycle.



Rover at a glance

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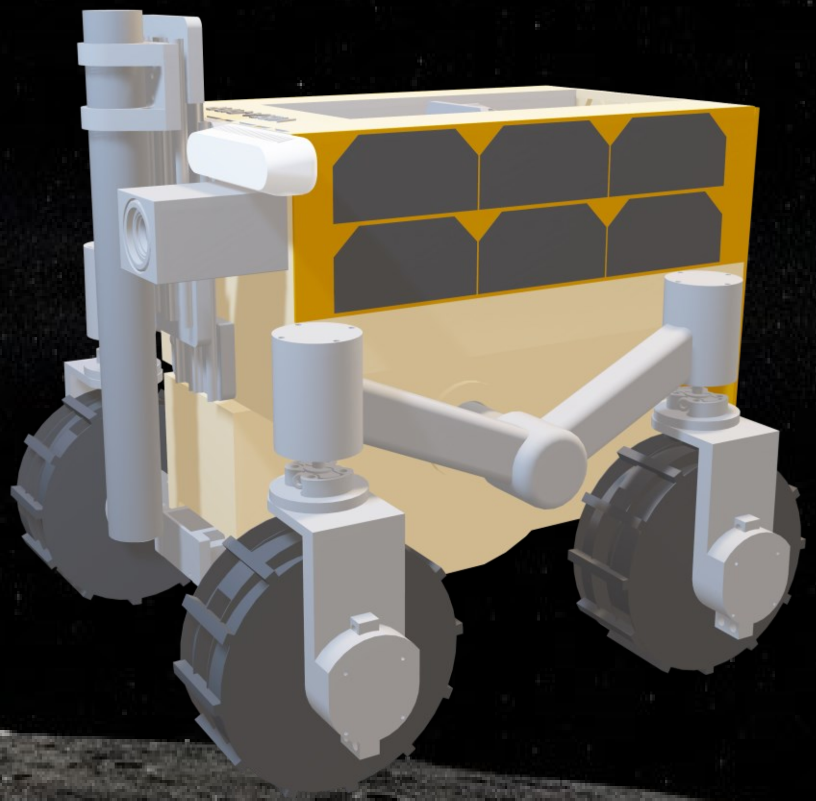
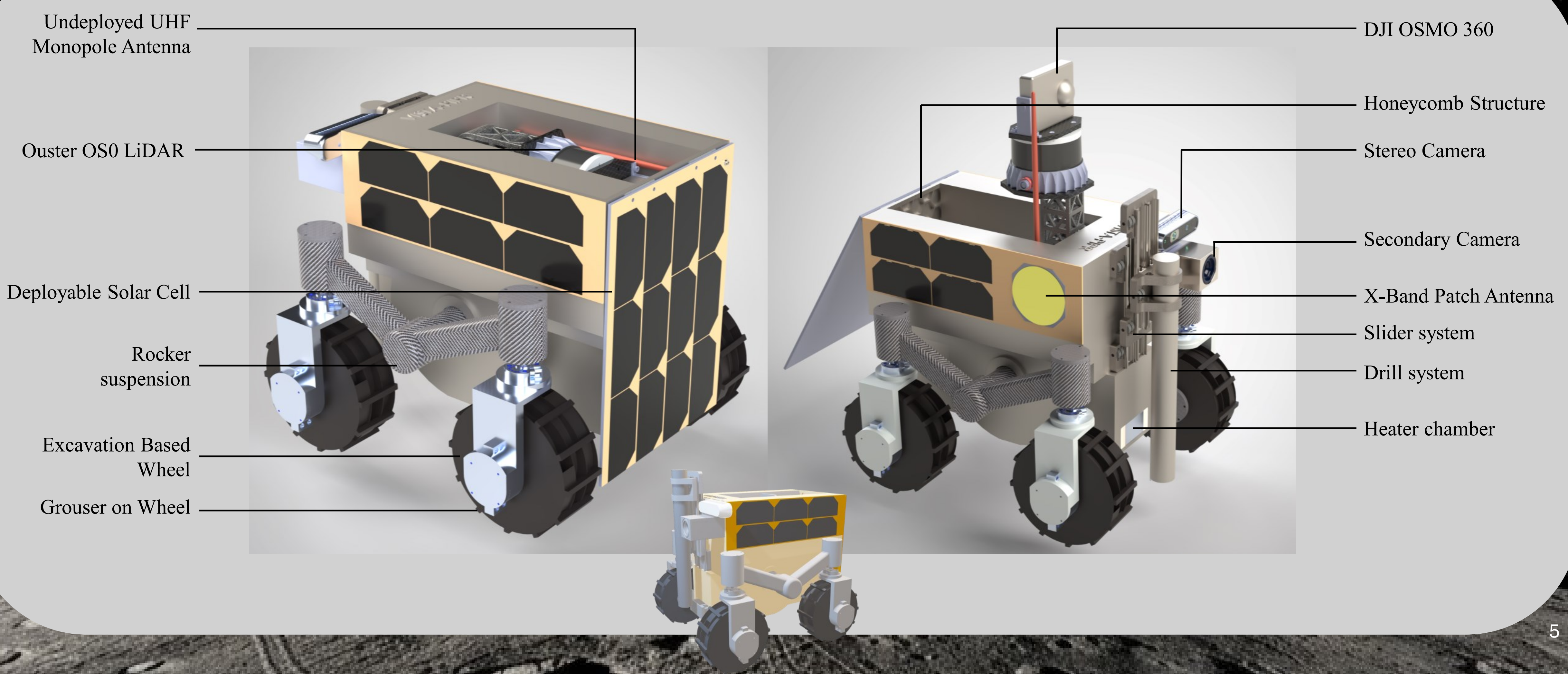
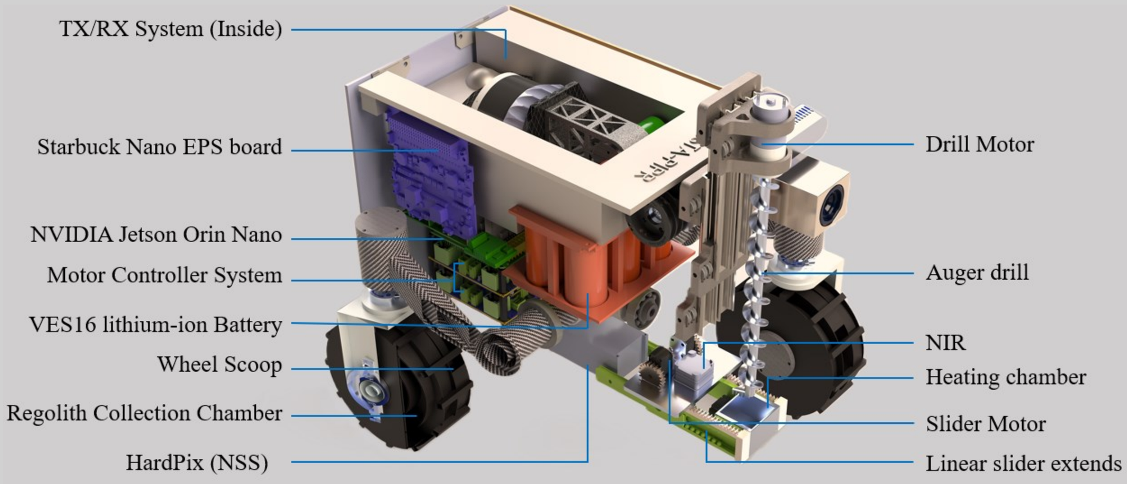
- $35 \times 30 \times 30$ cm; 4WD/4WS; rocker suspension; grouser wheels (20–25° slopes).
- Weights 9.79 Kg
- OBC: Jetson Orin Nano (~10 W, ~70 TOPS), ROS 2; multi-bus (CAN/I^2C).
- Mast: 120 MP RGB + 32-ch LiDAR ($360 \times 30°$, ≤10 Hz); chassis stereo backup.
- Localization: VIO + LiDAR SLAM (± 5 cm per traverse).

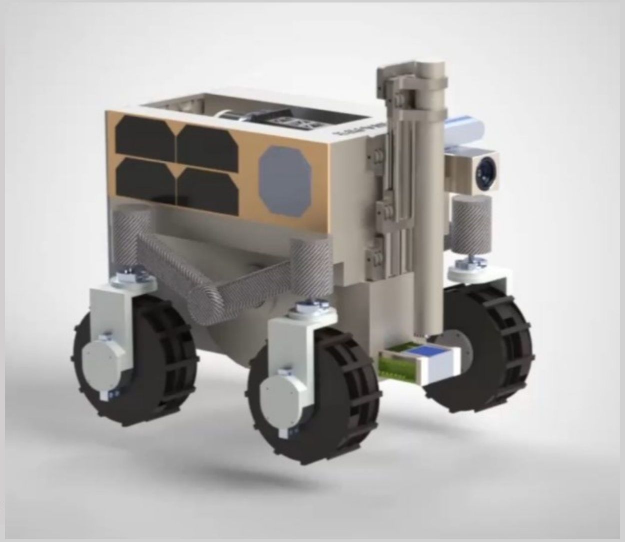


Rover at a glance



Rover at a glance





Scientific payload

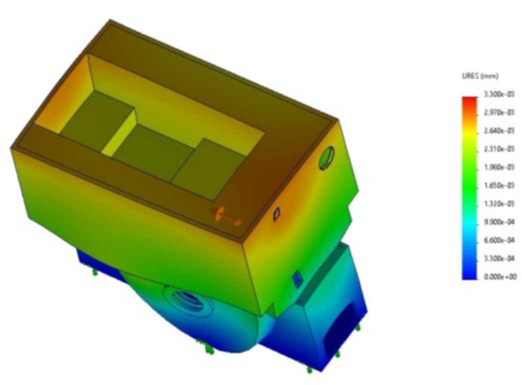
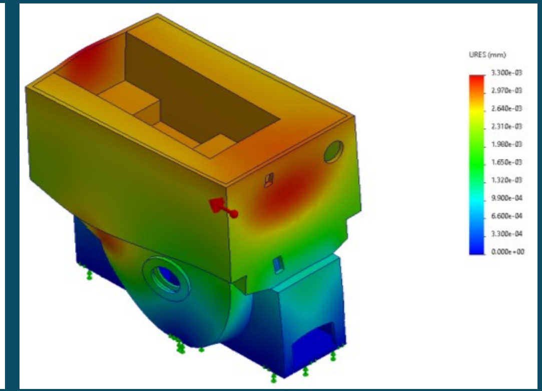
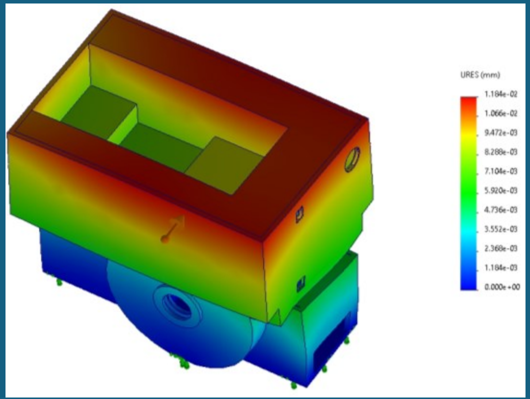
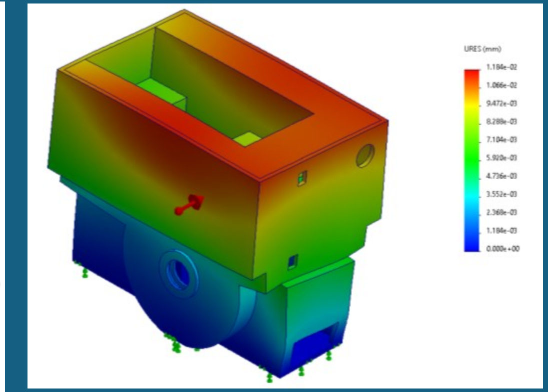
- Mini neutron spectrometer (thermal/epithermal).
- Near-IR spectrometer (1.3–2.5 μm) for H_2O/OH bands.
- Sample drill (≤30 cm) + sealed micro-oven (150–200 ° C).

Analysis Conditions

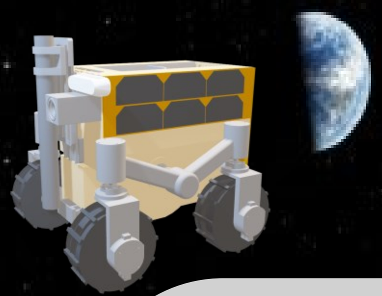
- Bottom surface fixed
- Apply 10G load to front and sides for comparison

Summary

- The mechanical strength of honeycomb structures varies with the direction of the applied force.
- Nevertheless, they maintain adequate strength and offer significant advantages in terms of weight reduction.

	Honeycomb structure	Non-honeycomb structure
Case 1: Front-Loaded Workload		
Case 2: Side-Loaded Workload		

Performance Capability



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Energy budget

- GaAs solar (tilt-adjustable) ~30 W peak; EPS with MPPT.
- Battery: Li-ion 64 Wh; ops focus on daylight (no night survival).
- Daily ops ~8.5–12.5 Wh, ample margin with modest insolation.

Links

- UHF rover ⇔ lander (435 MHz, 32–128 kbps, 0.5–2.0 km LOS).
- Lander ⇔ Earth X-band (≥256 kbps via DSN-class ground).
- ≥1.6–6.4 GB return over 14 days; prioritized store-and-forward.

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Concept of Operation

1 **Delivery & Initialization**
- Deploy from lander, establish comms, perform system checks
- Initial 360º panorama + LiDAR sweep > baseline map

2 **Navigation**
- Traverse short distances (10-50 m)
- Autonomy handles hazards (rocks, slopes)

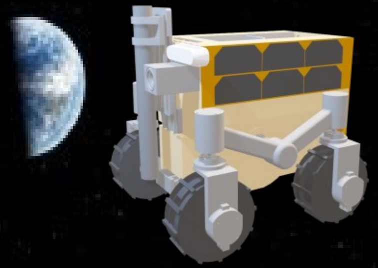
3 **Survey**
- Panoramic imaging + LiDAR mapping
- Update terrain models & VR digital twin

4 **Prospecting**
- Neutron spectrometer
- Detect possible subsurface ice deposits.

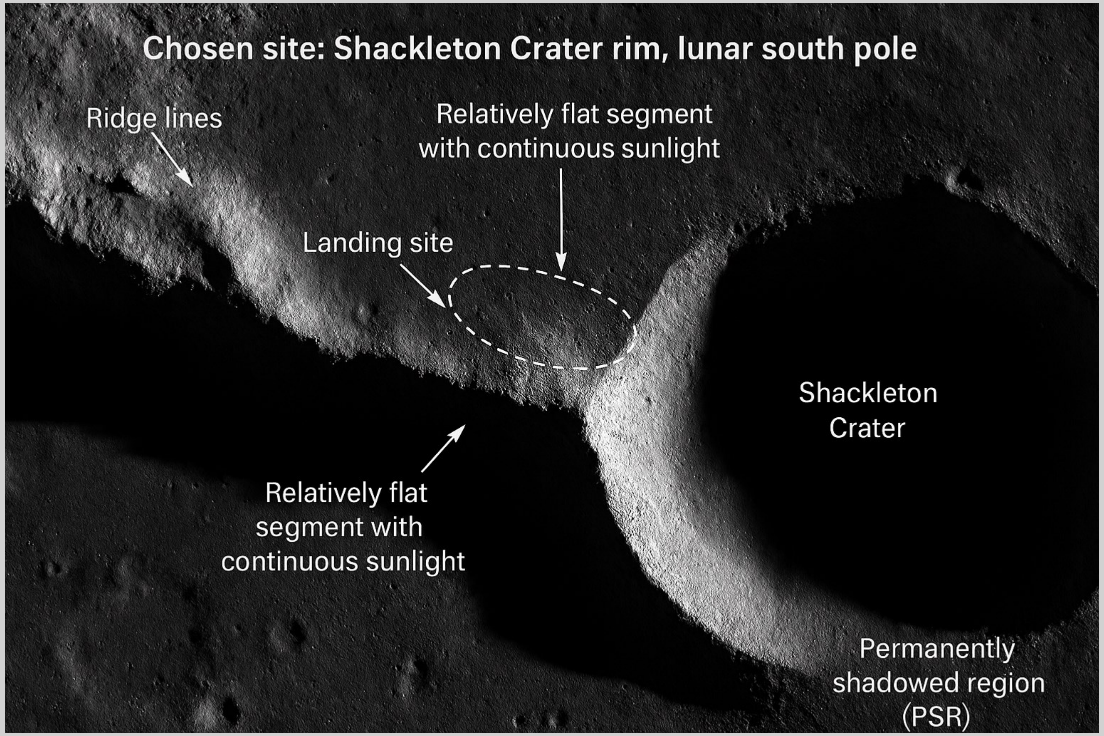
5 **Sampling & Analysis**
- If hydrogen >1 wt%, drill upto 30 cm, heat sample
- IR spectrometer measure hydrogen
- Measure released volatiles (water vapor, others).

6 **Data Transmission**
- Relay high-priority science data first.
- Bulk panoramas & 3D maps steadily downlinked.

Landing site: Shackleton rim



- Extended illumination on ridges (10–12 Earth days continuous).
- Proximity to PSRs for hydrogen sensing and context imaging.
- Rugged but traversable; operations 500–1000 m from rim for safety.



Impact beyond a single mission

- **Societal:** immersive public access to the south pole; equitable STEM inspiration.
- **Technical:** autonomy (Meta-RL), neutron sensing, high-res mapping for Artemis era.
- **Commercial & Education:** share datasets & lower barriers for emerging space nations/startups.

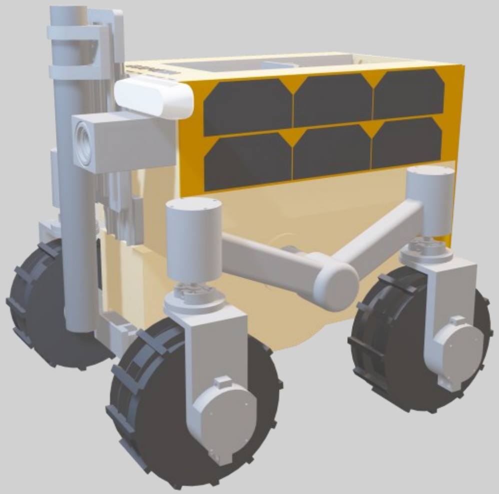
Top Risks & Mitigations

1 **LiDAR failure**

Redundant stereo vision path
Thermal/vibe screening pre-flight

2 **Comms loss**

Relay via lander + DTE beacon
Adaptive rate & prioritization



5 **Data Loss**

Dual Storage Buffer
Incremental data Transmission

3 **Power shortfall**

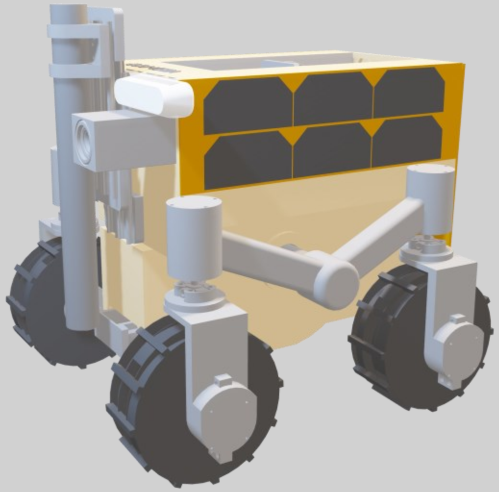
Inclined panel design
Conservative, noon-biased scheduling

4 **Sampler issues**

Mechanical redundancy
Alternate ops reconfiguration

VISTA-PIPR Budget Breakdown

Category	Estimated Cost (USD)	Description
Hardware & Materials	~$1.5M	Sensors, avionics, solar panels, batteries, chassis fabrication
Testing & Facilities	~$1.0M	Environmental tests (TVAC, vibration, EMC), regolith sandbox, PSR imaging simulations
Personnel & Operations	~$1.5M	Student stipends, staff support, mission ops, VR outreach/data pipeline
Total	$4.0M	Excluding lander and launch (partner provided)



PHASE 4

PHASE 1

PHASE 2

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M1-3	M4-6	M7-9

REQUIREMENTS & TRADE STUDIES

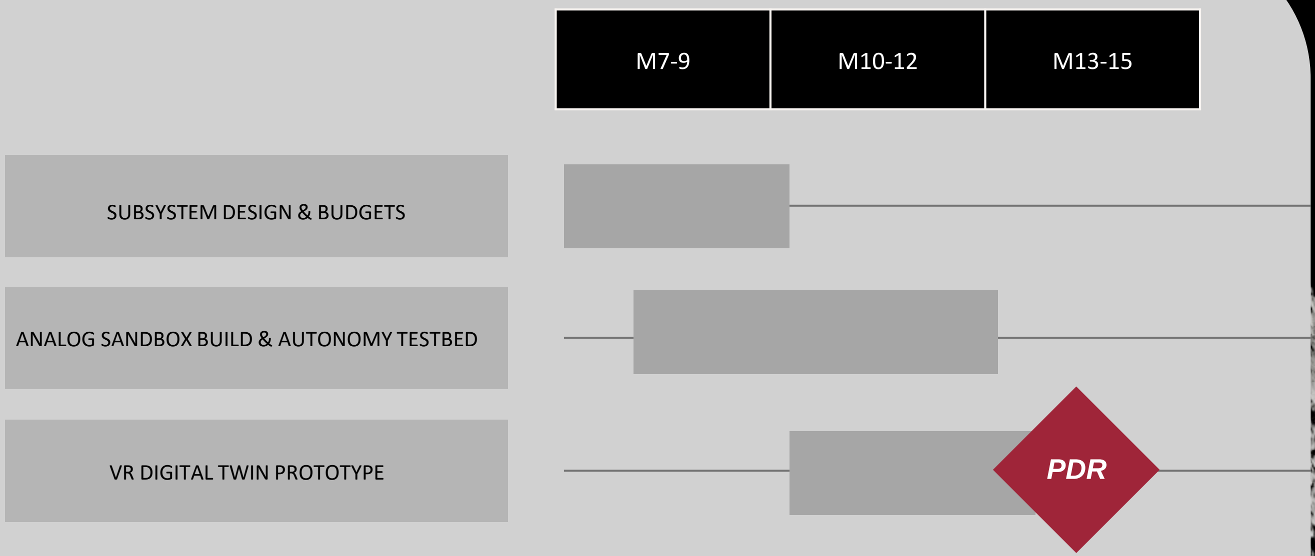
PROTOTYPE BREADBOARD TESTS

SRR

CAD & THERMAL/STRUCTURAL ANALYSES

PHASE 1

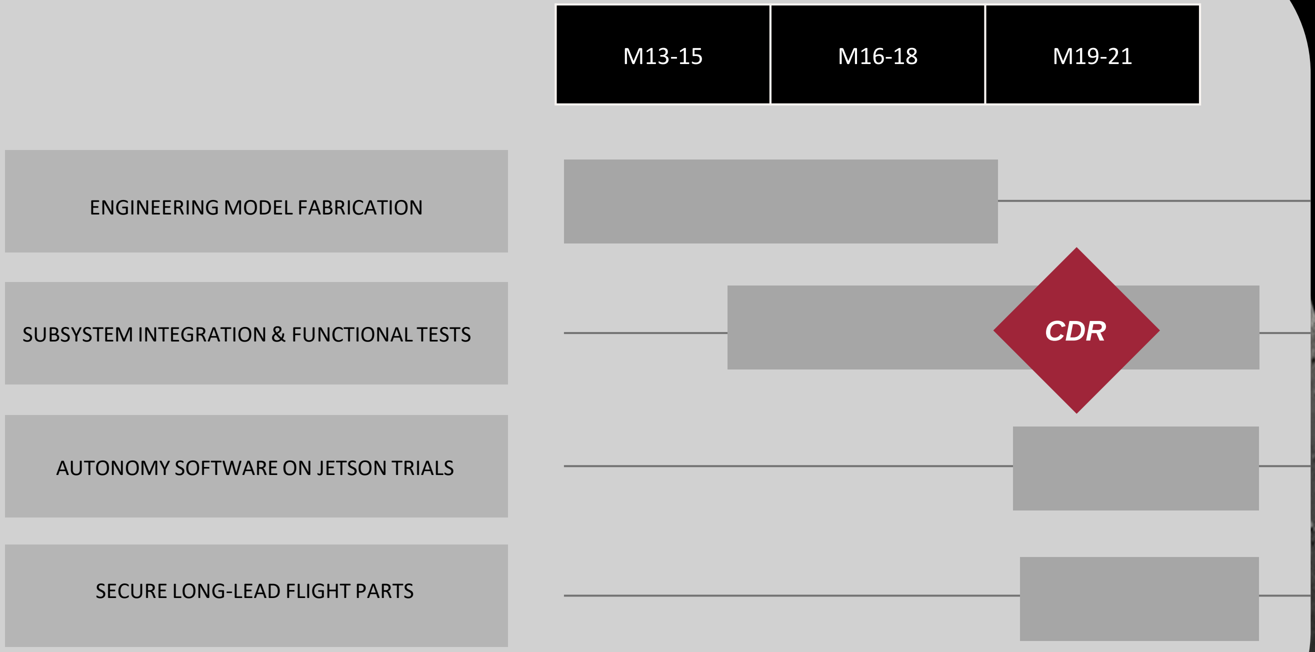
PHASE 2



PHASE 3

PHASE 2

PHASE 3



PHASE 4

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PHASE 3

PHASE 4 & 5

PHASE 1

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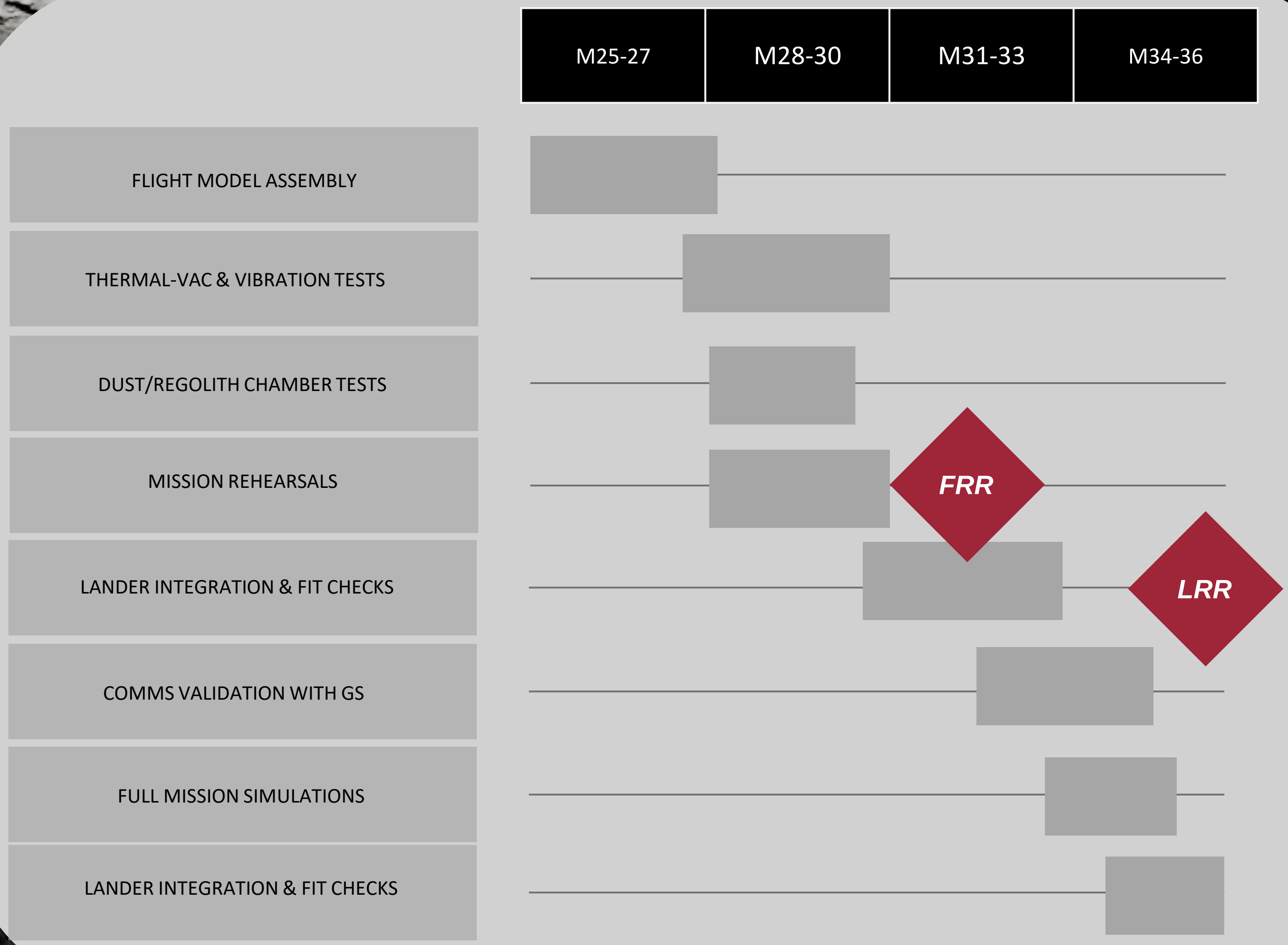
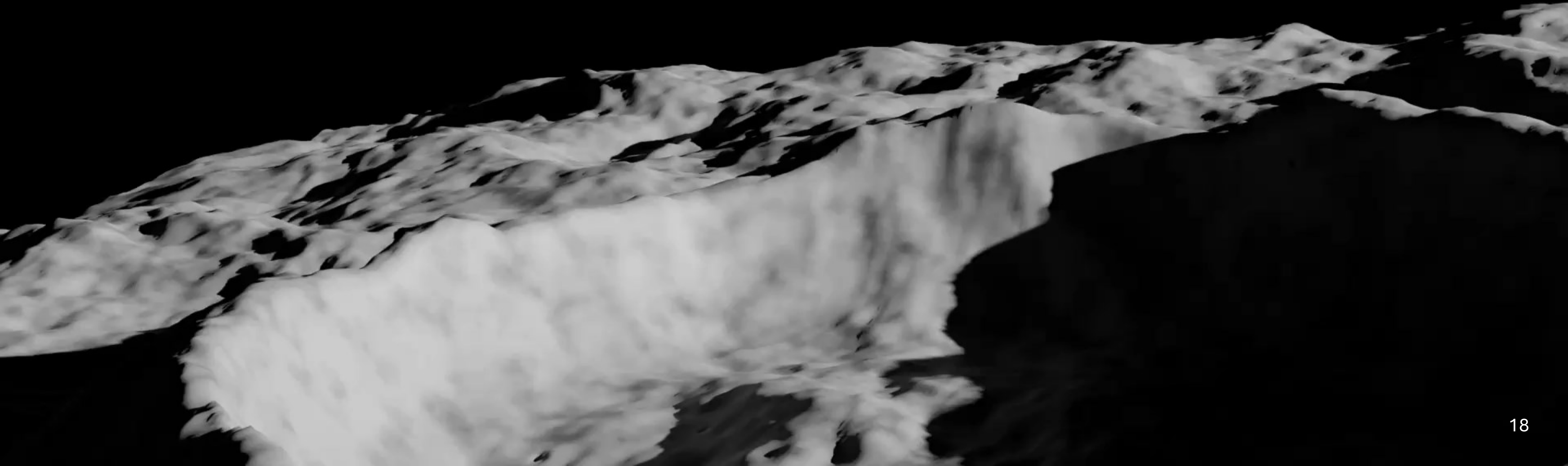
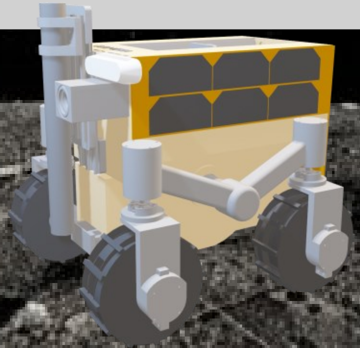




Thank you

Questions, collaborations, and flight opportunities welcome.



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Appendix

Appendix

A1. Rover Traversal Capability Equation

To verify the rover's ability to complete a 500 m traverse within a single lunar day:

$$t = \frac{d}{v}$$

where:

- $d = 500\,\mathrm{m}$ (planned traverse distance),
- $v = 0.05\,\mathrm{m/s}$ (nominal speed).

$$t = \frac{500}{0.05} = 10{,}000\,\mathrm{s} \approx 2.78\,\mathrm{hours}$$

Even doubling for contingencies (slip, detours, replanning) gives ~6 hours — well within the 14 Earth-day lunar daylight window.

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A2. Power Budget Validation

Energy Consumption

Activity	Power (W)	Duration	Energy (Wh)
Driving (per day)	30	12 min	6 Wh
Science/Scanning	15	10 min	2.5 Wh
Housekeeping/Comms	5	Continuous	~2 Wh
Total (avg/day)			**~10 Wh/day**

Available Energy

Solar array: 30 W peak × 2 h of good sunlight = 60 Wh/day

→ Energy margin ≈ ×3 safety factor.

This confirms no risk of depletion during daytime operation.

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A3. Data Transmission Capacity

Surface–Lander UHF Link

- Frequency: **435 MHz**, Range: **0.5–2.0 km**, Data rate: **32–128 kbps**.
- Link margin: **3–10 dB** depending on terrain.

Lander–Earth X-Band Relay

- Frequency: **8.4 GHz**, Data rate: **≥256 kbps** (DSN class 34 m antenna).

Total return over 14 days:

≈ 1.6 GB (at 32 kbps) up to 6.4 GB (at 128 kbps).

That's enough to downlink compressed panoramas, neutron data, and decimated LiDAR point clouds still fit within the 32 GB onboard storage.

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A4. LiDAR and Mapping Accuracy

- **LiDAR Performance:** 1.5 M points/sec, ≤5 cm accuracy.
- **Coverage per stop:** ≈100 m^2 after occlusion corrections.
- **Total area:** 5 science sites → ~500 m^2 static mapping + 500 m^2 in-transit mapping.
- **Resolution goal:** ≤10 cm horizontal, ≤5 cm vertical.

This accuracy enables **realistic VR rendering** and **autonomous hazard assessment**.

A5. Neutron Spectrometer Sensitivity

Hydrogen is detected through **neutron flux moderation**:

- Hydrogen absorbs and slows epithermal neutrons.
- Comparing counts from cadmium-covered and bare detectors allows identification of hydrogen presence.

Detection threshold: **≥1 wt% hydrogen equivalent** within the top 30 cm consistent with ISRU relevance and the precision of instruments like LEND and HardPix-class spectrometers.

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A6. Thermal Sampling Analysis

- Drill depth: ≤30 cm
- Heating: 150–200 °C
- Expected vapor pressure: detectible within 30–60 s.
- Confirmed using **NIR spectral absorption** at 1.4 μm and 1.9 μm for H_2O/OH.

This combination validates both **detection** and **proof-of-concept extraction** of volatiles.

Appendix

A7. Landing Site Context – Shackleton Rim

Parameter	Value / Description
Latitude	89.9° S
Illumination	80–90% of the year (10–12 Earth days continuous sunlight)
Temperature	−50 °C to 0 °C (sunlit); down to −100 °C in shadows
Terrain	Slopes 5–15°, rugged but traversable
Science benefit	Adjacent to Permanently Shadowed Regions (PSRs) rich in hydrogen
Operational benefit	Continuous line-of-sight for UHF and X-band comms

Appendix

A8. Mass Budget Summary

Subsystem	Mass (kg)	Margin	Final (kg)
Structure & Chassis	1.50	+10%	1.65
Mobility (motors, wheels)	1.50	+10%	1.65
Power (battery, solar)	2.10	+10%	2.31
OBC & Avionics	0.50	+10%	0.55
Comms	0.40	+10%	0.44
Navigation & Sensors	0.50	+10%	0.55
Payload	1.60	+10%	1.76
Thermal + Cabling	0.55	+10%	0.60
Total	—	—	**9.79 kg**

Two-Way Extendable Mechanism

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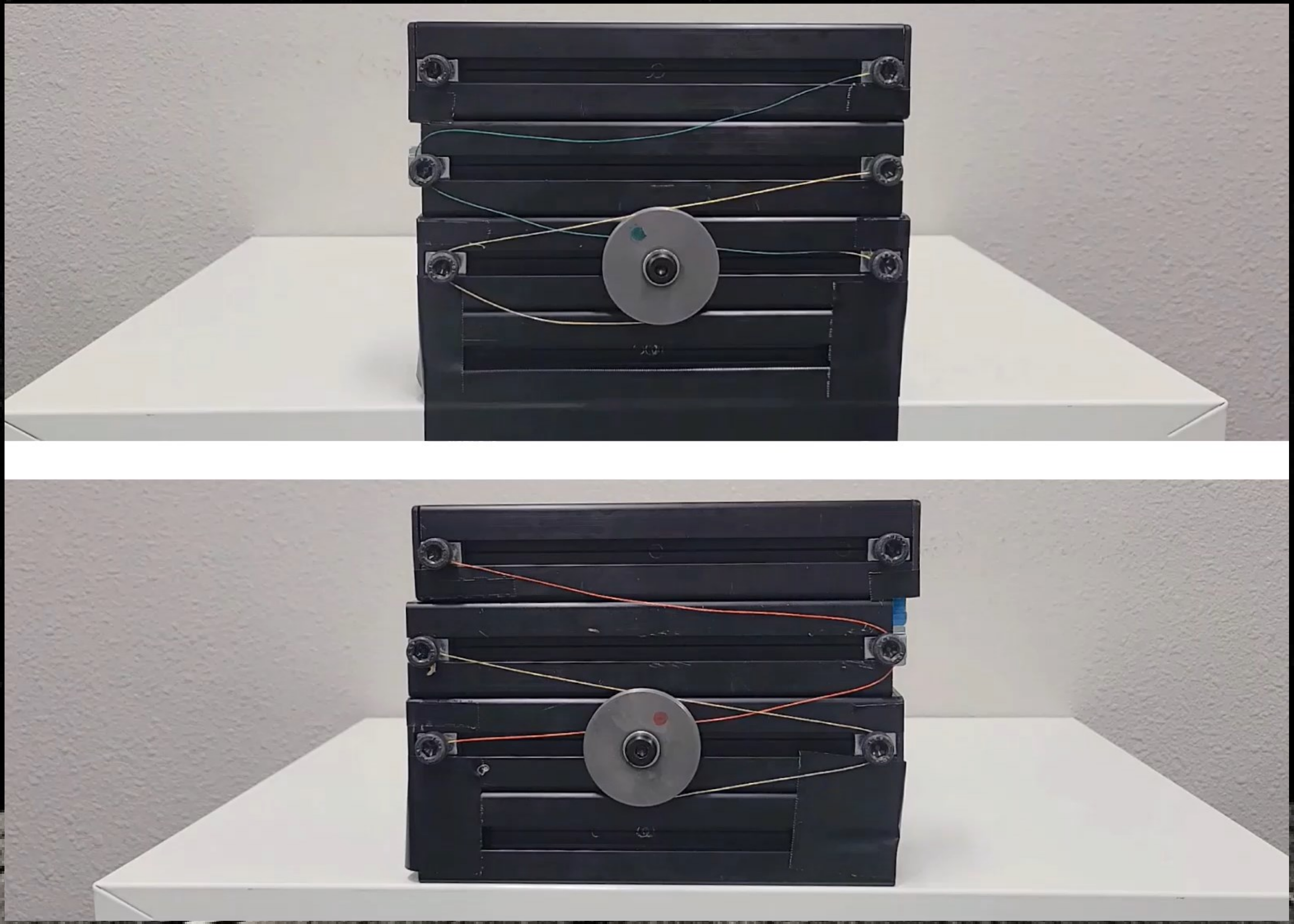

Bogie mechanism

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