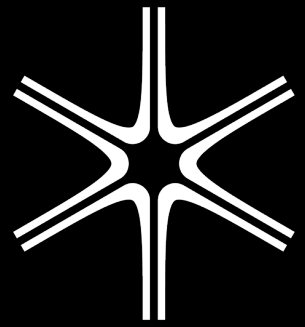

STARPATH

STARMINE

A FULL-STACK LUNAR PROPELLANT PRODUCTION SYSTEM

Space Resources Roundtable XXV 6/4/25

D. A. Aden, G. Acosta Quiros, M. Gondhalekar


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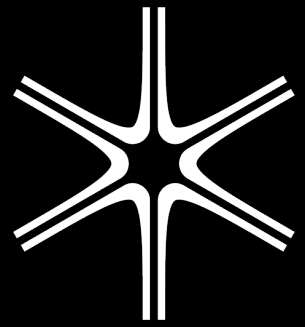

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A FULL-STACK LUNAR PROPELLANT PRODUCTION SYSTEM

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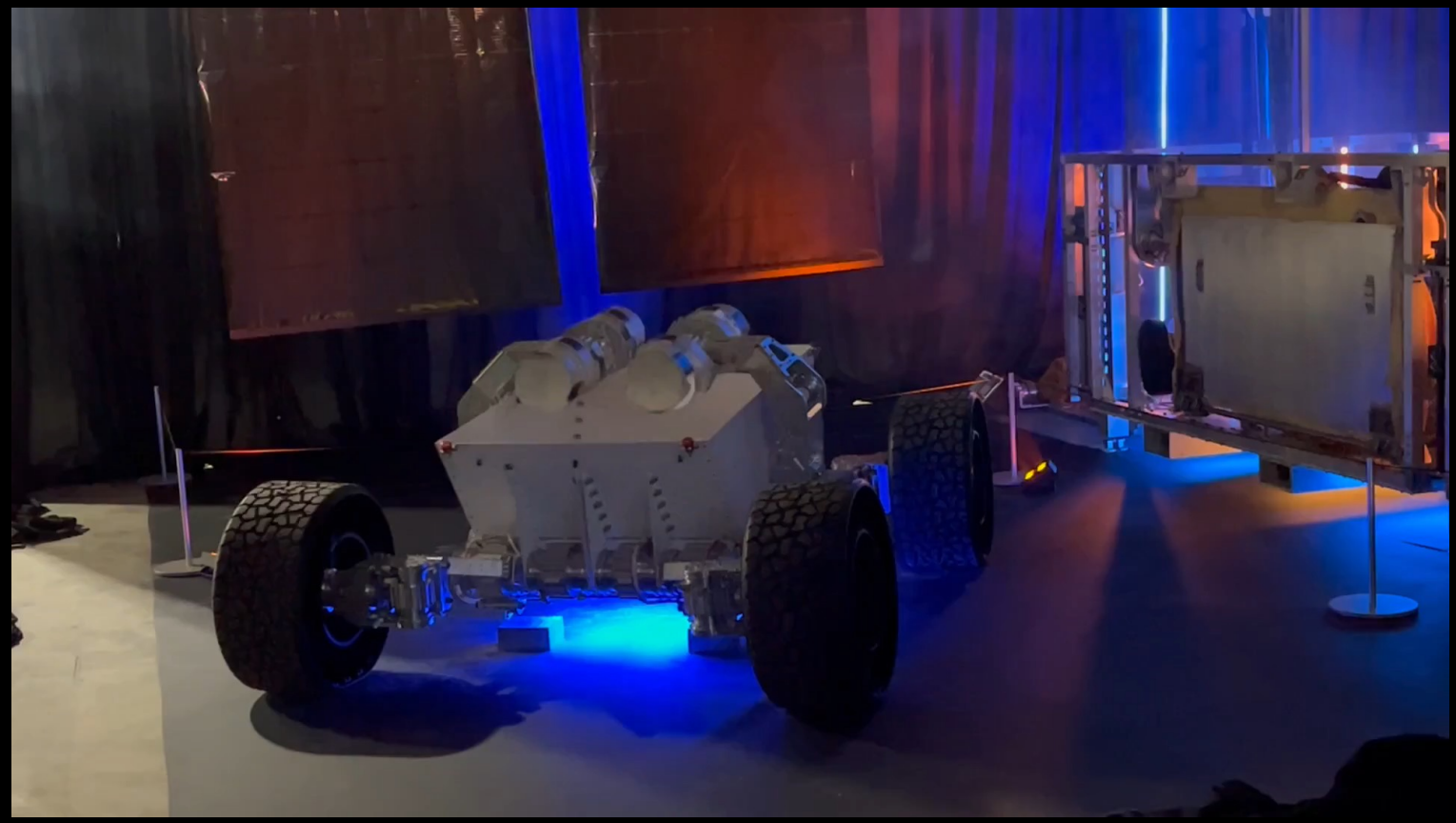
Overview

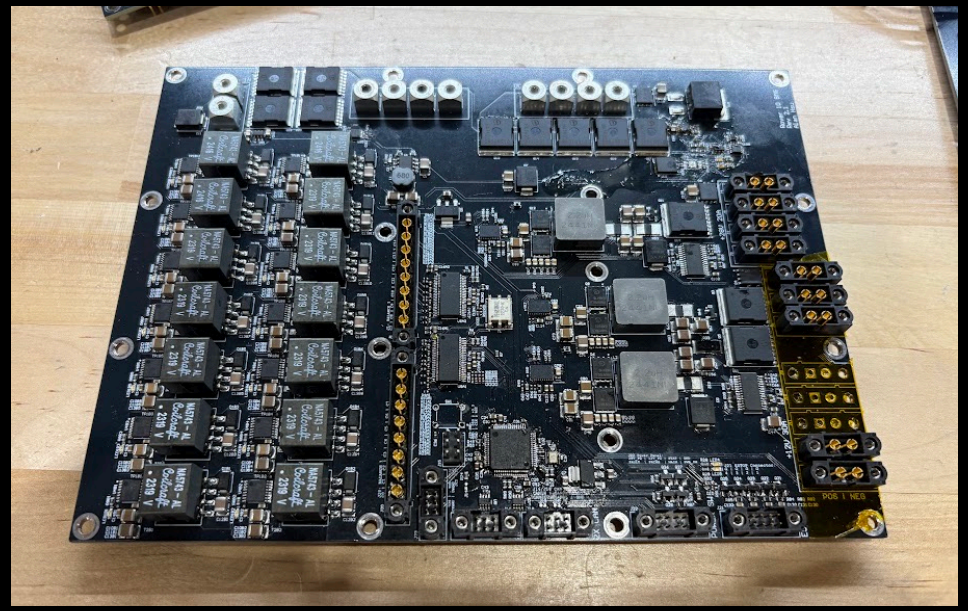
- Starmine
- Rover
- Plant
- Tower
- Integrated Testing
- Next Up



Starmine

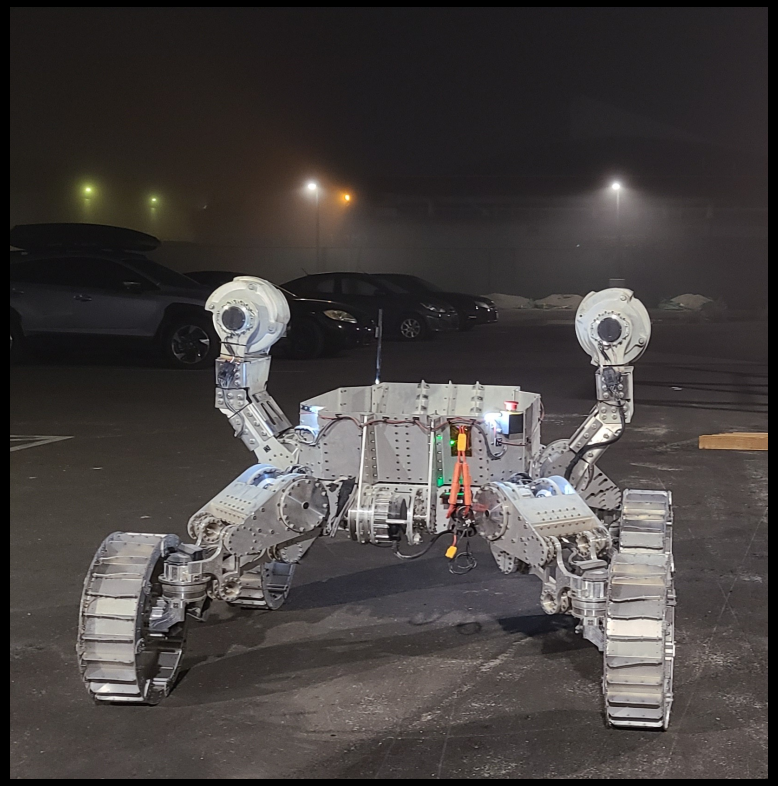
Vertically integrated self-sufficient Lunar resource production system

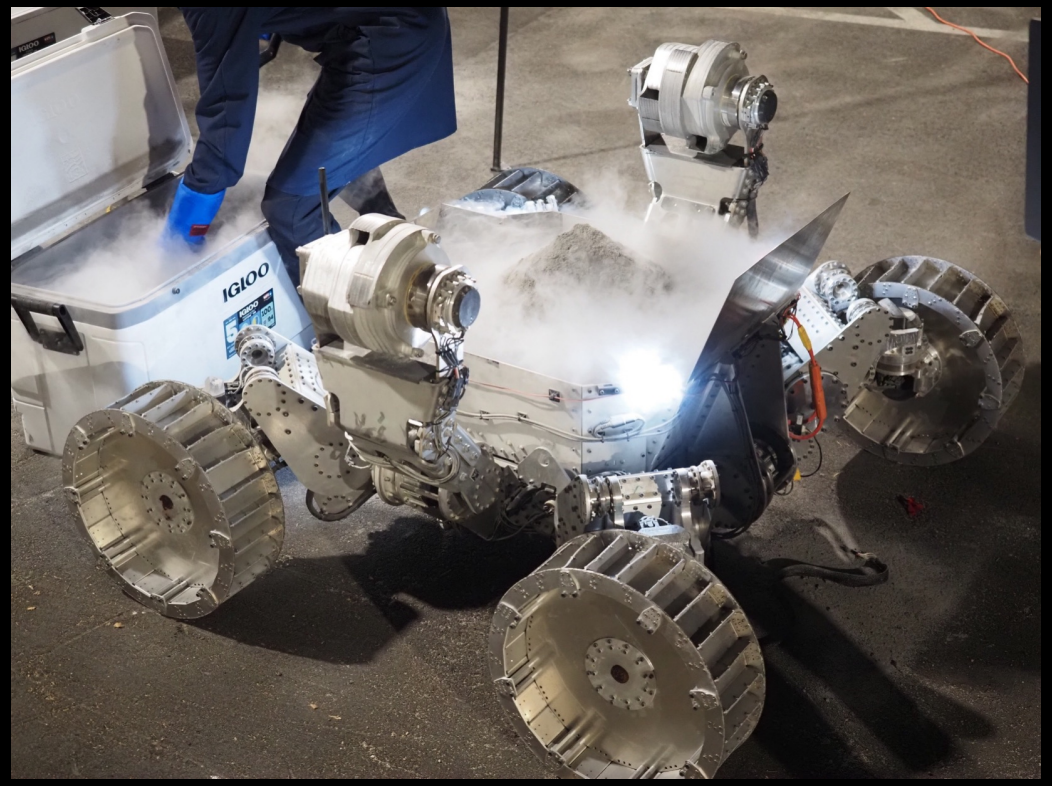
- Rover mines icy regolith from PSR → Plant turns water into oxygen
- Power supplied by 100 kW-scale vertical deployable solar array
- Partial use of H_2 as process gas; NRE is gate to product offering
- In-house electronics & actuator development; In-house autonomy
- Leveraging LTV for system placement; using FLEX payload spec
- Ton-scale lander downmass requirement for full system

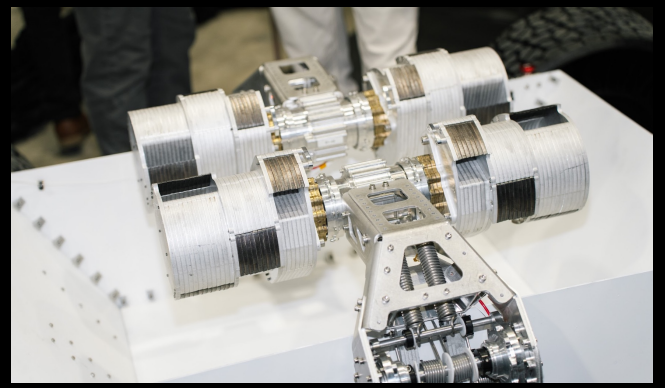


Rover

- First Starpath program – development started 2022
- Rover 8: Break the Ice Phase II, Fall 2023
- Rover 9.2: Break the Ice Phase III, Summer 2024
  - Thanks to NASA for the video!
- Rover 10: TVAC prep, autonomy pathfinding, current
- Counter-rotating drum barrels, actuated dump bed, independent active suspension

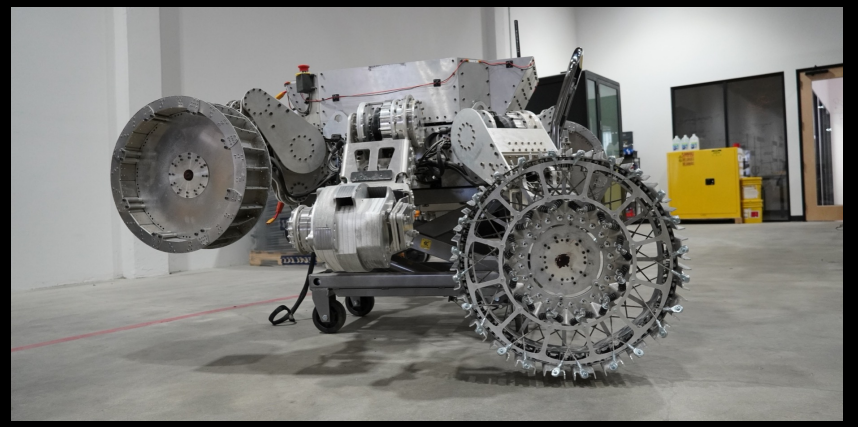


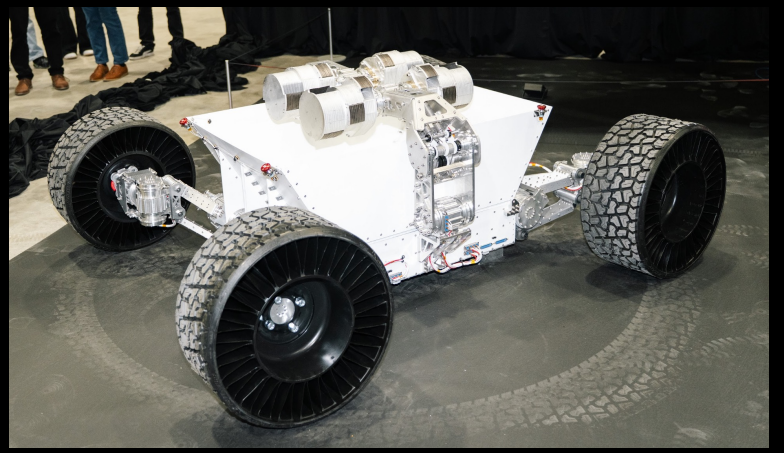


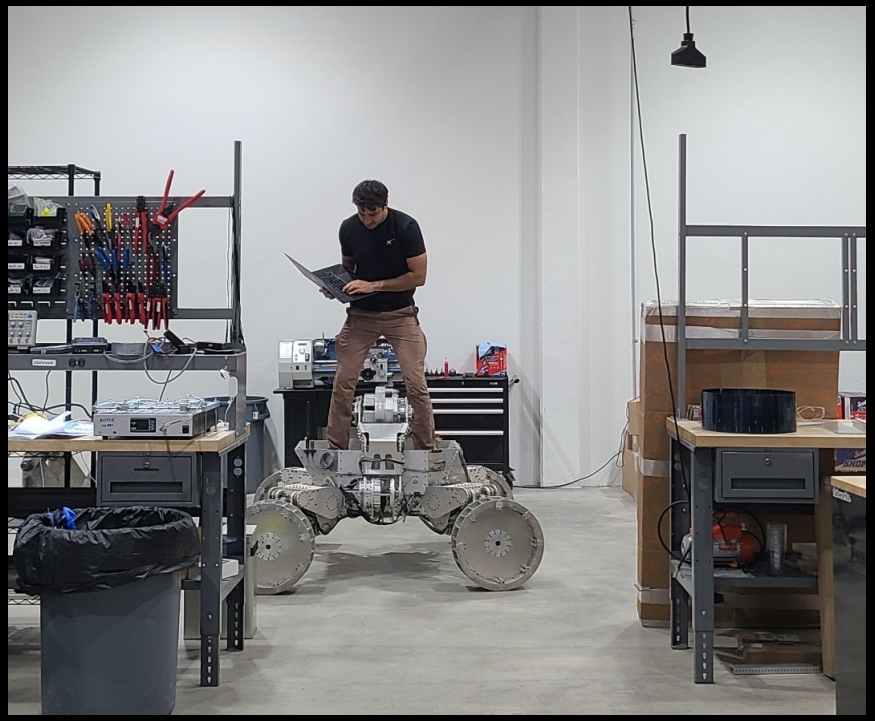


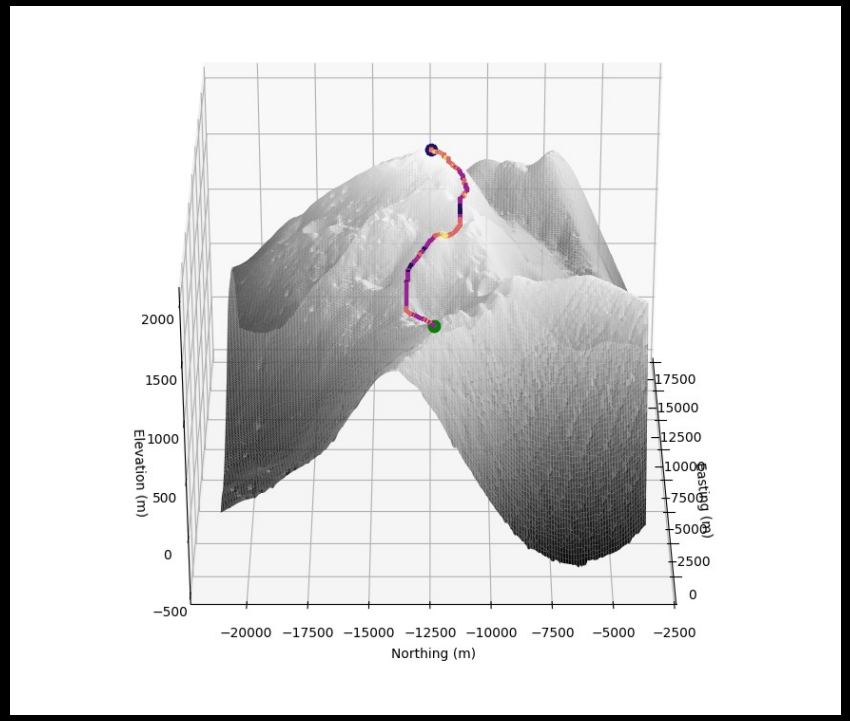
Rover

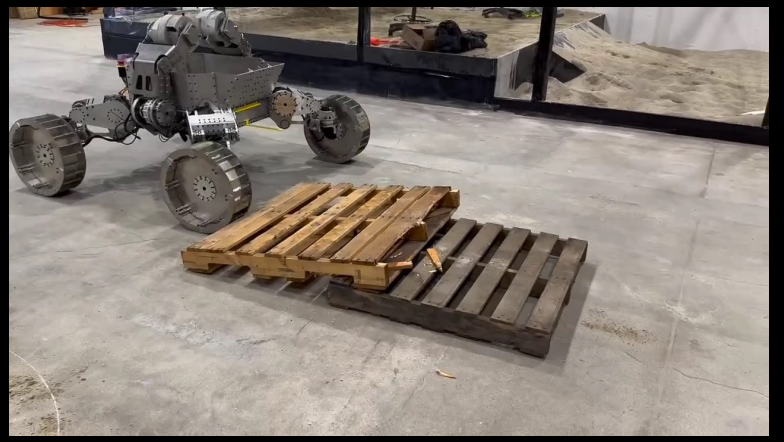
- Crater traversal significant concern
  - Rigid wheels on Rover 9
  - Active suspension developed from Rover 8 onward
  - Rubber wheels to not destroy floor with Rover 10
  - ~8 compliant wheel prototypes in
- Traverse planning via processed data from Moon Trek
  - Mons Mouton PSR1 -> Peak 3 below - 8x vertical scale
  - This traverse 15.3 km one-way





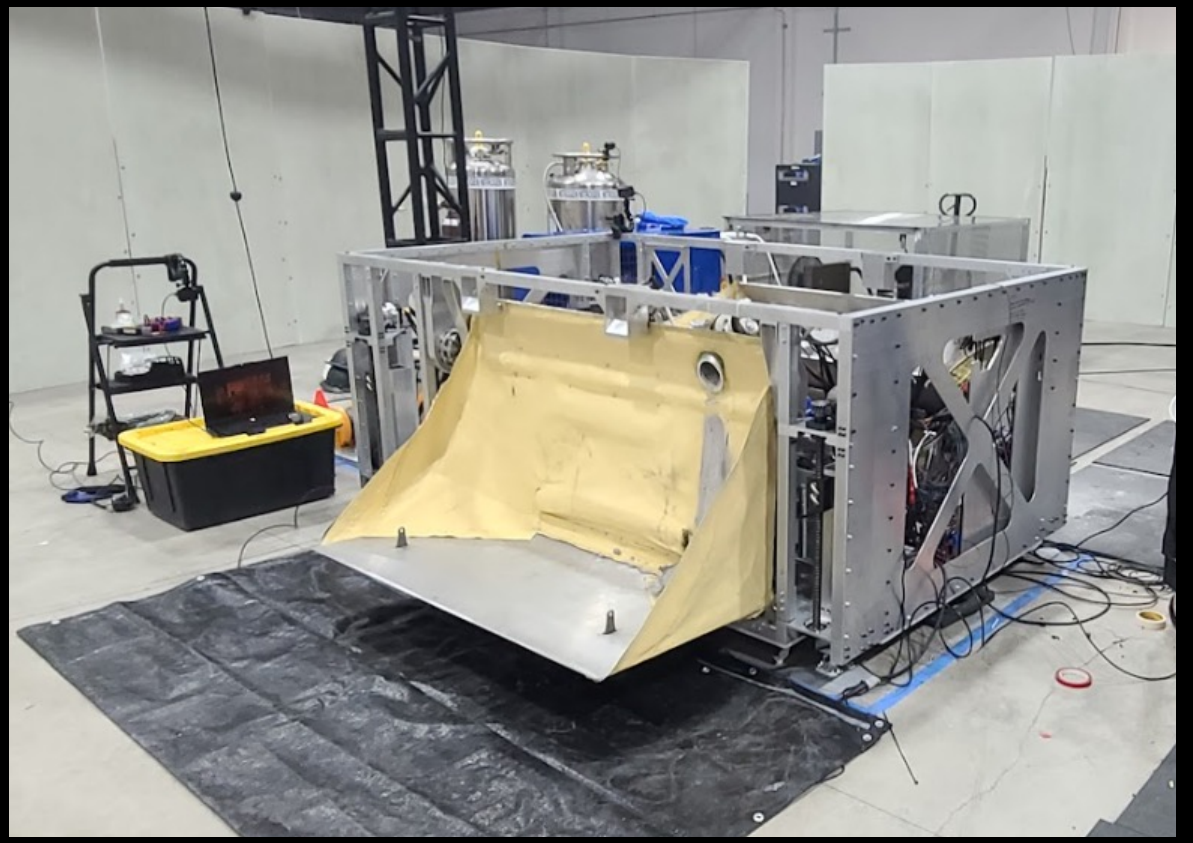


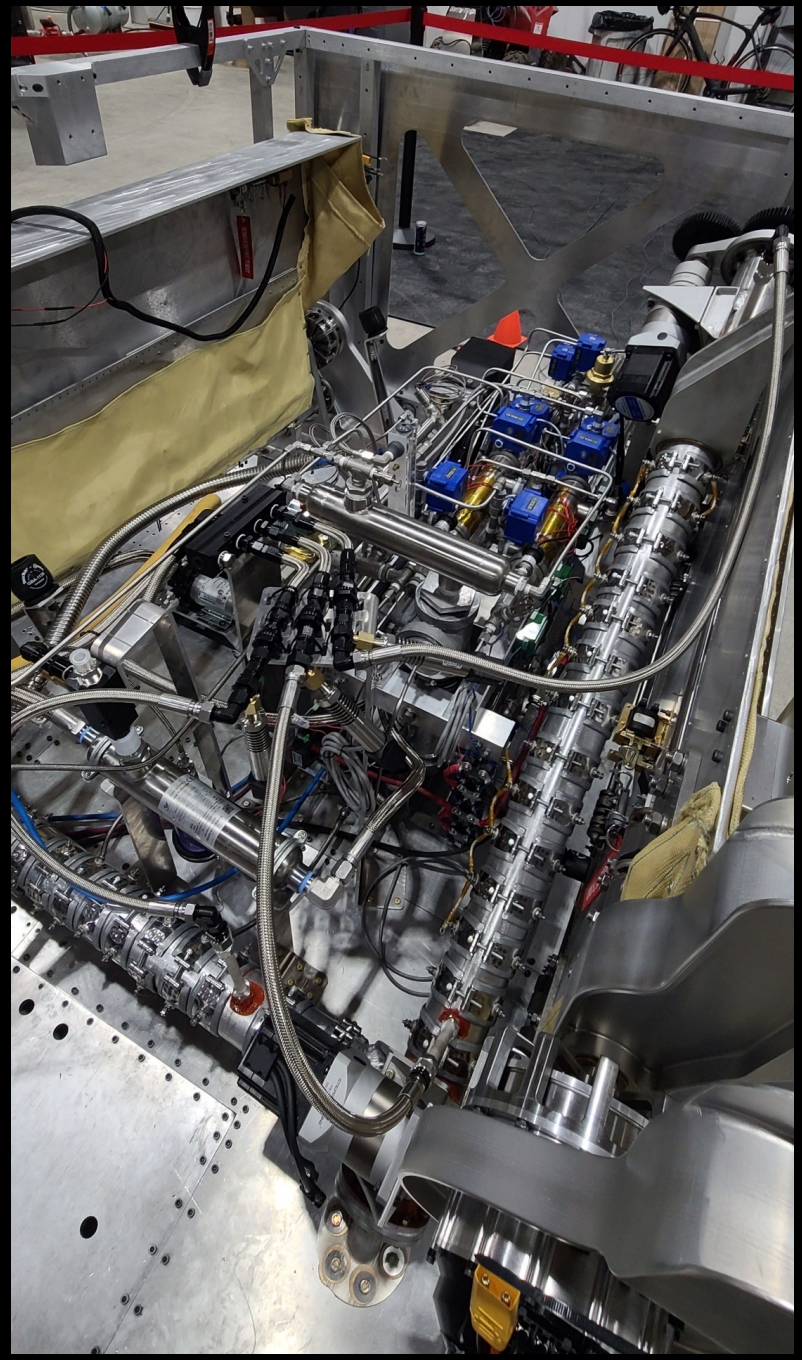




Plant

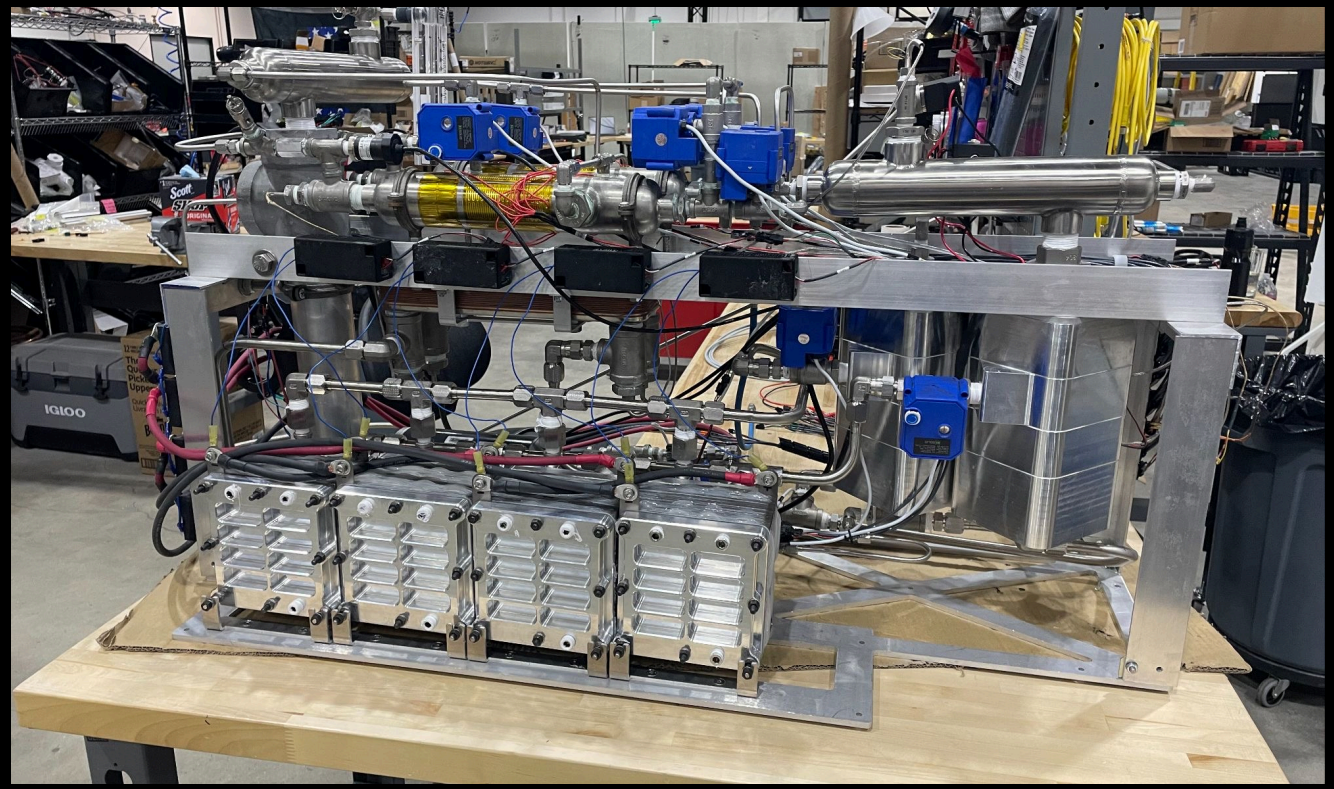
- Production target of 60 mT/yr pure O_2
  - 5.5 wt% water content in icy regolith assumed
- Regolith moved & heated with integrated auger-based system
- Multi-stage purification system for water, PEM electrolysis, PSA dryer
- Dual-routing liquefaction – commercial possibilities & in-house dev program
  - Scoping capability for full-scale demonstration mission

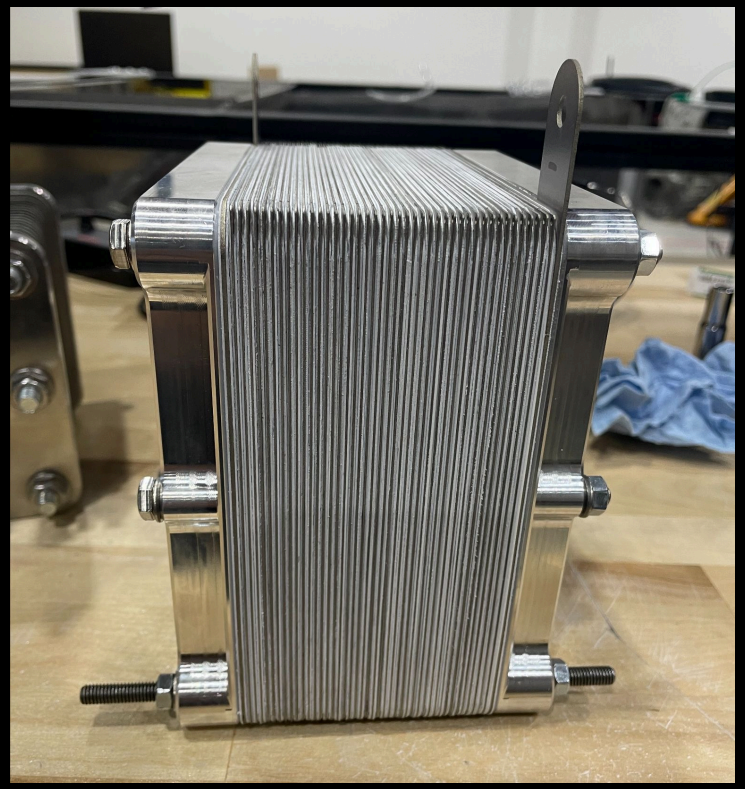




Plant

- Water extraction system
  - Successfully desiccated 6.1 wt% water regolith → 0 wt%; 42 g/s regolith
  - Distillation – partial volatile removal
- Conversion system – purifies, splits, dries
  - Vortex separators, stripping column
  - Deployed 53 kW in-house PEM stack

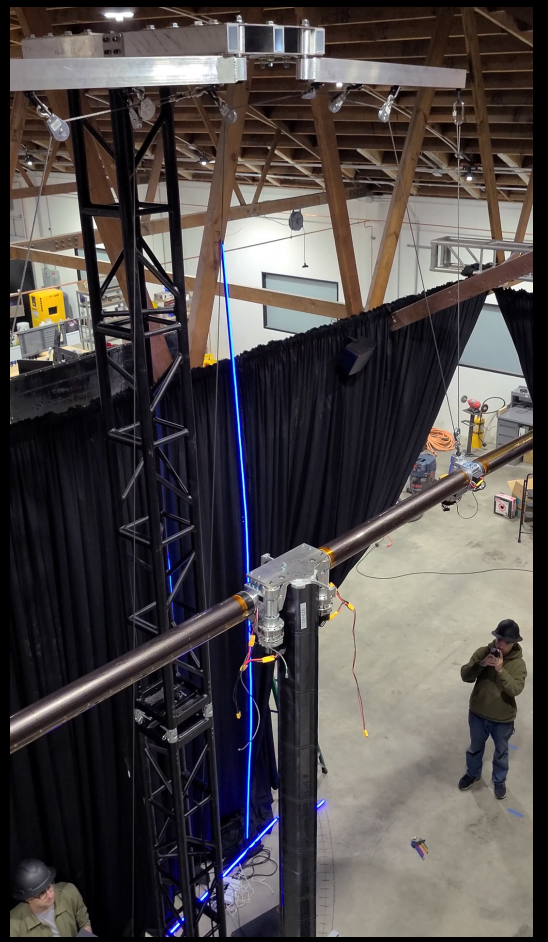


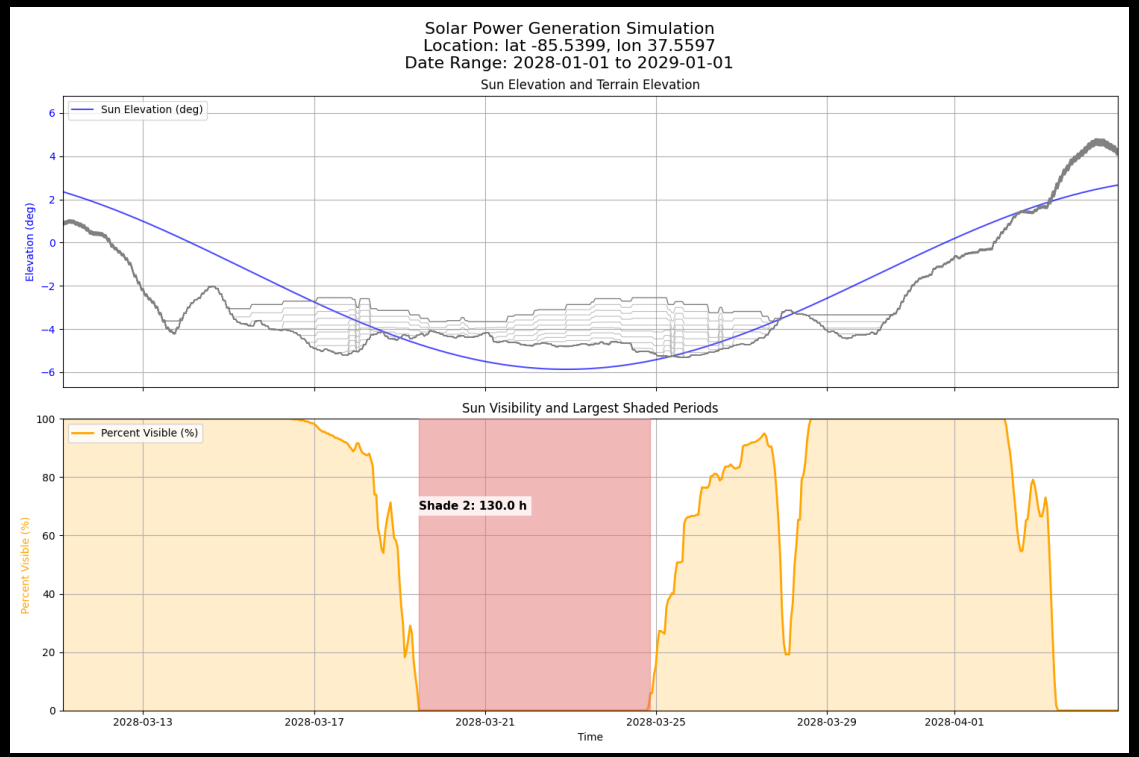


Tower

Vertical Solar Array Tower for highly illuminated regions on the Lunar Poles

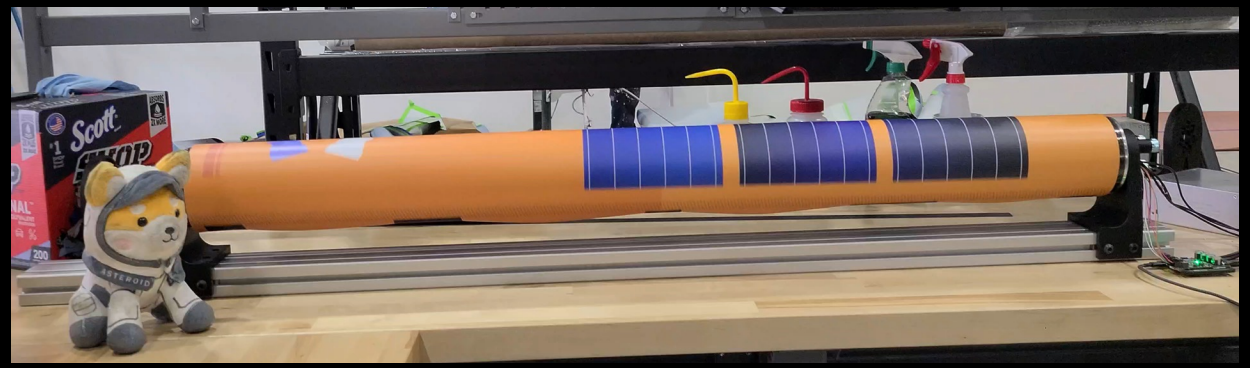
- Target power generation of 100 kW (< 500 kg out of 1.6-ton system)
  - Standalone tower at 300 kW+ with 100-kWh battery
- Single-axis tracking follows the Sun throughout illumination periods (+/- 180° joint)
  - Levelling legs in Starmine Box align to local gravity up to 15°
  - Partial retraction of blankets to survive partial shade-periods
  - Complete retraction of blankets and keep-alive heaters to survive full-shade periods

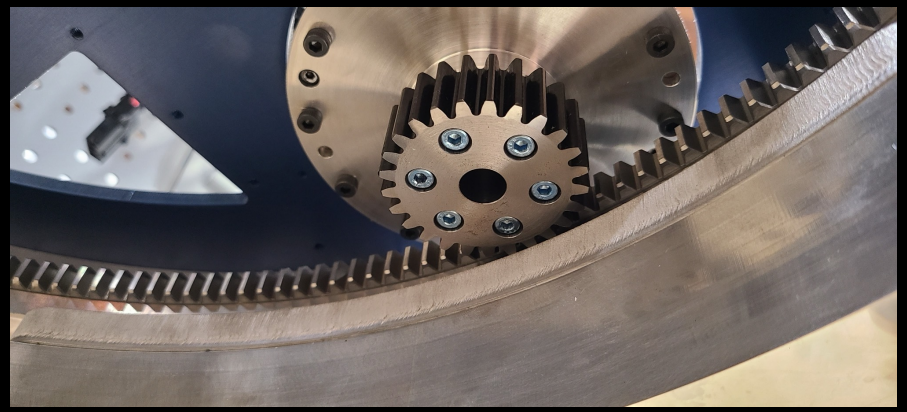




Tower

- Z-fold deployment of photovoltaics using winches & carriage
  - Modular boxes for each blanket stowed and deployed with hinges
- Central mast extended by high-strain composite boom deployer
  - 45 m, nominal 300 mm diameter double-Ω
  - Lunar mast in development via partnership with Atomic-6
- Mechanisms share common actuators with Rover
  - Inherently dust-tolerant, high-power, high-torque; parallel qual
- Tested this spring:
  - 17 ft deployment under Earth-g with a mass offloader
    - Boom & deployer in collaboration with Opterus
  - Rollable architecture banner deployment system
  - Axial hinges for banner stow/deploy
  - Full-tower rotary joint

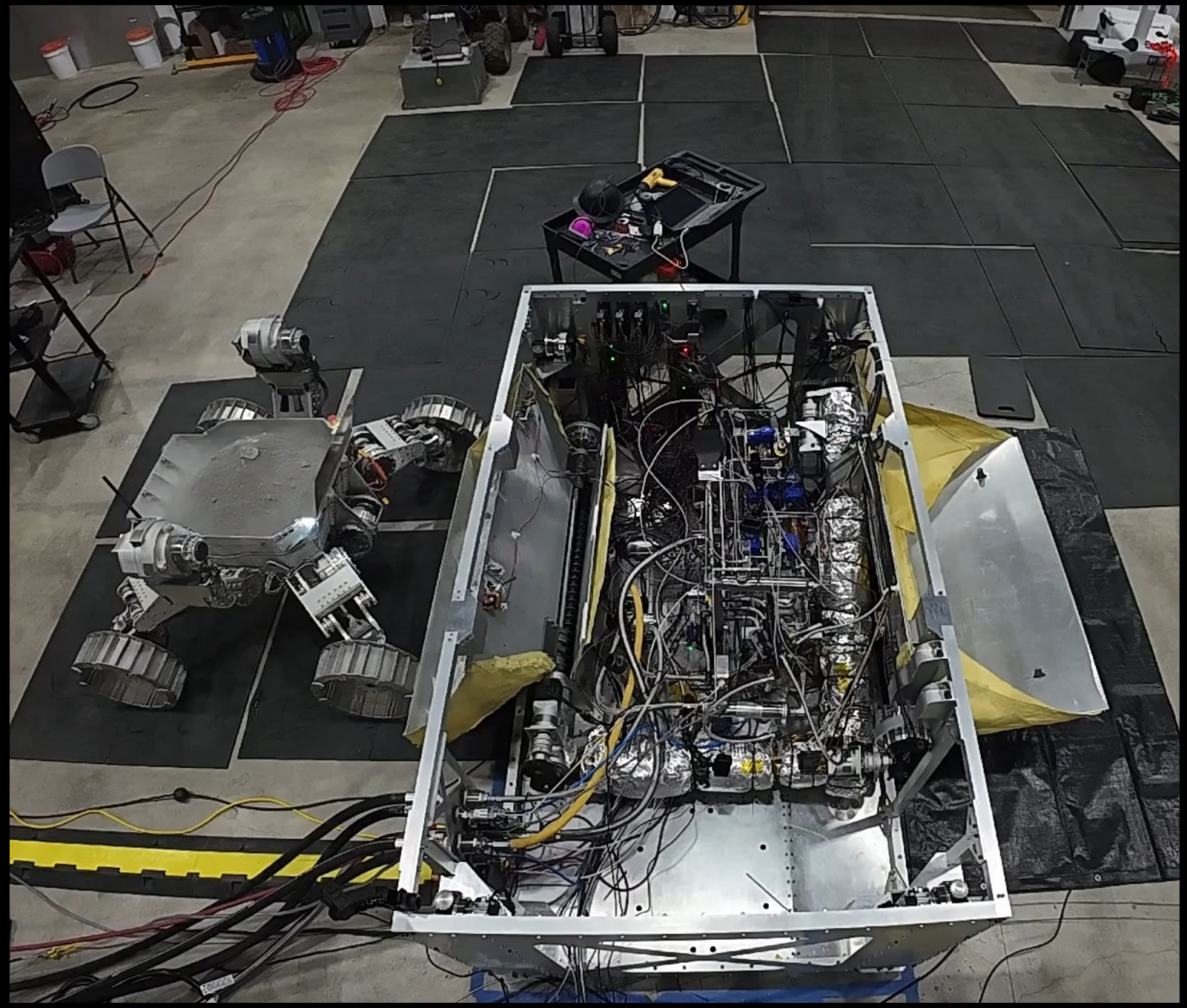




Integrated Testing

- Rover → Plant icy regolith dump (Feb ‘25)
  - Commercial Lunar highlands regolith simulant
  - Premixed water
  - Liquid nitrogen-cooled

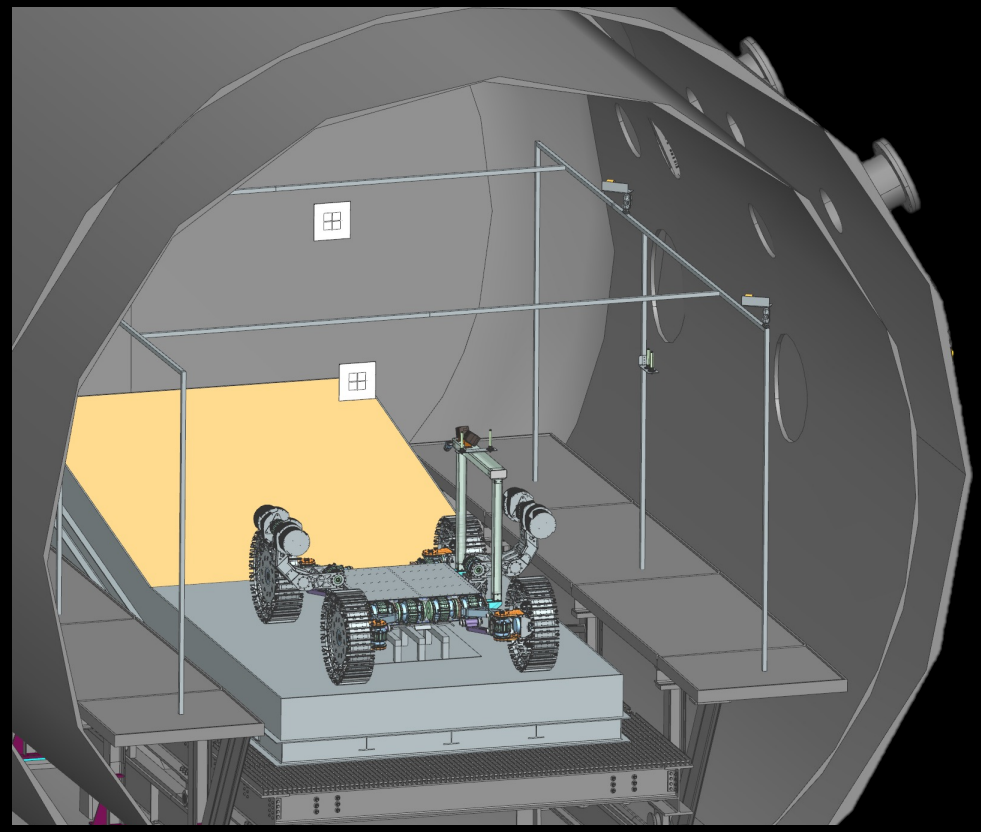
- Scoping next iteration of integrated testing November ‘25
  - Rover 11 – fully autonomous
  - Plant 3, w/ Lunar-analogous thermal management system
  - Tower 2 – full Z-fold architecture
  - Long-duration - ~3 full cycles of 100 kg-scale Rover inputs

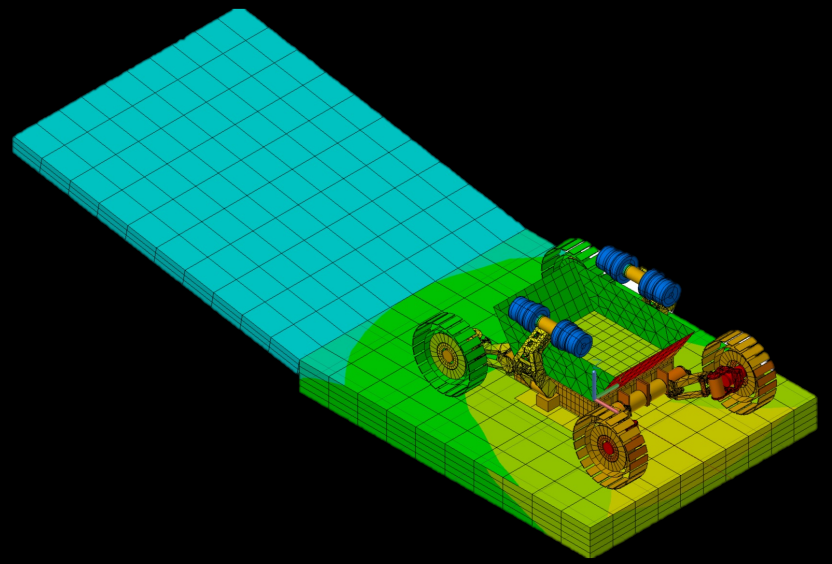


Next Steps

TVAC Testing in Marshall V-20 Chamber

- Reward from BTI Phase III
- Scheduled for this July
- Fully-integrated Rover 10
  - Full-scale dynamic mining, charging, and mobility
- Simulated Lunar conditions
  - 10^{-6} Torr vacuum
  - LN_2 cold shroud; heat lamps
  - Mining pit of icy regolith simulant
  - 10° traversal slope, also simulated regolith
- Quantitative and qualitative results for actuators, charger, avionics, autonomy sensors, wheels, and excavation barrels
  - Correlation to thermal models
  - Lessons on integrated testing for future campaigns





Flight Opportunities

- Near-term prospecting mission as early as 2026
- Medium-term Lunar Starmine demo, Martian tests
- Long-term full-scale deployment

Thanks!
Questions?

Starpath Vital Stats:

- Headquartered in Hawthorne, CA
- 23 employees, contractors, and interns
- Check us out! ↴