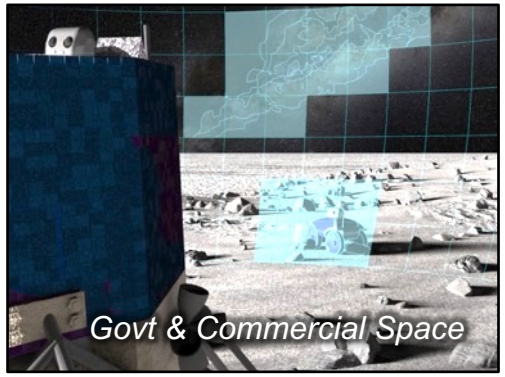
CANADENSYS

Canada's Lunar Rover Mission
Mobility on the Moon

June 6th, 2023

Who We Are

- Canadensys Aerospace was founded in 2013
- Space exploration systems and advanced vehicle development
- Headquartered near Toronto, Canada
- Satellite office in Stratford, Ontario



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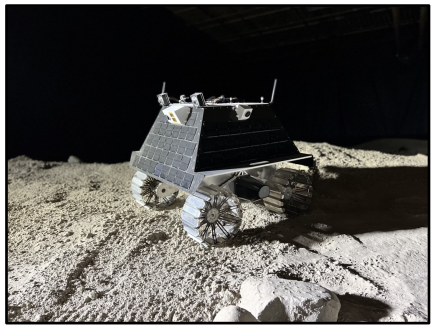
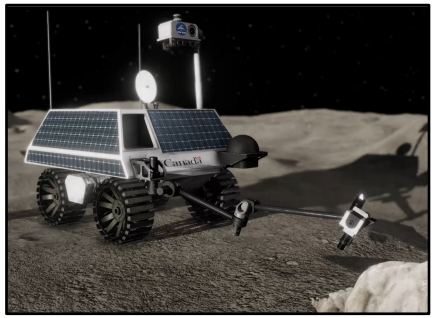
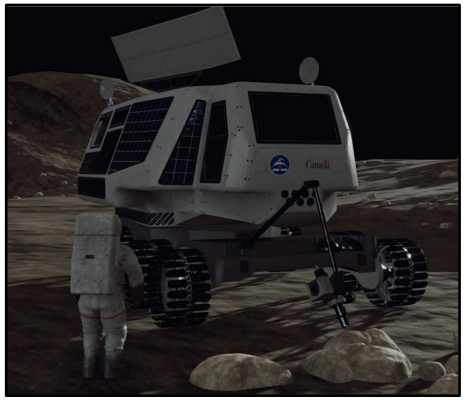
Canada's Rover Program

- The Canadian Space Agency has been working on lunar rovers since ~2006-present
  - Multiple concept studies and prototyping activities
  - 5 kg to 5000 kg







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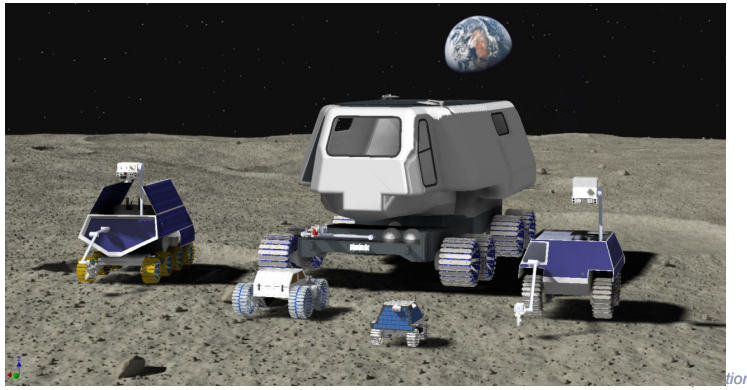
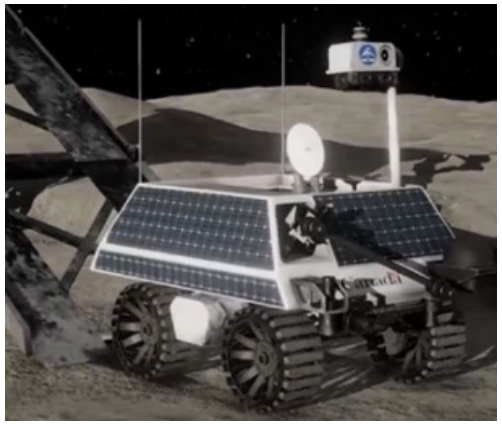
Previous and Ongoing Rover Development

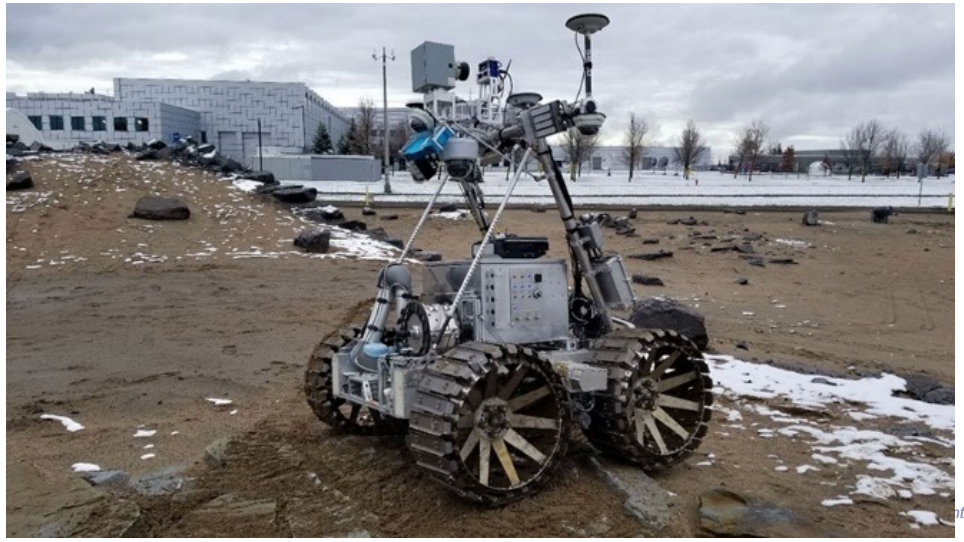
- Multiple classes of lunar rover developed in Canada over past 10-15 years
- Rugged, high-reliability, long-range lunar mobility
- TRL5/6 locomotion system (actuators, transmissions, wheels)
- Polar and equatorial regions compatible thermal system

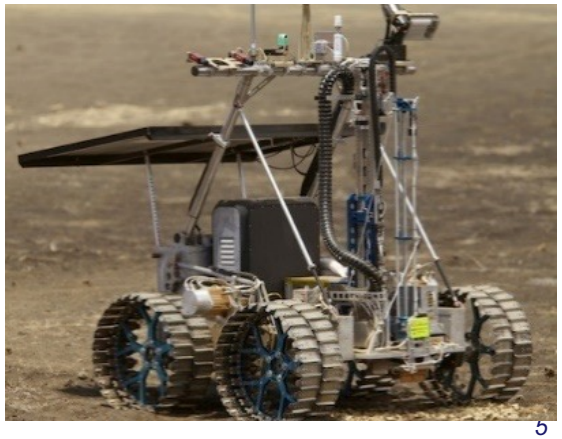


Mid-size Rovers

- Eight concept studies (Phase 0 and Phase A) completed between 2013 and 2022
- Designed, built, and delivered multiple prototypes ranging from 100kg to 500kg
- TRL5/6 development of key sub-systems (thermal, avionics, mechanical, mobility)

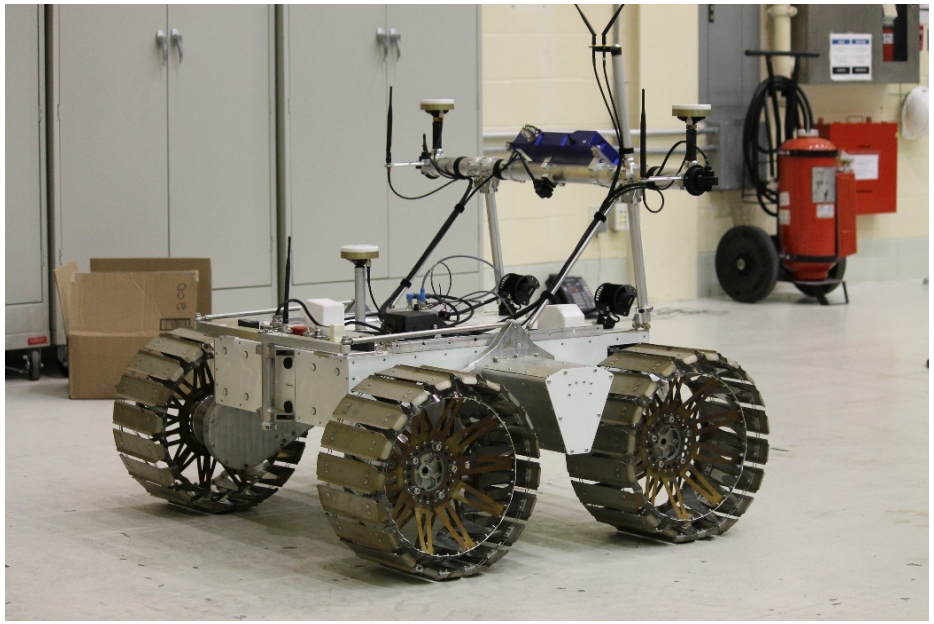


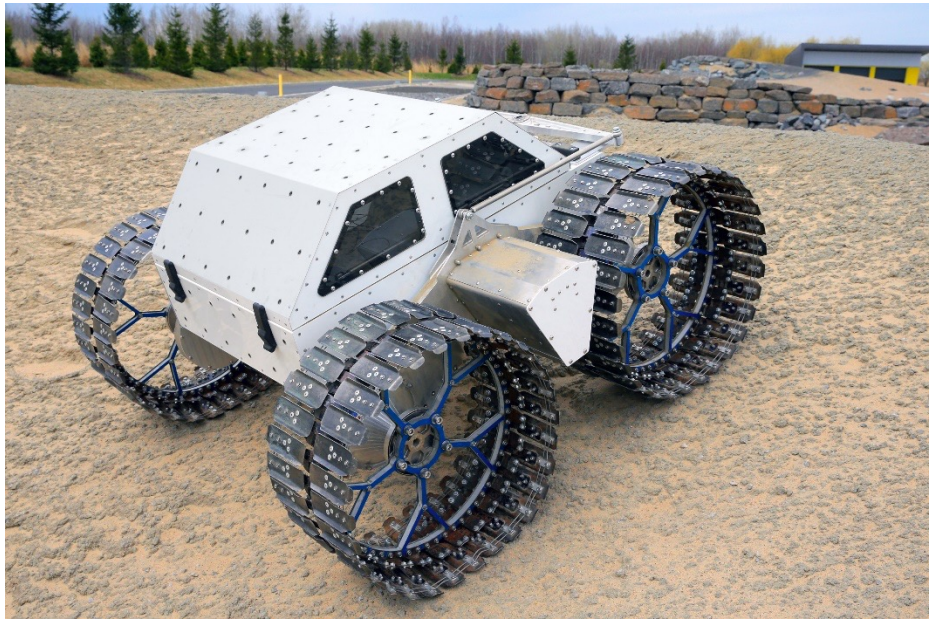




Small Rovers

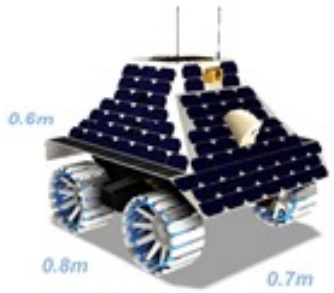
- Robust mobility architecture (four-wheel, skid steer)
- 90 kg curb mass, 50 kg payload capacity
- Development platform for Canadian Space Agency
- High TRL drivetrain and locomotion system

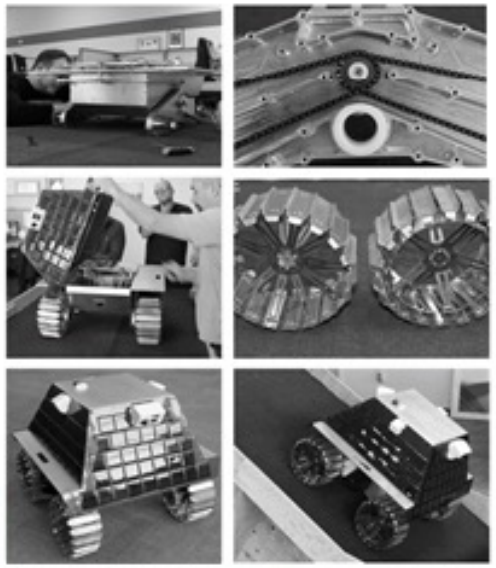


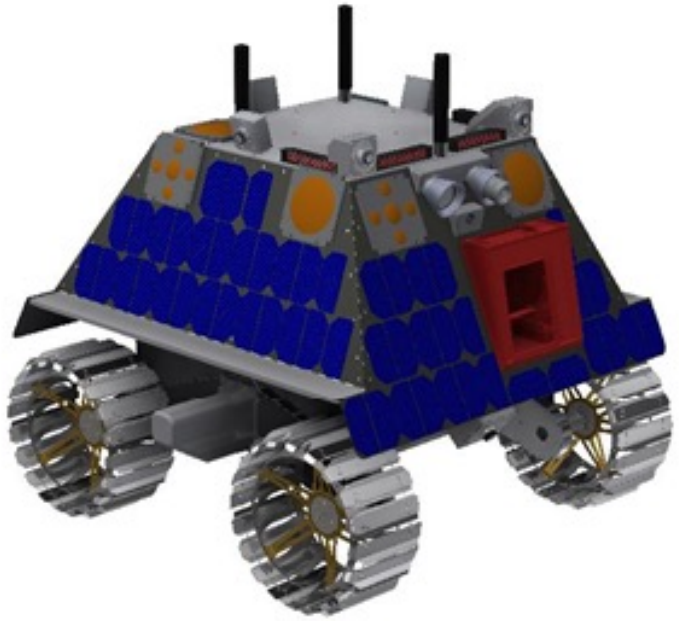


Micro-Rover Development

- Multiple concept studies, prototypes, and technology development projects
- Scalable architecture (20kg-500kg)
- Phase A completed, flight program starting Q4 2022

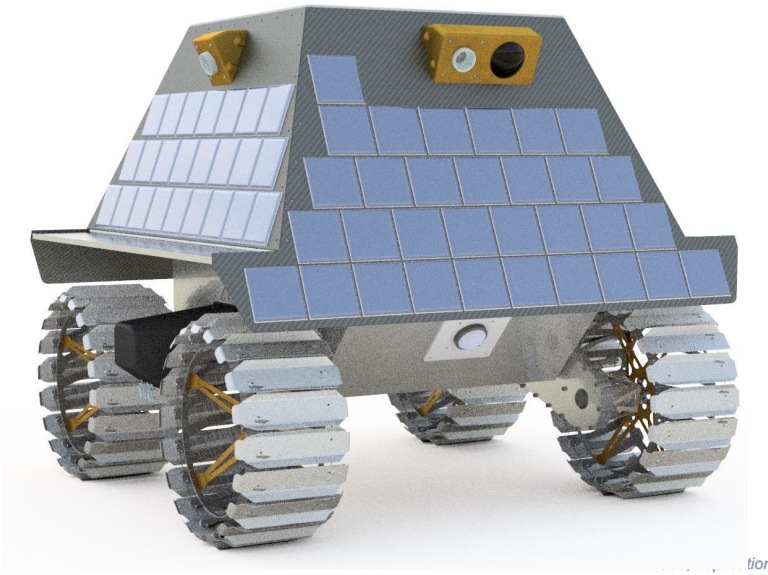






Canada is Going to the Moon!!

- Announced early 2022
  - 30 kg platform, joint project with NASA
  - Survive at least 1 lunar night
- Two teams participated in Phase A (CSYS and MDA)
- One team down selected for Phase B+



Mission Objectives

- Four mission objectives: **Rove, Gather, Overcome, and Inspire**
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LRM – Main Features

Top-mounted radiators

Robust communications architecture

360º situational awareness

Sealed lower chassis

Body-mounted solar arrays

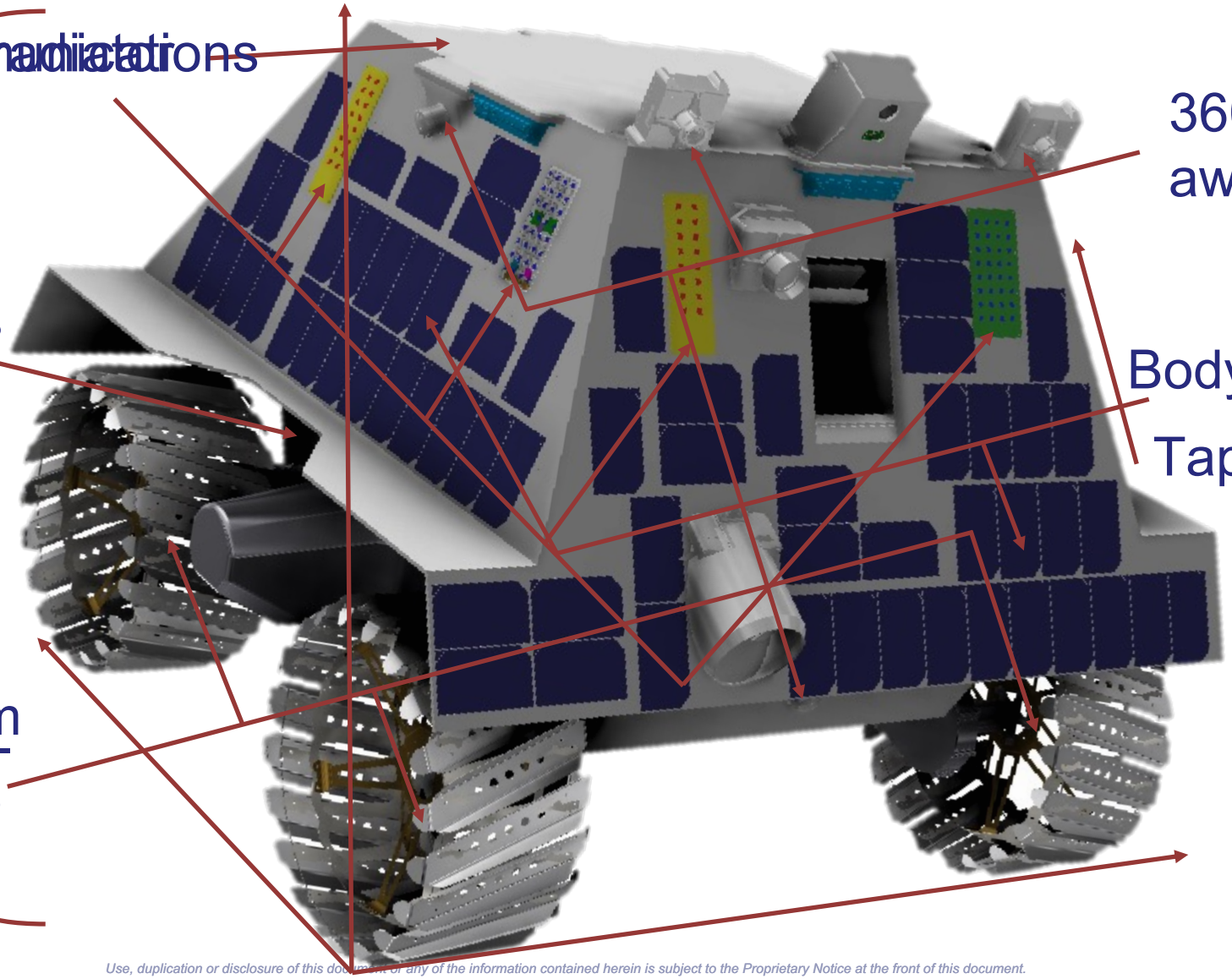
Single fault tolerance across critical systems

Tapered upper shell

~70 x 70 x 70 cm

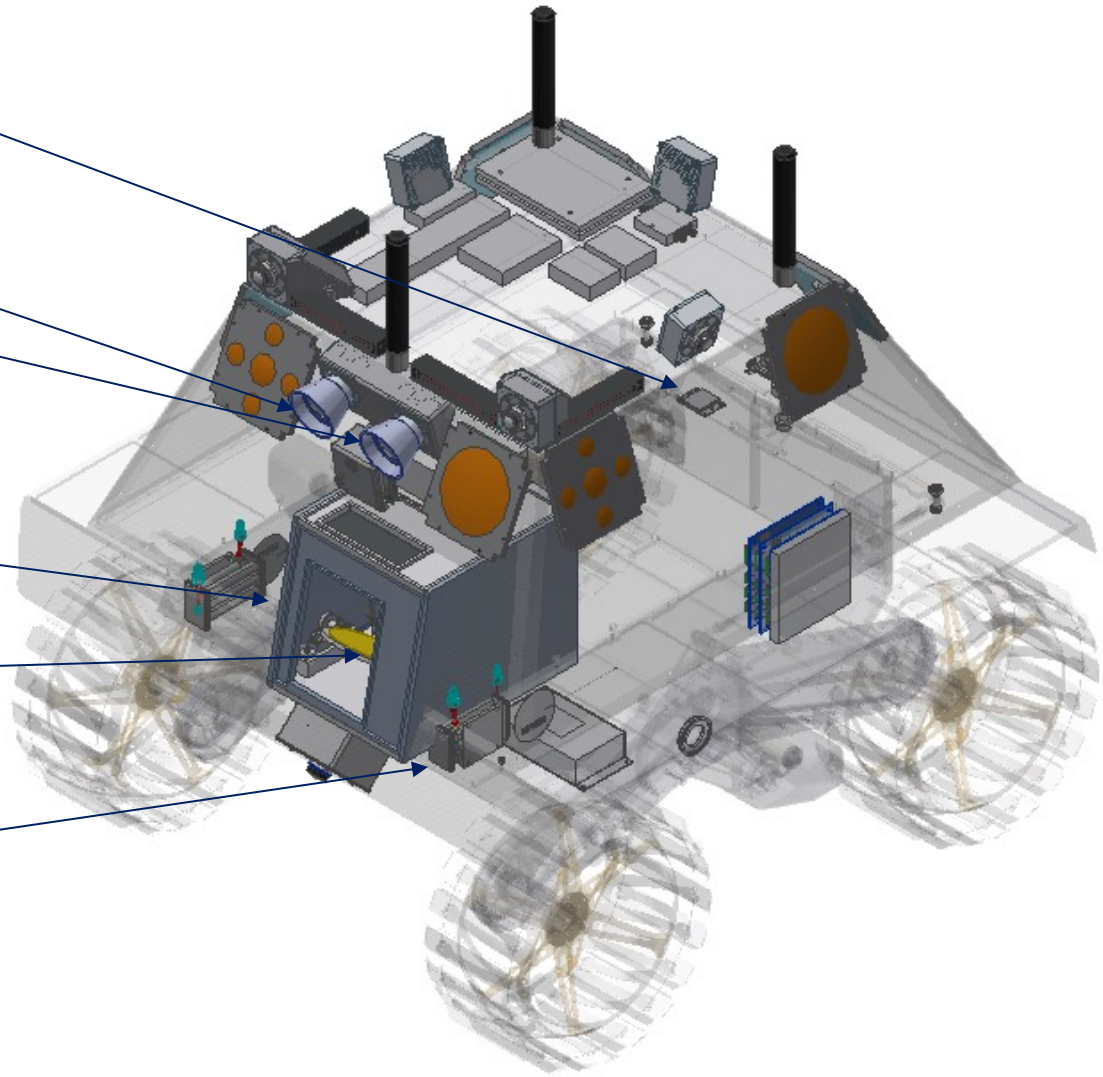
30 kg total mass

Simple but robust 4-wheel skid steer drivetrain



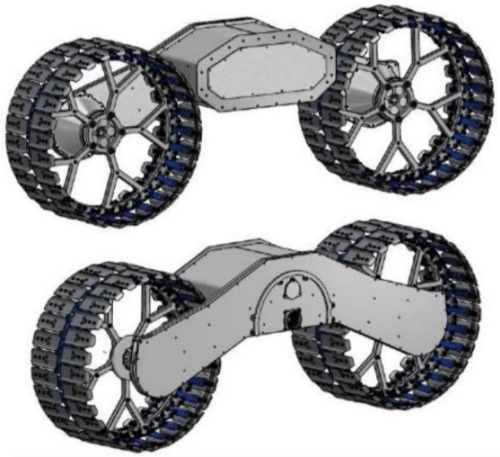
Payloads

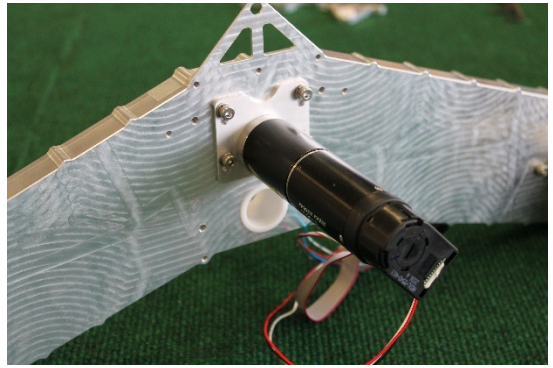
- Radiation Micro-Dosimeter – provided by Teledyne Dalsa, Canada
- Lyman-Alpha Imager – provided by Canadensys
- Multispectral Imager – provided by Canadensys
- Lunar Hydrogen Advanced Neutron Spectrometer (LHANS) – provided by Bubble Technology Industries (BTI), Canada
- Lunar Advanced Filter Observing Radiometer for Geologic Exploration (LAFORGE) – provided by Johns Hopkins University Applied Physics Laboratory (APL), USA
- Multispectral Imager-Macro – provided by Canadensys
- 6 Context Cameras – provided by Canadensys



Mobility / Drivetrain Development

- Nine generations of prototyping/testing
- Fault tolerant locomotion mechanism
- Non-contact dust seals
- Low speed/high speed mechanism enables dual mode operation (robotic/manned)
- Key Milestones
  - 2013 – Hawaii field test (CSA and NASA RPM and MMAMA)
  - 2016 - Dusty TVAC test completed at NASA Glenn Research Center
  - 2019 – 600 km durability test completed in regolith simulant



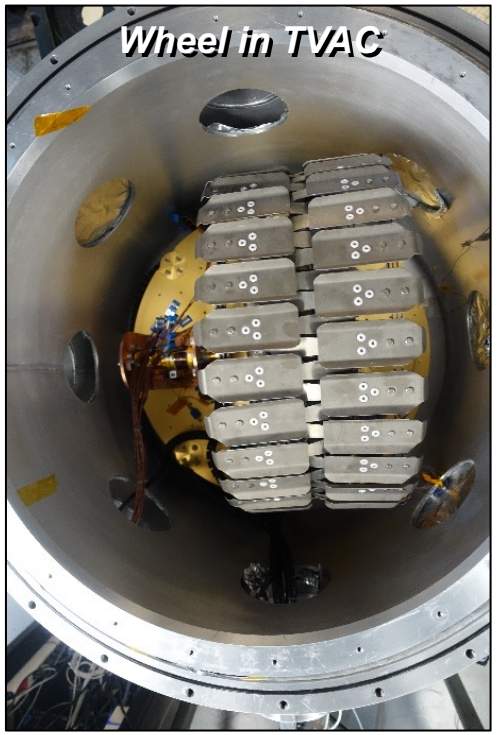


Mobility System Environmental Testing

- Extended motor module & wheel testing in 2017
- Combined dynamometer + TVAC test @ NASA Langley
- Exposure to <40 K survival temperature

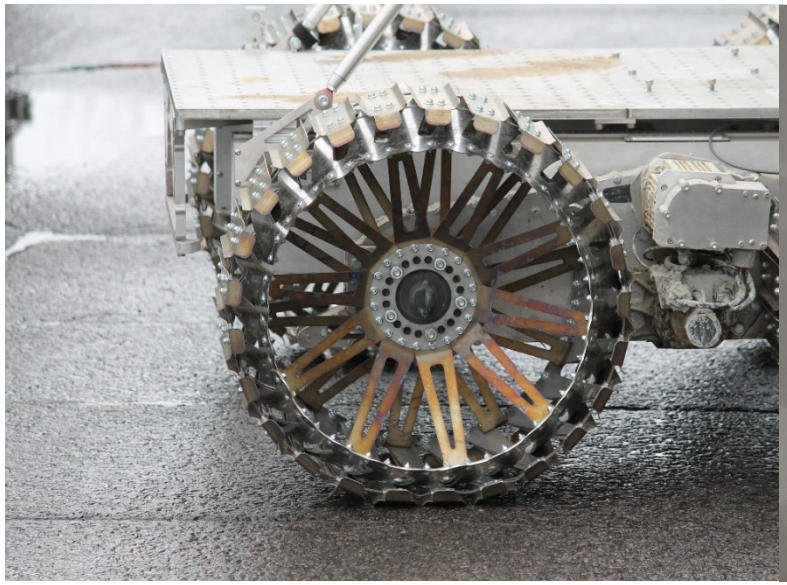

Cryo-Mechanisms Test Facility at NASA Langley


Motor Module Connected to Dynamometer in TVAC


Wheel in TVAC

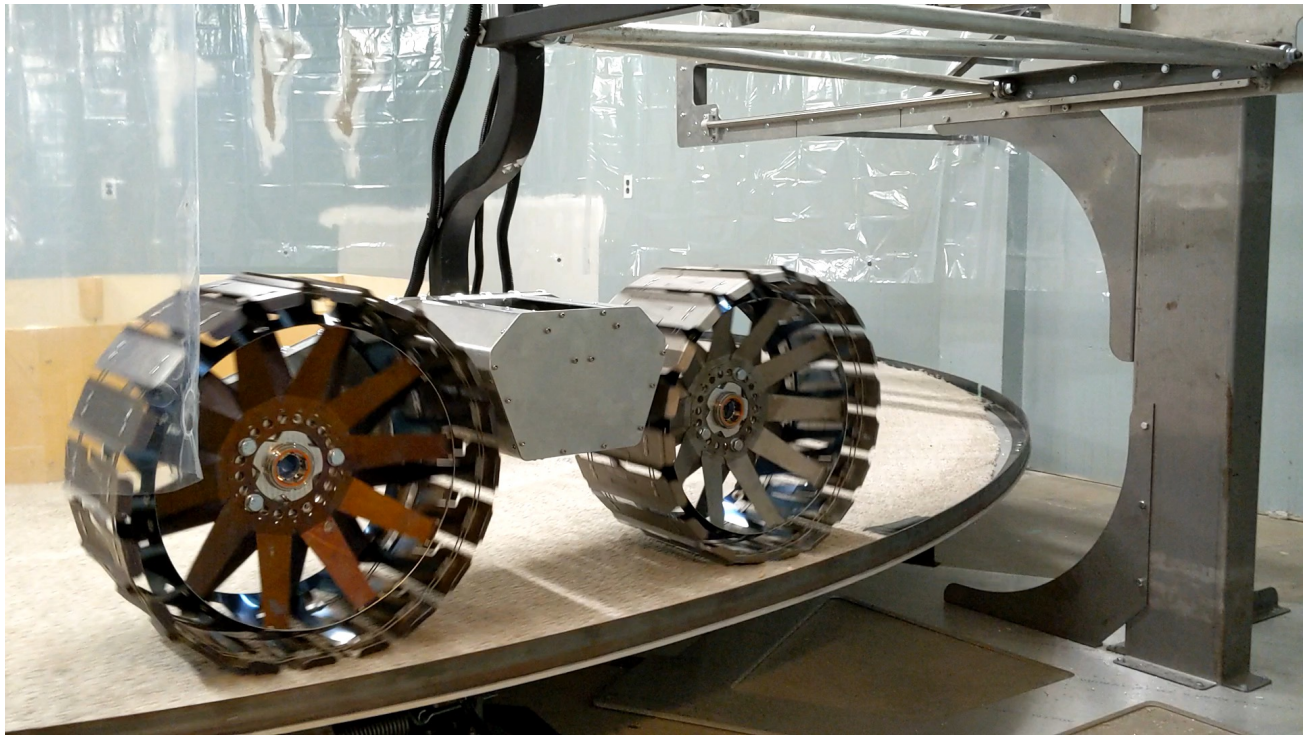
Lunar Wheel Development

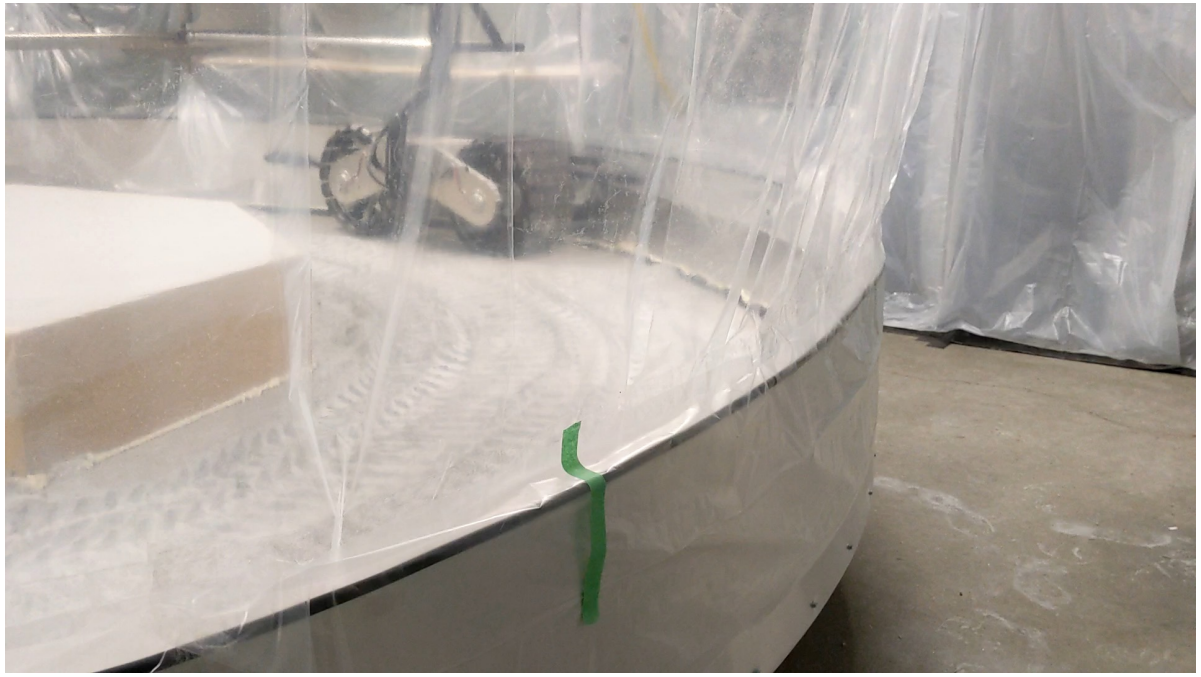
- 10+ generations of non-rubber lunar wheels
- Scalable wheel design, prototypes developed in multiple sizes (24cm, 45cm, 50cm, 60cm, 90cm)
- Compliant design increases traction and reduces sinkage
- Key Milestones
  - Multiple field tests in analogue terrain
  - **600 km test in regolith simulant (45cm)**
  - **2,000 km test in regolith simulant (90cm)**



MERIT and SWARM

- CSA Technology Development
- Scalable wheel design: 25cm – 90cm
- Upgraded locomotion mechanism
- 600 km test in regolith simulant
- 2,000 km for single wheel

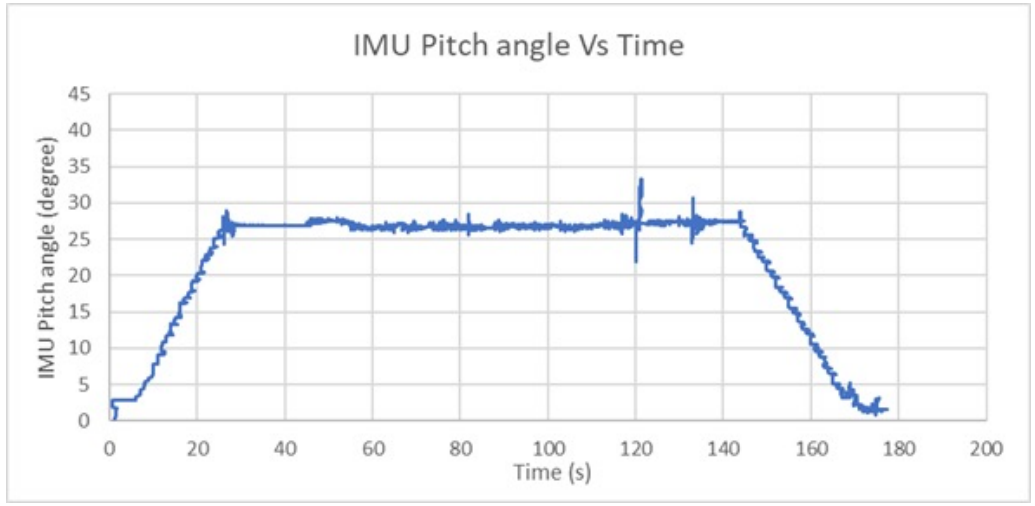




Maximum Gradient – 25-degree slope

Side View

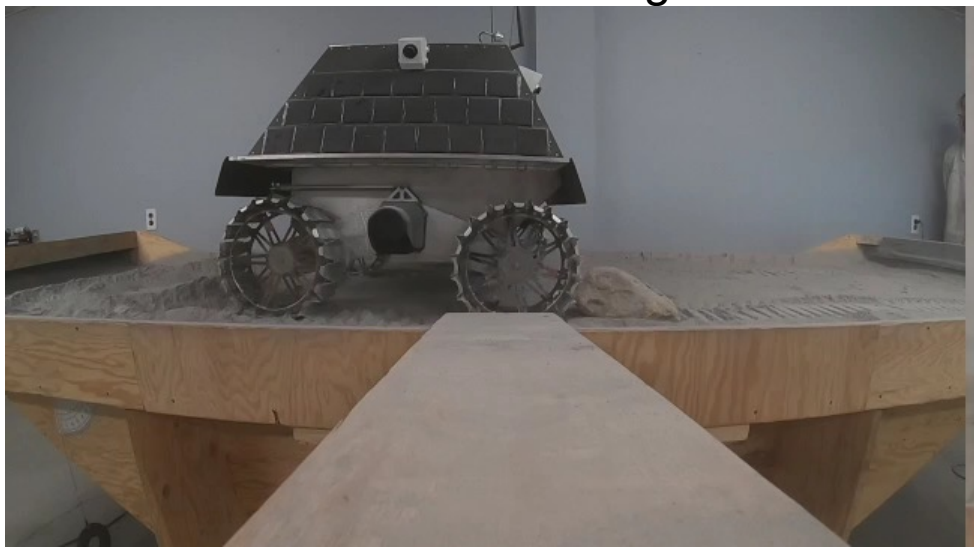
Iso View



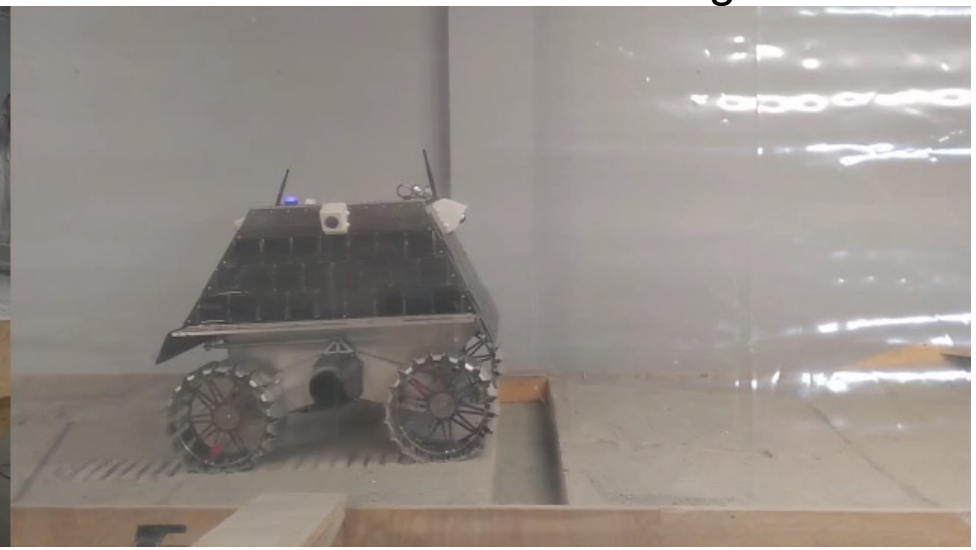
Wheel Slip measured between 40 and 45 %

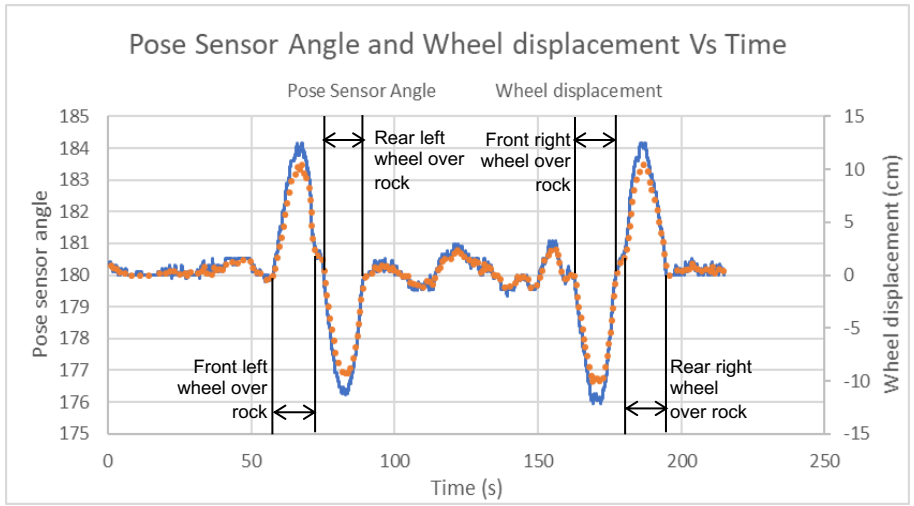
Obstacle & Crevasse Crossing

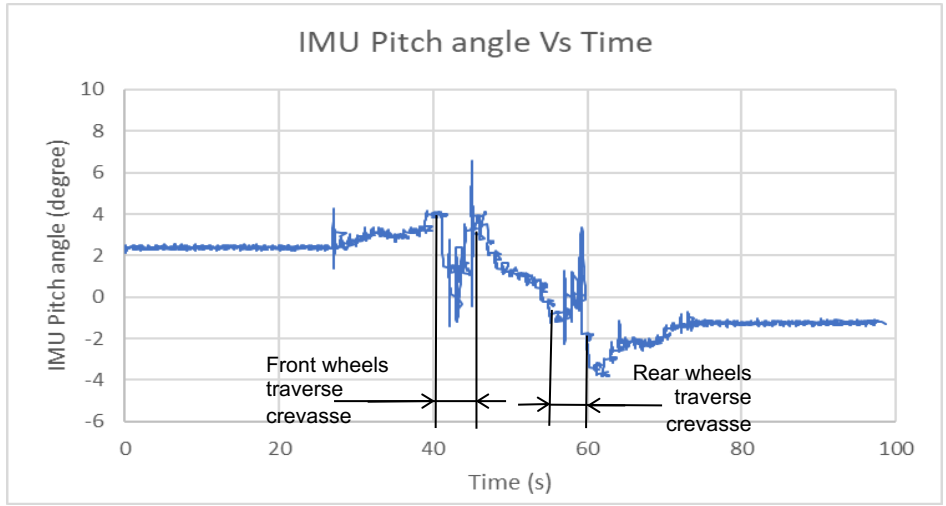
Obstacle crossing



Crevasse traversing





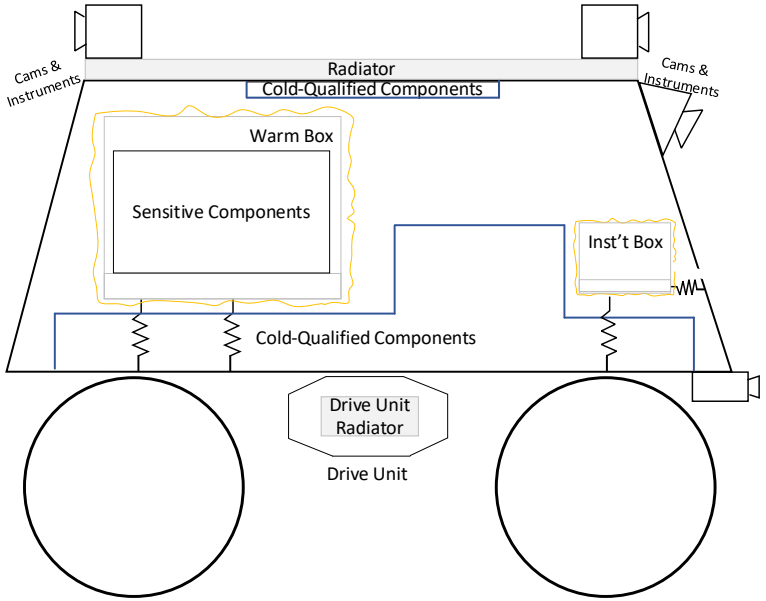


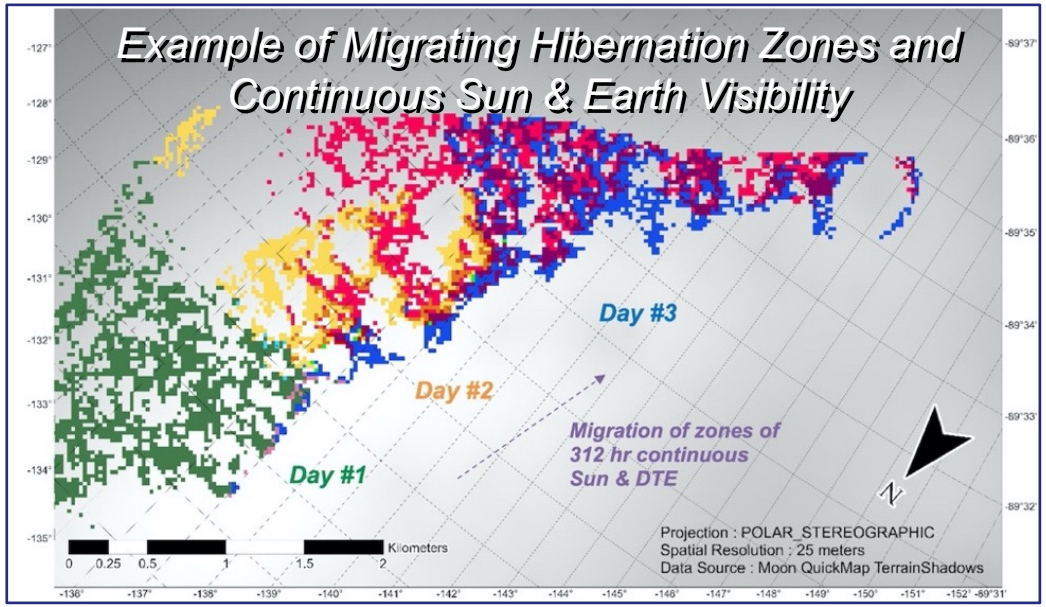
Lunar Night Survival

- Night Survival on the Moon is very hard – 354 hours long and -200°C conditions

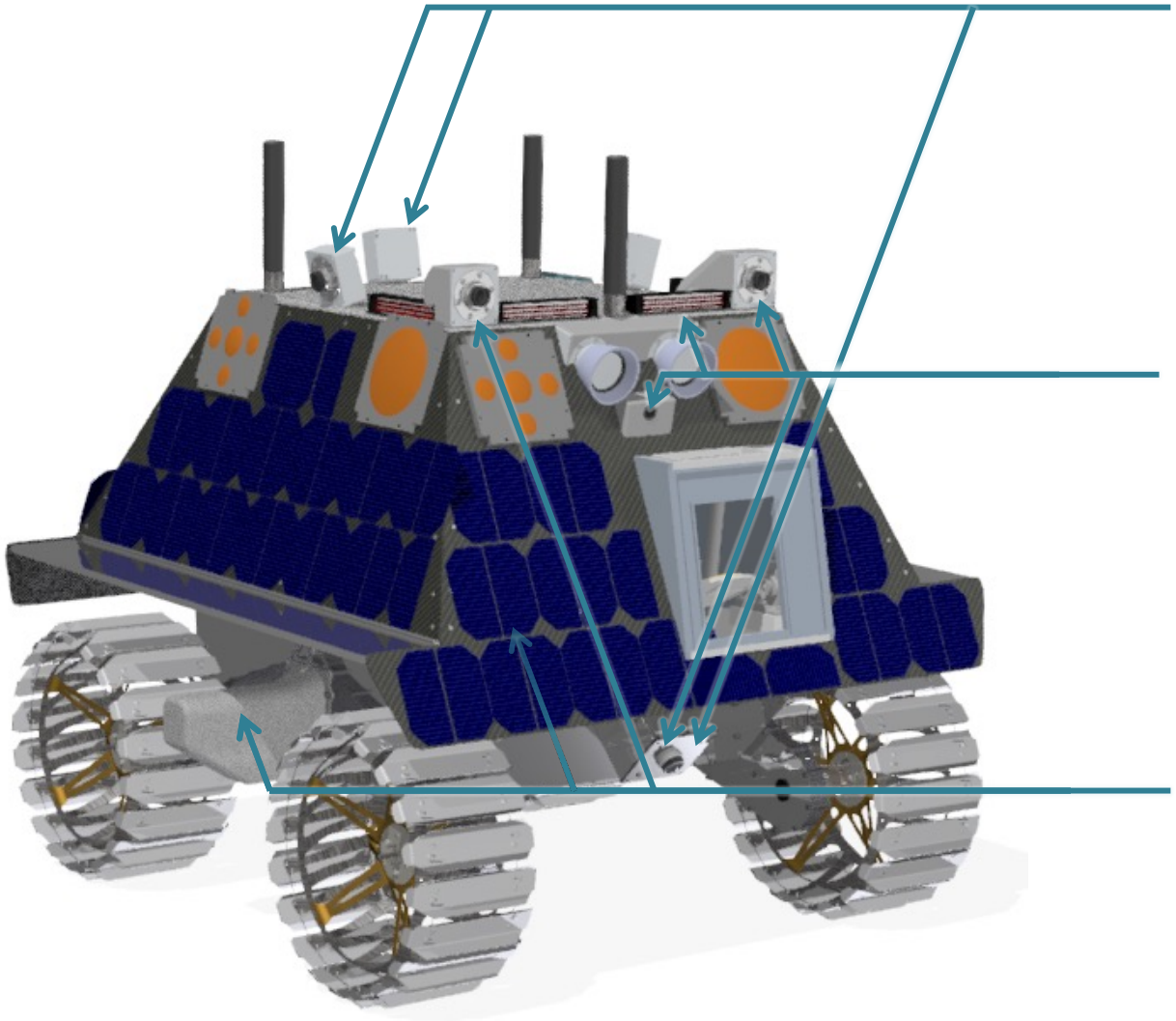
Three-pronged approach

1. Qualify as many components as possible to survive
2. Isolate sensitive components (e.g. batteries)
3. Risk reduction through graduated night approach





GN&C Technology Development



Panospheric Imaging

Stereo Camera + Wide-Angle Cameras + Haz Cam

- 360° image stitching from static rover position
- Simulated PTZ functionality for rover operator
- Sun- & Earth-sensing for antenna pointing
- Situational awareness around & under rover

Obstacle Detection

Stereo Camera + Depth (Time-of-Flight) Sensor + Haz Cam

- High-frequency & low-accuracy time-of-flight imaging
- Low-frequency & high-accuracy stereo imaging
- Flash illumination for exploring shadows
- Fine positioning at science targets
- Determination of object position/size under rover

Relative Navigation

IMU + Wheel Odometry + Stereo Camera

- Low-computation EKF on distributed architecture
- Low-frequency exteroceptive measurements
- Updates via sporadic orbital/ground measurements

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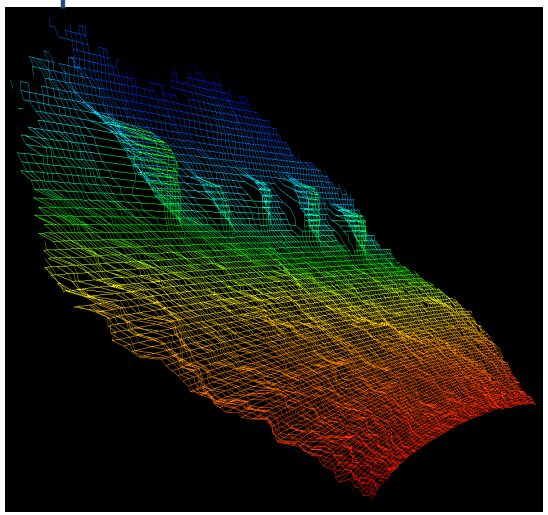
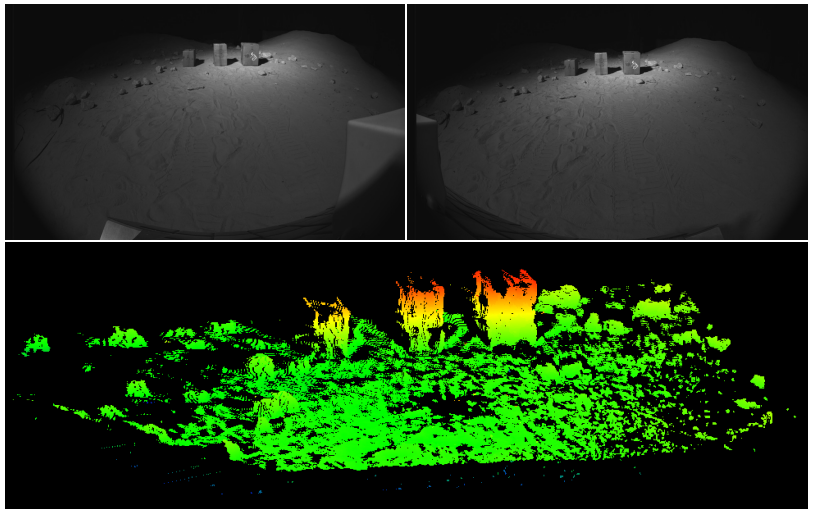
GN&C Technology Development

Depth Sensor Point Cloud



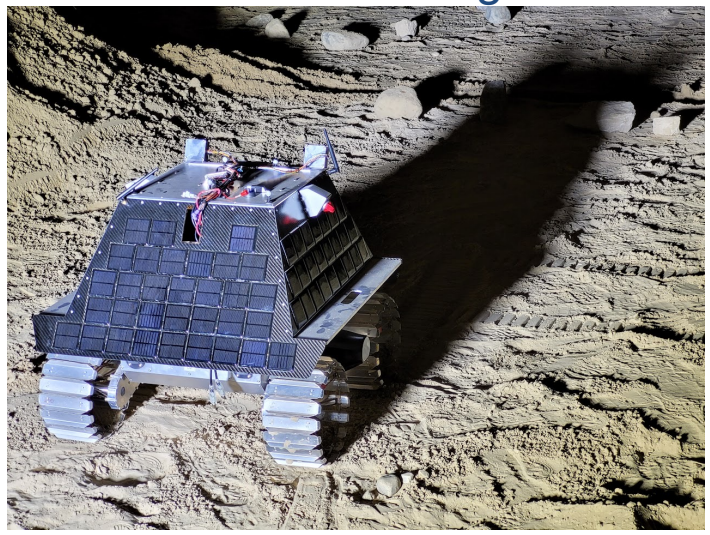
NISA Stereo Camera Point Cloud



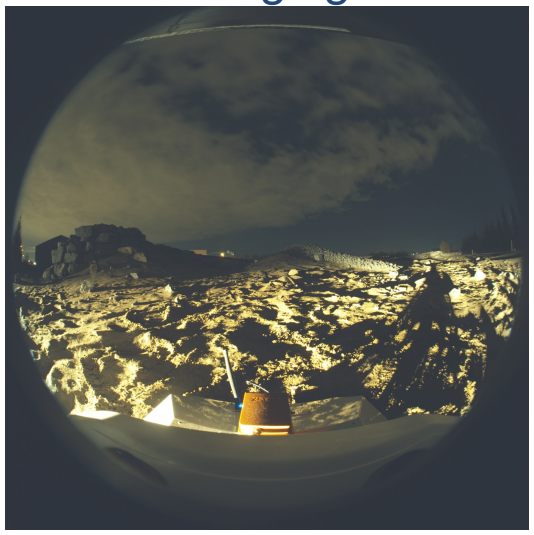
Dead-Reckoning on Uneven Terrain

Illumination Tests

VO Self-Shadowing Tests



NISA Imaging Tests



Testing and Demonstration - Indoor Analogue Terrain

- Analogue Rover Region Advancing Knowledge In Science

- **ARRAKIS**


LUNAR ROVER
RESEARCH CHALLENGE

Acknowledgements

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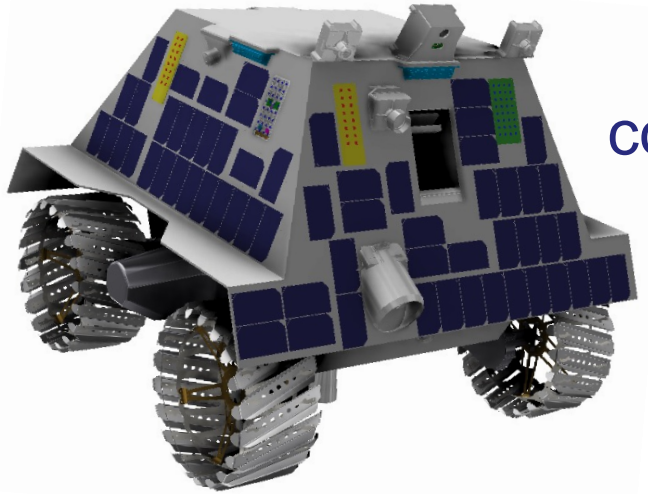

This activity is undertaken as part of a contract for the CSA Lunar Rover Mission