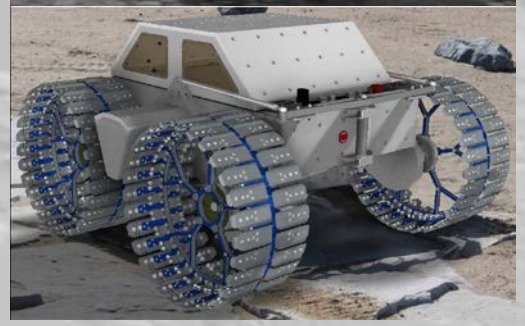
Canadian Lunar & Planetary Rover Development

Guy who likes rovers

Lunar Exploration Analysis Group Meeting

October 21, 2015

Peter Visscher, P.Eng. – Argo/Ontario Drive & Gear Ltd.
Perry Edmundson, P.Eng. – Argo/Ontario Drive & Gear
Nadeem Ghafoor – Canadensys Aerospace Corp.
Howard Jones – Canadensys Aerospace Corp.



CANADENSYS

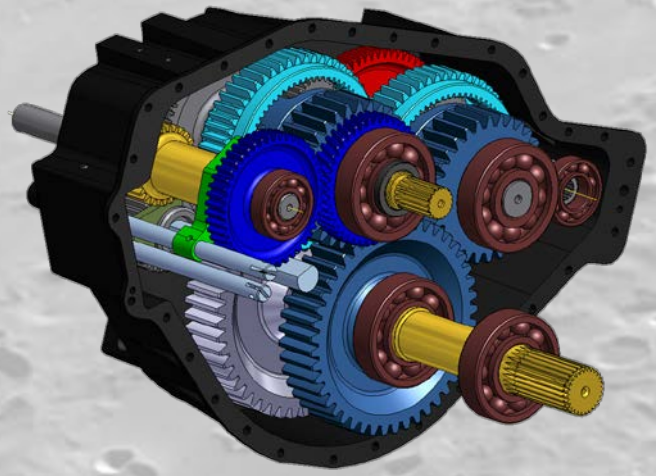
A DIVISION OF ONTARIO DRIVE & GEAR LTD.

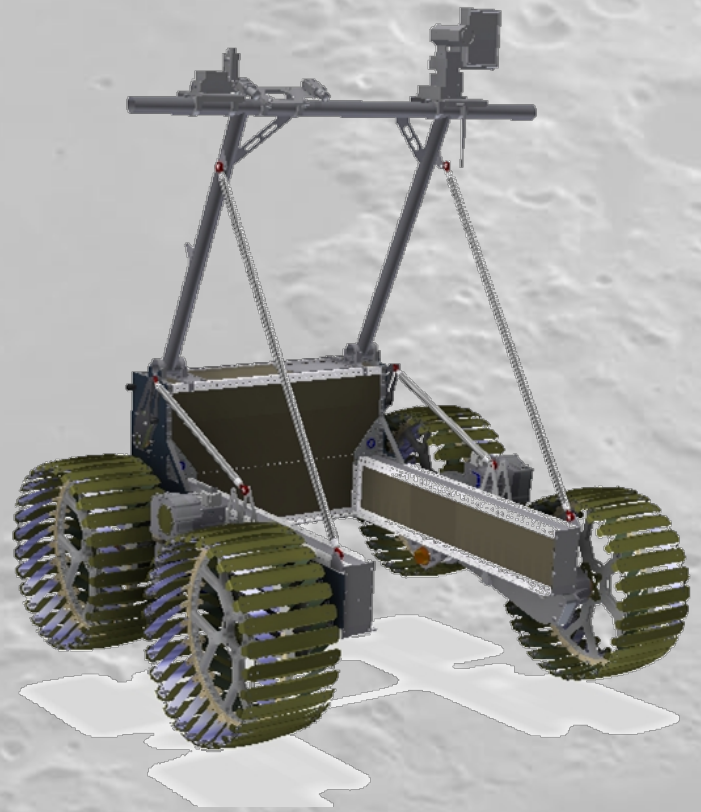
Ontario Drive & Gear Ltd.

ODG Gear Division (transmissions & gears)

ARGO Vehicle Division (extreme terrain amphibious vehicles)

Space/Robotics Division (lunar/planetary & terrestrial robotic vehicles)

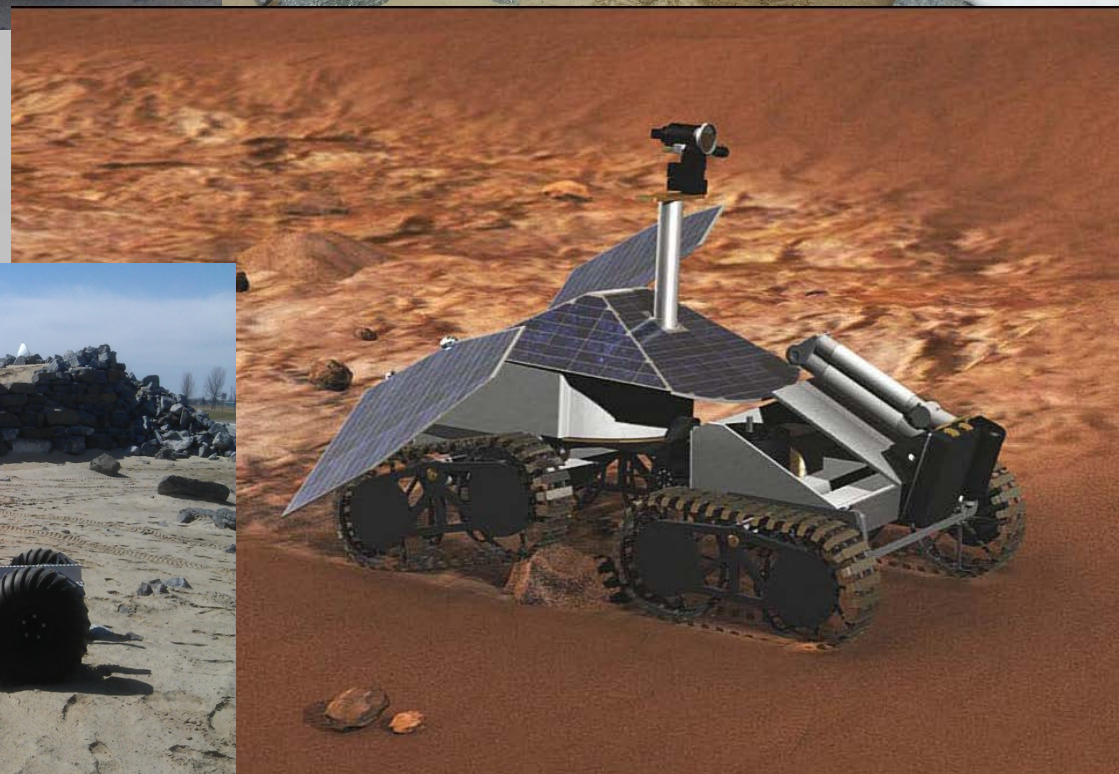


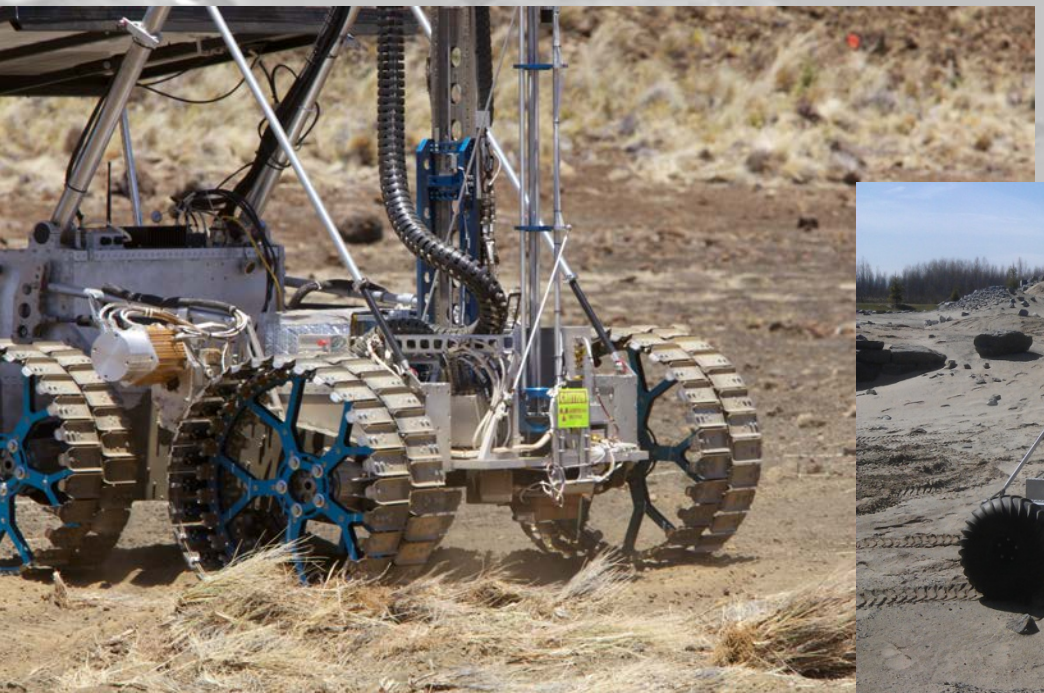


A DIVISION OF ONTARIO DRIVE & GEAR LTD.

ODG Space/Robotics Division

- Est. 2008
- Concept Generation
- Design & Analysis
- Manufacturing & Assembly
- Deployment & Support





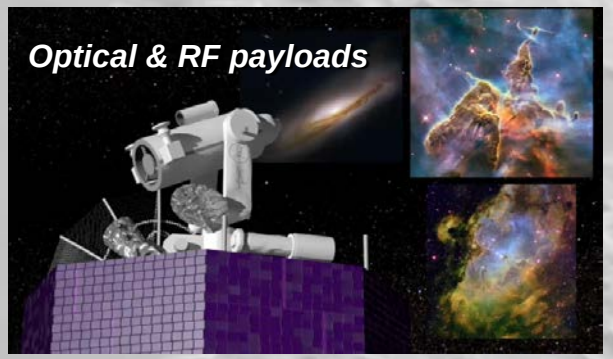
Canadensys Aerospace

- **Space systems company based in Toronto, Ontario, Canada**
  - Staff drawn from across Canadian space industry landscape with extensive flight heritage from big & small space
- **Focus on *"Accessible Space"***
  - Small exploration systems & commercial space
  - Participative science & exploration
- **Enabling technologies for New Exploration**
  - Micro / Nano platforms
  - Lunar surface instruments
  - Lunar environment robustness
    - Lunar night survival
    - Thermal & Energy storage
    - Low temperature systems

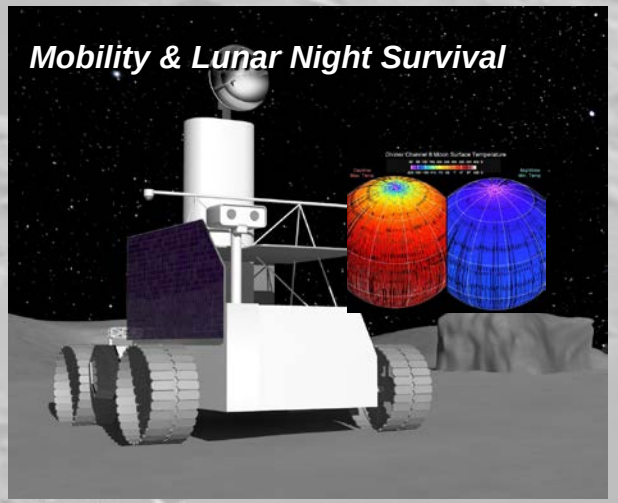
Role on Current Rover Programs

- *Path-to-flight design*
- *Thermal design & analysis*
- *Lunar environmental qualification*

Canadensys HQ, Toronto ON



Optical & RF payloads



Mobility & Lunar Night Survival

CANADENSYS

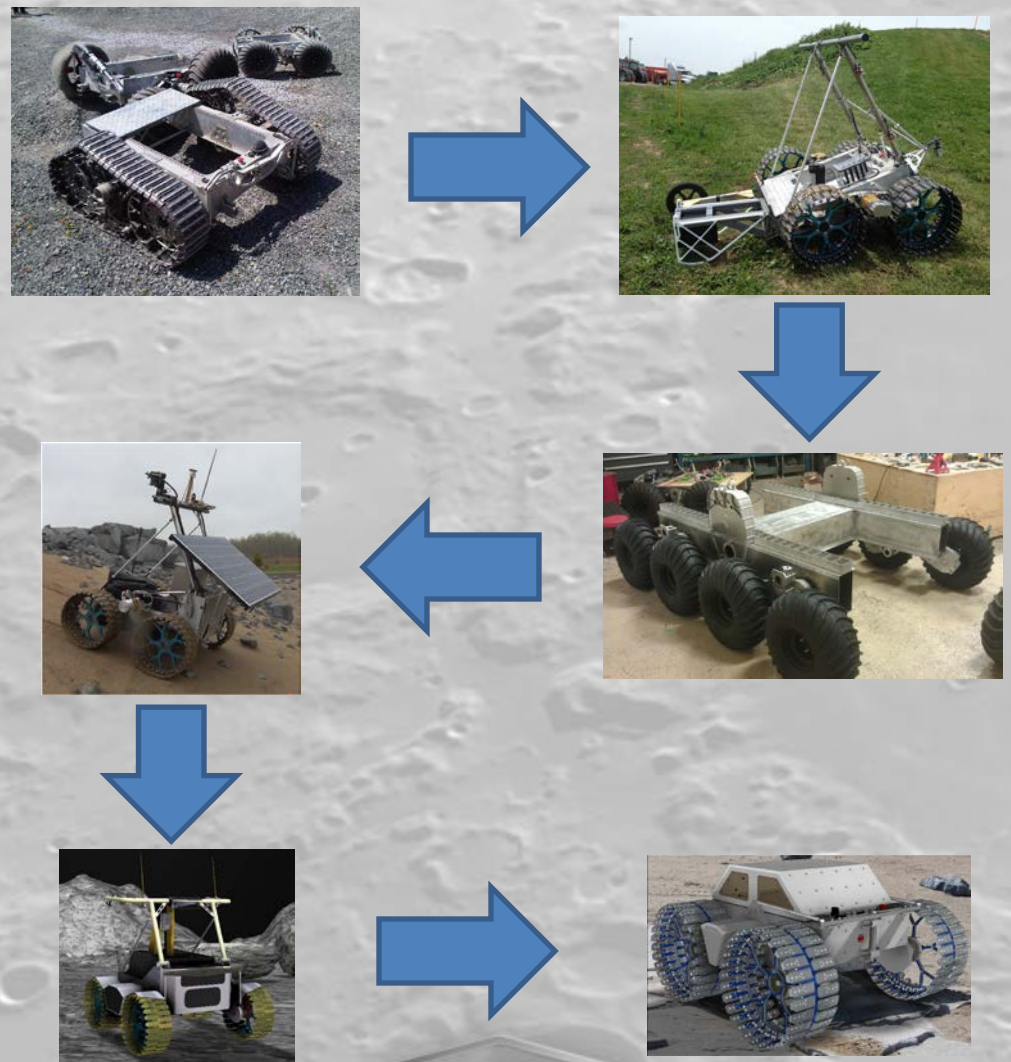
A DIVISION OF ONTARIO DRIVE & GEAR LTD.

Lunar Rover Development in Canada

Current Projects

- **Midsize Rover Development** (TRL-6 Drivetrain)
  - ODG-Argo (Canadensys, Bombardier Rec.)
- **Lunar Rover Night Survival**
  - Canadensys (ODG-Argo)
- **Lunar Rover GN&C**
  - MDA, NDG
- **Small Lunar Rover Development**
  - ODG-Argo (Canadensys, Bombardier Rec.)
- **Soil Hazard Detection**
  - Mission Control (ODG-Argo, Canadensys)
- **Lunar Rover Wheel**
  - ODG-Argo

Lunar Rover Development at ODG



- First became involved in lunar rover prototype development for the Canadian Space Agency in 2008
  - CSA was looking to inject terrestrial off-road vehicle design expertise into lunar rover program
- Led mobility platform design for six generations of rovers, including prime on two current programs
  - Juno → Juno II → Artemis → Artemis Jr. → LRPDP → SPRP

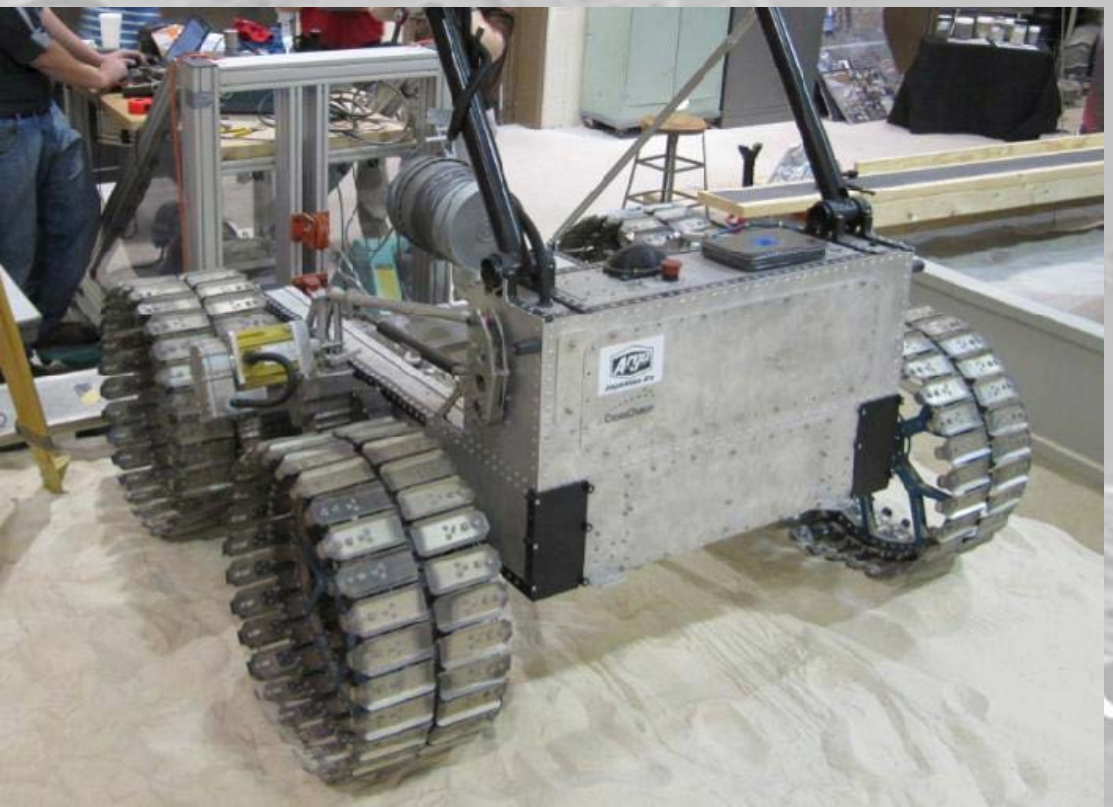
A DIVISION OF ONTARIO DRIVE & GEAR LTD.

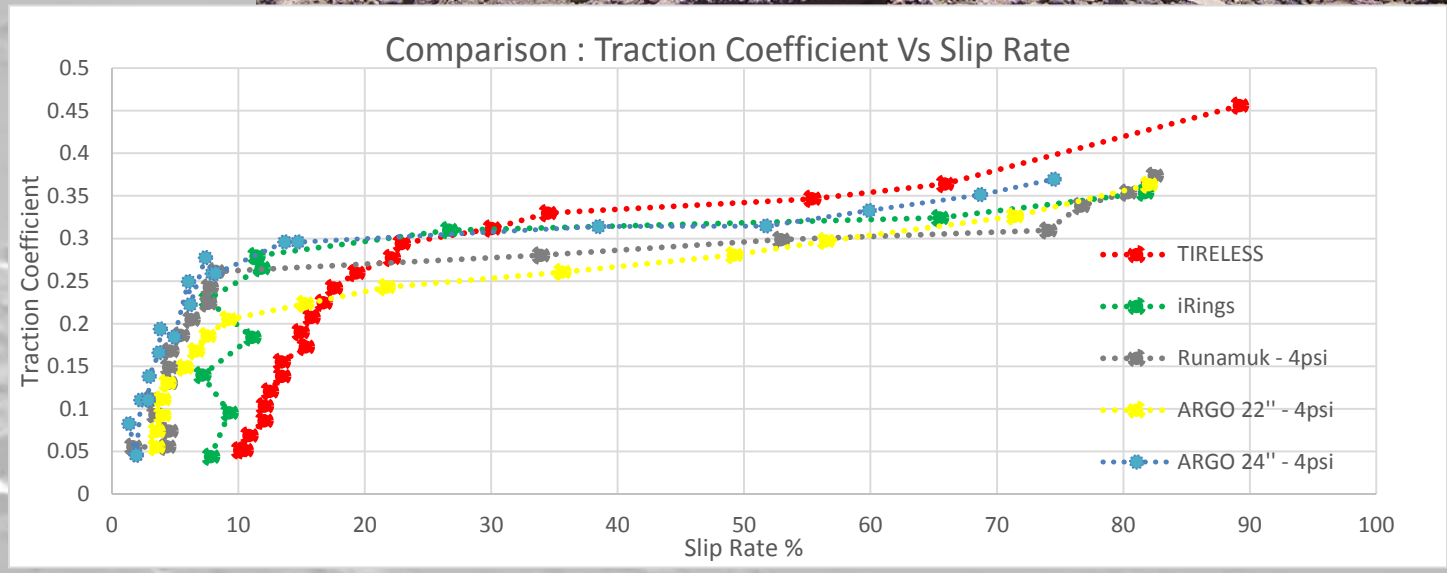
Rover Traction Systems

- Two generations of metallic tracks for Canadian Space Agency
- Five generations of compliant metallic wheels

Rover Traction Systems

- Lab testing in GRC-1 simulant
- Over 100 km of real world testing in analogue terrain
- Scalable: ~25-100 cm





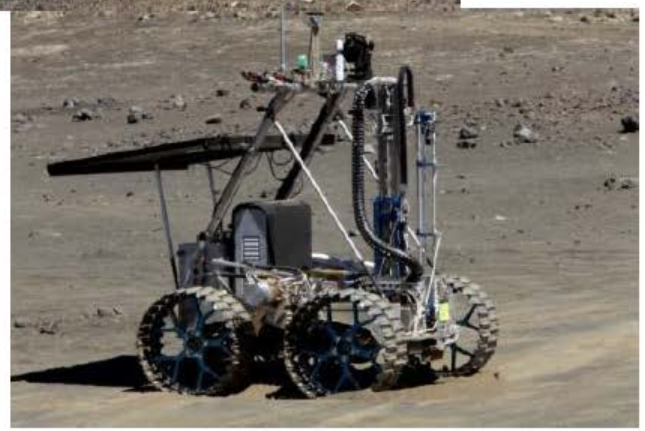
RESOLVE Analog Field Tests

Nov. 2008

- **RESOLVE Gen II on Scarab Rover**
- Power, avionics, and ground support equipment on separate trailer

FEB. 2010

- **RESOLVE Gen II+ on CSA Juno Rover**
- Power, avionics, and ground support equipment on separate Juno



July 2012

- **RESOLVE Gen IIIA on CSA Artemis Jr. Rover**
- Everything on single rover platform

March 2016

- TRL-6 Drivetrain
- 120 kg platform mass
- 280 kg launch mass

Apollo Valley Hawaii

MMAMA testing

- Rover
- Wheel
- Rough terrain mobility
- Power system

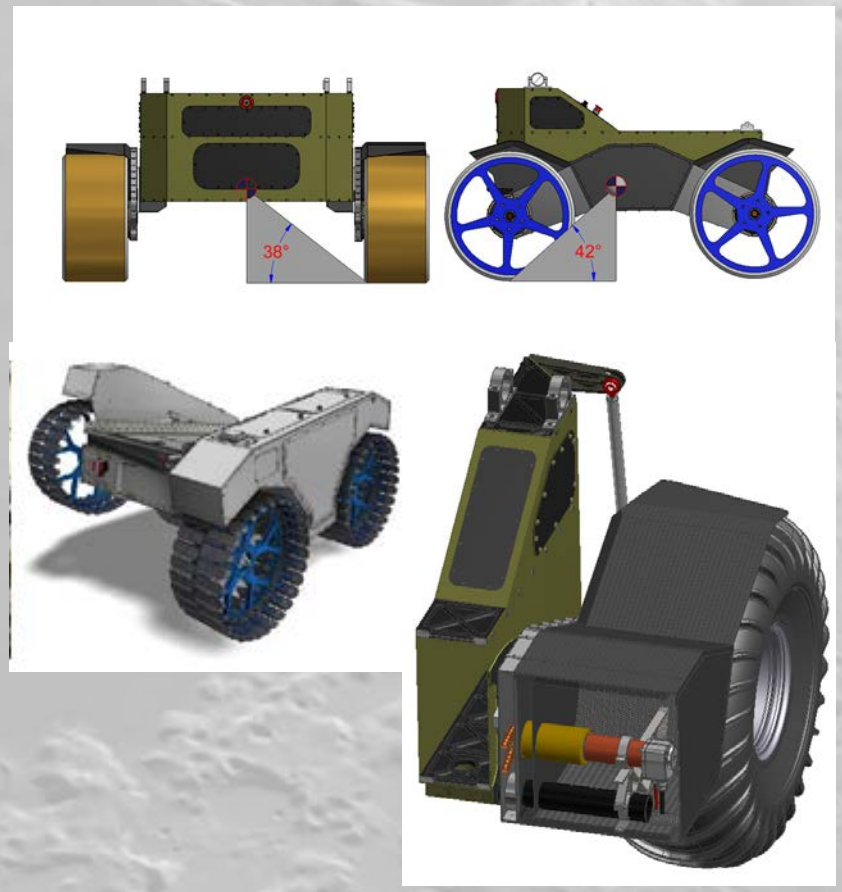
Mauna Kea
Hawaii

RESOLVE test
- Wheel
- Drive system
- Power system
- De-landering

ODG Rover Design Philosophy: K.I.S.S.

(Keep It Simple, Scientist)

- Fewer parts
  - 2 inboard motors with chain drive vs. 12 outboard motors
  - Reduced mass
  - Lower cost
- Skid steering
  - Typical for terrestrial vehicles operating with low ground pressure
  - Reduces envelope of vehicle, allows for bigger wheels
- Modular
  - Self-contained drive system
  - Accommodates multiple payloads
  - Multiple mission compatibility
- Highly Mobile
  - High terrainability reduces risk and reliance on navigation
  - Ability to enter PSR's



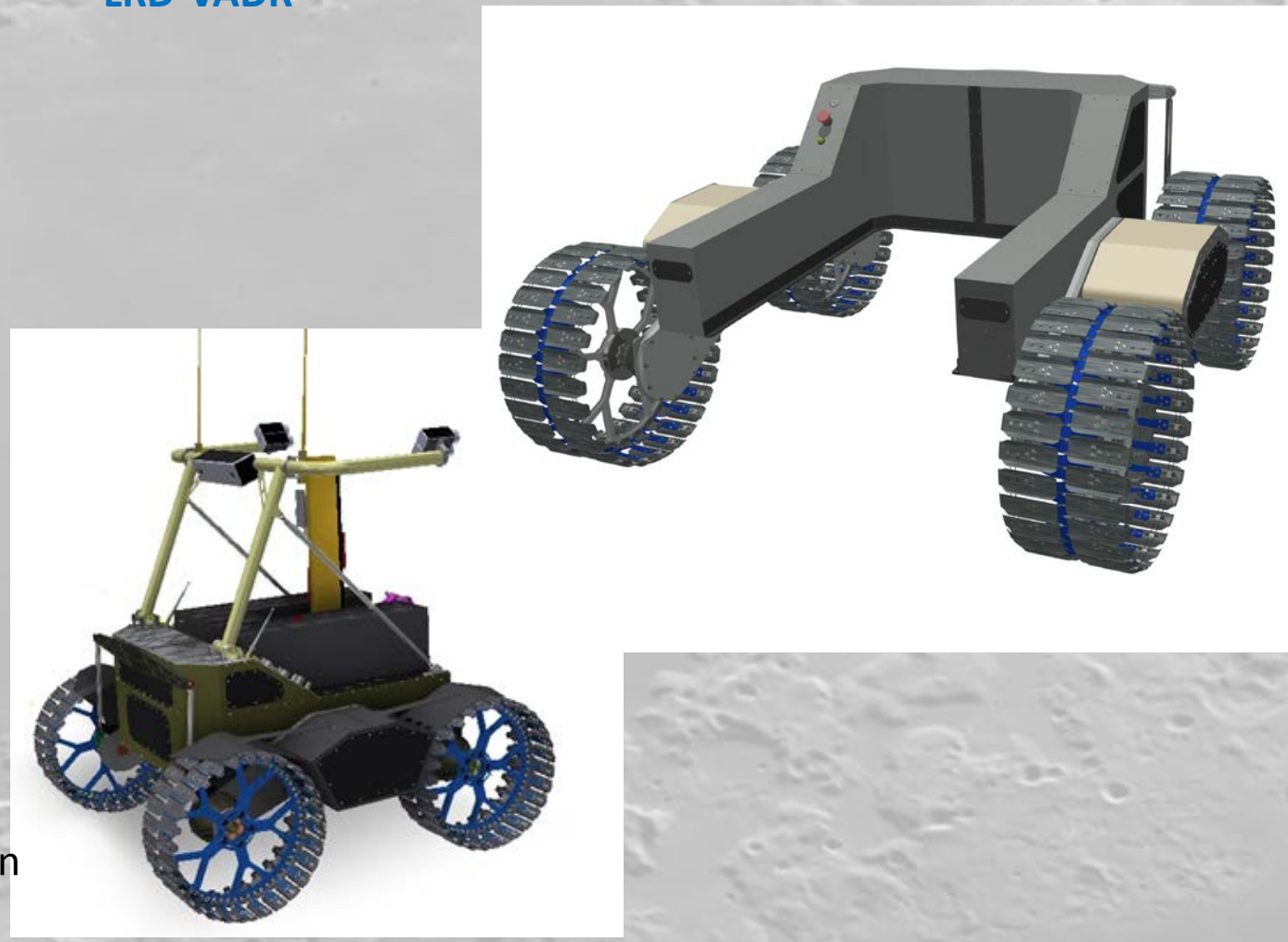
Current Activity

- Leading two CSA contracts on development of rover technology
  - Lunar Rover Platform and Drivetrain Prototype (LRPDP)
    - includes drivetrain to be qualified to TRL-6 in “dirty TVAC” test (simultaneous vacuum, temperature & regolith exposure) at NASA-GRC in Nov. 2015
  - Next-Generation Lunar Wheel Development
  - Small Planetary Rover Platform (SPRP)
- Key technologies for ISECG Roadmap

LRPDP (aka Lunar Rover Drivetrain – Vacuum And Dust Rated)

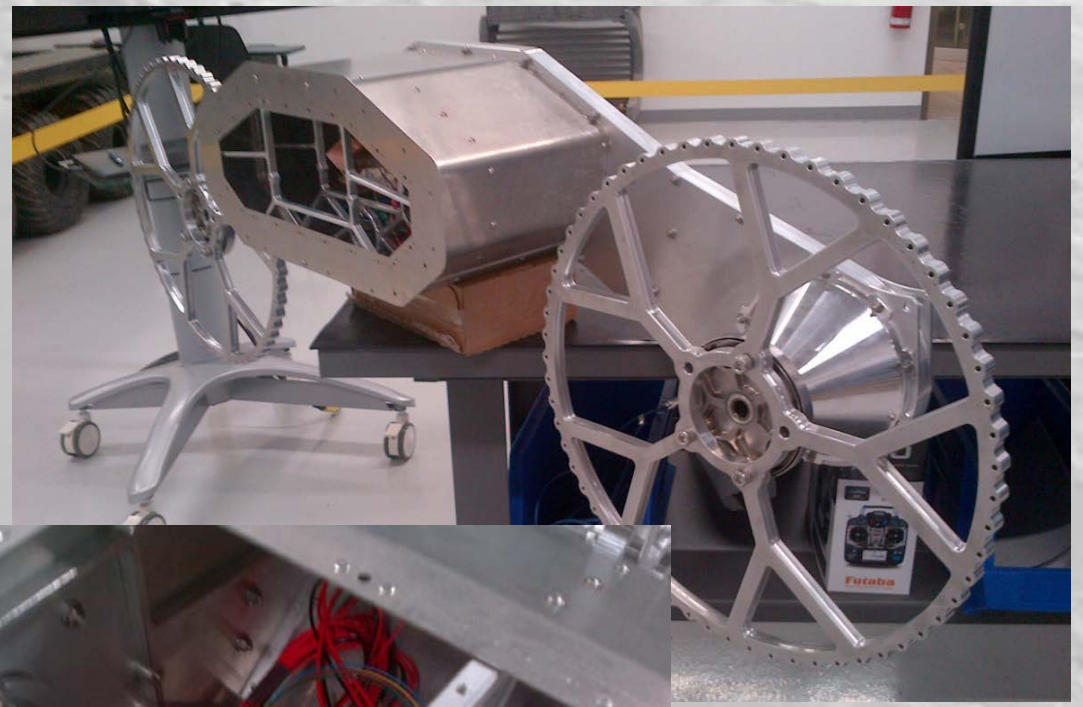
LRD-VADR

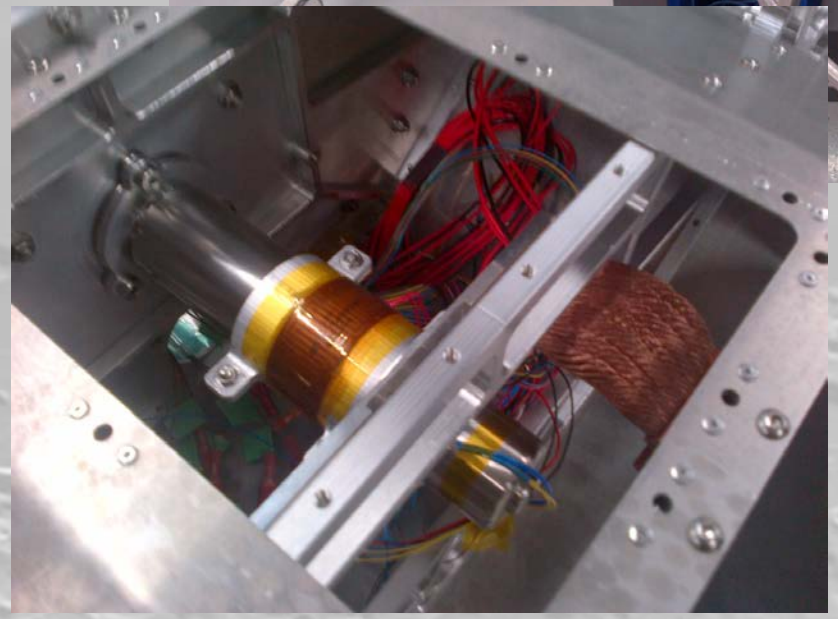
- Dimensions
  - 120 kg base mass
  - 1.6 X 1.6 meters
  - 55 cm wheels
- Modular payload interface
  - Large, central payload
  - Up to 160 kg
- High mobility
  - Enables operation in and around PSR's
  - 50 cm/s
  - Obstacles up to 450mm high
- Rejected acronymical name
  - Canadian Lunar Initiative for Volatile Extraction



Rover Drivetrain

- Central Motor
  - Thermal and contamination protection
- Multi-stage non-contact dust seal
  - Minimal drag
  - Minimal wear
  - Eliminates dust ingress into wheel bearing
- Minimal complexity/mass
  - Reduced number of failure points
- Optimized for terrainability
  - Slopes
  - Rocks
  - Soft/deep regolith



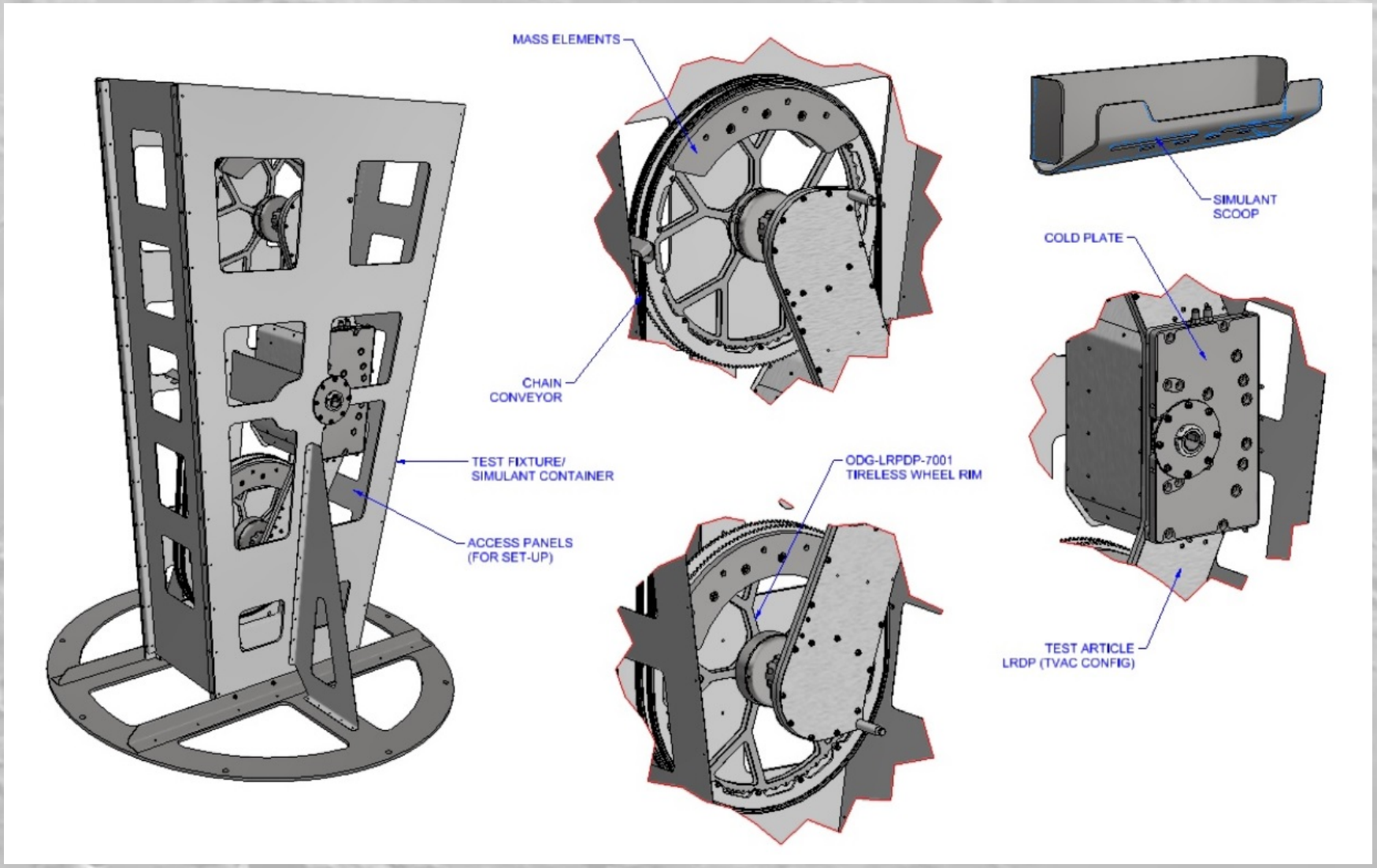


TRL-6 Drivetrain Environmental Design & Test

- TRL6 Design
  - Lunar Thermal
  - Lunar Dust
  - Radiation; Vacuum
- Drivetrain unit
  - 1 motor, 2 chains, sprockets, bearings, housing
  - Exposed to vacuum & Chenobi regolith simulant in NASA Glenn VF-13 “dirty TVAC” chamber
- Operated over temp range of -70°C to +130°C
- Exposed to cold survival temp of -180°C
- Total test time approximately 15 days

TRL-6 Drivetrain Environmental Testing

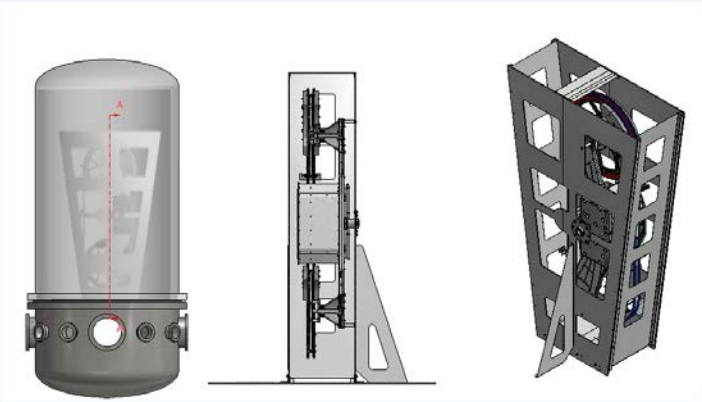
- Test rig for VF13 “dirty TVAC” test
- Based filled with Chenobi regolith simulant
- Conveyor system (external sprockets, chains and scoops) used to distribute simulant over drivetrain unit

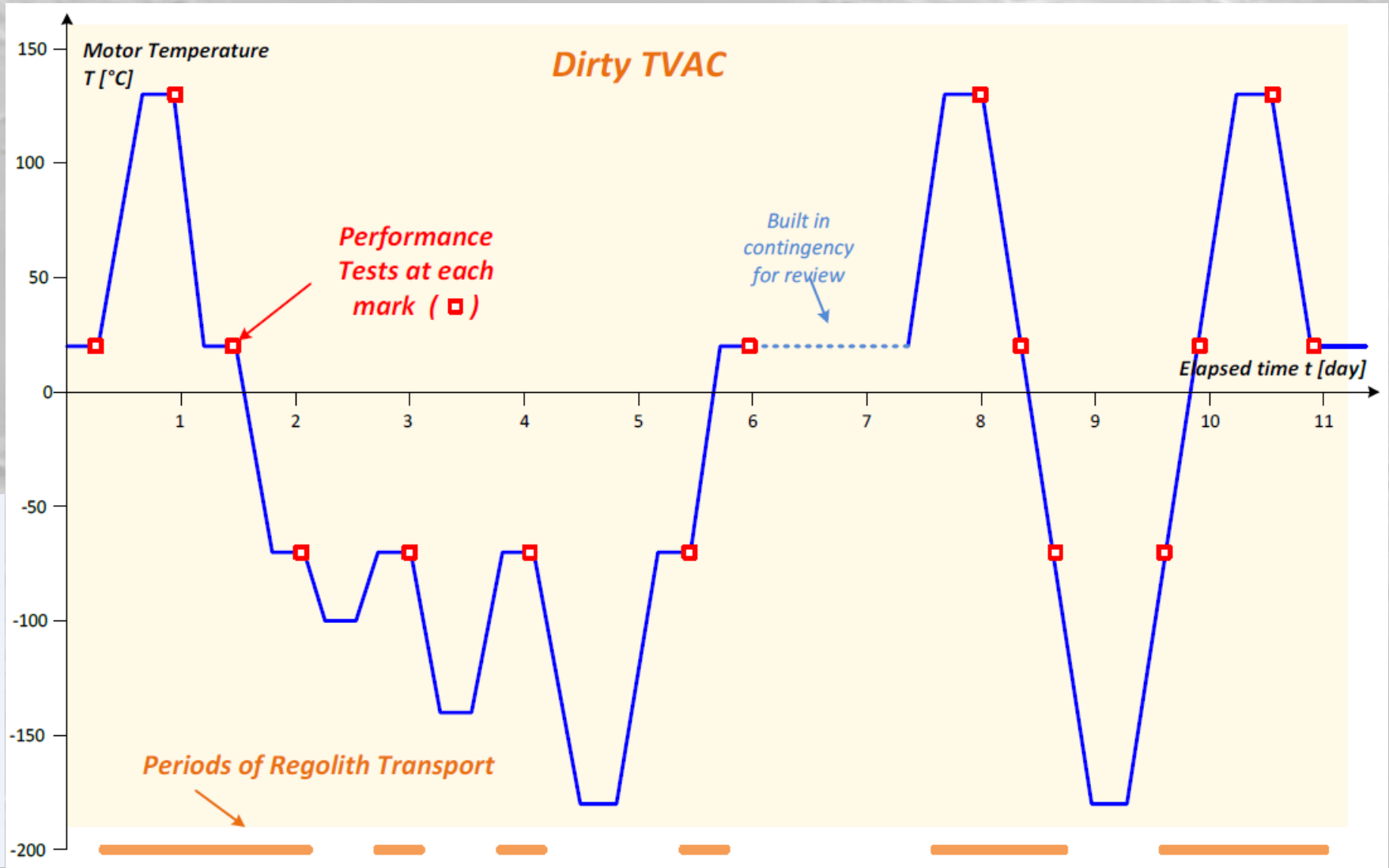


TRL-6 Drivetrain Environmental Testing

Test profile

- Reversing load
  - 25 degree slope equivalent
- Vehicle speed
  - 0-50 cm/s
  - Start/stop

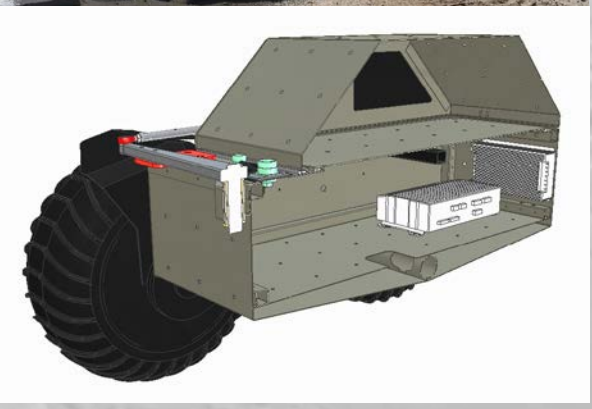




Small Lunar Rover (SPRP – Small Planetary Rover Platform)

- 1.2 X 1.2 meter
- High mobility
- TRL-6 compatible drivetrain
- 90 kg base mass
- 50 cm compliant wheels
- Q1 2016 delivery

- Scaled technology from LRD-VADR

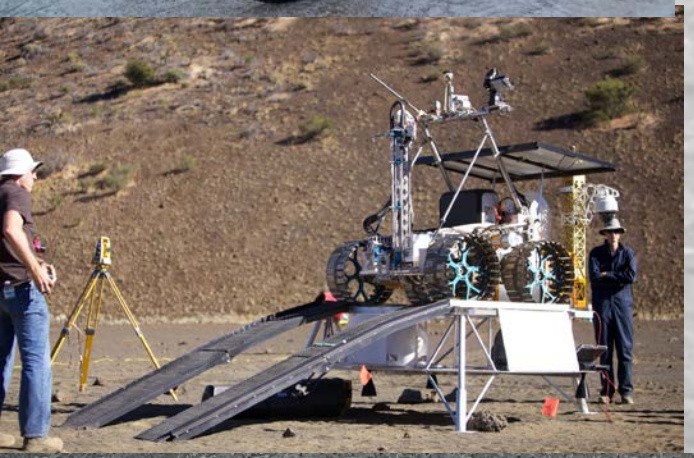


CANADENSYS

A DIVISION OF ONTARIO DRIVE & GEAR LTD.

Future Work

- Lunar night survival – up to 14 days in shadow (less in polar regions)
  - Long-duration survival of electronics in extreme cold temps (down to -233°C)
- Longer mission duration (> 14 days)
- Longer endurance
  - total distance travelled > 25 km
  - Longer-duration wear effects of lunar regolith
- High mobility
  - Take your rover, and put it where the sun don't shine.



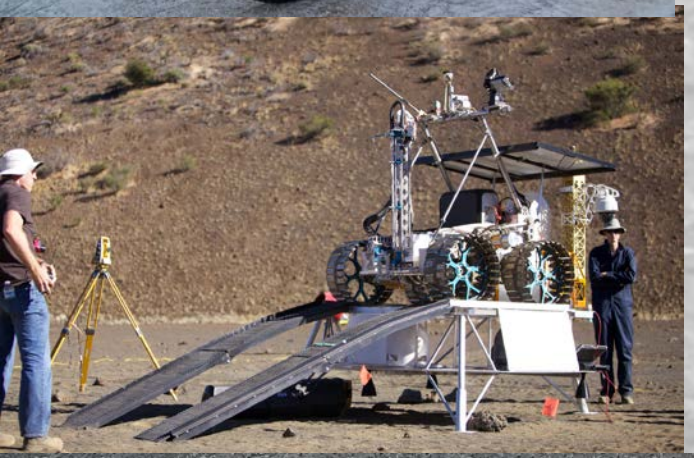
Thank You

Questions?

This is a duplicate slide to ensure that if I click accidentally I don't go to my backup slide without meaning to.

Thank You

Questions?



Rover Commercialization

Development of terrestrial rover – **ARGO J5**

- Improved dust/thermal protection
- Multiple battery options
- Multiple traction options

Applications

- Agricultural
- Security
- Military
- Industrial