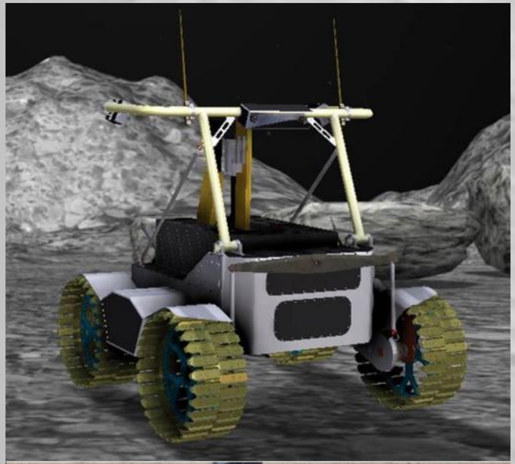
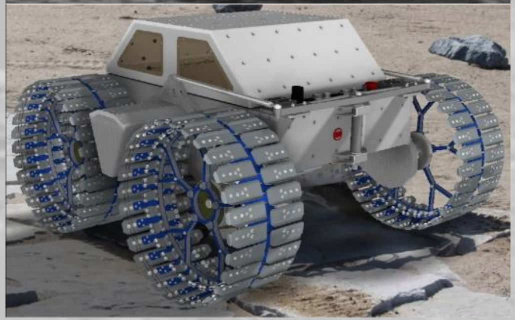
Canadian Lunar & Planetary Rover Development

Moon 2020-2030

December 14, 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 (ODG) Space/Robotics

- **Amphibious vehicles**
- **Terrestrial UGV's**
  - **Defense, research, industrial**
- **Planetary rover design and manufacture**
  - Focus on mechanical, mobility, and integration
  - Six classes of planetary rover – ranging from 90 kg to 600 kg
- **Manufacturing**
  - In house gear, shaft, machining capability
- **Testing**
  - Lab testing
  - Analogue campaigns
  - Qualification testing
- **Deployment and support**
  - Multiple analogue field missions

Role on Current Rover Programs

- *Prime contractor*
- *Systems design and integration*
- *Manufacture, assembly, test*
- *Lunar wheel design*

CANADENSYS

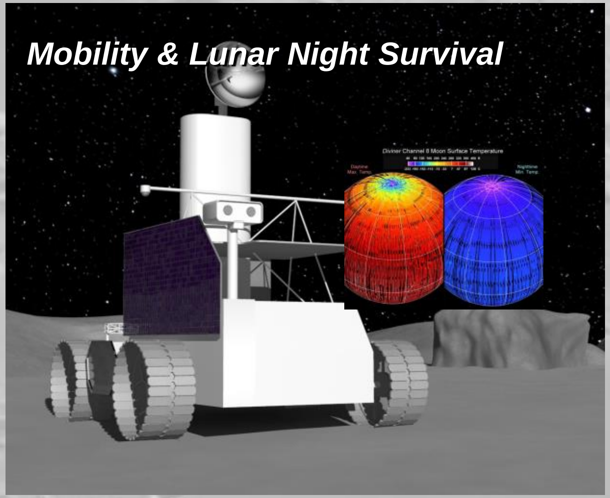
A DIVISION OF ONTARIO DRIVE & GE

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

A DIVISION OF ONTARIO DRIVE & GEAR LTD.

Lunar Rover Development in Canada

Current Projects

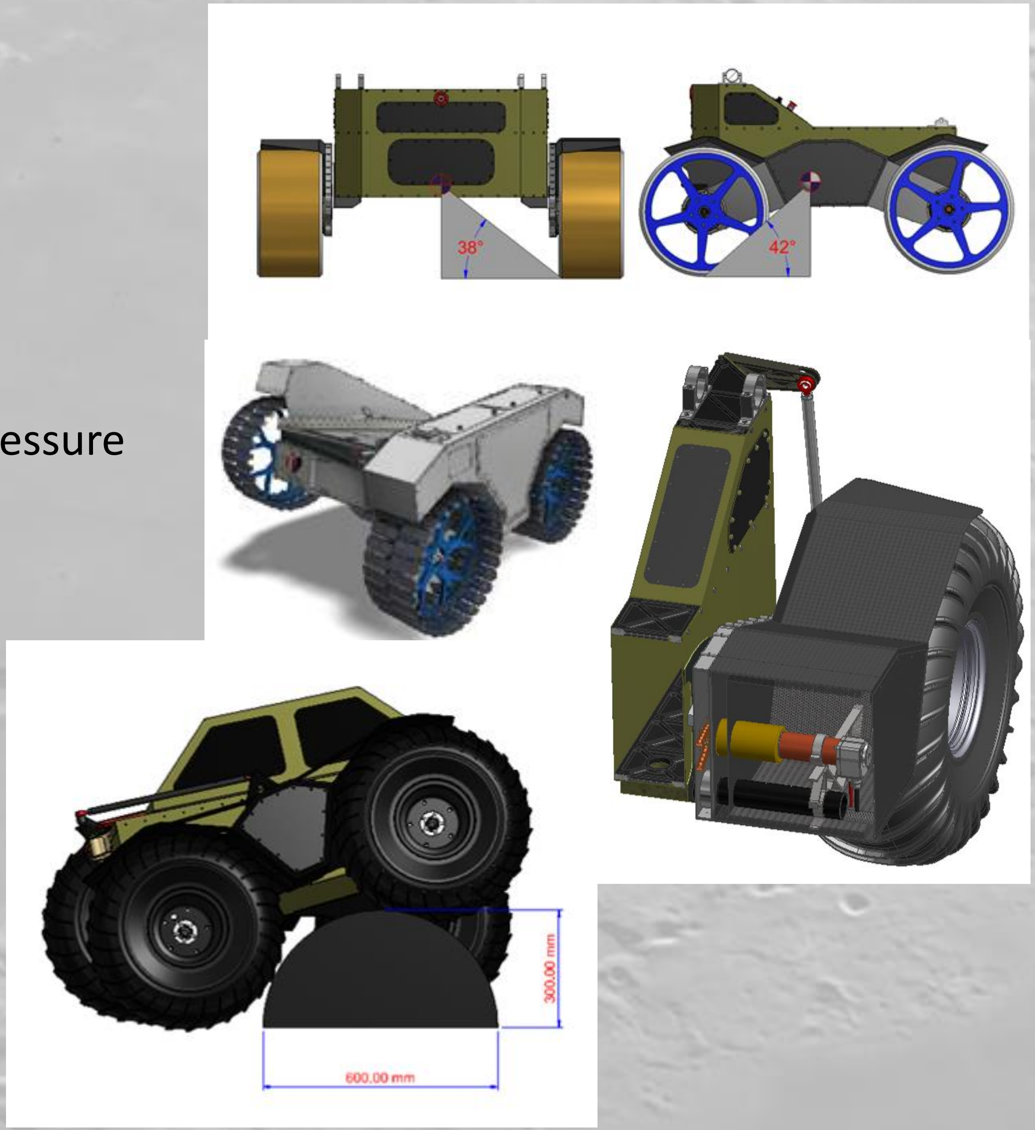
- **Midsize Rover Development** (TRL-6 Drivetrain)
  - ODG-Argo (Canadensys, Bombardier Rec.)
- **Lunar Rover Night Survival**
  - Canadensys (ODG-Argo)
- **Lunar Rover GN&C**
  - MDA, NDG
- **Small Lunar Rover Development**
  - ODG-Argo (Canadensys, Bombardier Rec.)
- **Soil Hazard Detection**
  - Mission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

A DIVISION OF ONTARIO DRIVE & GEAR LTD.

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

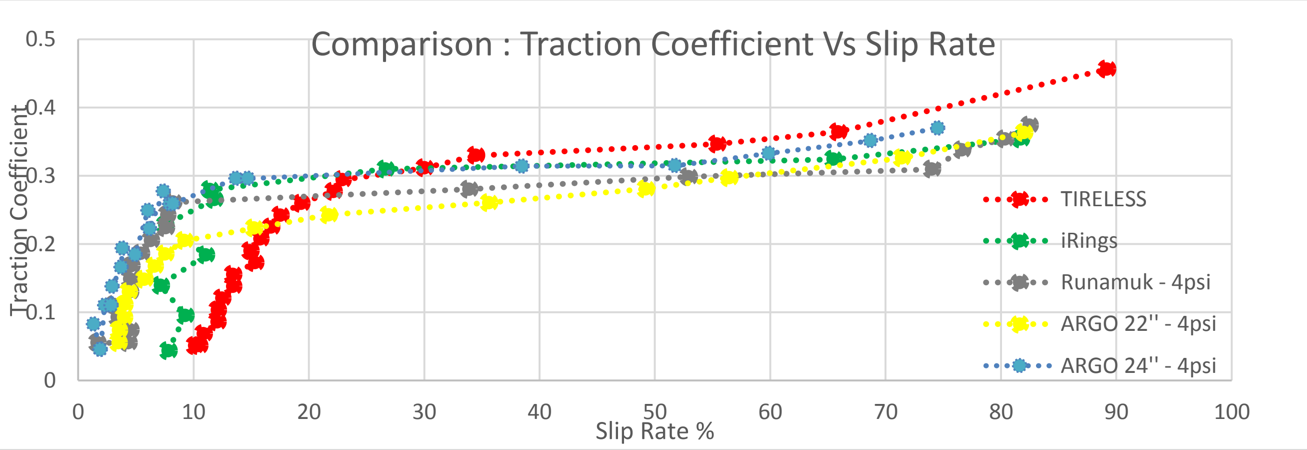
(Keep It Simple, Scientist)

- Fewer parts
  - 2 inboard motors with chain drive vs. 12 outboard motors
  - Reduced mass, lower cost
  - Rugged, high payload ratio
- 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
- High Mobility
  - High terrainability reduces risk and reliance on navigation
  - Ability to enter PSR’s



Rover Traction Systems

- Canadian Space Agency contracts
  - Two generations of metallic tracks
  - Five generations of compliant metallic wheels
- Lab testing in GRC-1 simulant
- Over 100 km of real world testing in analogue terrain
- Scalable: ~25-100 cm



CSA ASC

Apollo Valley
Hawaii

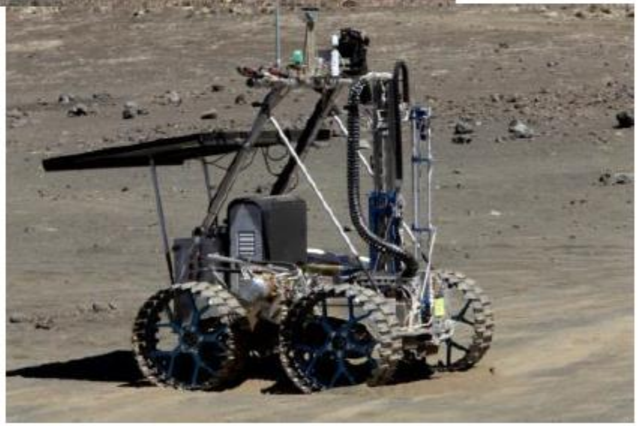
MMAMA testing

- Juno II Rover
- Compliant wheel
- Rough terrain mobility
- Power system
- Payload integration

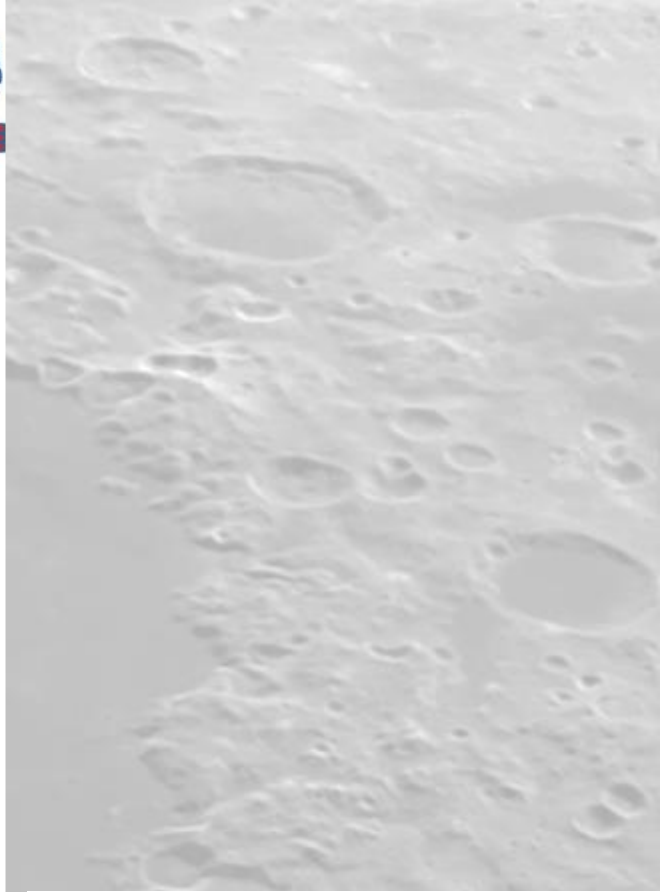
RESOLVE Analog Field Tests

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

Mauna Kea
Hawaii

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

Current Activity

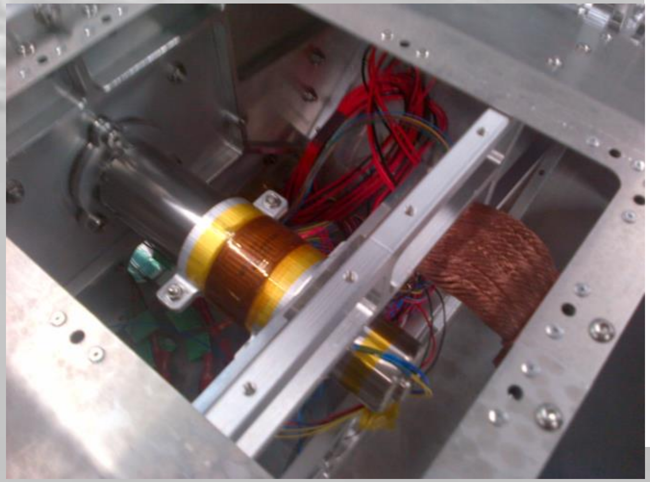
Leading two CSA contracts on development of rover technology

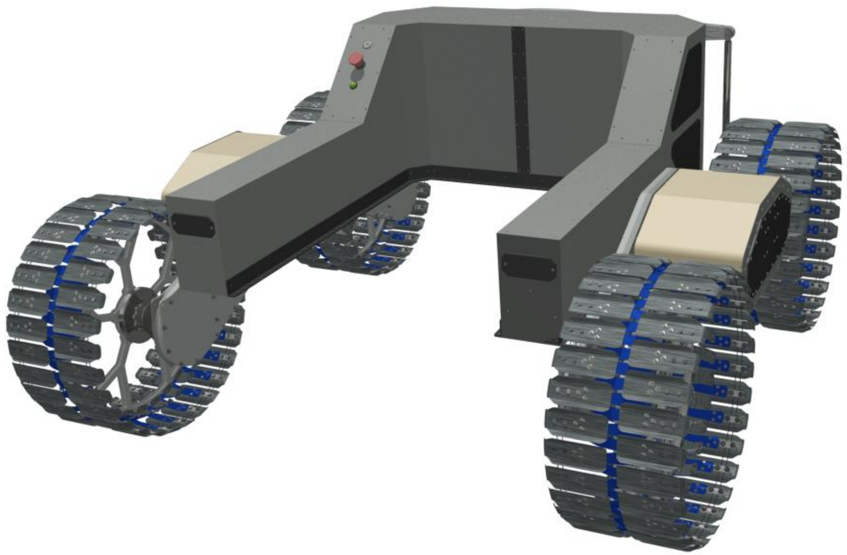
- Lunar Rover Platform and Drivetrain Prototype (LRPDP)
  - includes drivetrain to be qualified to TRL-6 in "dirty TVAC" test (simultaneous vacuum, temperature & regolith exposure) at NASA-GRC in Nov. 2015
- Next-Generation Lunar Wheel Development
- Small Planetary Rover Platform (SPRP)

- 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 top speed
  - Obstacles up to 450mm high
  - Rocks, soft/deep regolith, slopes
- Central Motor
  - Thermally protected and controlled
  - Contamination protection
- Multi-stage non-contact dust seal
  - Minimal drag/wear
  - Eliminates dust issues at all ingress points
- Minimal complexity/mass
  - Reduced number of failure points

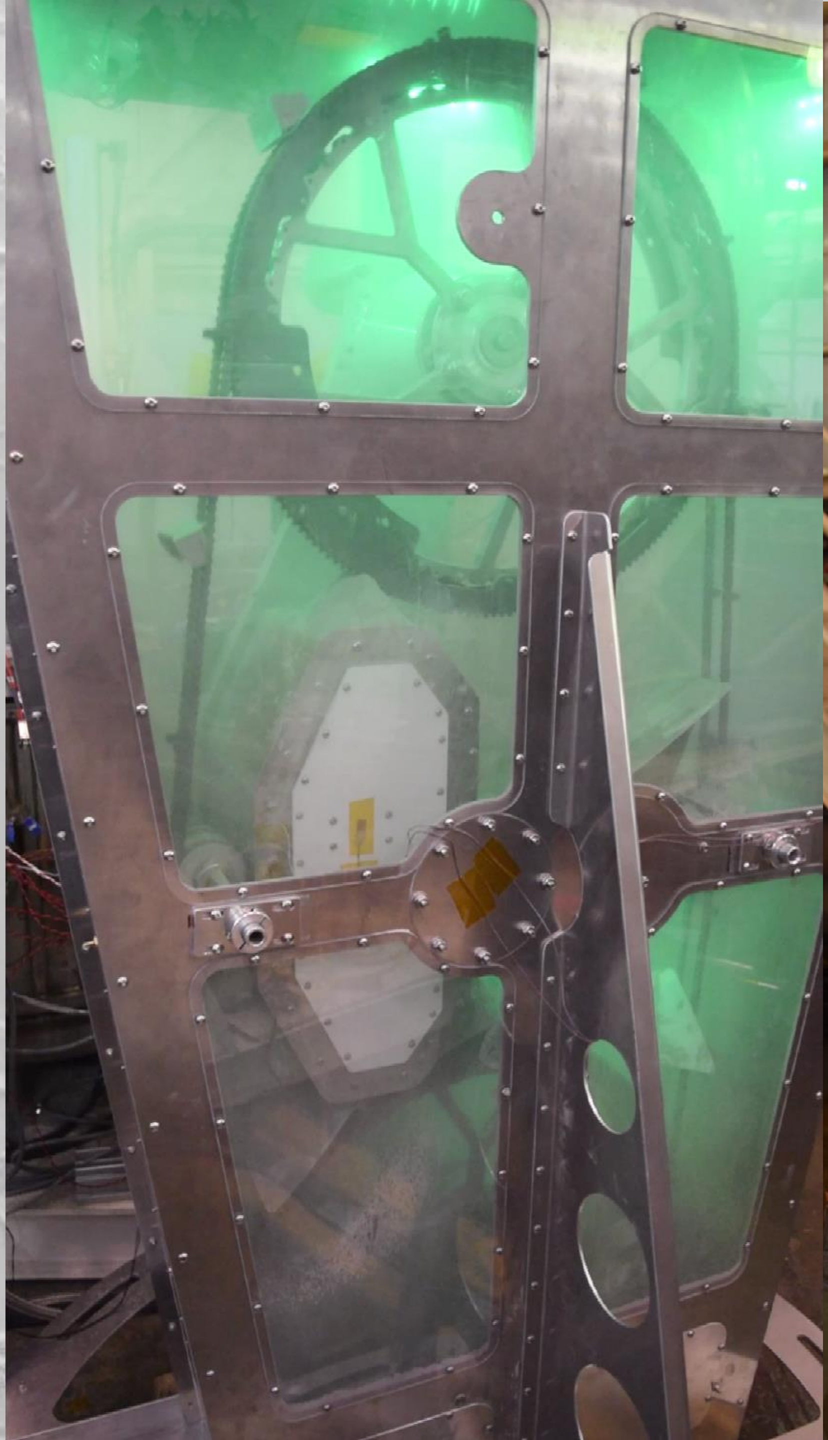
A DIVISION OF ONTARIO DRIVE

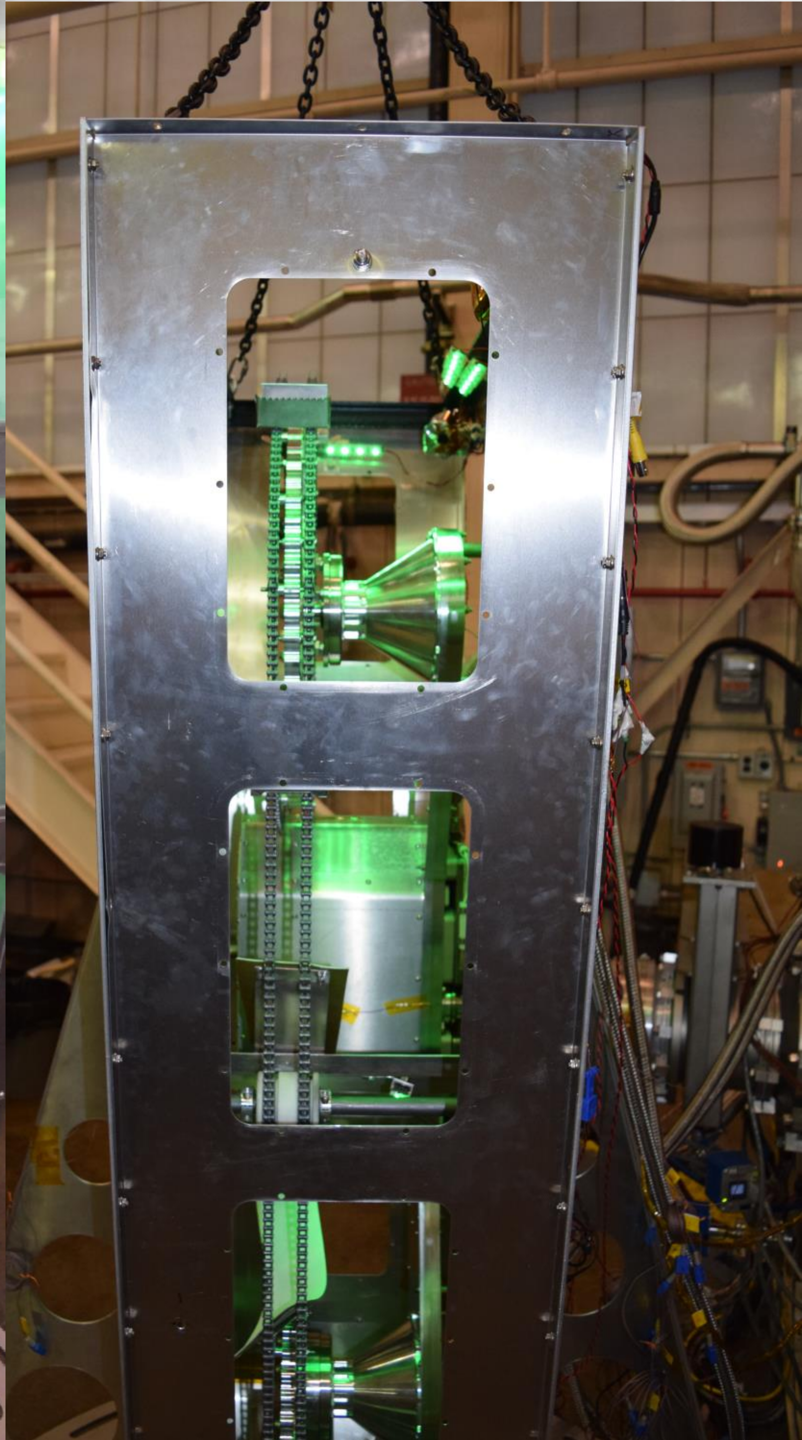
TRL-6 Drivetrain Environmental Design & Test

- 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 20 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 continuously





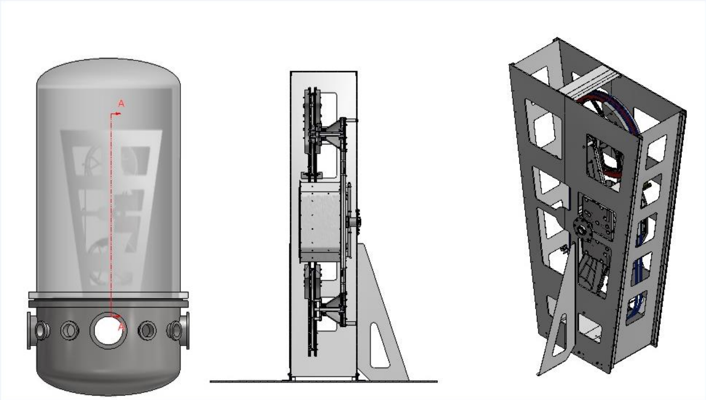
CANADENSYS

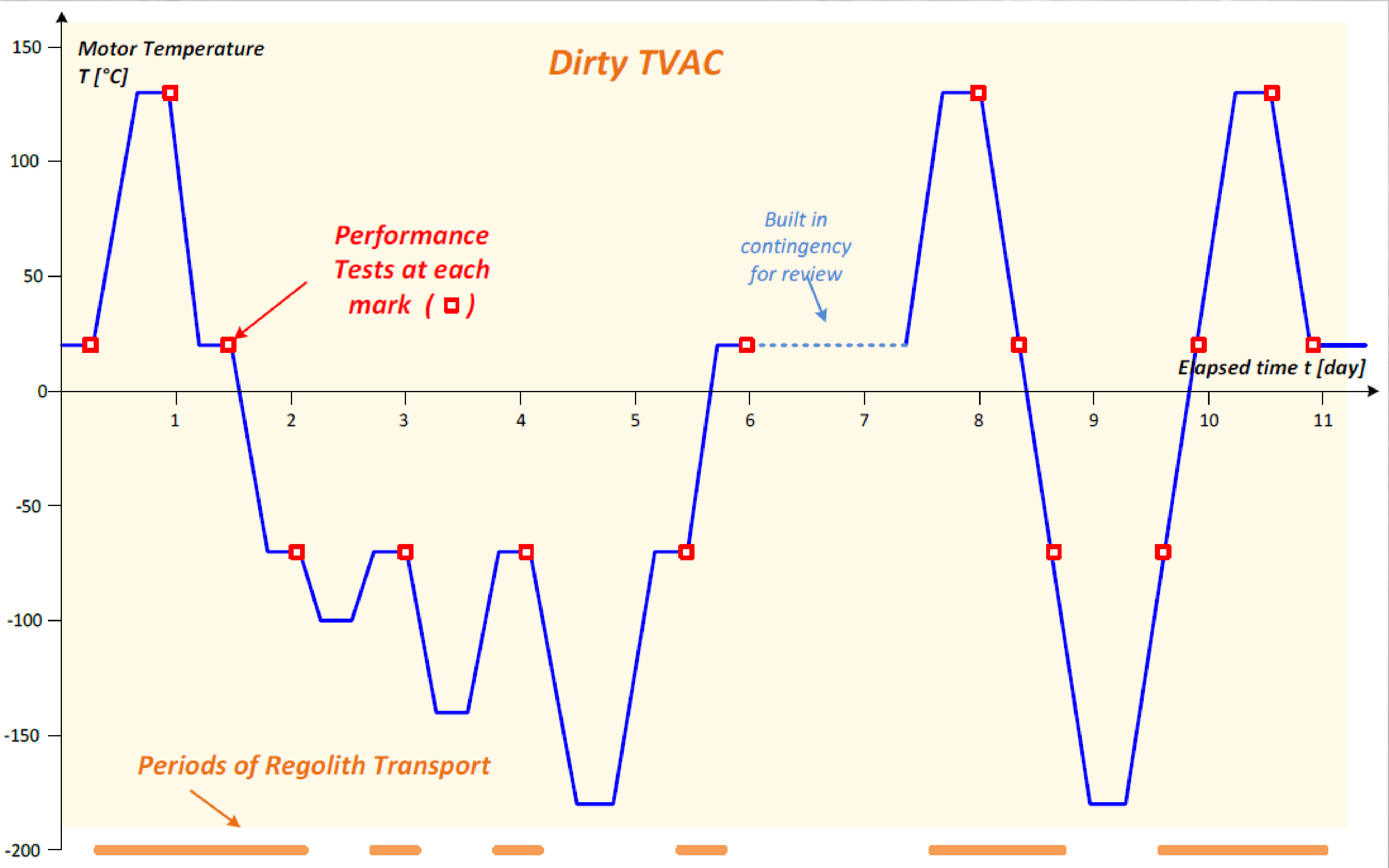
A DIVI

TRL-6 Drivetrain Environmental Testing

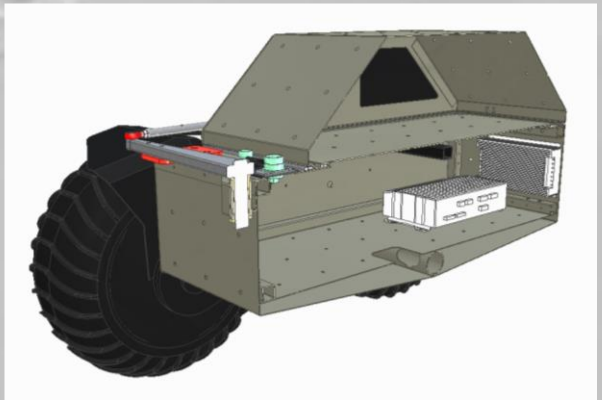
Test profile

- Reversing load using 20 kg offset masses
  - 25 degree slope equivalent
  - Severe test, overload
- Vehicle speed
  - 2.5, 5.0, 10, 40, and 50 cm/s
  - Start/stop
  - Incremental motor current recorded

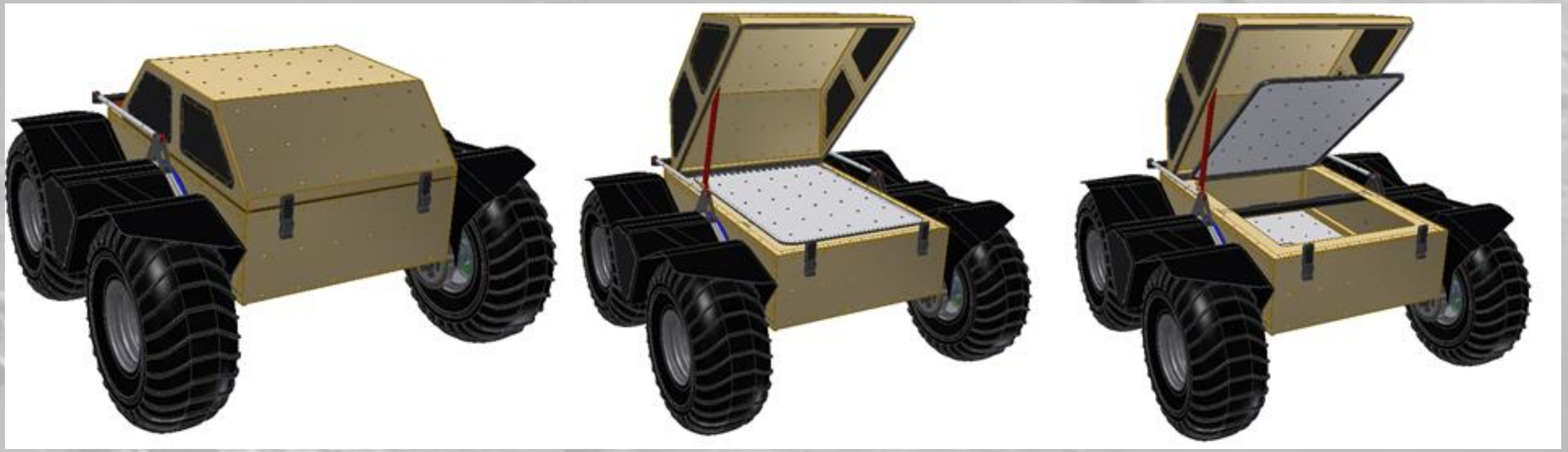




Small Lunar Rover (SPRP – Small Planetary Rover Platform)

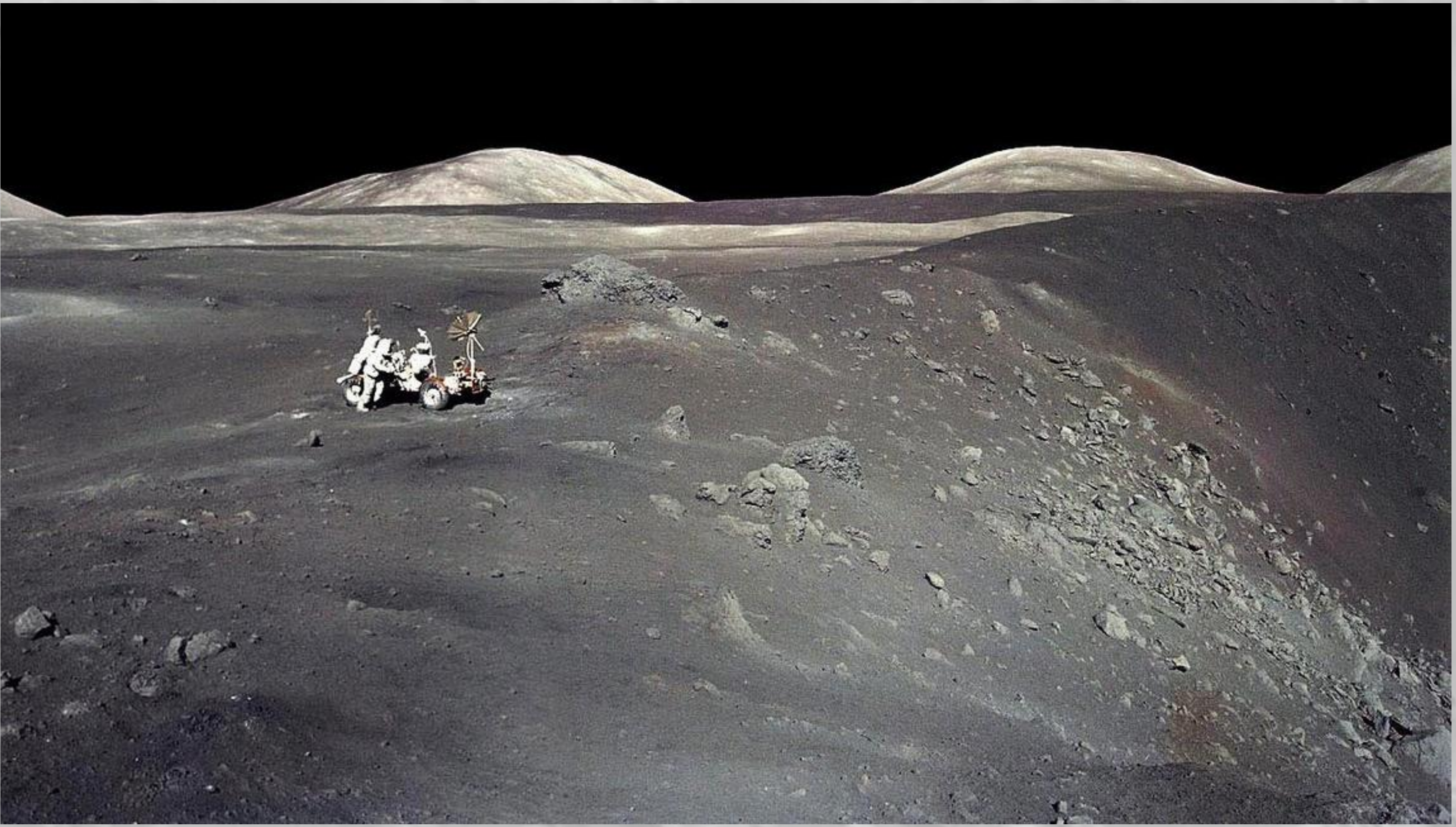


- 1.2 X 1.2 meter
- High mobility
- TRL-6 compatible drivetrain
- 90 kg base mass
- Traction options
  - 50 cm compliant metallic wheels
  - 55 cm pneumatic rubber tires
- Q1 2016 delivery

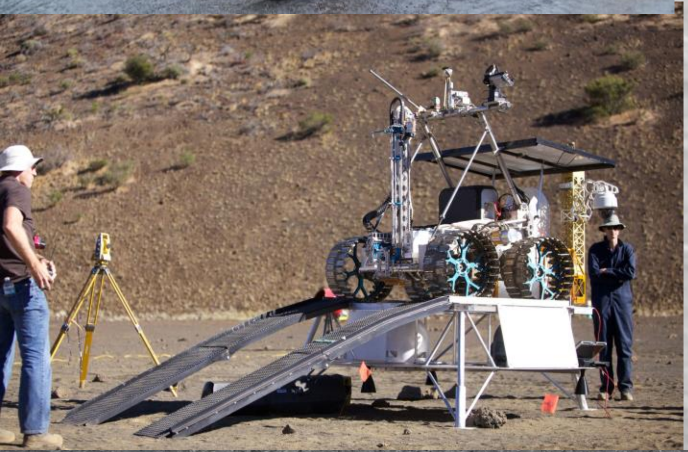


- Scaled technology from LRPDP

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)
- Design for longer mission duration (> 14 days)
- Design for greater endurance
  - total distance travelled > 25 km
  - Longer-duration wear effects of lunar regolith
- Increased mobility
  - Take your rover, and put it where the sun don't shine.



Thank You

Questions?

A DIVISION OF ONTARIO DRIVE & GEAR LTD.