Artemis Rovers

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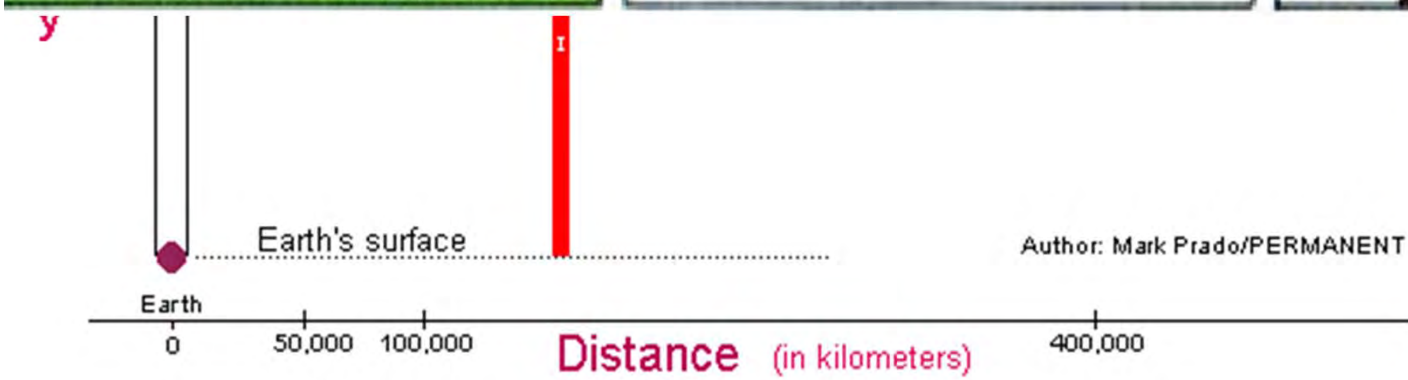
CELEBRATING 50 years 1962-2012 ...and geared up for our next 50

Argo® ODG 50 YEARS 1962 – 2012

The Moon: It has been so lo

Recently…

- Recent scientific discoveries indicate a great deal of water on the moon
  - Chandrayaan, Casini, LCROSS
- Water production on the moon will ultimately lower the cost of space exploration. Ultimately, this will be an industrial or even commercial activity.



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Future of lunar activity

Exploration – driving further, looking for resources

Groundworking – drilling, blading, shoveling

Logistics – moving equipment around

Commercial activity – Shorter development cycles, lower cost.

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- Several phases of commercial lunar surface activity
  - **Precursor – Find the water and "characterize the ore body" - RESOLVE**
  - Intermediate – several generations of pilot production, increasing volume
  - Long term – increasing production to meet demand
- As the nature of lunar robotic activity changes, so too will the nature of the equipment used.
- Mobility platforms will need to change to accommodate shift in activities and the shift towards commercially driven enterprise.

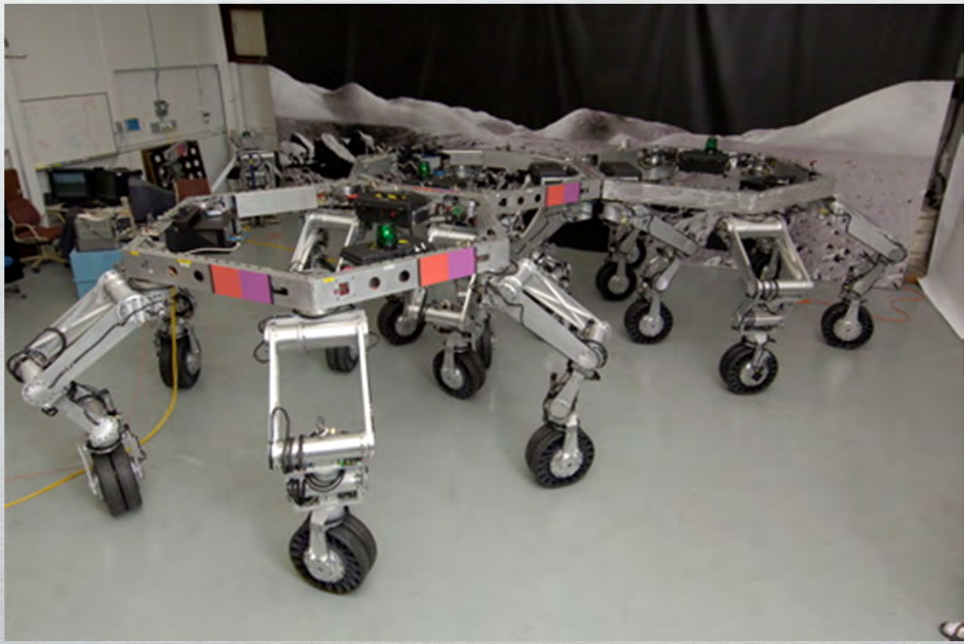
1. **Cost/complexity**
2. **Durability and ruggedness**
3. **Payloadcentricity**
4. **Traction**
5. **Modularity**

1. Lower Cost

- Lower design cost
- Lower production cost
- Lower repair and maintenance cost

By using:

- Few components
- Stronger components
- Interchangeable components



2. Increase Durability

- Ground-working tasks involve unexpected loads – fewer and stronger components
- Reduced complexity (pivots, joints, motors)

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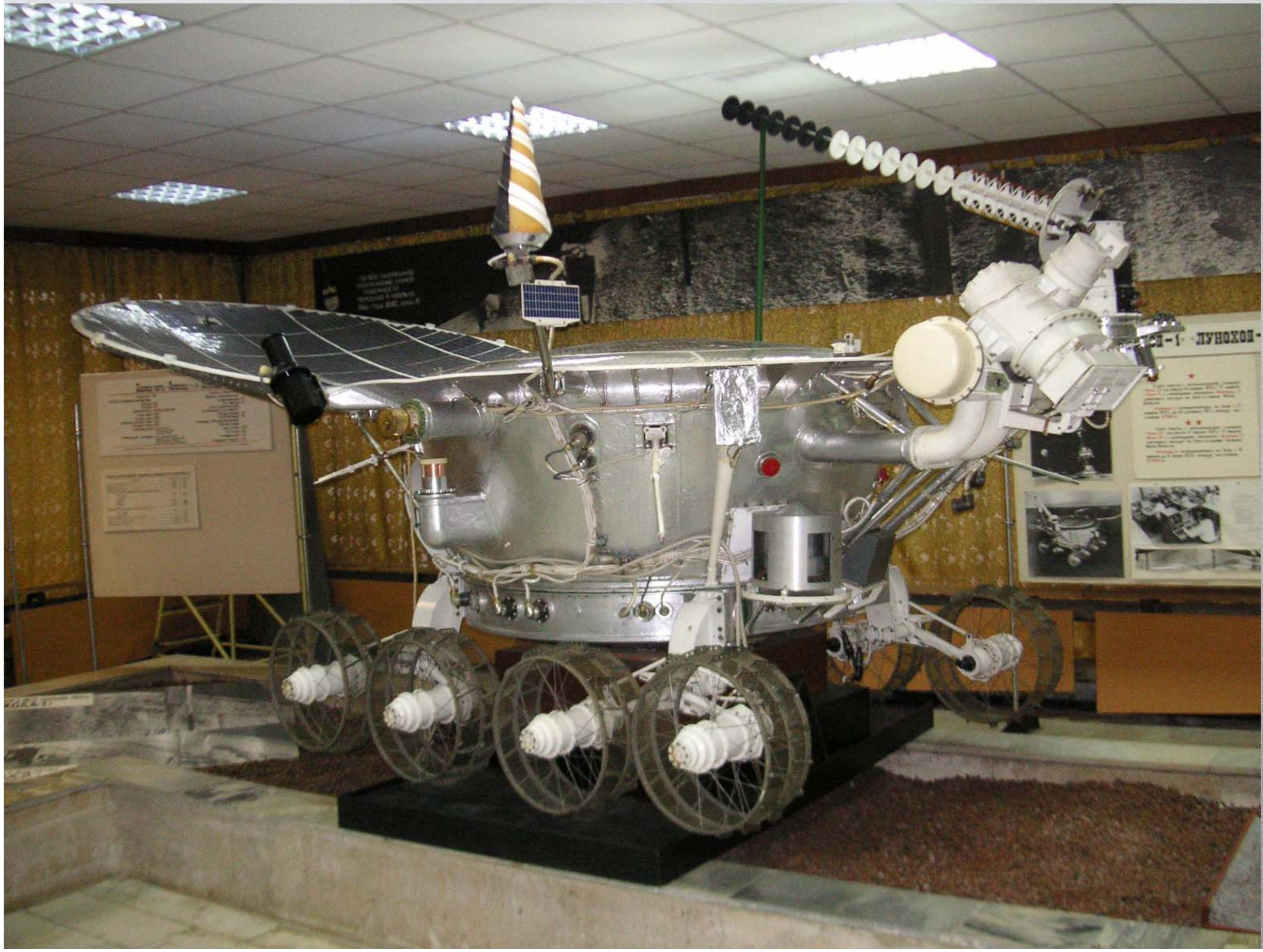
Skid steering

- Typical for terrestrial vehicles operating with low ground pressure
  - Below 5 psi.
- Reduces envelope of vehicle
- Reduces complexity of vehicle



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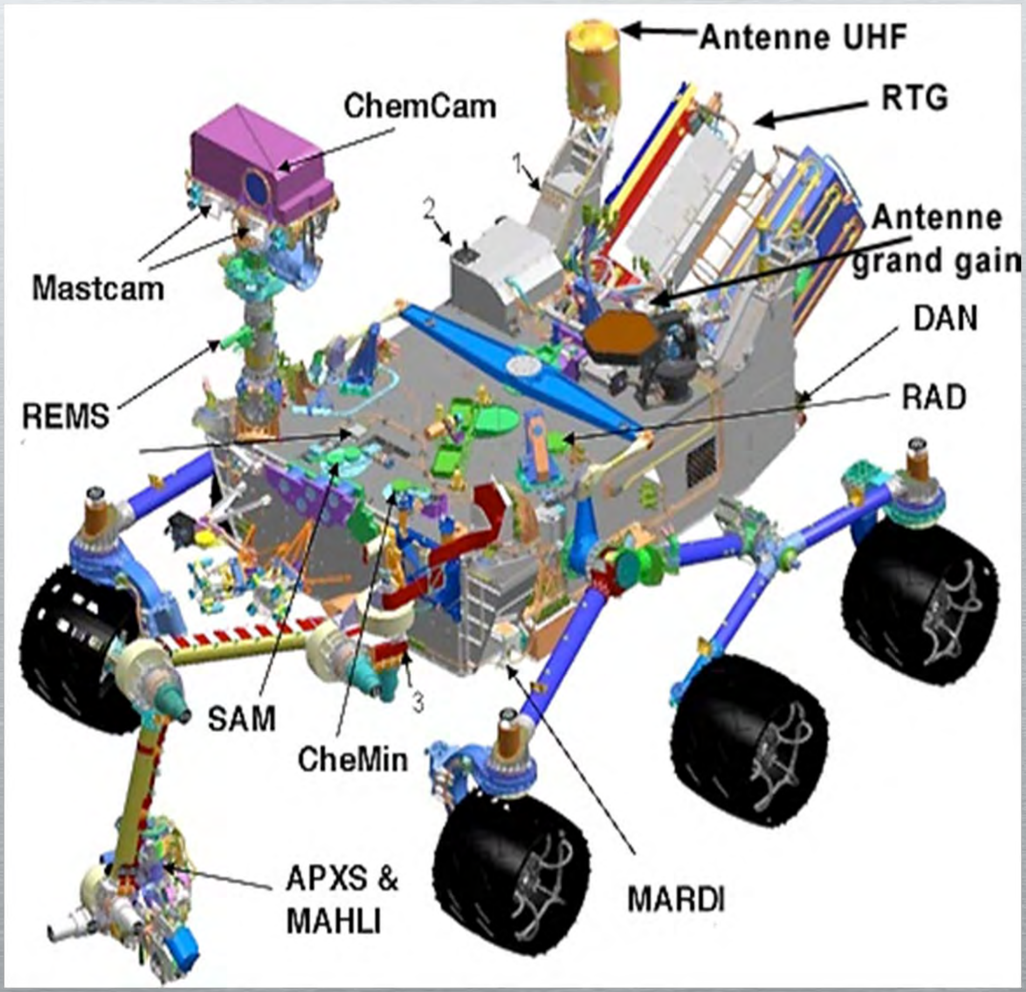
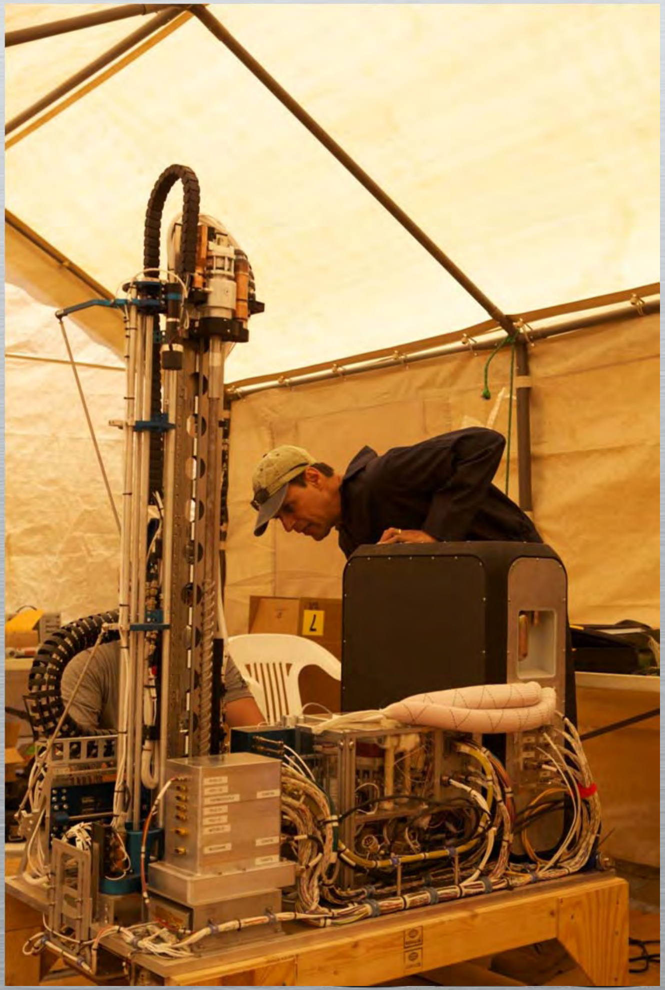
3. Payloadcentricity

- Suite of instruments vs. integrated payload
- Larger, heavier, power hungry
- Reaction loads from ground working (blading, drilling)





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4. Improved Traction

- Groundworking tasks increase required tractive forces by almost an order of magnitude
- Current rovers use small diameter, rigid wheels
- Terrestrial solutions
  - Large diameter rubber pneumatic tires
  - Tracks – steel or rubber

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5. Increased Modularity

- Multi-mission capability
  - Use the same mobility platform for multiple missions.
- Long-term fleet activity will benefit from modularity on the component level.
  - May be able to fly payloads and/or component rather than entire systems

Mauna Kea Hawaii, 2008

Local Fauna

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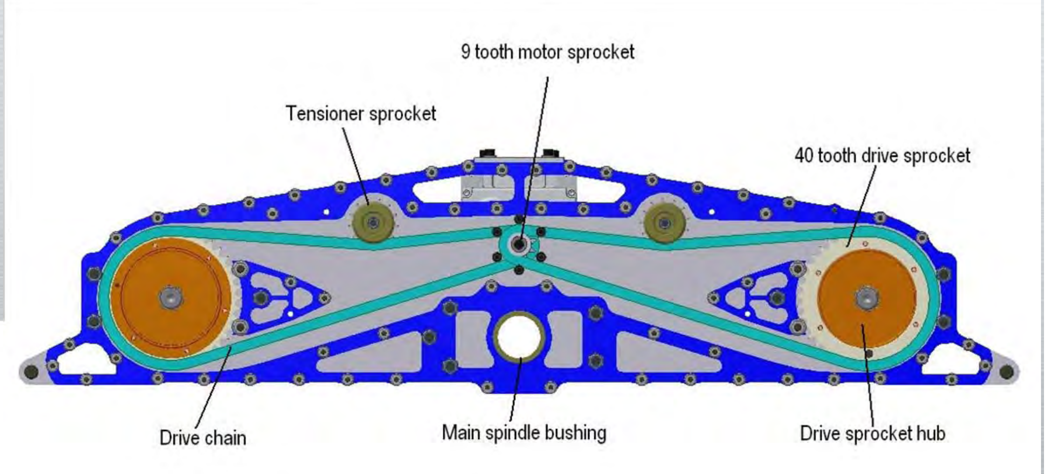
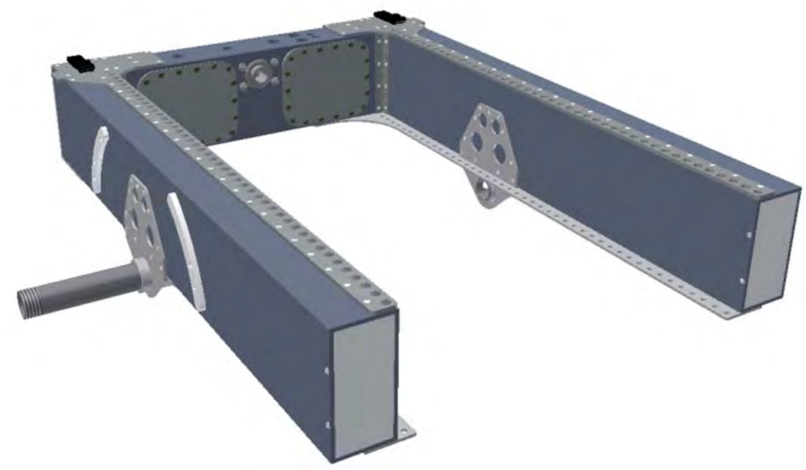
Artemis Rover Background

Juno I Rover (2008)

- Skid steer – two motors
- Simple, lightweight, rugged
- High payload/mass ratio
- Modular design
- Large battery volume (replaceable)





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Juno Tandem rover (2009)

- Improved efficiency
- More traction
- Better redundancy

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2010 Hawaii Field Deployment

RESOLVE payload and associated GSE (500kg) was mounted to a tandem of Juno Rover

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2010 Hawaii Field Deployment

Extrer

Juno II Rover Upgrades – New Features

- Motors
- Transmissions
- Suspension
- Traction
- Control
- Battery
- Mast

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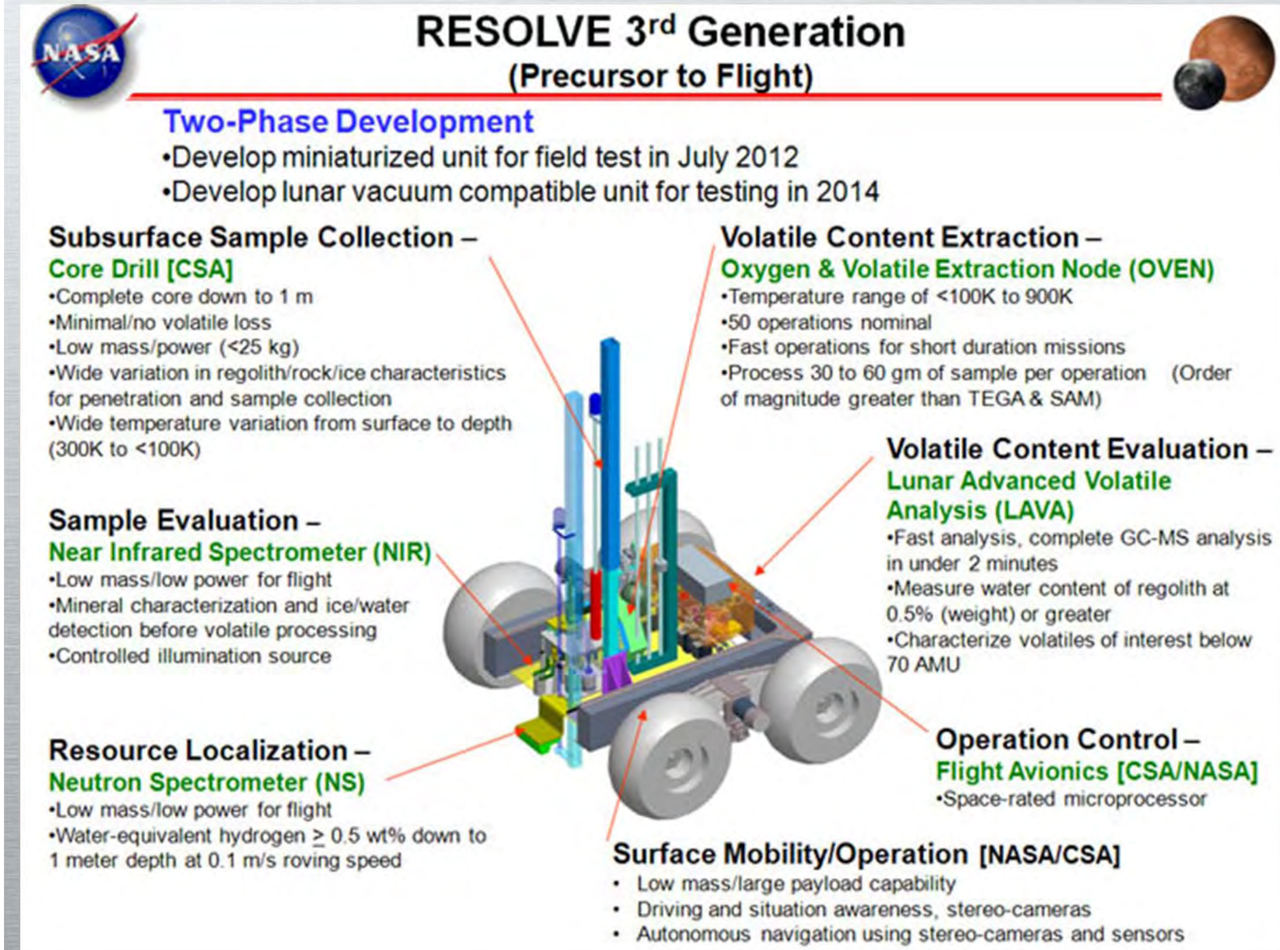
Traction – Titanium Tracks

Artemis Jr. Development



- Integrated RESOLVE payload led to redesigned rover.
- Sketches began in January, 2011.
- Program officially began in May, 2011

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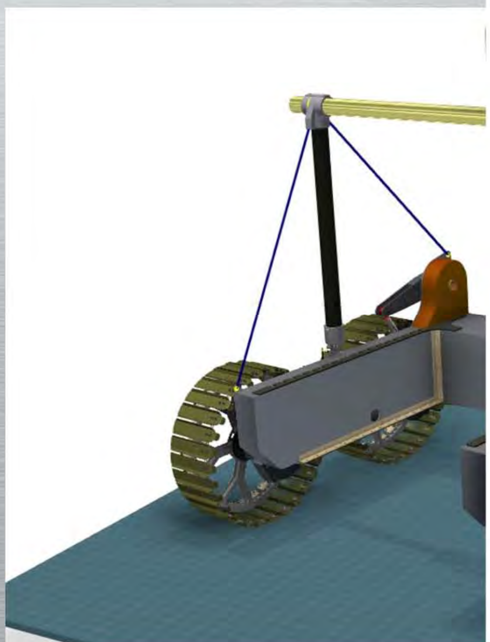
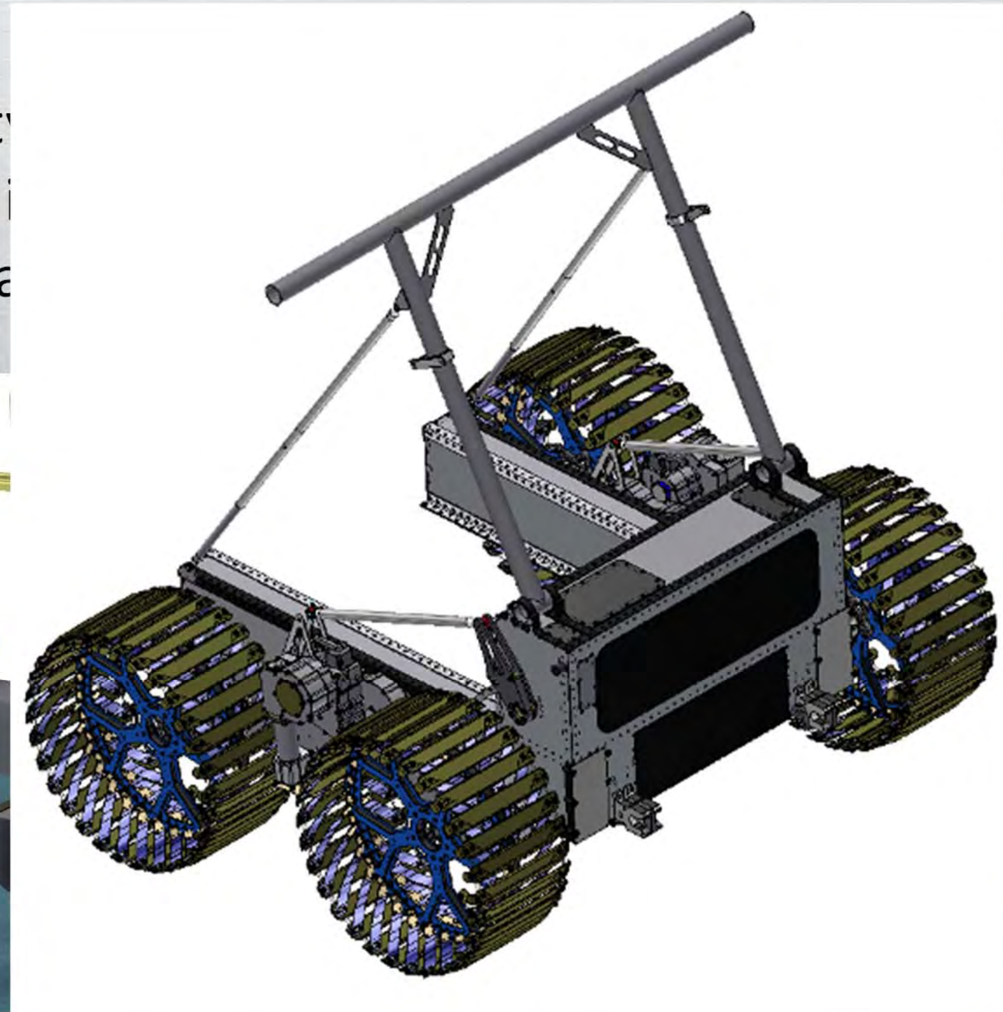
Artemis Jr. Development

Objectives:

- Provide mobilit … oads
- Maintain mobili
- Maintain / Adva … t





ARtemis JUnior Design 2 = AR-JU-D2

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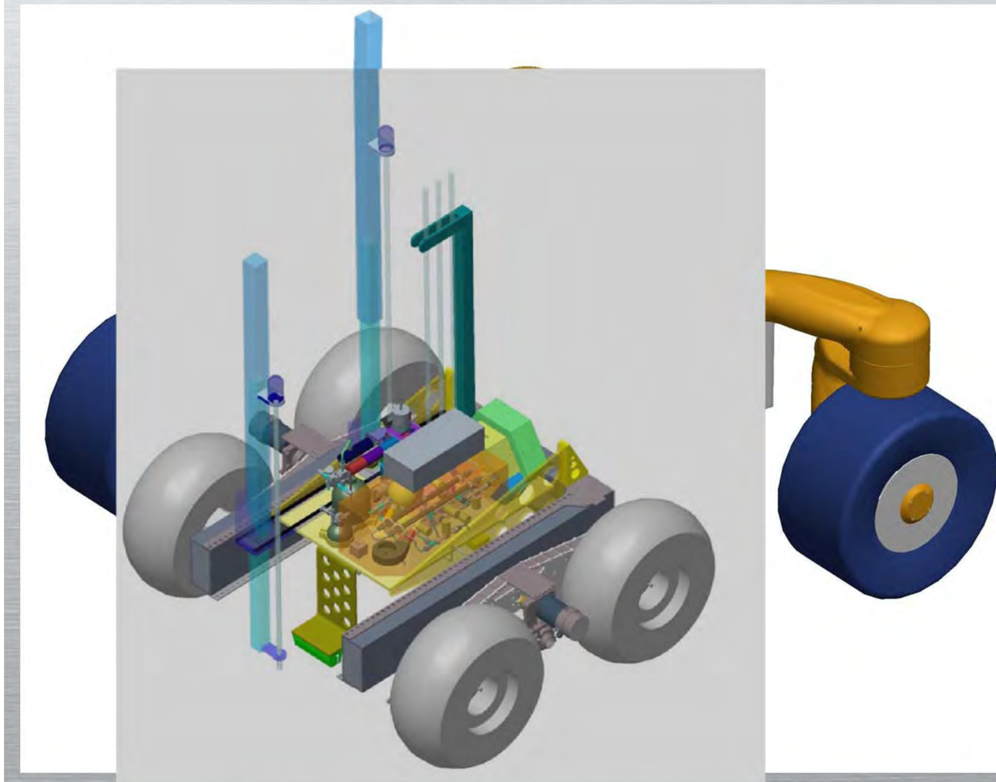
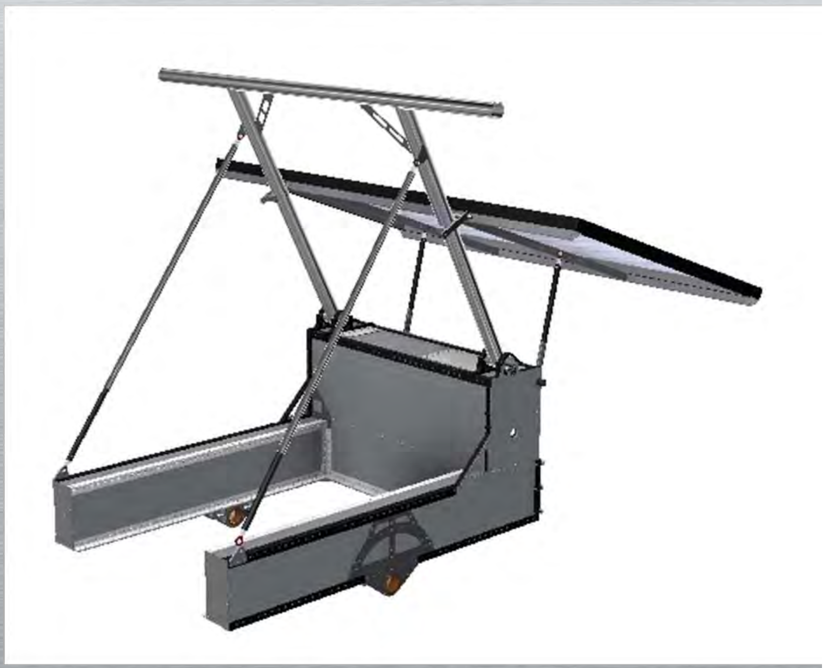
Payload-centric chassis

Payload volume and mass vs.
vehicle volume and mass



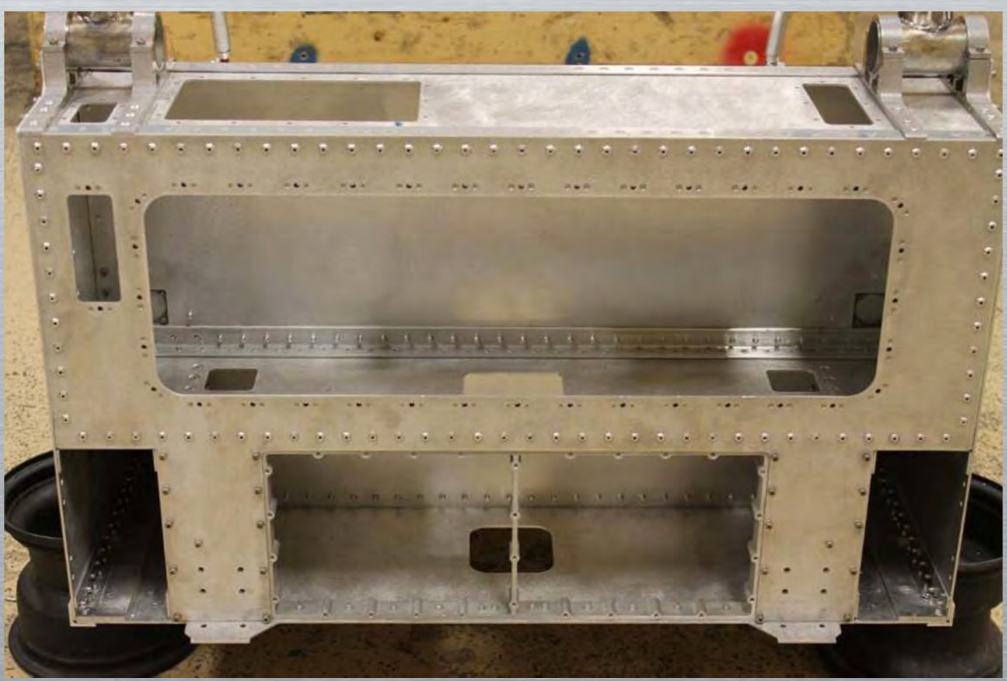
Chassis

- Features
  - Lightweight, rigid structure; less than 45 kg (about half the mass of previous generation)
  - Payload mounted quickly to lower flange
  - Solar panel easy to adjust or remove
  - Mast provided rigid structure for cameras



Chassis

• Large, centralized payload bay
• Batteries, electronics, and suspension housed within single volume – protected from dust and thermal extremes.



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Drive System

- Features
  - Custom designed gearbox doubles as a suspension element
  - Reduced mass
  - Multiple operational modes (two-speed gearbox, neutral, brake)
  - 10 cm/s and 100 cm/s

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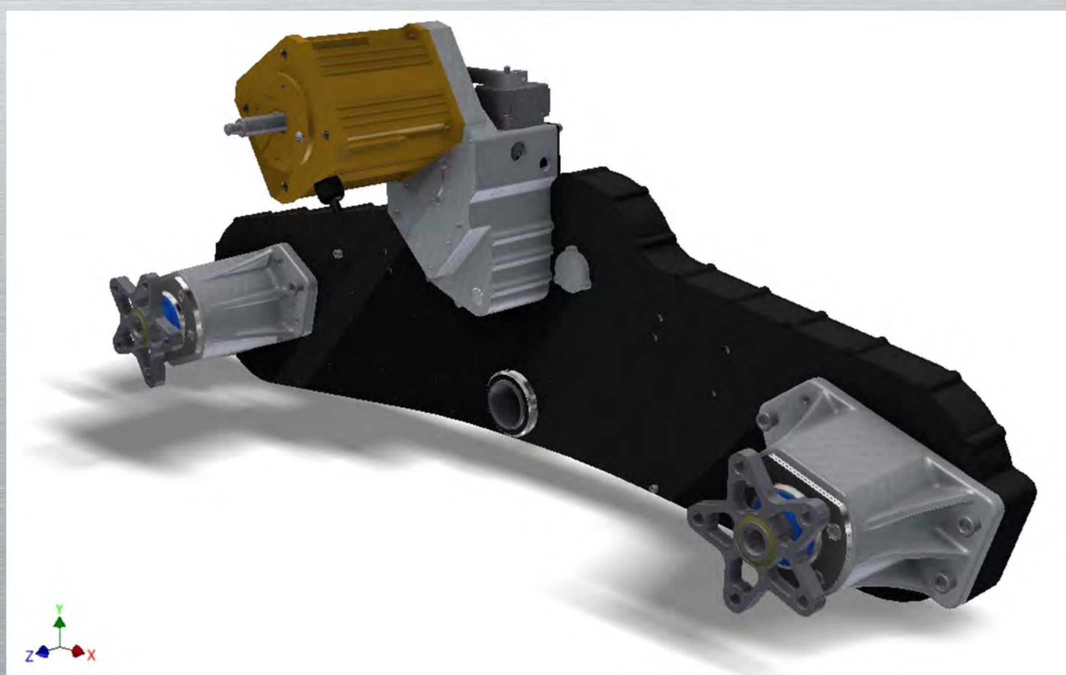
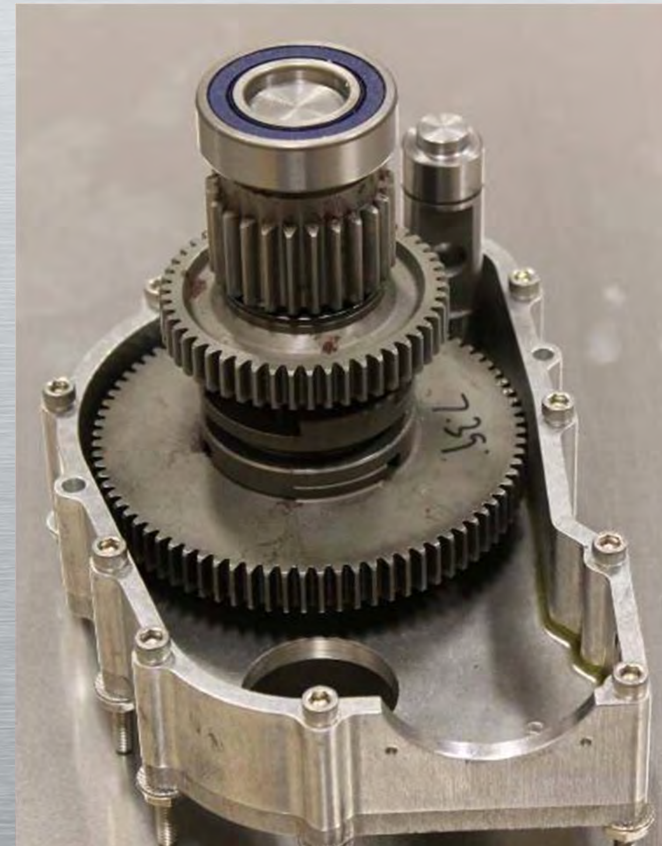
Drive System

- Single stage chain reduction
- High-Neutral-Low gearbox





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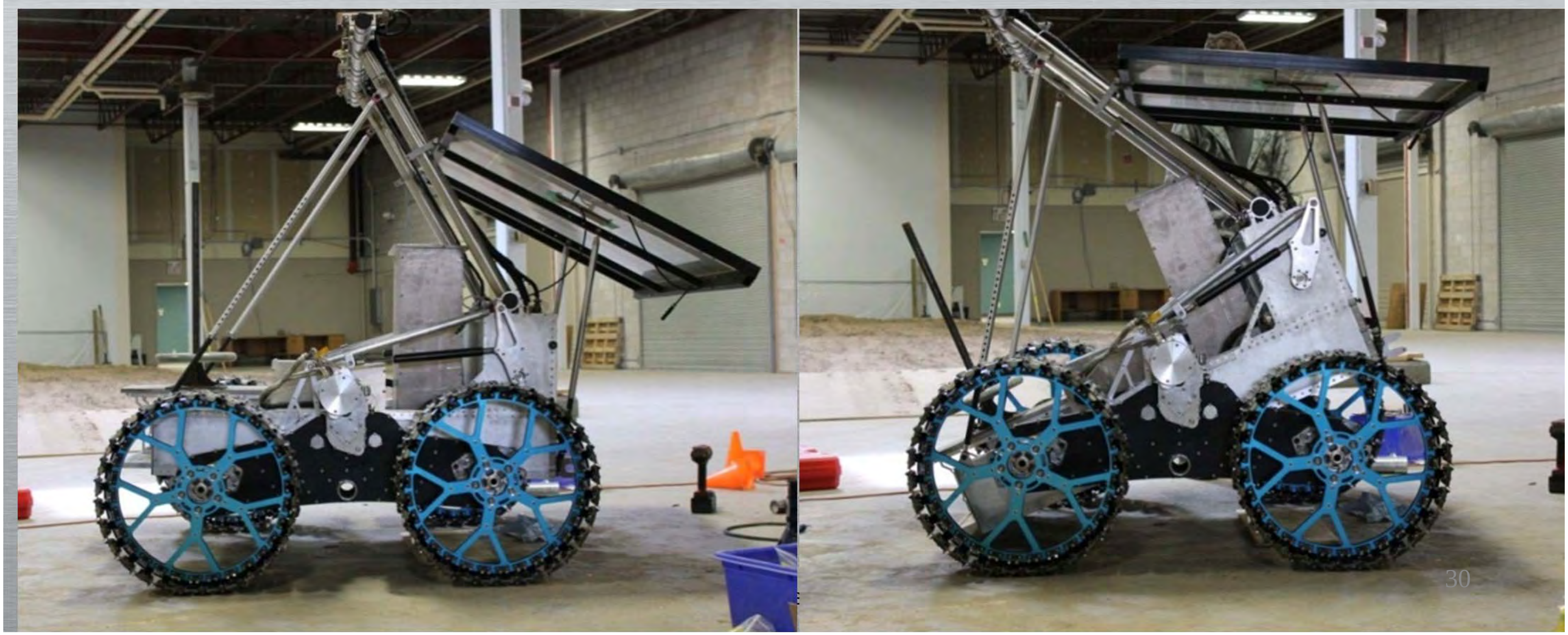
Suspension

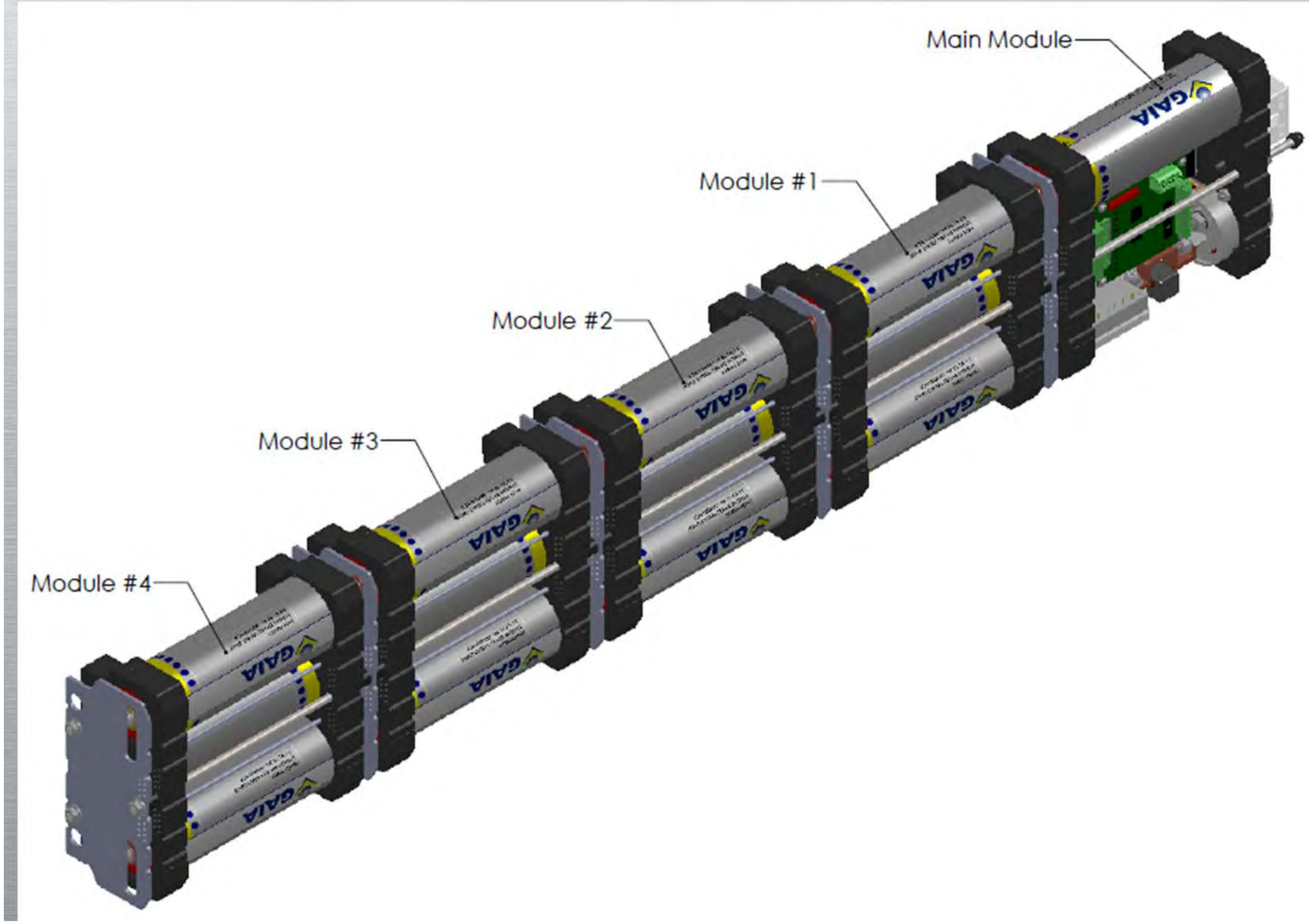
- Features
  - Geometric suspension
  - Actuator allows rover to pitch fore and aft.
  - Protected from contamination and thermal extremes



Power

Lithium-Ion battery packs:

- Built by Lithium Technology Corporation
- 2.57 kWhr per pack
- 5.14 kWhr total
- 110 Amp continuous current
- 30% reduction in mass



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Traction Elements

Work completed during Juno Upgrade led to development of lightweight wheels.

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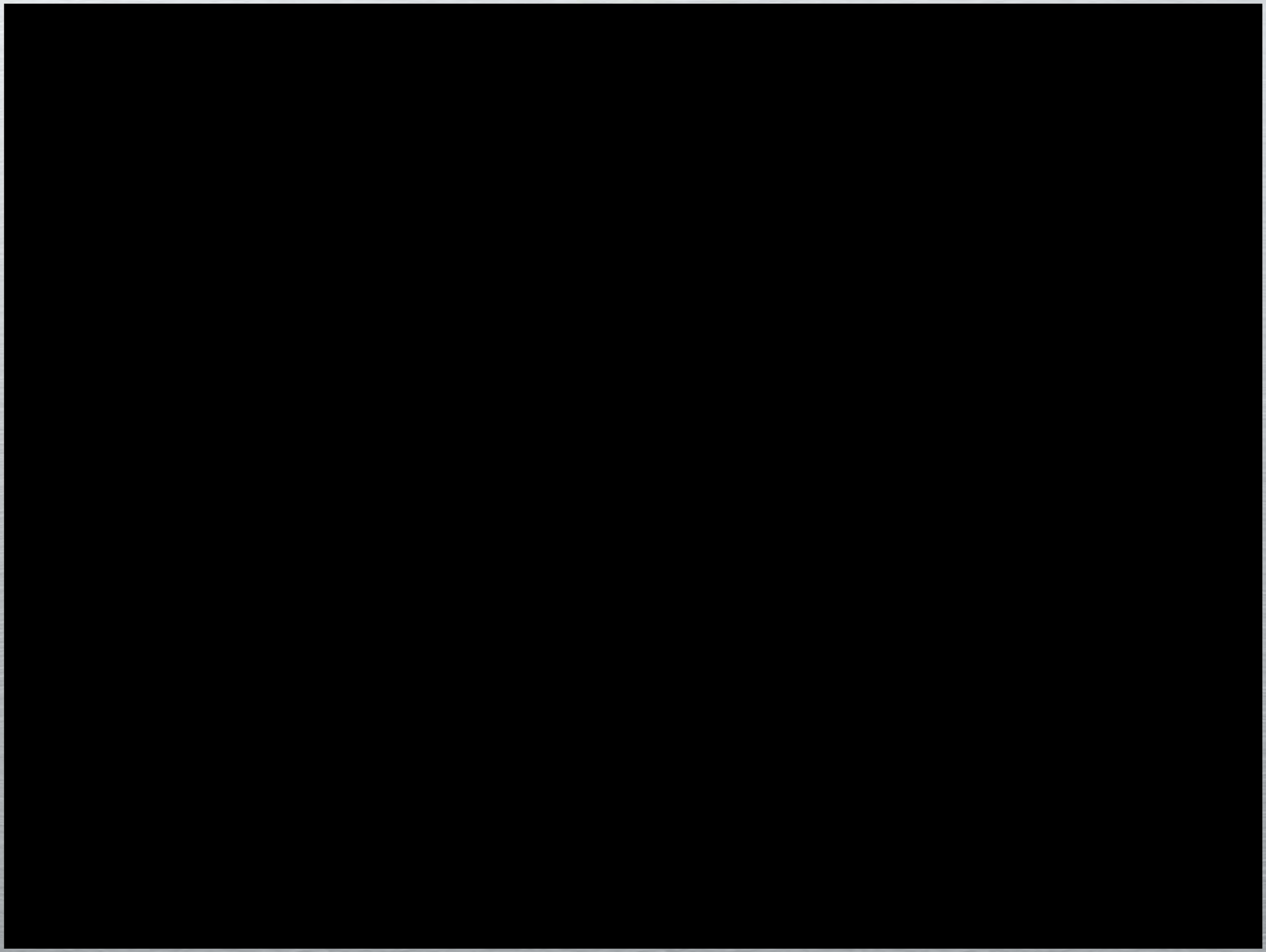
Wheel testing at CSA



RESOLVE / Destin Drill

RESOLVE (Regolith & Environment Science, and Oxygen & Lunar Volatile Extraction)

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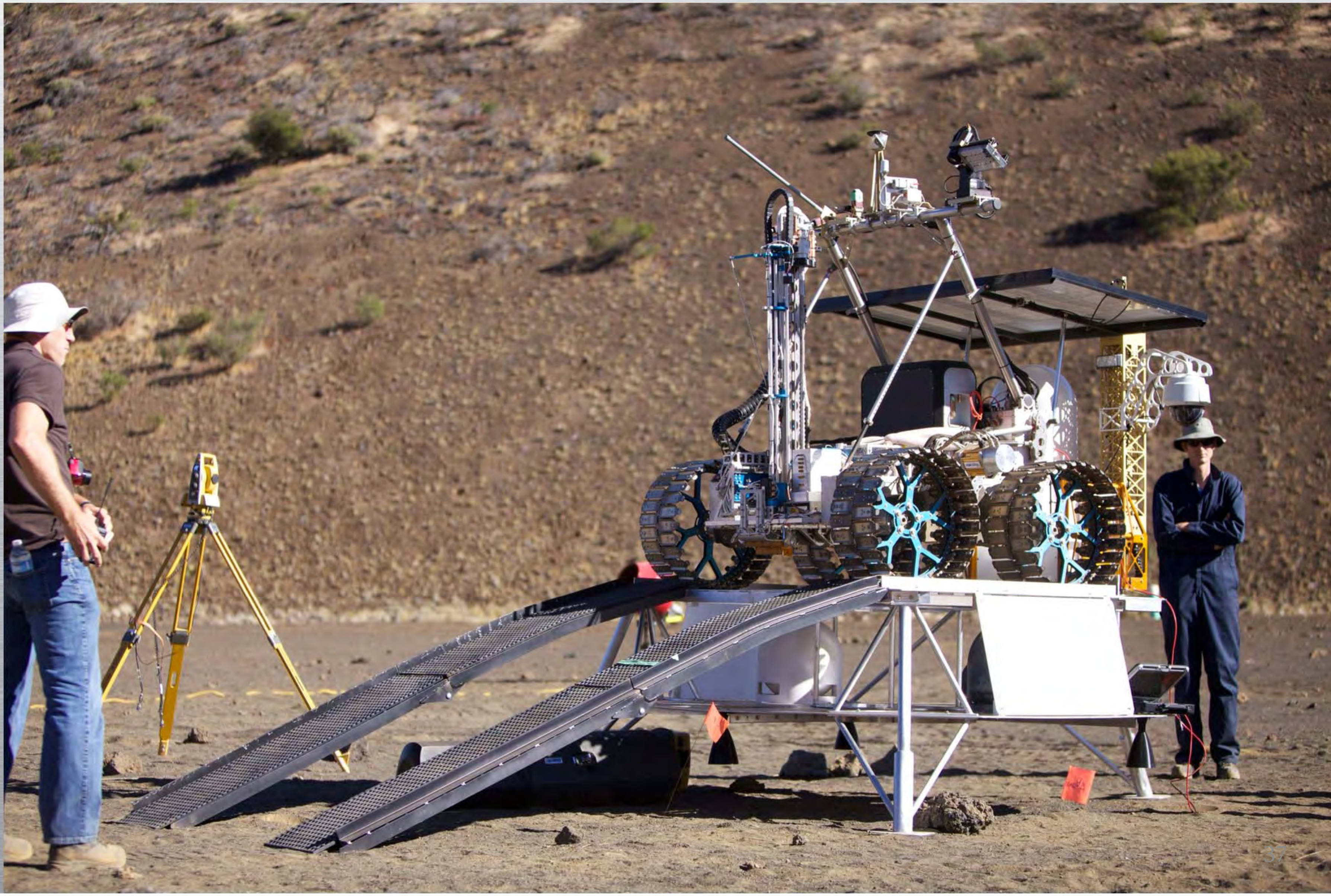
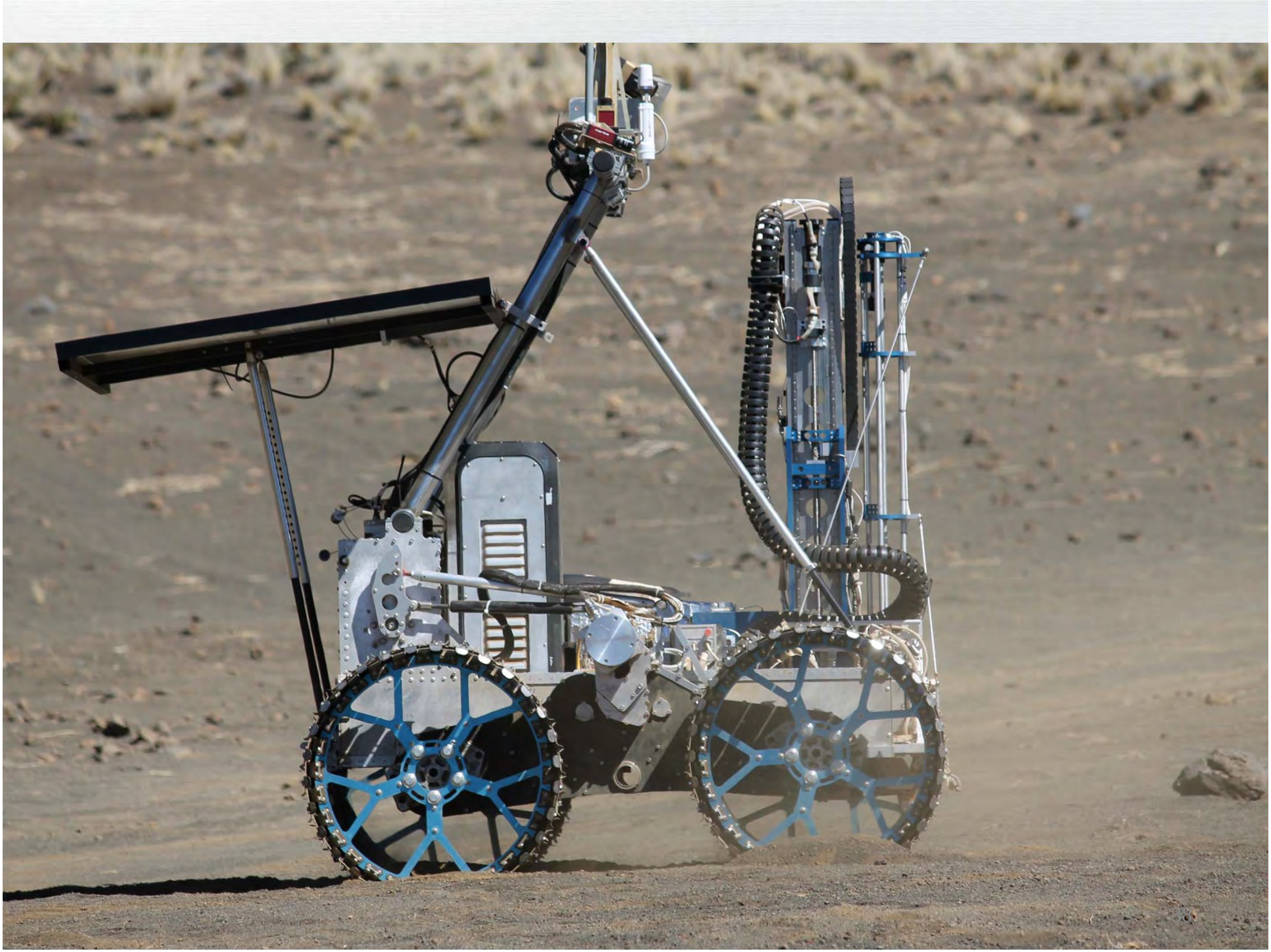
RESOLVE, July 2012, Mauna Kea Hawaii





Hawaii, 2012: RESOLVE

- 1.1 km total traverse, both tele-operated and autonomous.
- Multiple sample capture with NORCAT's DESTIN drill.
- Multiple sample processing (RESOLVE).

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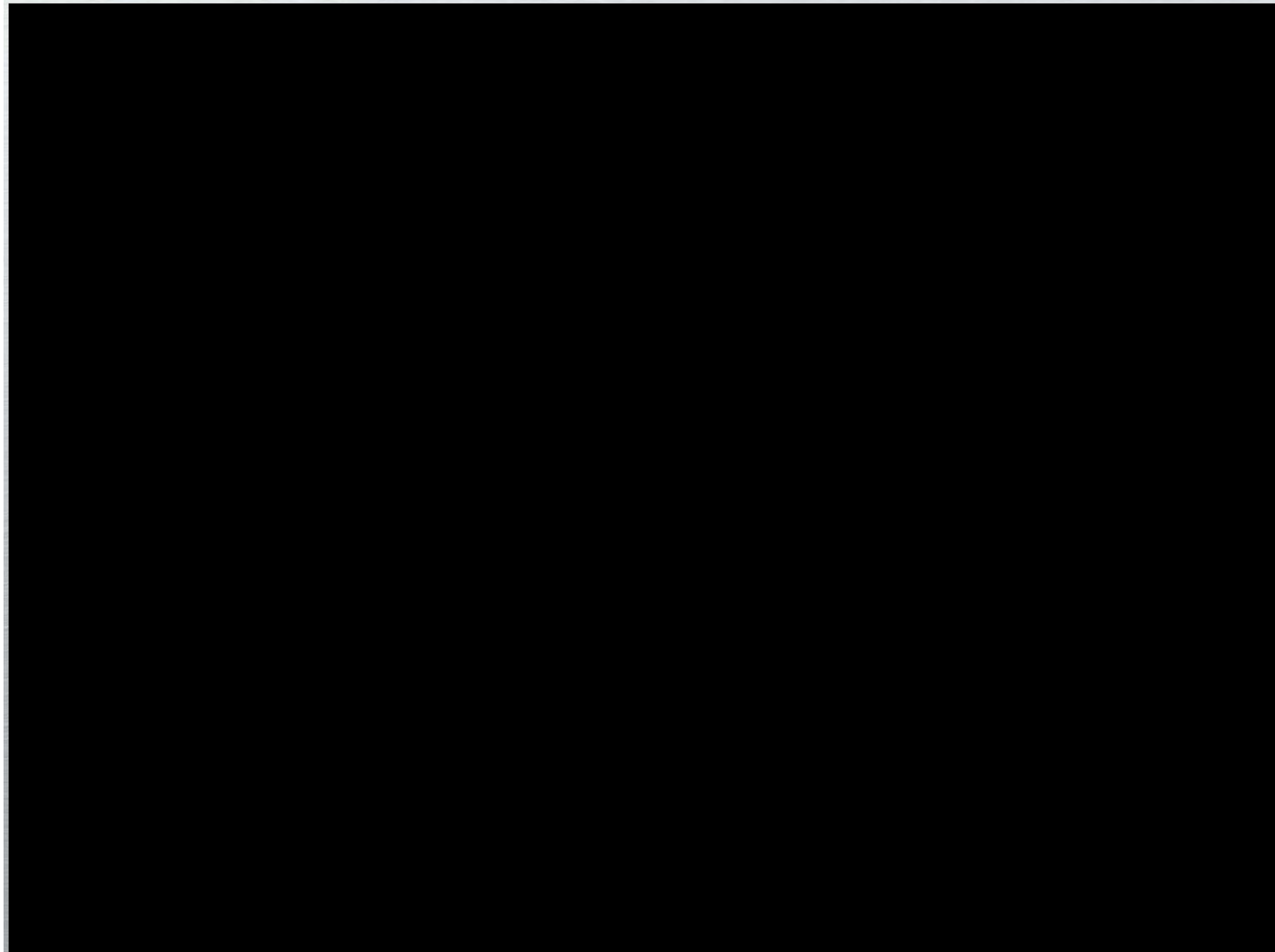
Hawaii, 2012: RESOLVE



- Tilting feature allowed for a steeper ramp.
- Steeper ramp is a shorter ramp.
- Shorter ramp is a lighter ramp.

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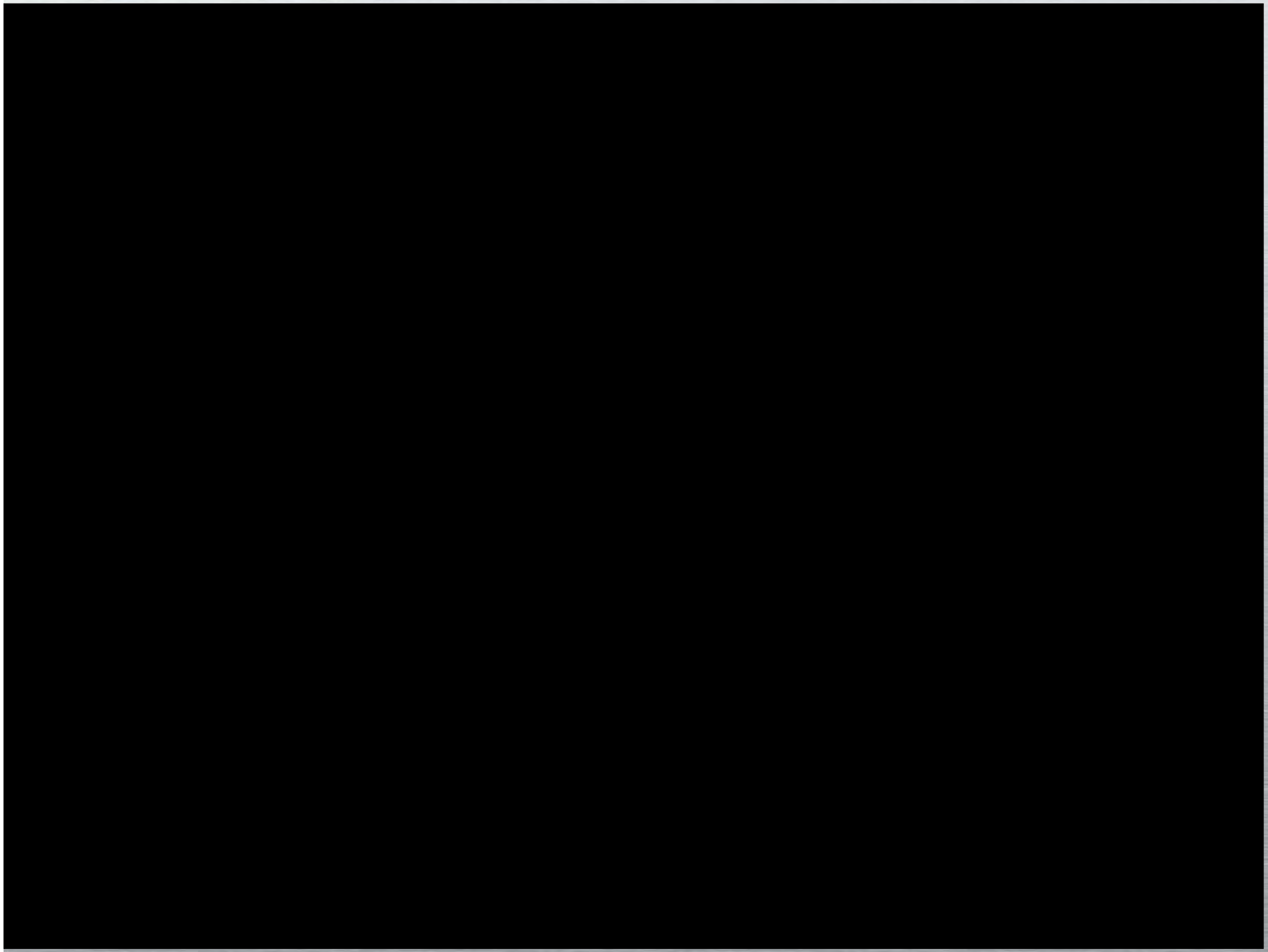
MMAMA – 2012 – Apollo Valley

Hawaii, 2012: Apollo Valley



- 23 km total traverse in Hawaii.
- Multiple mobility tests with various wheels.

Hawaii, 2012: Apollo Valley

- Soft sand is the other extreme.
- This has proven to be a problem on Mars and may be an issue at the edges of lunar craters.

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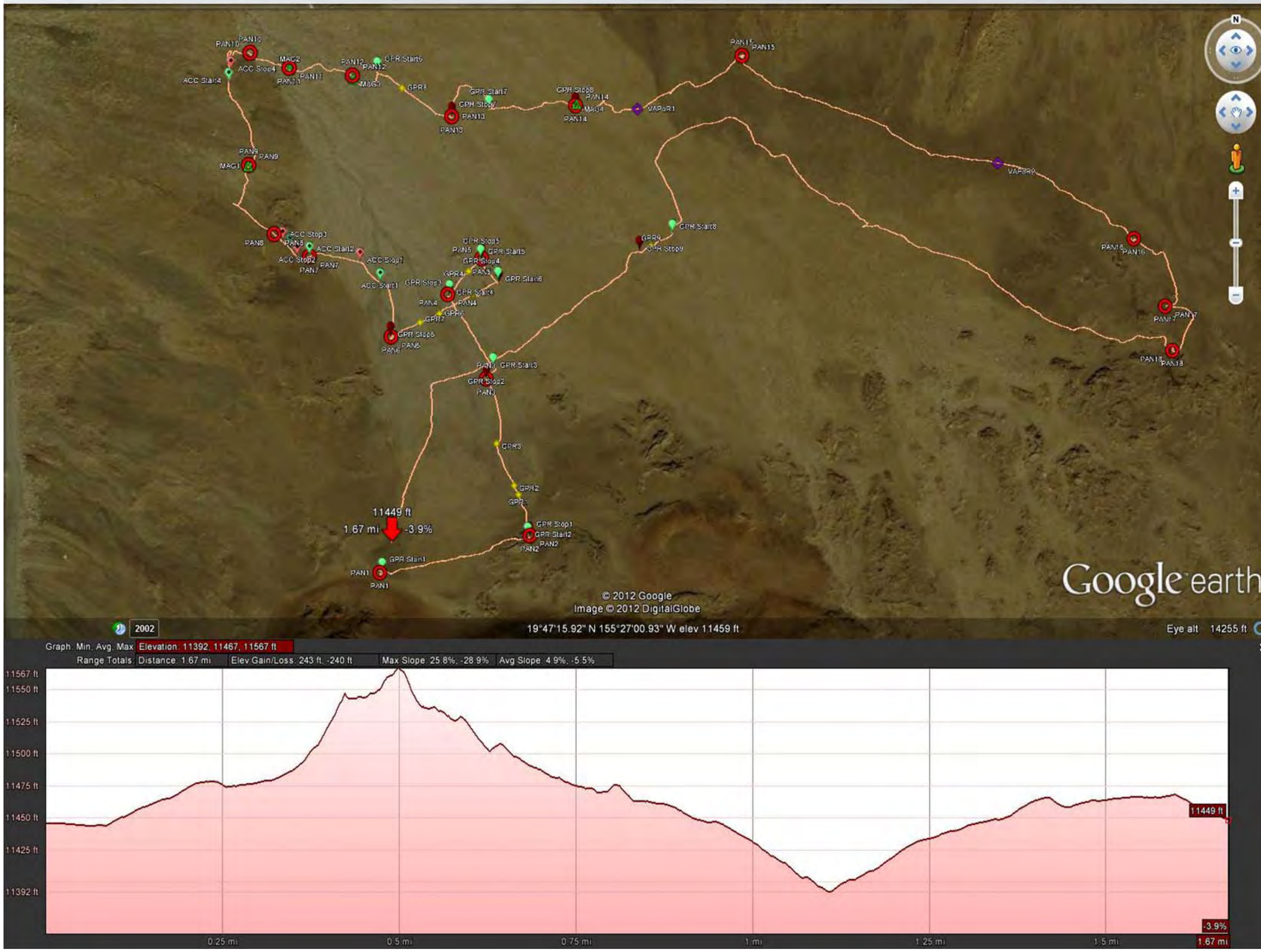
Rover Traverses – Apollo Valley



- GPS equipped, routes mapped.
- Enabled us to construct a traverse profile with respect to power consumption.

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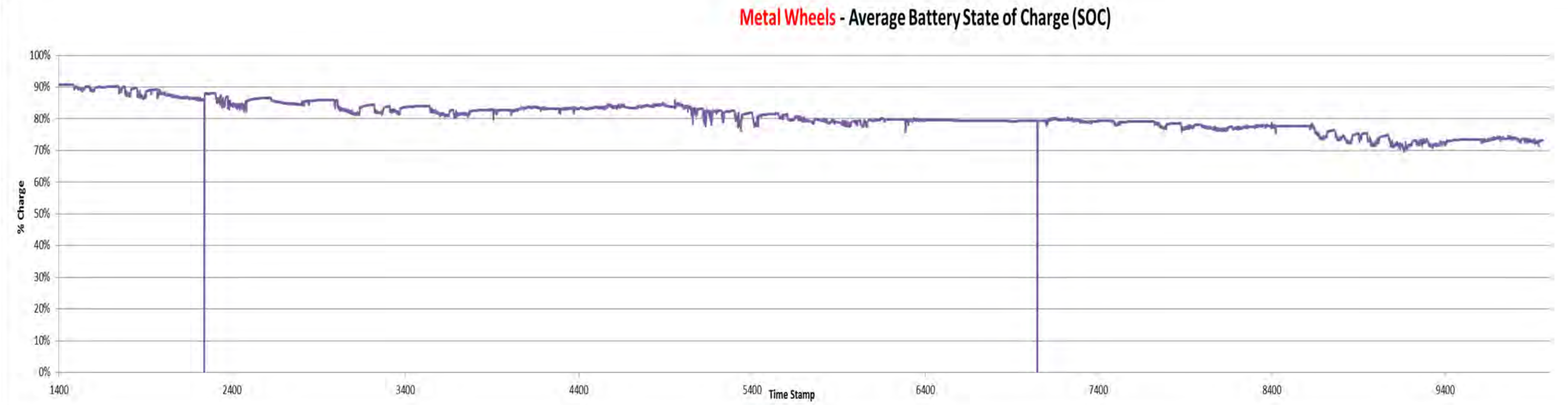
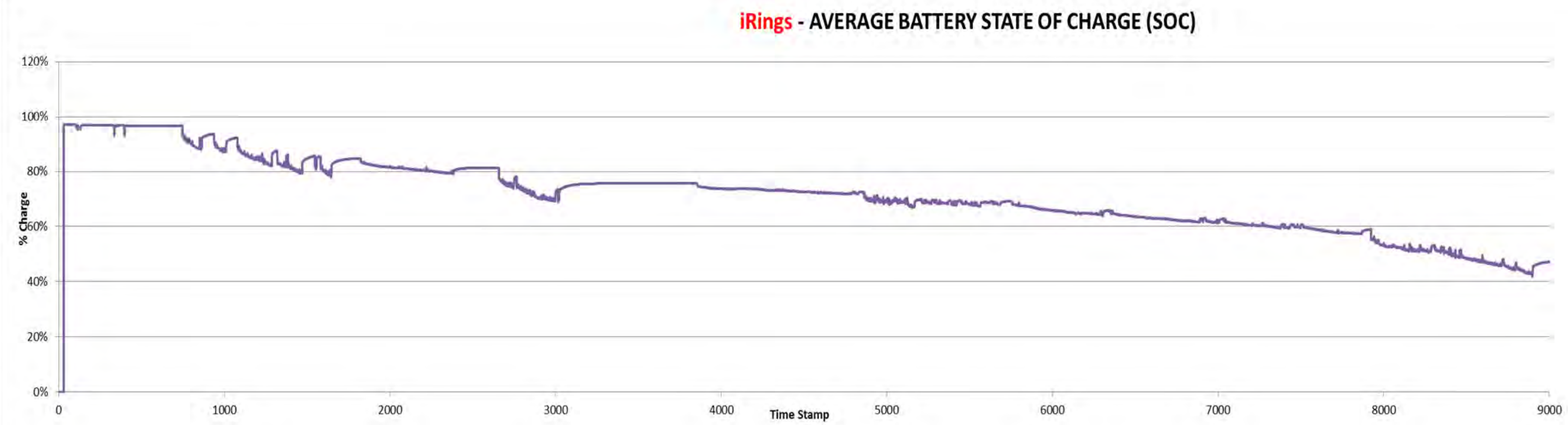
Power Consumption – Wheel Test





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Wheel Efficiency Results

Data	Metal Wheels	iRings
--Total Traverse--		
Motor Temperature, Peak (deg C)	48	75
Motor Temperature, AVG (deg C)	34	40
Ambient Temperature (deg C)		
Starting Voltage (%)	92	97
Ending Voltage (%)	77	41
Distance Traversed, Total (km)	4.2	4.4
Energy Consumed (kWh)	0.382	1.01
----------------------Common Traverse (Staging Area to near peak on Upper Access Road)------------------------		
Motor Temperature, Peak (deg C)	35	75
Motor Temperature AVG (deg C)	24	50
Starting Voltage (%)	92	97
Ending Voltage (%)	82	76
Distance Travelled (km)	1.2	
Energy Consumed (kWh)	0.086	0.239

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Other Payloads

[redacted]

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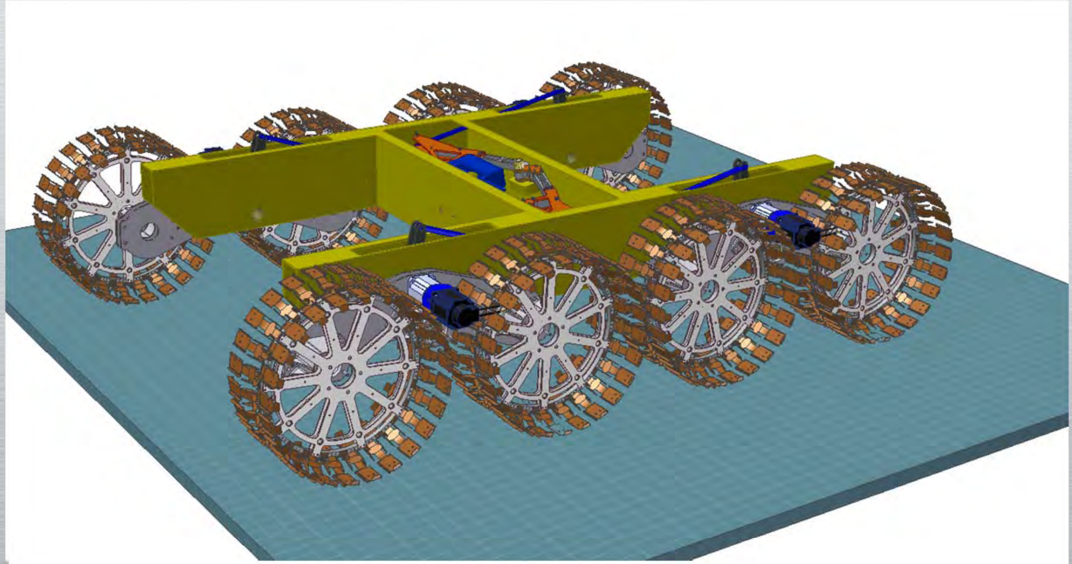
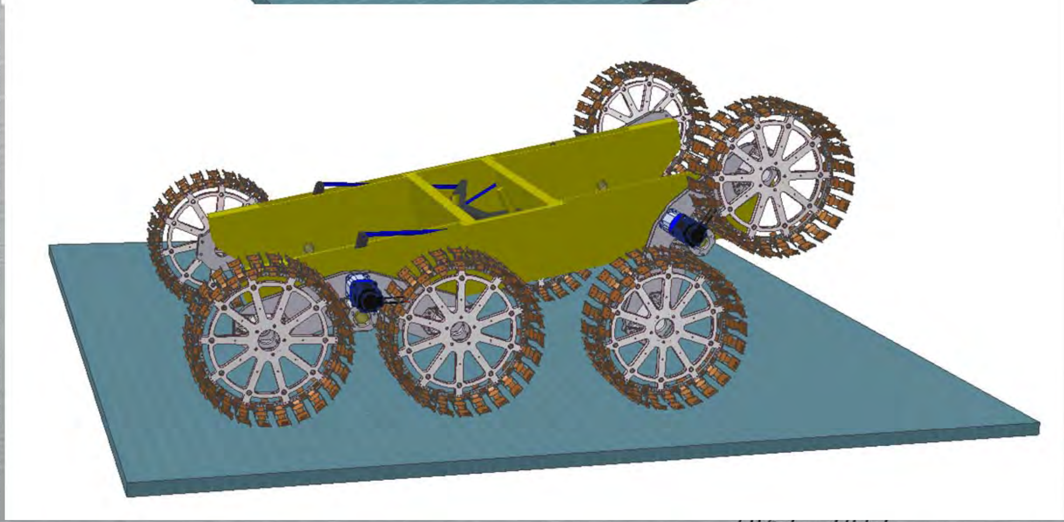
Artemis Rover Concept

- 500 kg empty
- 15 km/h
- 300 kg payload

- Modular design enabled interchangeability between Artemis Jr. and Artemis Sr.






ARTEMIS

Conclusion

- Successfully demonstrated various Artemis rover technology in various analogue settings.
- Showed the advantage of modular architecture in terms of design and fabrication schedule.
- Designed and tested viable alternative to rubber tires.

Acknowledgments:

ComDev
Neptec Design Group
NORCAT
NGC
Provectus Robotics
Canadian Space Agency
NASA

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Questions?

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