The Lunar Analogue Rover "Artemis Jr."

Peter Iles – May 15, 2013

ASTRA 2013

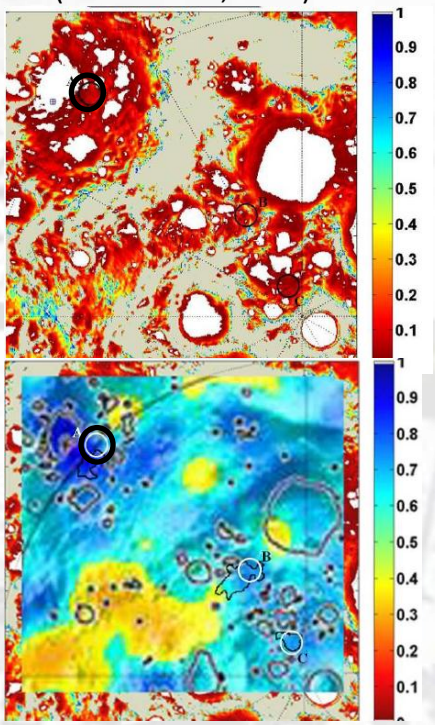
Overview

- In-Situ Resource Utilization (ISRU) motivation
- Artemis Jr. rover
  - Mobility
  - Power and Avionics
  - Communication and Control
  - Navigation and Vision
- Mission Simulation Performance
- Path to flight

ISRU Motivation

- Use water, oxygen, hydrogen in the lunar regolith to support lunar activities
- Previous missions found evidence of water and volatiles at south pole
- Desire to verify and map these materials on the ground

(Larson et al., 2011)



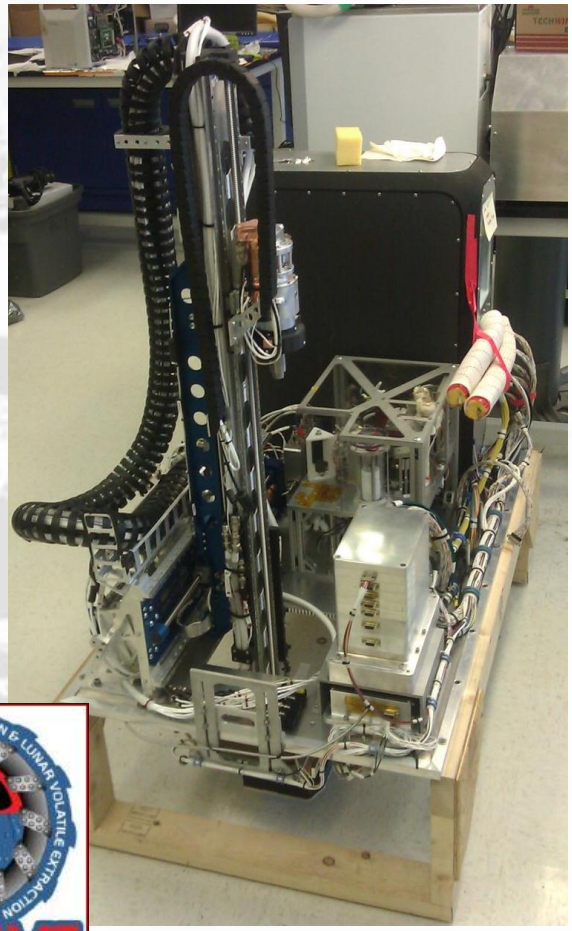
Cold traps

Hydrogen concentrations

Cabeus Crater:
Traversable terrain
Partial illumination
Direct-to-Earth comms

ISRU Motivation - RESOLVE payload

- NASA and CSA developed payload
- RESOLVE can:
  - Measure hydrogen in regolith during rover traverse
  - Extract core samples to a depth of 1m
  - Heat core sample to separate volatiles for analysis
  - Produce water from extracted oxygen and hydrogen

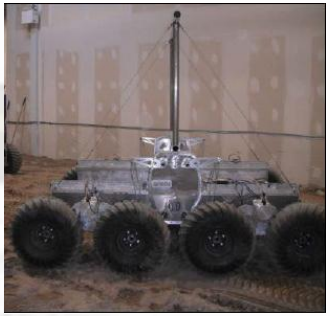


(Sanders et al. 2012)

Canadian Lunar Rover Team

- Team led by Neptec Design Group
- CSA funded concept studies and prototyping contracts



NGC Aérospatiale Ltée
NGC Aerospace Ltd

Argo

Neptec

COM DEV

Provectus Robotics Solutions Inc.

McGill

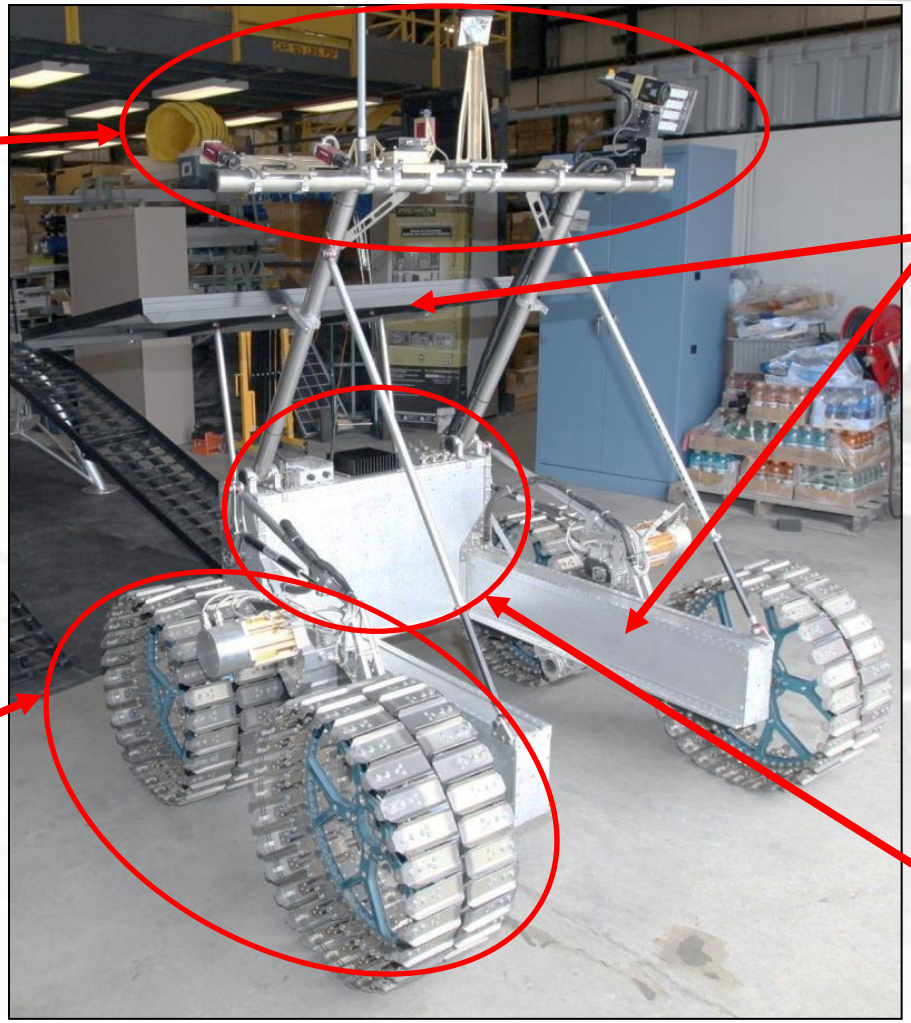
CrossChasm

Proto Innovations

NORCAT

Artemis Jr. - Overview

Navigation & Vision Sensors

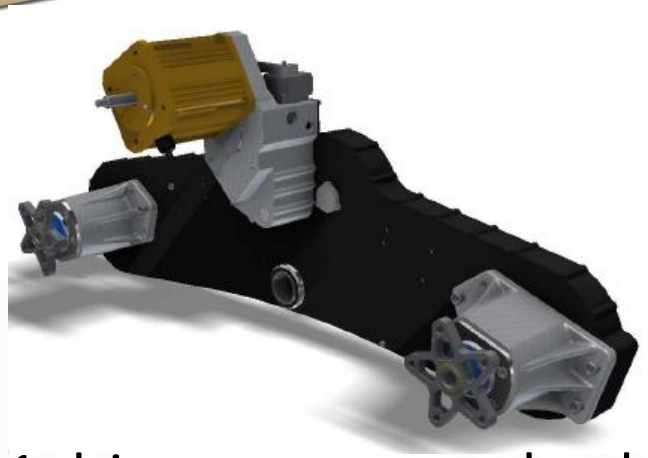


Power subsystem

Chassis & Mobility subsystem

Communications & Avionics

Chassis & Mobility



1 drive motor per wheel pair/chain drive (skid-steer)

(Visscher et al., 2011)

Large **compliant** metallic wheels

Modular U-shaped payload bay with 150kg capacity

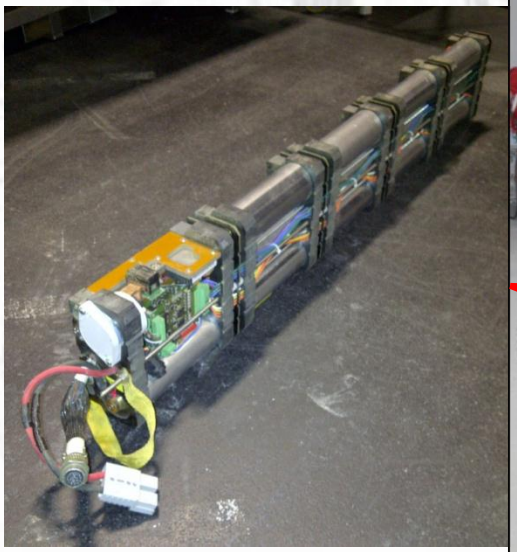
Chassis & Mobility

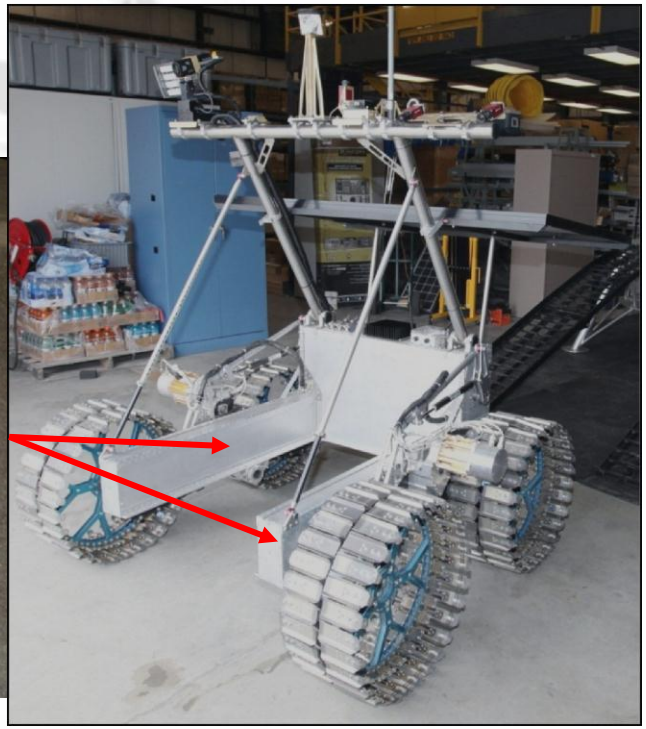
Chassis pitch control
through actuated suspension

Rough terrain traversal

Power and Avionics

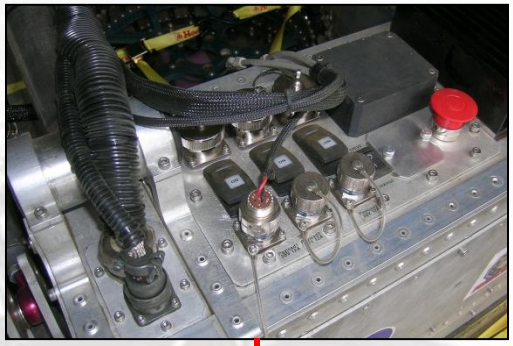
- Battery system:
  - Pair of lithium-ion battery packs installed in frame rails
  - More than 5 kWhr of available energy
- Three (3) Payload power ports
- Solar panel

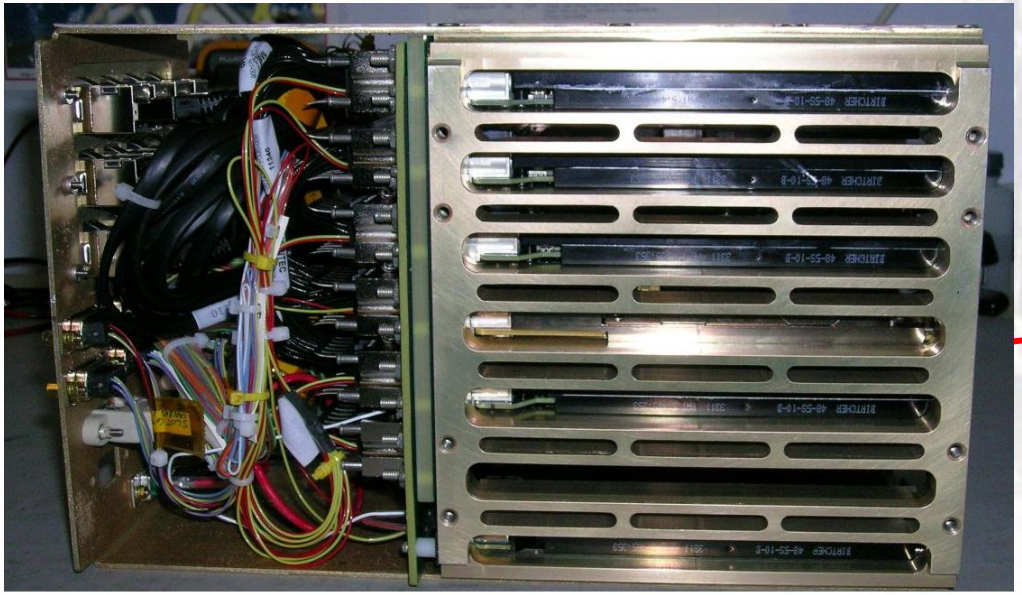


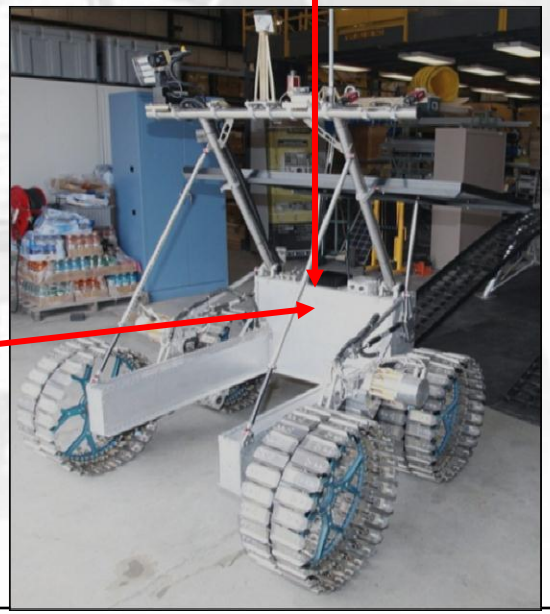


Power and Avionics

- Central Electronics Unit:
  - 3 single-board computers
  - Gigabit Ethernet network
- Rugged external harness design

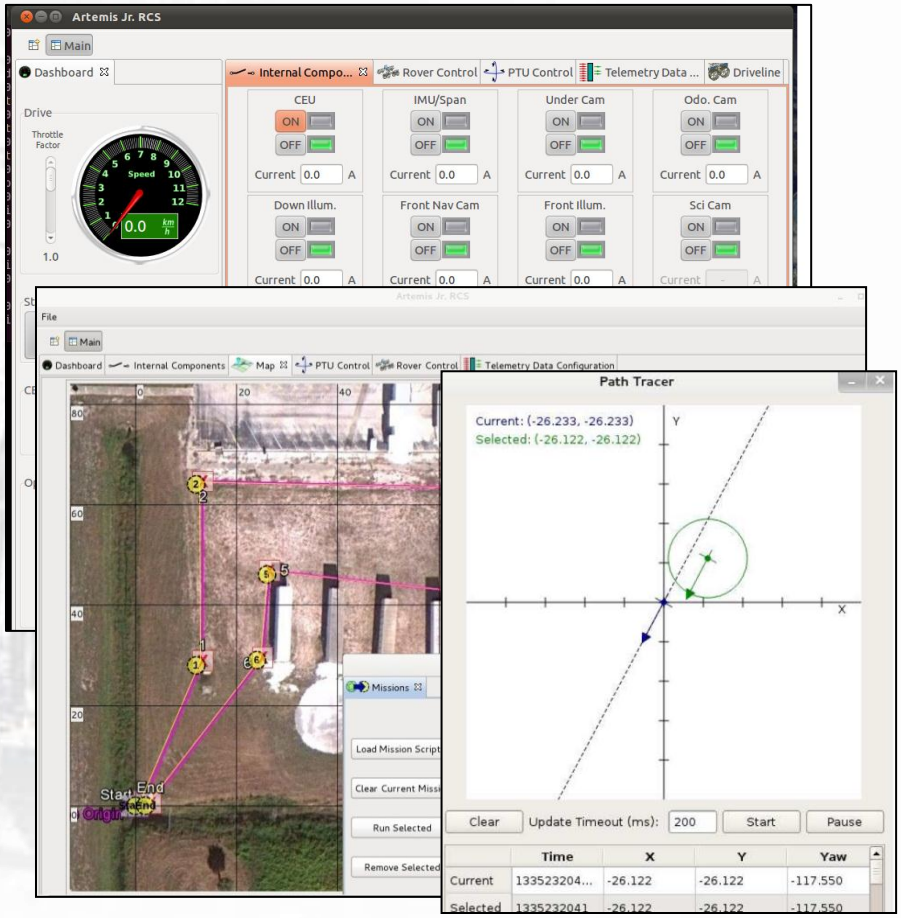




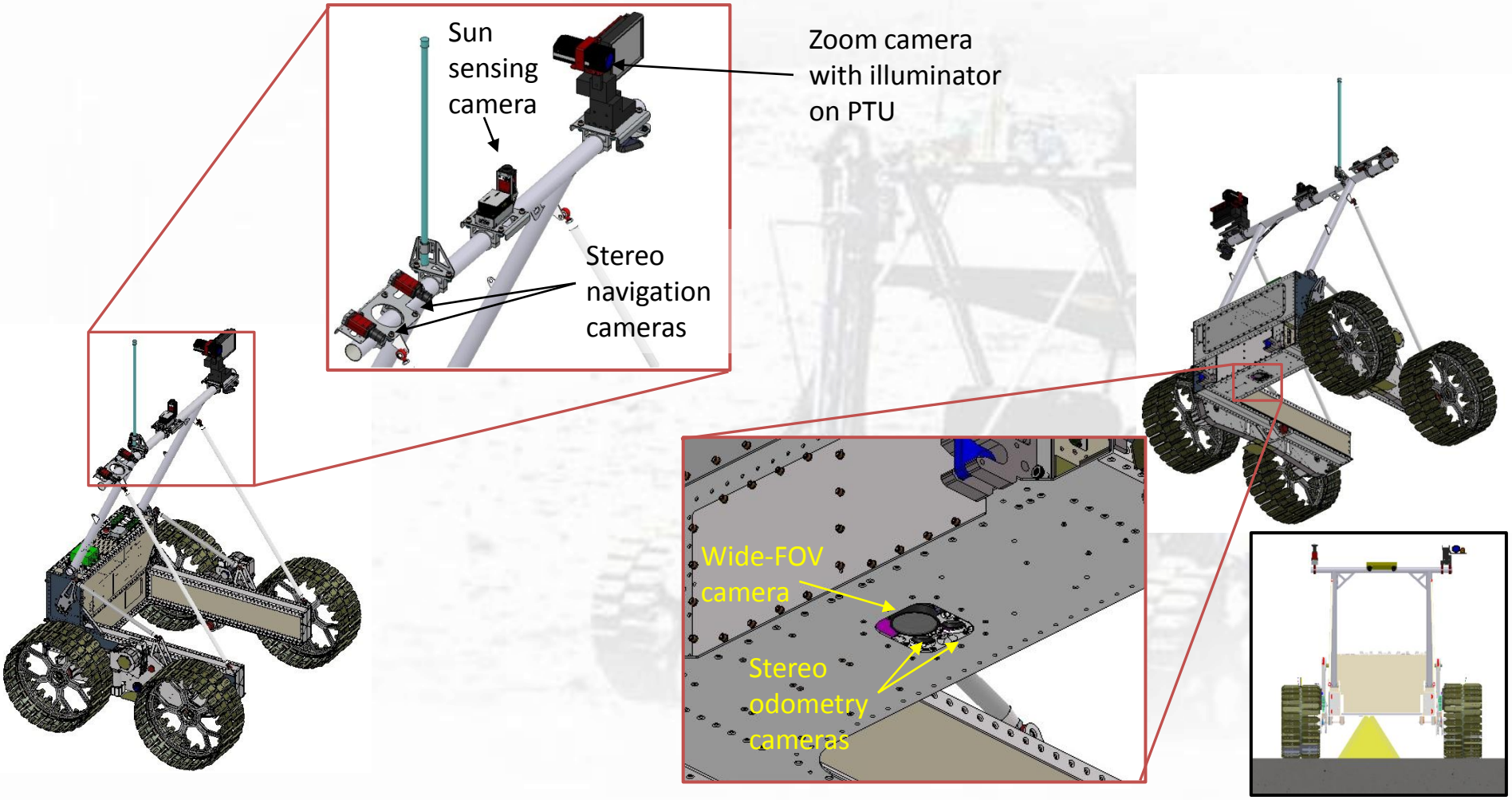


Communication and Control

- Remote control station
- RF control, remote teleoperation, autonomous navigation
- Fully configurable telemetry stream

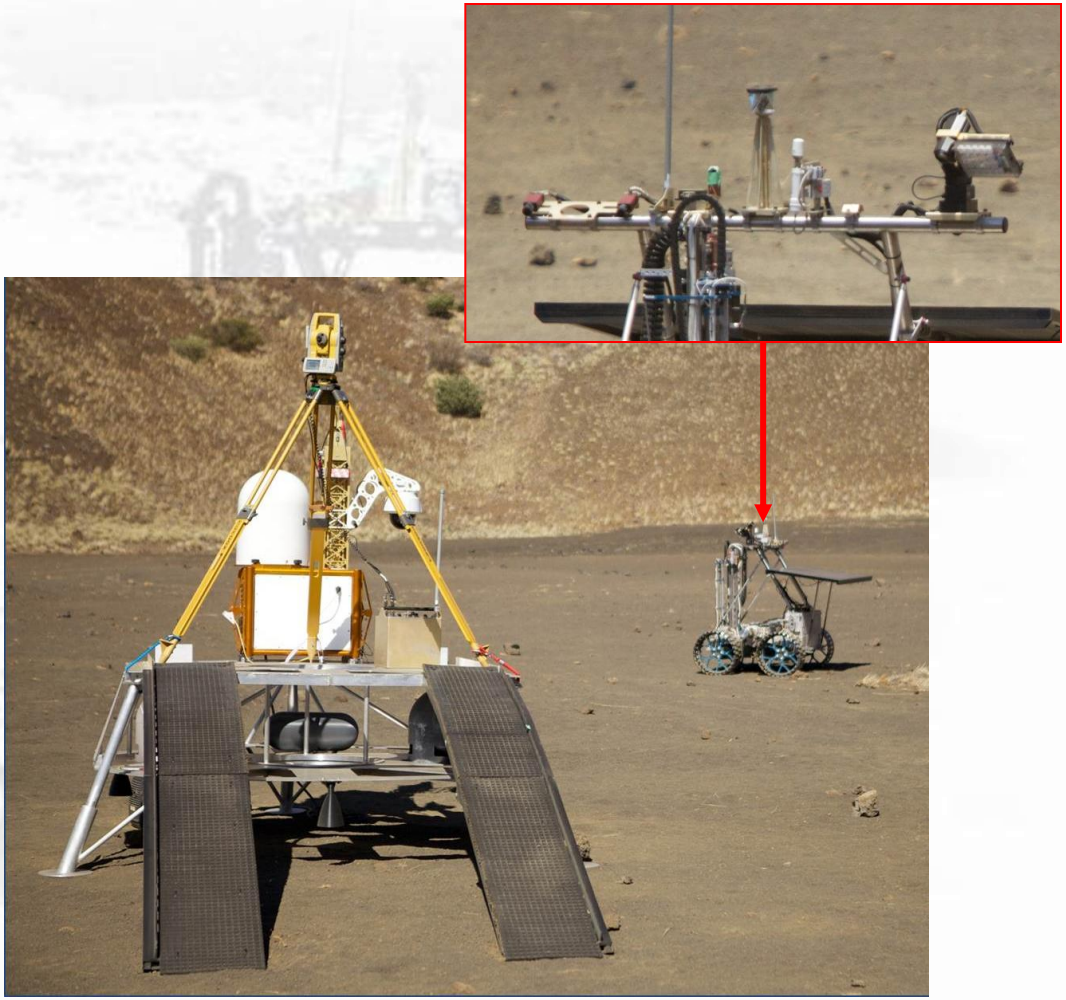


Navigation and Vision



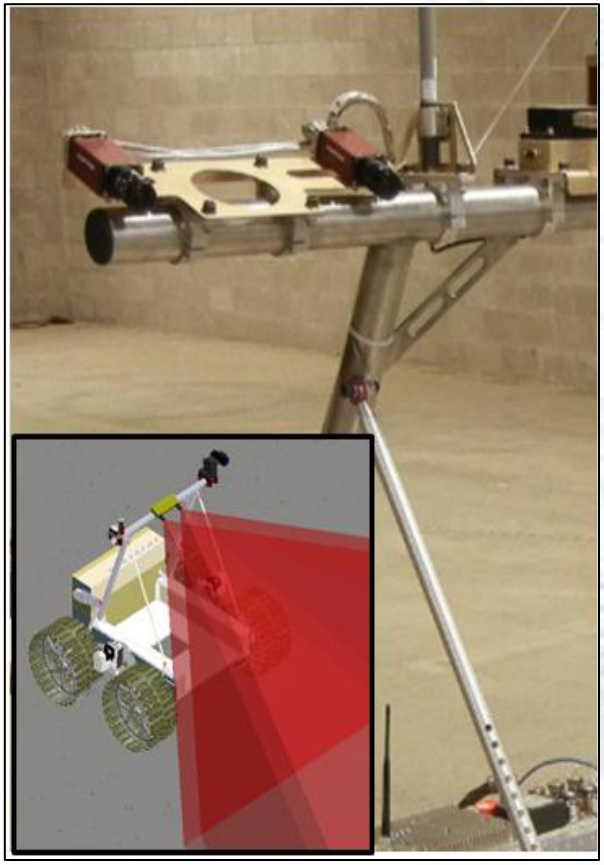
Navigation and Vision

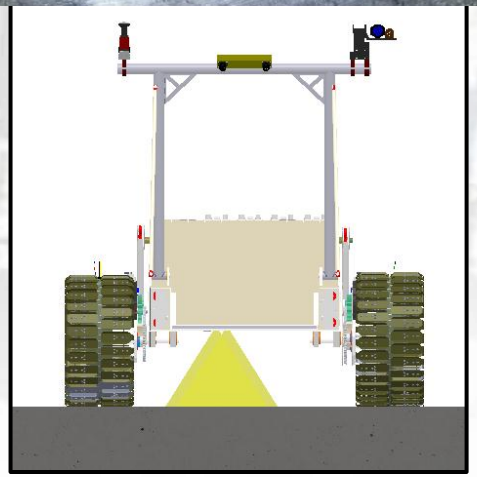
- Absolute localization
- Relative localization:
  - Visual odometry x 2
  - Inertial localization
  - Wheel odometry
  - Sun sensor
- Autonomous navigation



Navigation and Vision

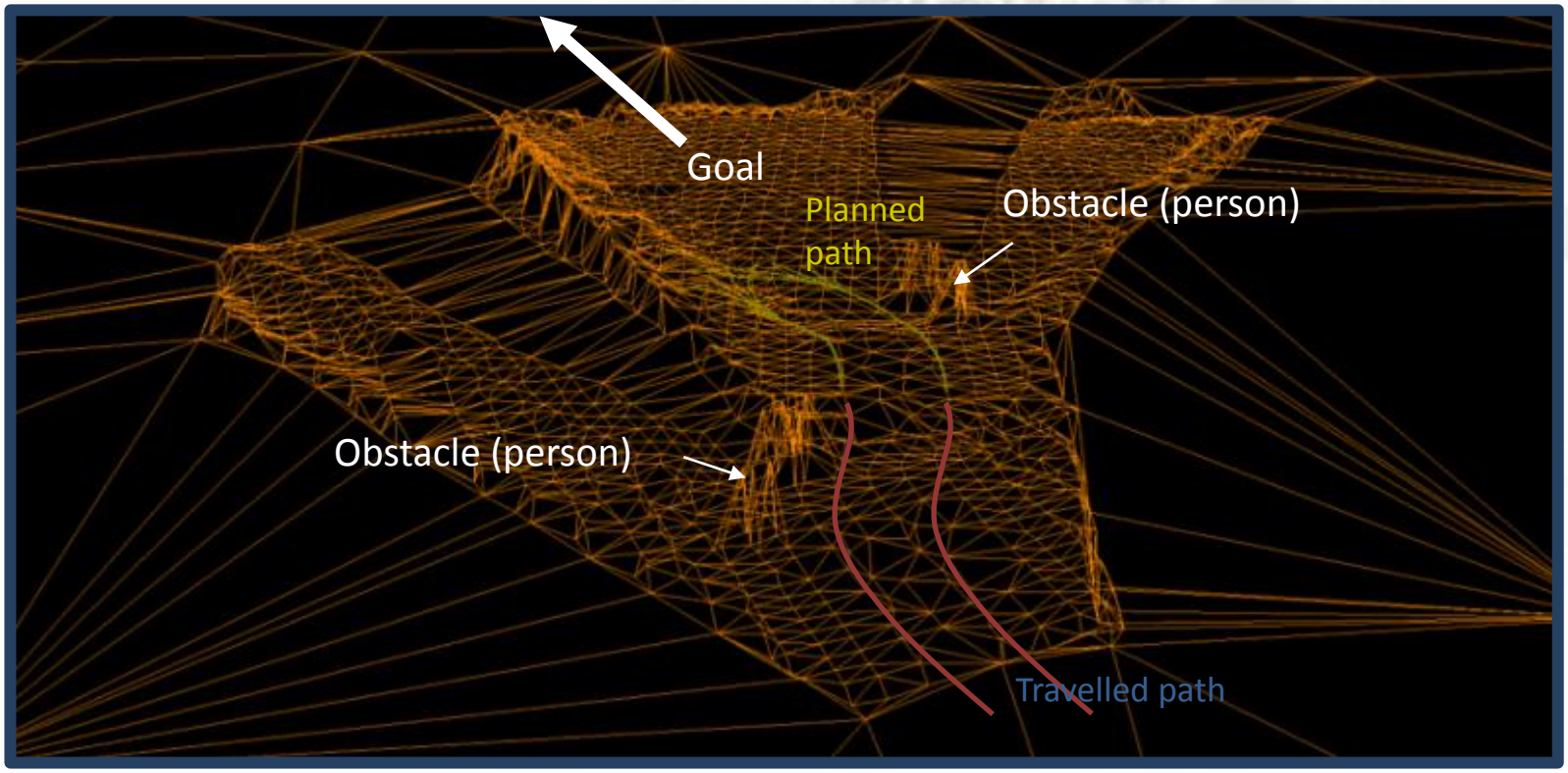
- Complementary visual odometry techniques





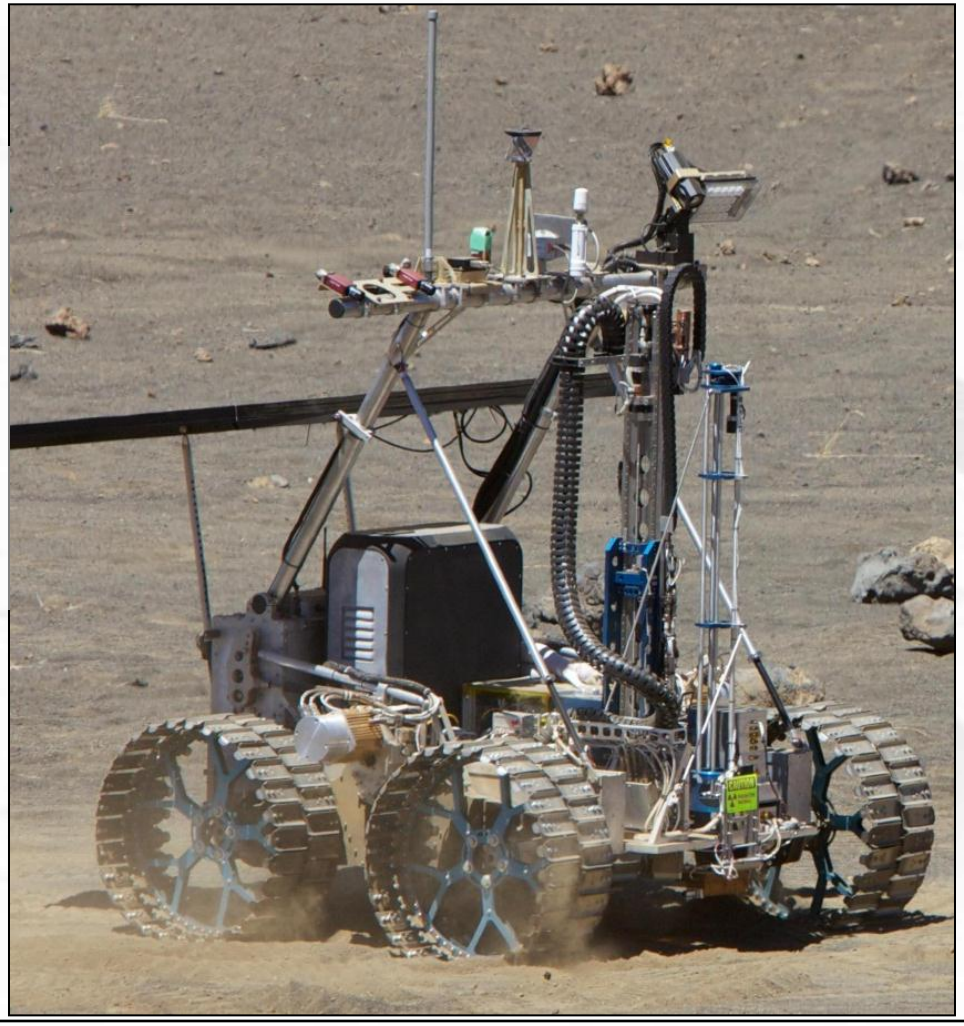
Navigation and Vision

- Autonomous navigation: path planning and obstacle avoidance

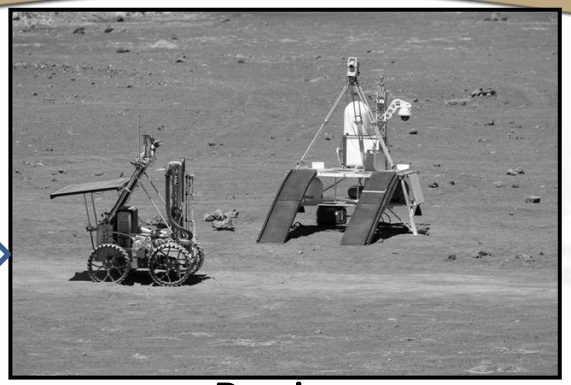


2012 Mission Simulation

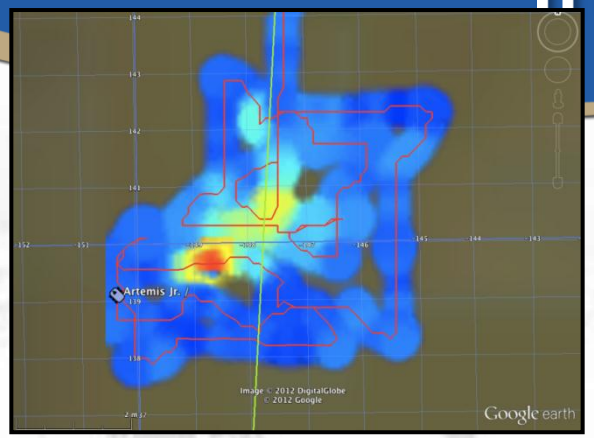
Artemis Jr. with RESOLVE payload



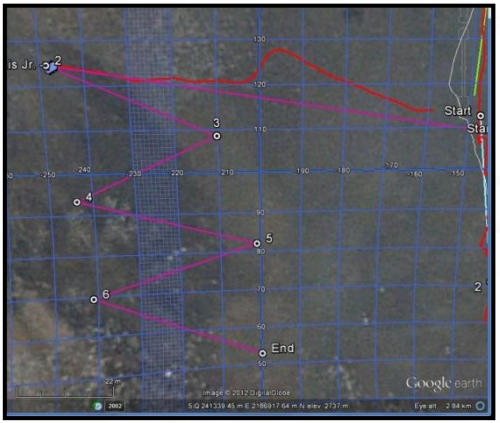
2012 Mission Simulation



Roving

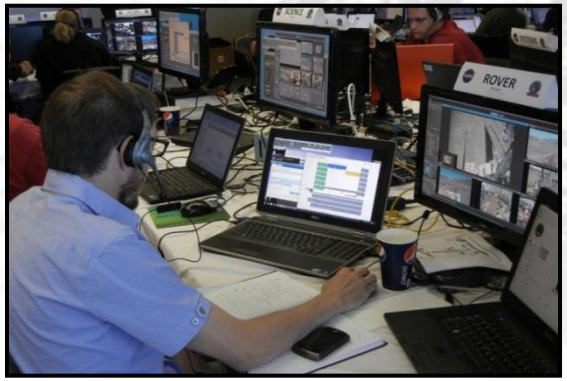


'hot spots' identification

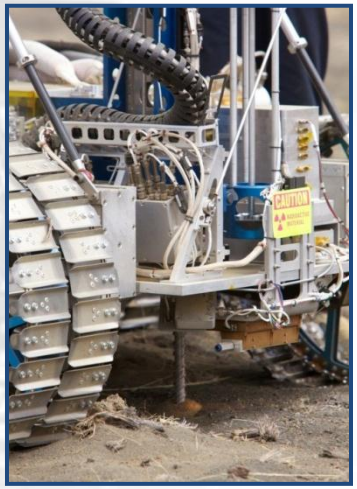


Traverse planning

Analog ISRU technology demonstration mission:



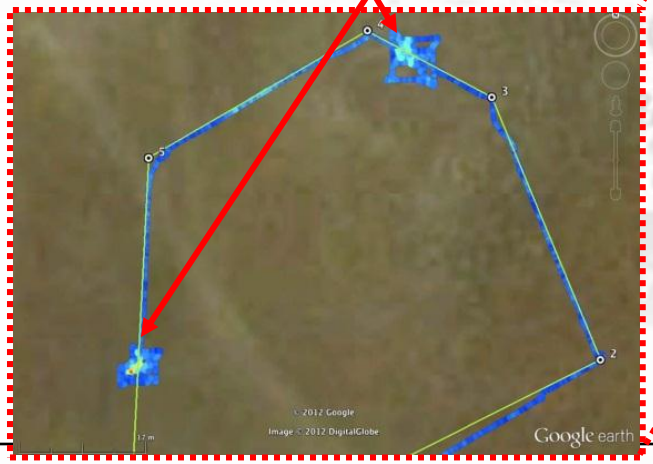
Mission operations

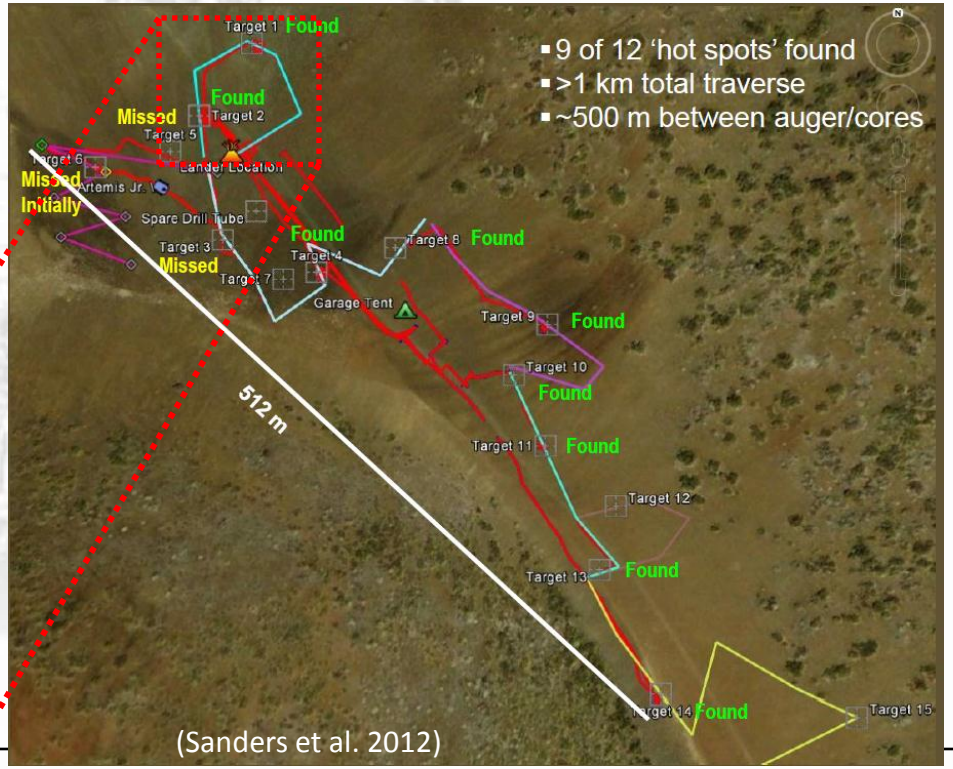


Sample acquisition and analysis

Mission Simulation Performance

- Supported mandatory mission simulation objective to map volatiles across >100m
- Carried payload and drill to support coring operations at three locations





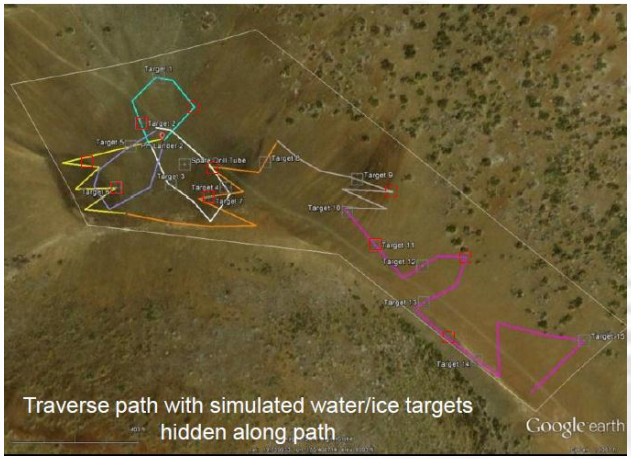
(Sanders et al. 2012)

Mission Simulation Performance

- Rover-specific:
  - 2km without issues on-site demonstrated robustness and reliability
  - Power system provided reliable power to RESOLVE; no need to recharge during mission day
  - Localization system demonstrated <1m accuracy during mission out to 500m from lander
  - 2% relative localization error demonstrated
  - Teleoperation and autonomous traverses

Path to Flight

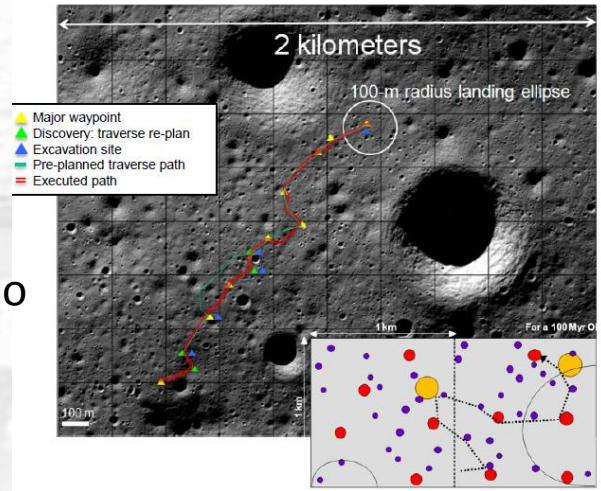
Hawaii



Similar terrain

Similar scenario

Moon



Weather is slightly different…

Path to Flight

- Ongoing CSA funded Phase 0 Concept study:
  - Environmental considerations: thermal, radiation
  - Power self-sufficiency
  - Lander interface
  - Payload interface refinement
  - Communications
  - Shadowed operations and night survivability

Requirements

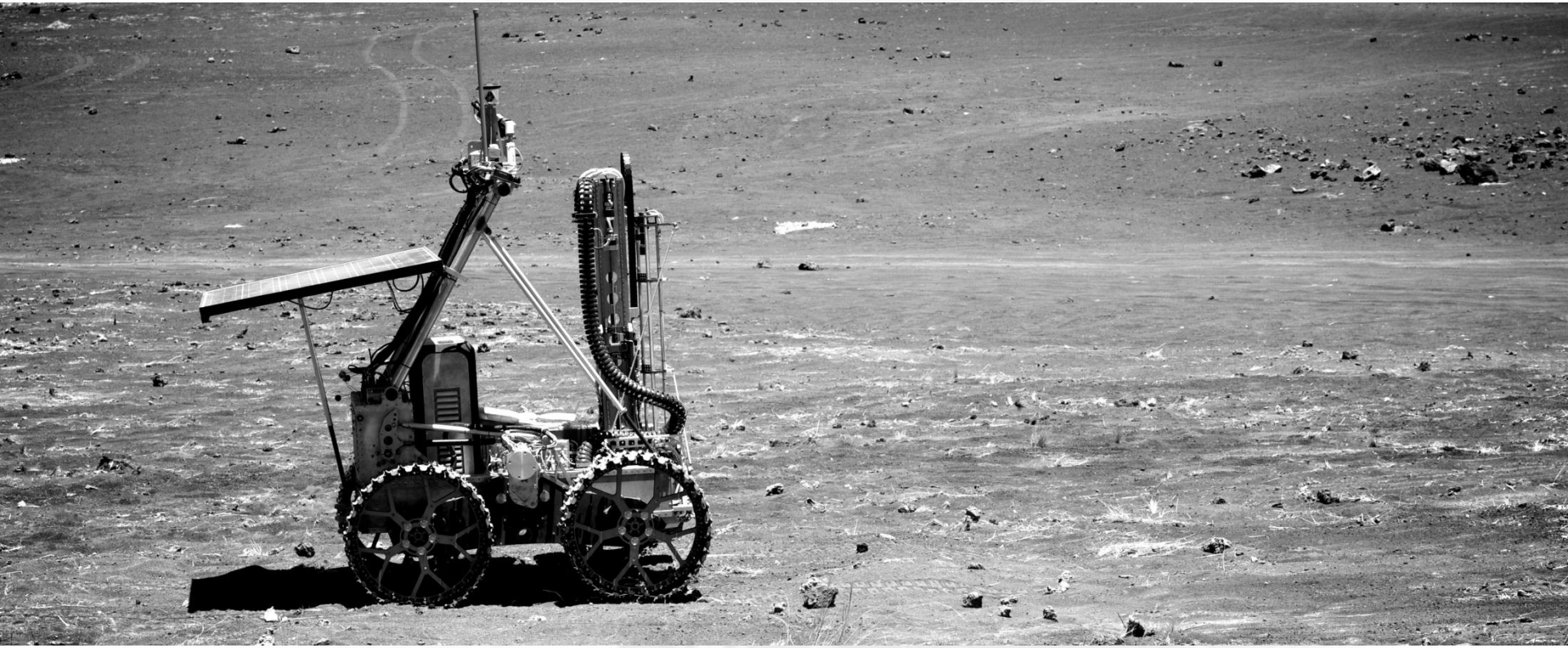
Requirement	Value
Volume Enveloppe	2m x 1.4m x 1.6m (H x L x W)
Maximum Mass	150 Kg
Driveline	All-Wheel-Drive
Speed	10 cm/s (nominal) .. 50 cm/s (max)
Maximum Range	5 km (radius of 1Km, 3Km max traverse 2)
Maximum Gradient	15 degrees
Side Slope	10 degrees
Ground Clearance	25 cm
Payload bay	670mm x 1000mm (propose to change to 0.7mX 1m)
Payload Mass	100 kg

Requirement	Value
Communication Delay	5 to 10 sec. round-trip (currently being clarified with DSN)
Bandwidth limits	Surface ops: 2 kbits/s (Uplink), 400 kbits/s (Downlink) while stationary minimum
Autonomous GN&C	As applicable to achieve the concept of ops
Navigation Accuracy	1-5% of the traveled distance (x, y, z) 1% error (yaw, pitch, roll)
Navigation Self-Sufficiency	No reference to external navigational aids (e.g. No total station)
Sun Shadow Operations	6 hours
Lunar Night Survivability	Augmented mission
Data Storage	32 GBytes

DRM

Destination:	**Moon South Pole**
Landing Site:	**Cabeus A1**
Latitude	85.75 S
Longitude	45 W
Surface Duration:	**10 days** (8 w/ sun)
Surface Dates:	**5/19-5/29/2016** (10 day)
2016 Secondary	6/18-6/25/2016 (7.5day)
2015 Primary	5/6 - 5/13/2015 (7 day)
2015 Secondary	5/31-6/10/2015(10.5day)
Primary Spacecraft:	**Rover**
Power Strategy:	**Solar PV + Battery**
Solar Array	250 We
Secondary Battery	3500 W-hr
Comm. Strategy:	**Direct-To-Earth**
	McMurdo+Troll
Survey Track:	**3,000 m** cumulative
Payload:	
Drill	5 x 1 m core
	10 x 0.5 m auger
ISRU Reactor	25 Samples @ 150 C
	4 ISRU Demos @ 900 C
GasChrom./MassSpec.	25 Samples
Neutron Spectrometer	3,000 m
Near-IR Spectrometer	3,000 m, 10 auger cuttings
Mission Energy:	**51,500 W-hr** available
Mission Ave. Power:	**181 W** predicted
Payload Mass:	**72 kg**
Rover+P/L Mass:	**243 kg**
Landed Mass:	**1,285 kg**
Wet Mass @ TLI:	**3,476 kg**
Launch Vehicle:	**Atlas V 411**

Questions



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