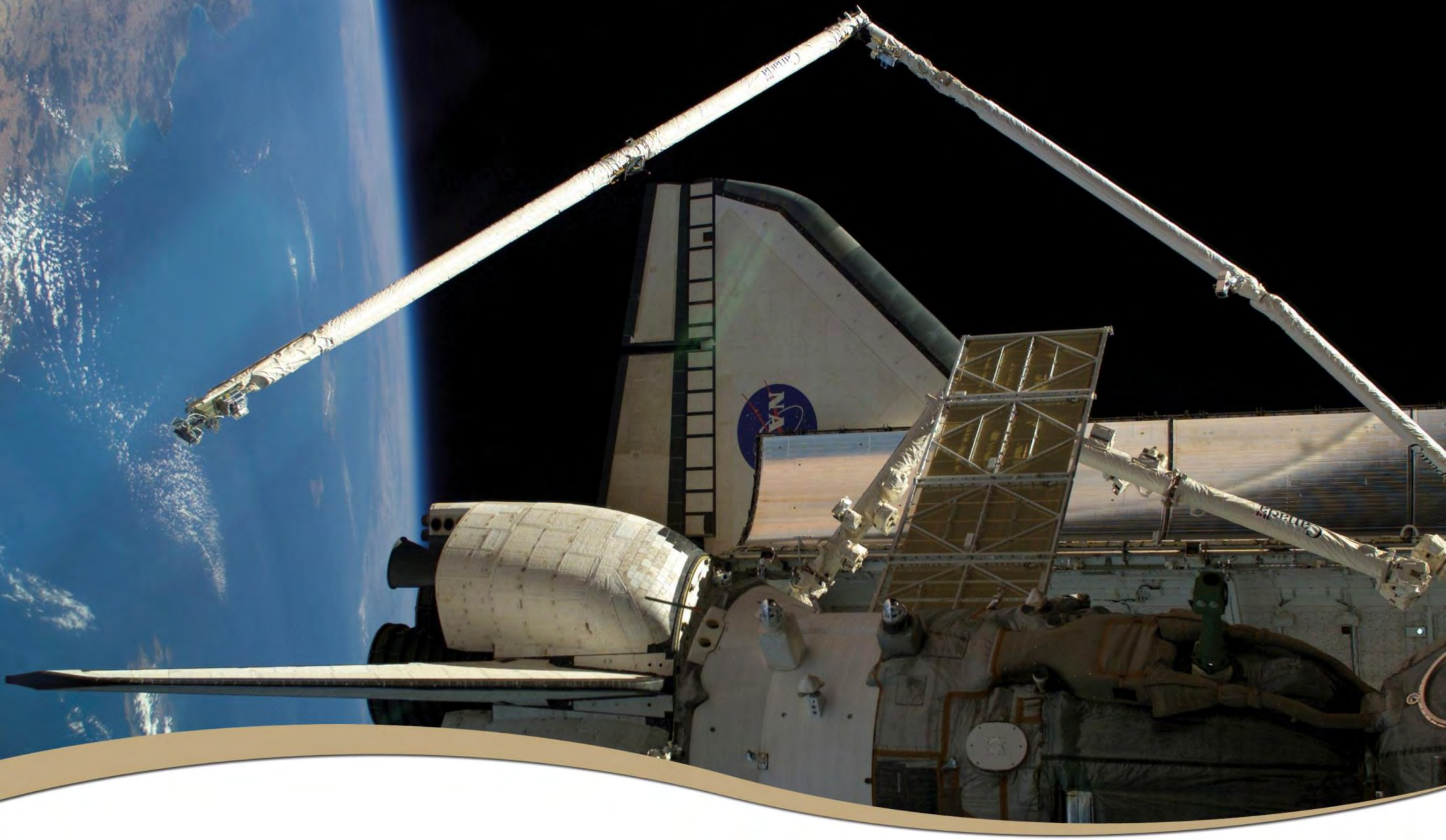


neptec

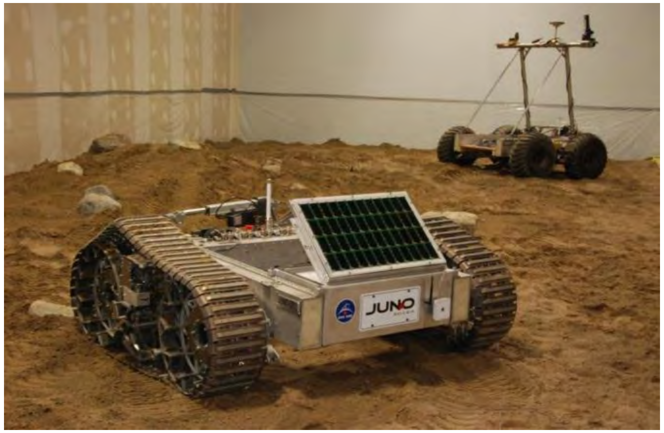
# PTMSS/CIM May 8th, 2013

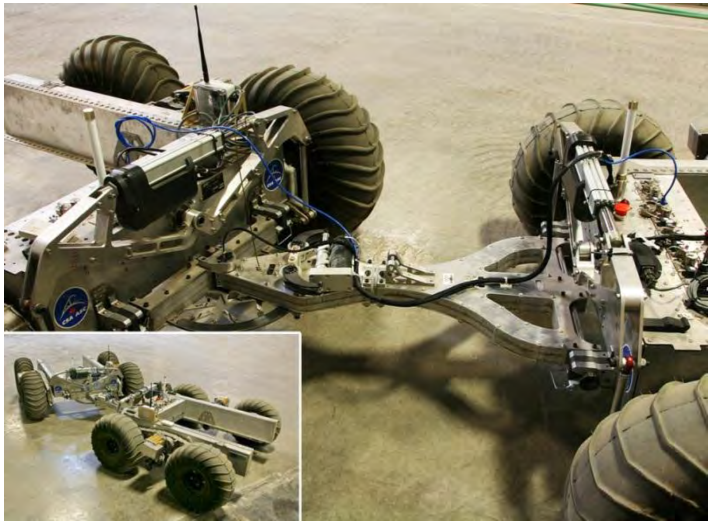
## Challenges of ISRU Rover Development

# Juno Rover

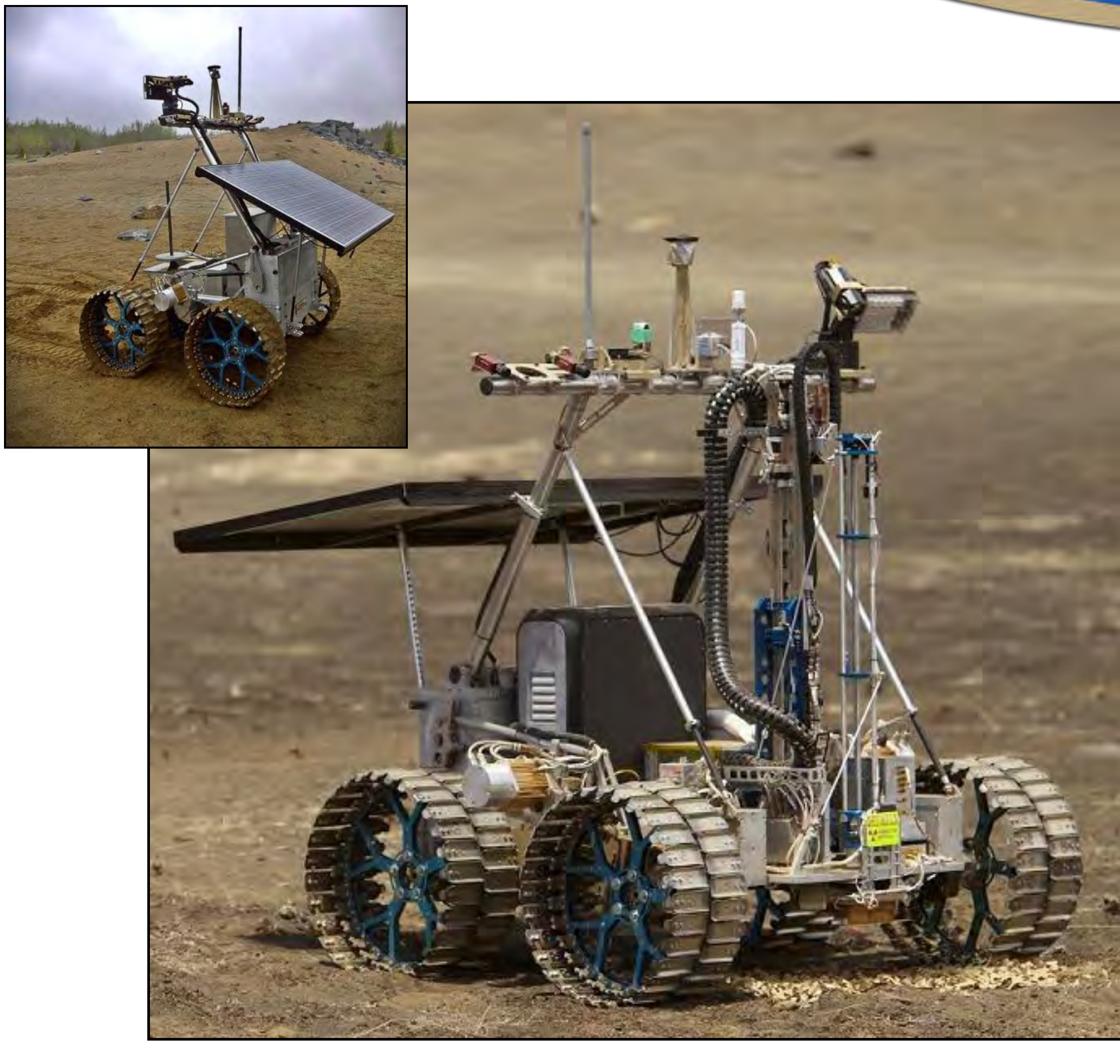
- Four-wheel, skid-steer, rover developed for CSA
- U-chassis for payload accommodation
- Passive geometric suspension
- Max speed 13km/hr
- Remote workstation
- 275kg payload capacity
- On-board processor, IMU, motor encoders
- 5.2kW-h battery capacity

# Juno Rover Variants

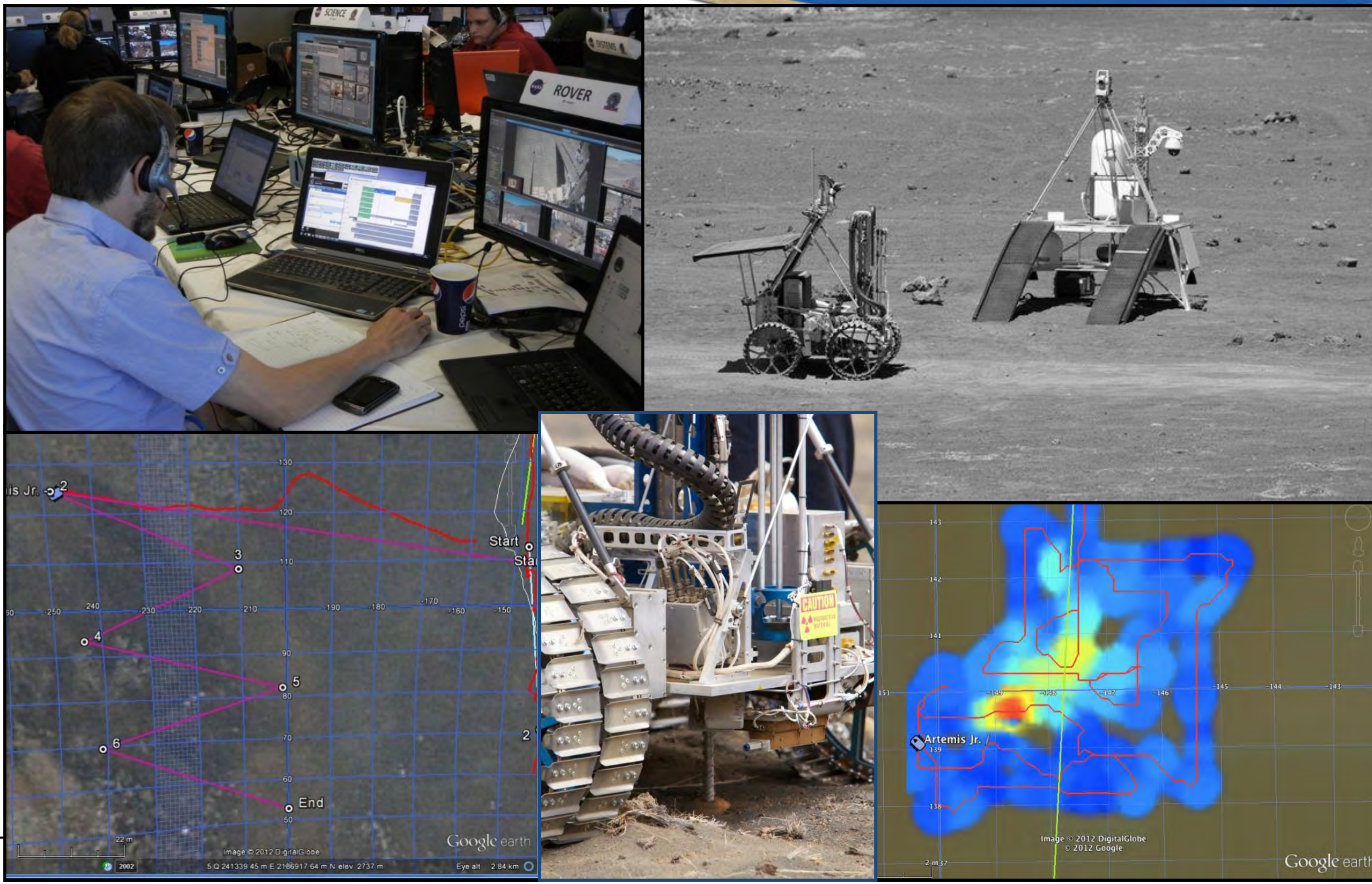



# The Artemis Jr. Rover



- Evolved from Juno rover design
- 10cm/sec nominal speed
- Autonomous or teleoperation control
- 150 kg payload capacity
- Sophisticated guidance, navigation and control system

# RESOLVE Mission Simulation



# Rovers – Neptec Partners

- Ontario Drive and Gear, New Hamburg
- NORCAT, Sudbury
- COM DEV, Cambridge
- NGC Aerospace, Sherbrooke
- Provectus Robotics Solutions, Ottawa
- ProtoInnovations, Pittsburgh
- CrossChasm, Waterloo
- Xiphos, Montreal
- McGill University, Montreal
- University of Ottawa

# The RESOLVE Mission

- Mission timeline – landing planned for late 2017/early 2018
- NASA/CSA collaboration
  - NASA provides RESOLVE payload, launch vehicle, lander and comms support
  - CSA provides drill and rover
- Objectives:
  - ISRU Prospecting
  - ISRU Processing

# Prospecting Activities

- Map the distribution of near-surface volatiles (generally hydrogen-rich)
- Determine mineral and chemical properties of regolith
- Extract core samples to a depth of 1 m (multiple sites)
- Heat samples to release volatiles for analysis
- Determine species and quantities of volatiles

# ISRU Processing Demonstration

- Heat core sample to reaction temperatures
- Pass $H_2$ through regolith to extract oxygen and produce water
- Contain, quantify and display the resulting water

# Key Technical Challenges

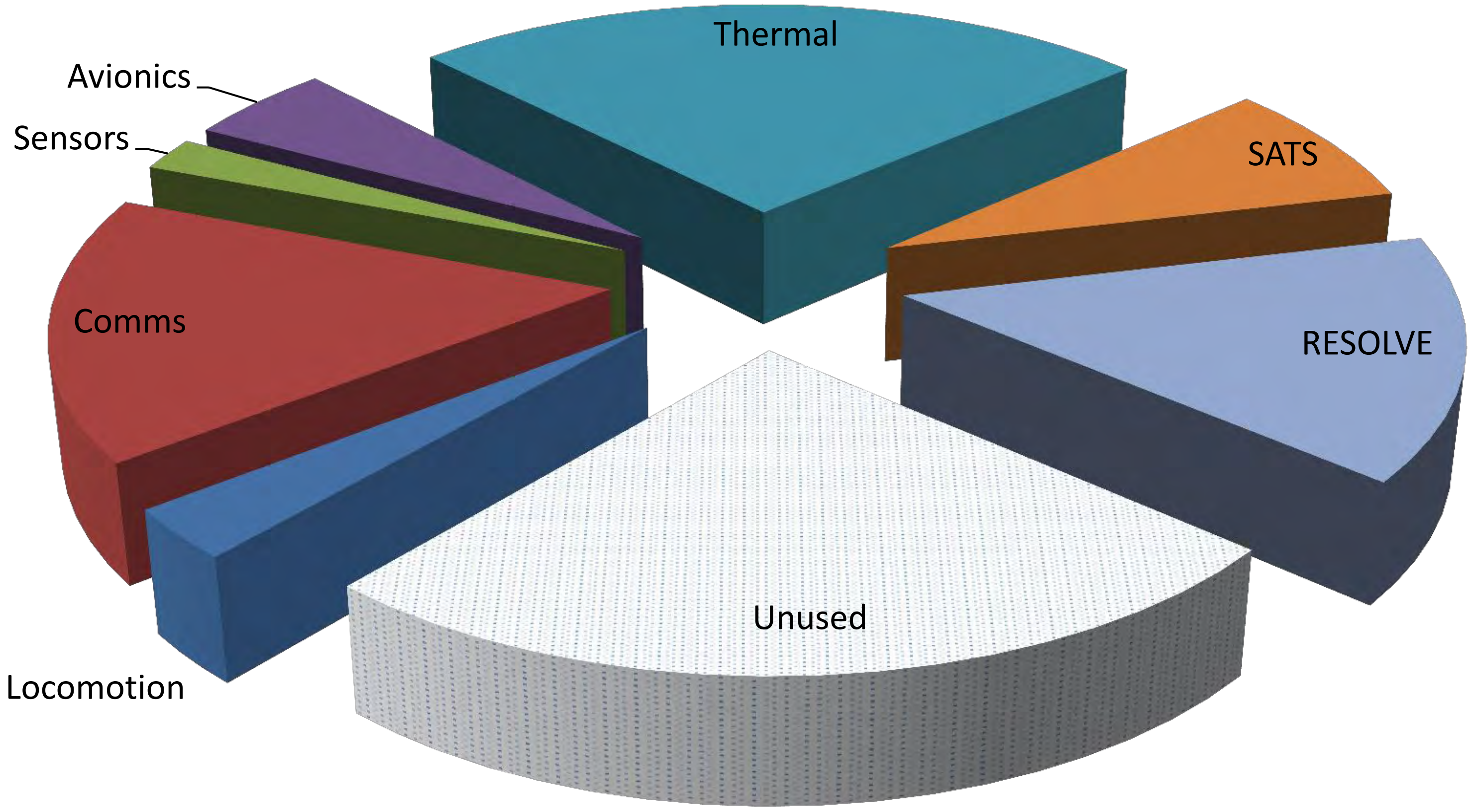
- Power storage, distribution and collection
- Mobility and traction
- Guidance, navigation and localization
- Environment Management
- Operational

# Power System

Primary Loads:

- Avionics
  - Guidance, Navigation and Control
  - Active sensors
  - Communications
- Traction and suspension motors
- Payloads
  - Drill
  - RESOLVE
- Heating and Cooling
- Power and Energy Budgets

# Energy Distribution



# Power System

Functional Design:

- Bus voltages and regulation
- Distribution and isolation strategies
- Battery chemistry and thermal management
- Primary vs secondary cells
- If secondary cells:
  - Recharge options (solar, lander power, etc.)
  - Battery management system

# Power System

Physical Design:

- Mass
- Volume
- Shape
- Wiring

# Mobility and Traction

External Functions:

- Lander size and capacity
- Terrain type:
  - Sloped vs flat
  - Size and distribution of rocks and boulders
- Surface regolith properties
  - Loose vs consolidated
- Rover speed requirements

# Mobility and Traction

Payload Accommodations:

- Payload(s) characteristics
  - mass (and mass distribution)
  - shape and placement
  - behaviour
- Sensor Placement
- Avionics & Power
  - mass/volume/thermal/access

# Mobility and Traction

Thermal Accommodations:

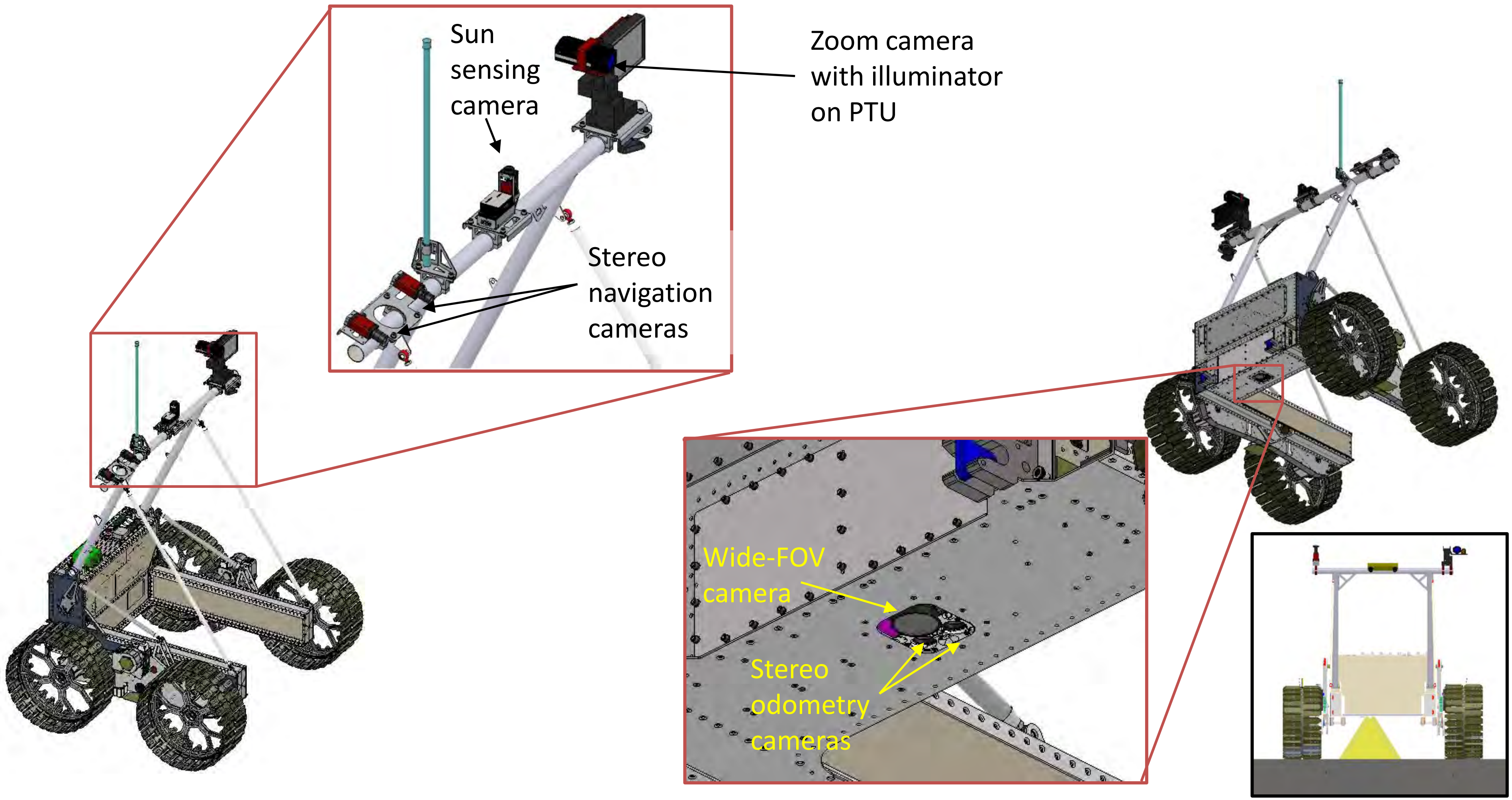
- Radiator(s) design and placement
- Solar Panel(s) design and placement
- Traction motor placement
- Chassis material selection

# Guidance, Navigation and Control

Functional Design:

- Absolute vs relative localization
- Available navigation infrastructure
- Accuracy/repeatability
- Navigation/localization techniques
- Tele-op vs semi-autonomous vs autonomous
- Sensor types

# Artemis Jr. Rover: Vision System

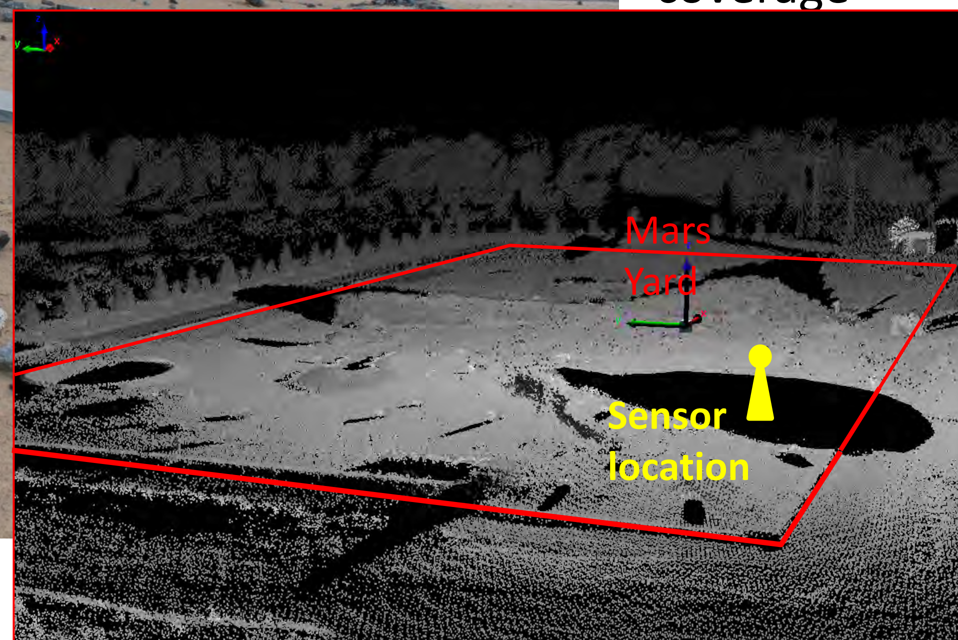


# Artemis Jr. Rover: Navigation

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

# Sensors - *IVIGMS*


Juno equipped with IVIGMS sensor at CSA Mars Yard – 360° x 45 ° scan coverage



# Guidance, Navigation and Control

Implementation:

- On-board processors
- O/S and support
- H/W and S/W interfaces
- Thermal management (esp. external components)
- Sensor types

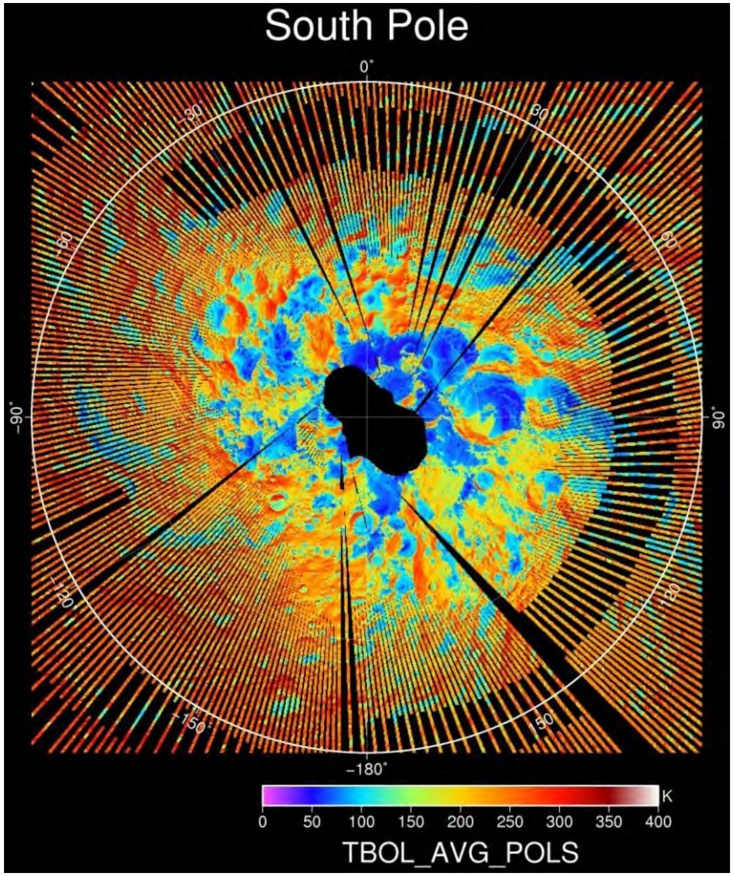
# Environmental Challenges

- Temperature extremes
  - Lunar day
  - Operate through partial and full shade
  - Lunar night (maybe)
  - Sample preservation
- Dust protection and mitigation
- Radiation exposure

# Lunar Day/Night Temperature Maps

Diviner surface temperature maps

July 23, 2012




August 6, 2012

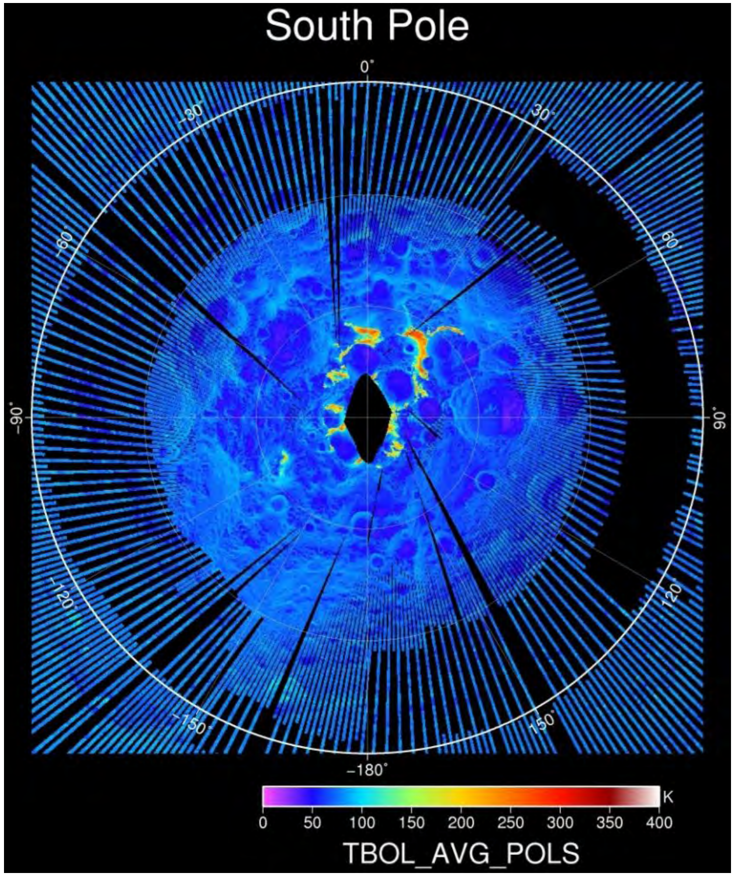



Image Credit: NASA Diviner

# Operational Challenges

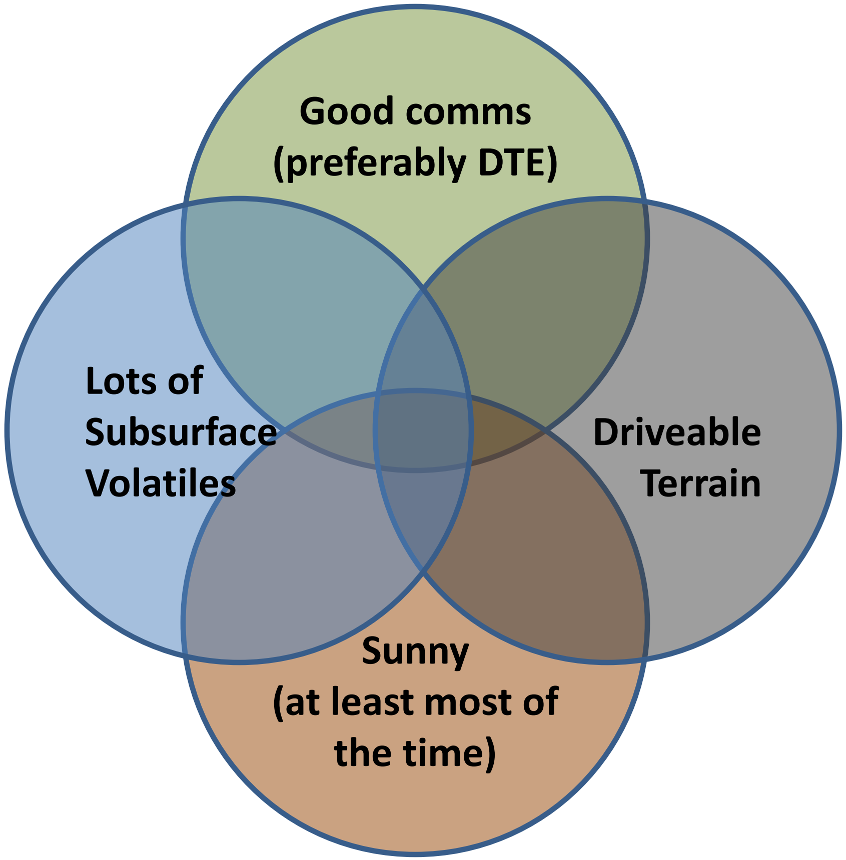
- Sorting out the Ops Concept:
  - Prospecting vs drilling vs science
  - Shadowed vs illuminated ops
  - Managing energy discharge/recharge
- What can/can't be accomplished by tele-op
- Determining  optimum level of autonomy
- Determining optimum comms architecture

# Design Reference Mission Def’n

| | |
|---|---|
| **Destination:** | **Moon South Pole**<br>(North location for assessment) |
| **Site (South Pole):** | **Cabeus A1** |
| • Latitude | 85.75 S |
| • Longitude | 45W |
| **Surface Mission Duration** | **10 days (8 days w/sun)** |
| **2017 Primary Opportunity** | **10 days (April, 2017)** |
| **Primary Spacecraft** | **Rover** |
| **Power Strategy** | **Solar PV + Battery** |
| • Solar Array | 250 We |
| • Secondary Battery | 3500 W-hr |
| **Comm Strategy** | **5-10 second delay DSN;**<br>**75W continuous** |
| • Option 1 | Lander Crosslink to Lander,<br>Lander DTE DSN |
| • Option 2 | Rover DTE DSN |
| • Option 3 | Both |

| | |
|---|---|
| **Survey Track:** | **3,000 m** |
| **Payload:** | |
| • Drill | 5x1m core, 10 x 0.5 m auger |
| • ISRU Reactor | 25@150C, 4@900C ISRU |
| • Gas Chrom. / Mass Spec. | 25 Samples<br>3000 m |
| • Neutron Spectrometer | 3000 m, 10 auger cuttings |
| • Near IR-Spectrometer | |
| **Mission Energy:** | **51,500 W-hr available** |
| **Mission Ave. Power:** | **181 W predicted** |
| **Mass:** | |
| • Payload Mass: | 100 kg |
| • Rover + P/L Mass: | 250 kg |
| • Landed Mass: | 1285 kg |
| • Wet Mass @ TLI: | 3,476 kg |
| **Launch Vehicle:** | **Atlas V 411** |

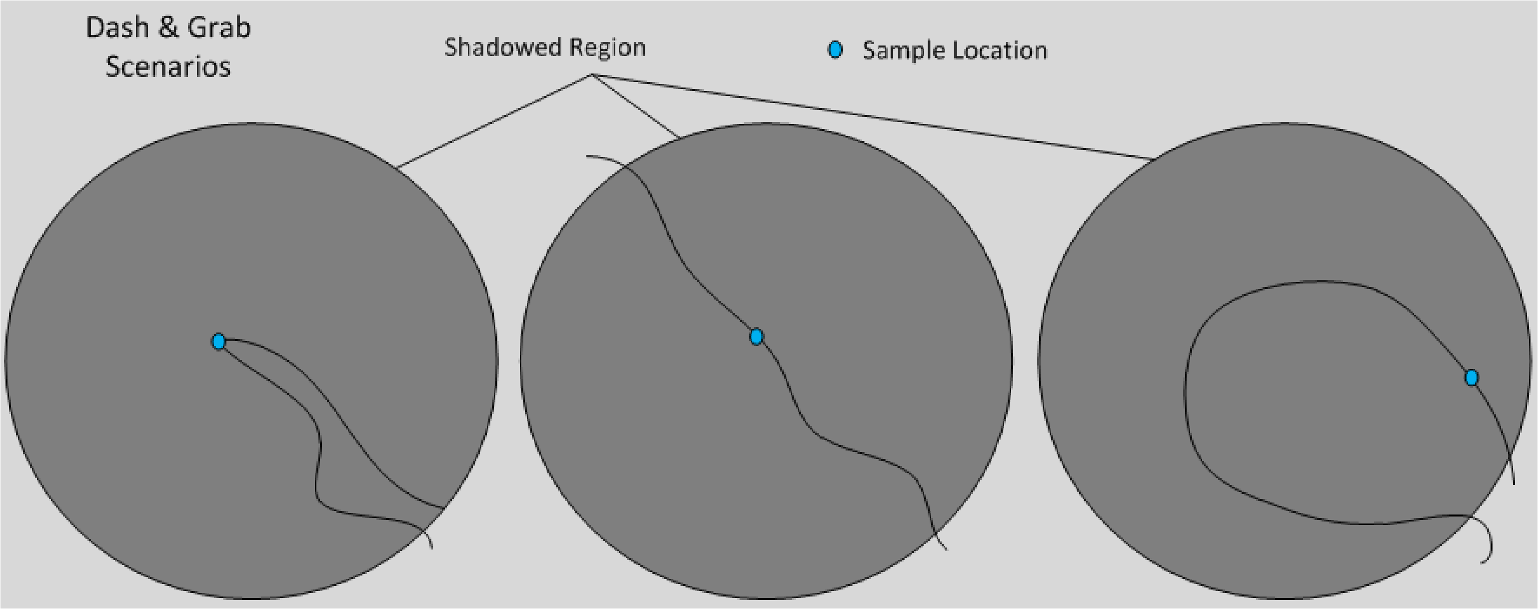
# Location, Location, Location…



# Concept of Operations

Prospecting and sampling in shadow:

- Includes a mixture of ops in shade, partial shade and full sun
- Dependencies include return journey length, continue prospecting to look for a more promising location, or take a sample and get out
- Most challenging from energy management point of view



# Rover Control Consoles


# Apollo Lunar Roving Vehicle (LRV)

- 1971 & 1972
- Operations:
  - 15 - 3h/28km
  - 16 - 3.5h/27km
  - 17 - 4.5h/22km
- Crew operated
- Lunar day only
- Basic systems
- No ISRU…

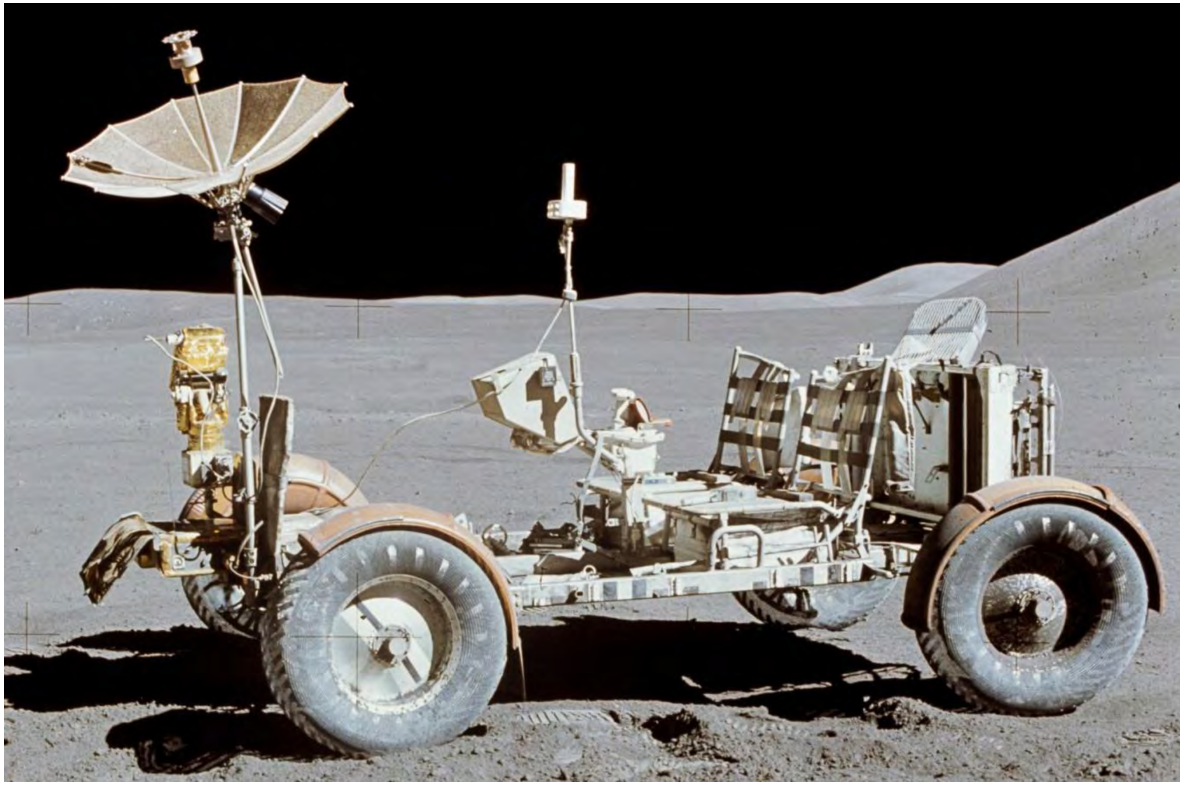


Image credit: http://www.hq.nasa.gov/office/pao/History/alsj/a15/images15.html

# Russian Lunokhod Moon Rovers

- 1970 & 1973
- Operations:
  - LK1 - 322 days
  - LK2 - 120 days
- Tele-operated
- Solar-charged batteries
- RTG heat source
- Several instruments
- No ISRU

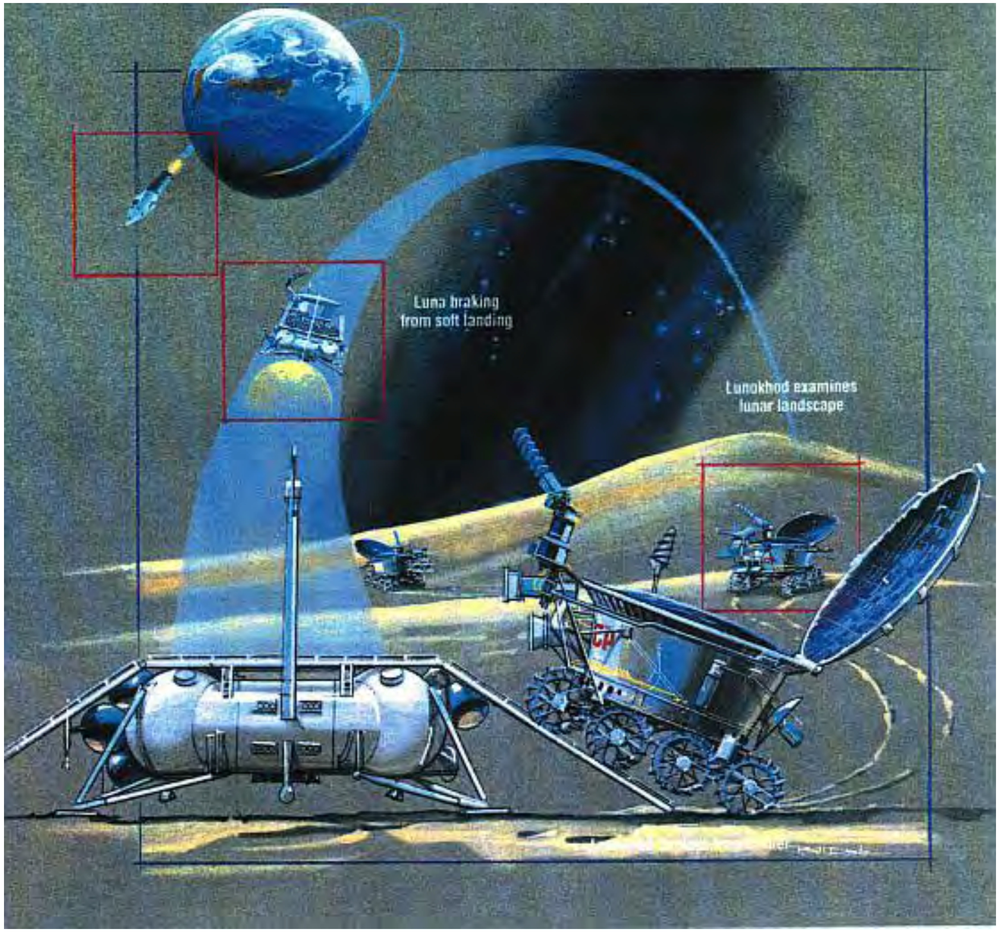
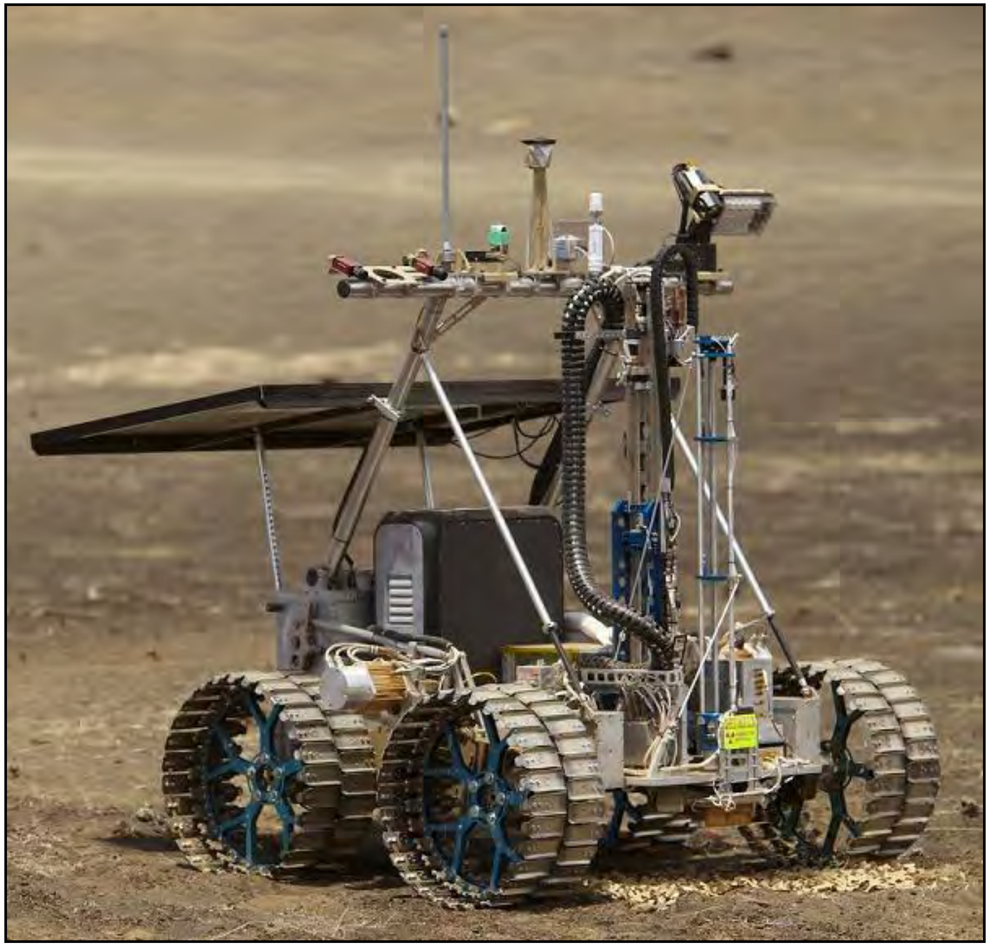



Image credit: PD-USGOV-NASA via wikipedia commons

# Artemis Jr/RESOLVE Rover

- 2017/2018
- Operations:
  - 5 – 8 days
  - Combination of tele-op and autonomous
  - Lunar day
- Solar-charged batteries
- RESOLVE and Drill payloads



# Questions?

# Background Slides

# Lunar Day/Night Temperature Map

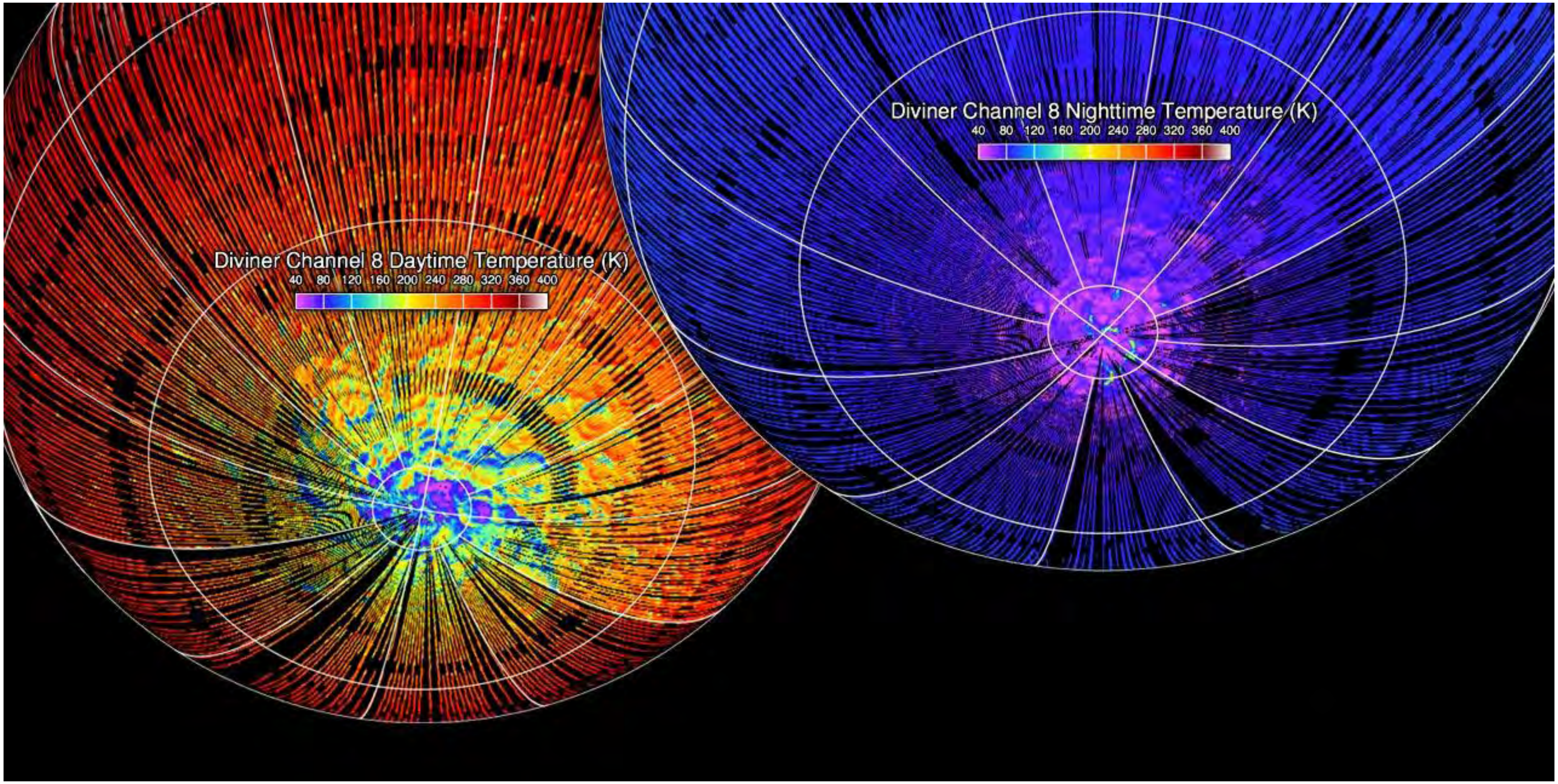



Image credit: NASA - http://www.nasa.gov/topics/solarsystem/features/divinerb20090917.html

# Navigating to a Hotspot