Resource Prospector

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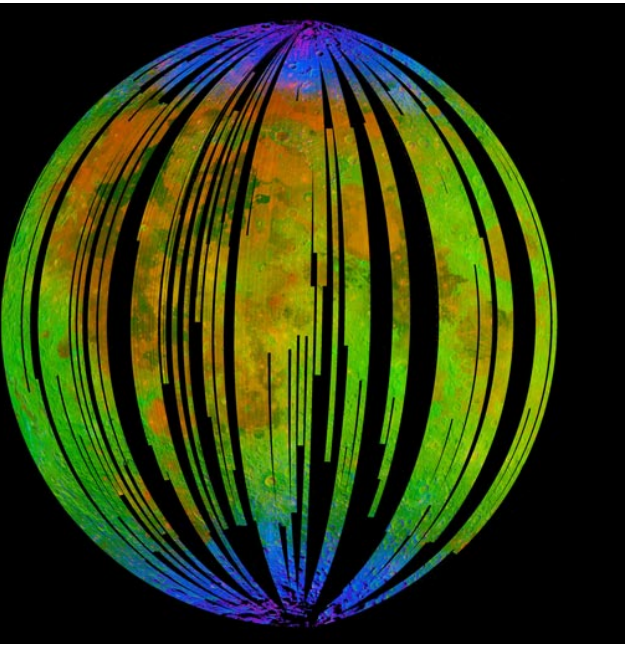
LEAG
10/15/2013

Resource Prospector – Water, water everywhere…

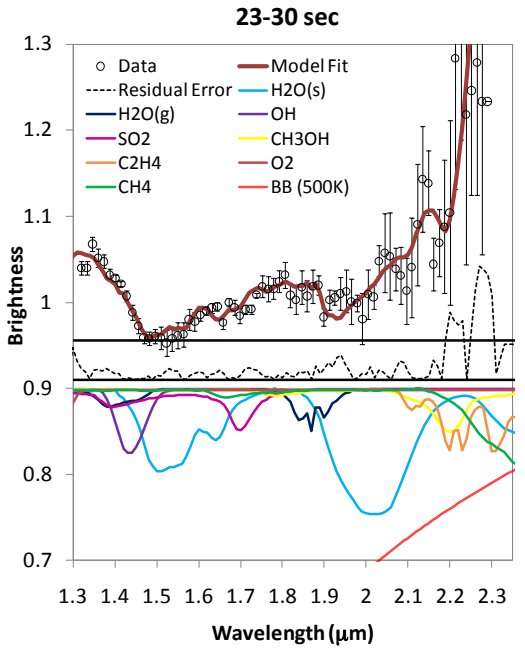
A range of forms, distributions and concentrations

~0.1-1%



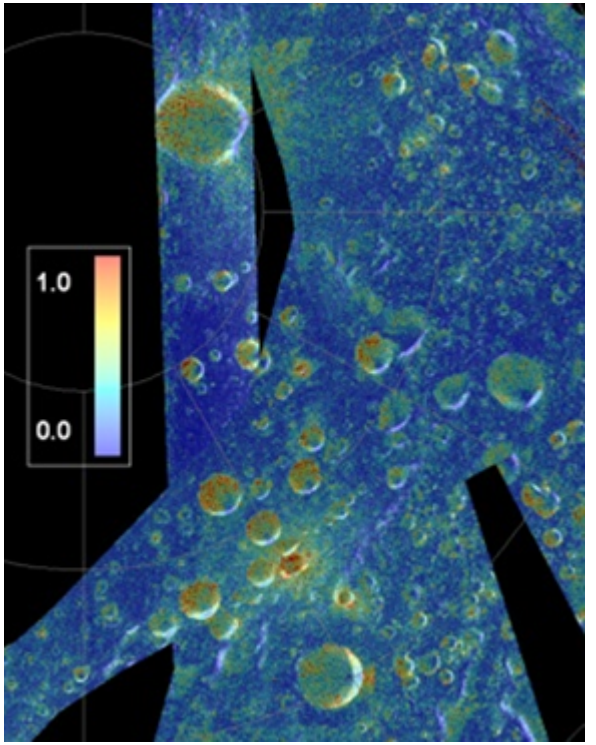
Pieters et al., 2003

~1-10%



Colaprete et al., 2010

~10-100%



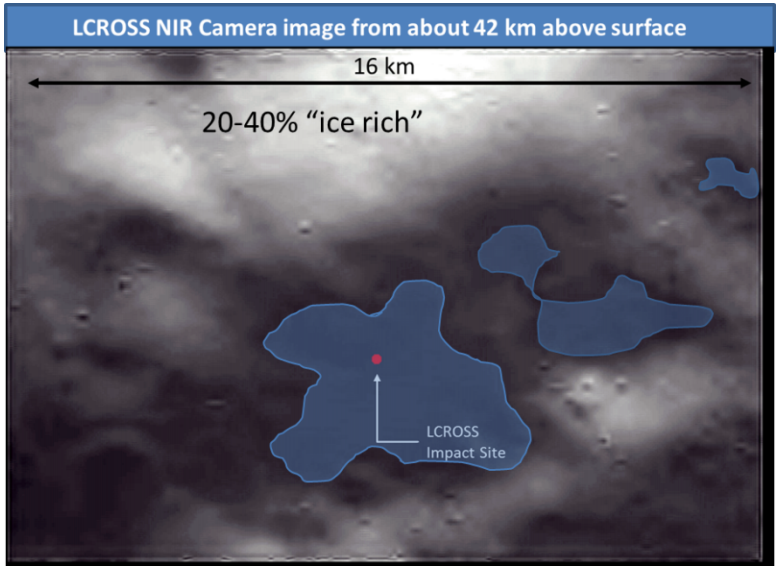
Spudis et al., 2010

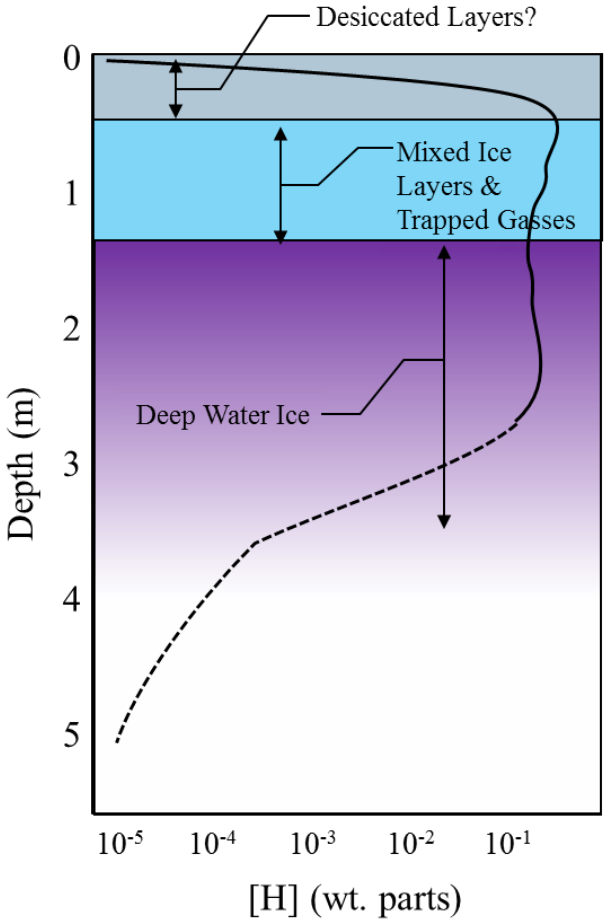
We know the water (and other H-bearing compounds) are there…

Resource Prospector – But exactly where?

…and at what concentrations? Forms?

- LCROSS + Neutron analysis suggest patchy or buried (or both) distributions of hydrogen
- Impact gardening will create heterogeneity at lengths scale of ~10-100 m
- Several data sets suggest time-dependent surface component
- In areas of limited sun near sub-surface temperatures are cold enough to retain water





Resource Prospector Mission "Big Picture"

The Resource Prospector Mission (RPM) is being jointly developed by NASA and the Canadian Space Agency to prospect for volatiles (water ice) in the polar regions of the Moon.

Utilizing lunar resources to produce oxygen and propellants could enable new mission architectures for human exploration.

RPM is targeted for launch in 2018.

Mission elements include a lunar lander, a rover, a sampling & analysis payload, and mission operations.

Payload consists of a drill, a small oven to heat the sample, and a suite of three different spectrometers to guide surface navigation and characterize the volatiles located in the lunar regolith.

RPM Mission Goals

From *LEAG Robotic Campaign Analysis (2011):*

Phase I: Lunar Resource Prospecting

- Defining the composition, form, and extent of the resource;
- Characterizing the environment in which the resources are found;
- Defining the accessibility/extractability of the resources;
- Quantifying the geotechnical properties of the lunar regolith in the areas where resources are found;
- Being able to traverse several kilometers and sample and determine lateral and vertical distribution on meter scales;
- Identifying resource-rich sites for targeting future missions

Resource Prospector is aligned with the community vision for the next lunar resource mission

SKGs and RPM – Address at Least 22 Lunar SKGs

Lunar Exploration Strategic Knowledge Gaps			Instrument or Activity	RPM Relevance
I. Understand the Lunar Resource Potential				
	B-1	Regollith 2: Quality/quanity/distribution/form of H species and other volatiles in mare and highlands	NSS, NIRVSS, OVEN-LAVA	VH
	D-3	Geotechnical characteristics of cold traps	NIRVSS, Drill, Rover	H
	D-4	Physiography and accessibility of cold traps	Rover-PSR traverses, Drill, Cameras	VH
	D-6	Earth visibility timing and extent	Mission Planning	VH
	D-7	Concentration of water and other volatiles species within depth of 1-2 m	NSS, NIRVSS, OVEN-LAVA	VH
	D-8	Variability of water concentration on scales of 10's of meters	NSS, NIRVSS, OVEN-LAVA	VH
	D-9	Mineralogical, elemental, molecular, isotopic, make up of volatiles	NIRVSS, OVEN-LAVA	VH- Volatiles L-M-Minerals
	D-10	Physical nature of volatile species (e.g. pure concentrations, intergranular, globular)	NIRVSS, OVEN-LAVA	H
	D-11	Spatial and temporal distribution of OH and H2O at high latitudes	NIRVSS, OVEN-LAVA	M-H
	D-13	Monitor and model movement towards and retenion in PSR	NIRVSS, OVEN-LAVA	M
	G	Lunar ISRU production efficiency 2	Drill, OVEN-ROE, LAVA-WDD	M
III. Understand how to work and live on the lunar surface				
	A-1	Technology for excavation of lunar resources	Drill, Rover	M
	B-2	Lunar Topography Data	Planning Products, Cameras	M
	B-3	Autonomous surface navigation	Traverse Planning, Rover	M-L
	C-1	Lunar surface trafficability: Modeling & Earth Tests	Planning, Earth Testing	M
	C-2	Lunar surface trafficability: In-situ measurements	Rover, Drill	H
	D-1	Lunar dust remediation	Rover, NIRVSS, OVEN	M
	D-2	Regolith adhesion to human systems and associated mechanical degradation	Rover, NIRVSS, OVEN, Cameras	M
	D-3	Descent/ascent engine blast ejecta velocity, departure angle, and entrainment mechanism: Modeling	Landing Site Planning, Testing	M
	D-4	Descent/ascent engine blast ejecta velocity, departure angle, and entrainment mechanism	Lander, Rover, NIRVSS	H
	F-2	Energy Storage - Polar missions	Stretch Goal: Lander, Rover	H
	F-4	Power Generation - Polar missions	Rover	M

VH = Very High, H = High, M = Medium, L = Low

Resource Prospector – A Prospector & ISRU Mission

A mission to examine polar for the distribution and potential for ISRU

Prospecting Mission:

- Characterize the distribution of water and other volatiles at the lunar poles
  - Map the surface and subsurface distribution of hydrogen rich materials
  - Determine the constituents and quantities of the volatiles extracted
    - Quantify important volatiles: H_2, He, CO, CO2, CH_4, H2O, N_2, NH_3, H_2S, SO_2
  - Measure or provide limits on key isotope ratios, including D/H, O18/O16, S36/S34, C13/C12

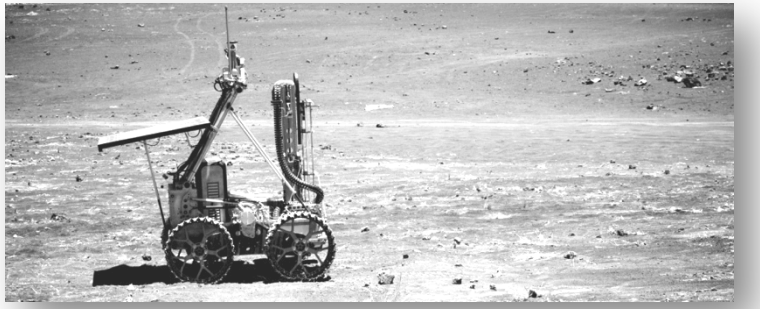
ISRU Processing Demonstration Mission:

- Extraction and capture of native water
  - Measure of energy required to extract water (and any other volatiles) from samples
- Demonstrate the Hydrogen Reduction process to extract oxygen from lunar regolith
  - Demonstrate the hardware (e.g., oven, seals, valves) in lunar setting
  - Capture, quantify, and display the water generated

Simplified view of Resource Prospector Mission

Get there…

- Launch
- Cruise
- Descent & Landing
- Quick Checkout
- Roll-off Lander
- Quick Checkout
- Begin Surface Ops



Find & Mine Volatiles…

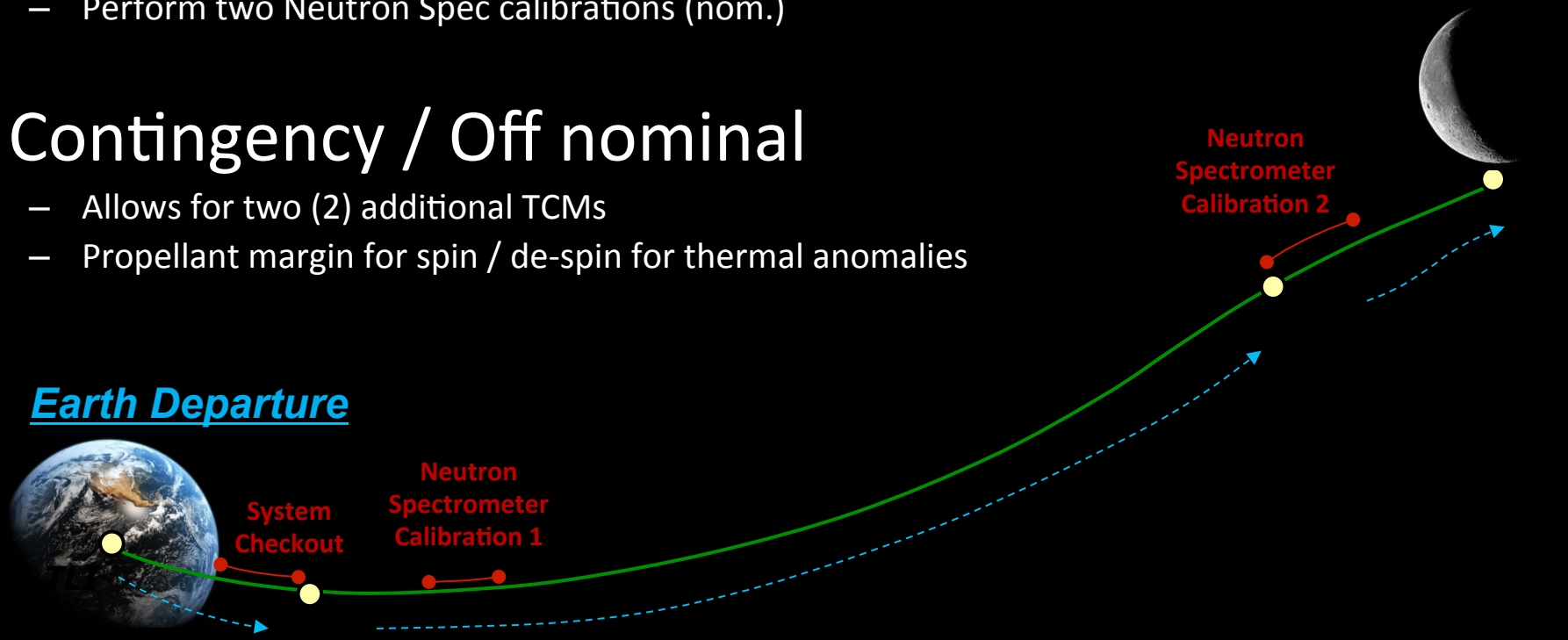
- **Map surface** — Use the Neutron Spec & Near-IR Spec to look for Hydrogen-rich materials
- **Extract soil core** — Use the Drill Subsystem to excavate up to 1[m] core sample
- **Heat soil** — Heat samples (150degC) in the OVEN Subsystem
- **Determine Volatiles** — Determine type and quantity of volatiles in the LAVA Subsystem, (H2, He, CO, CO2, CH4, H2O, N2, NH3, H2S, SO2)

Utilize the volatiles…

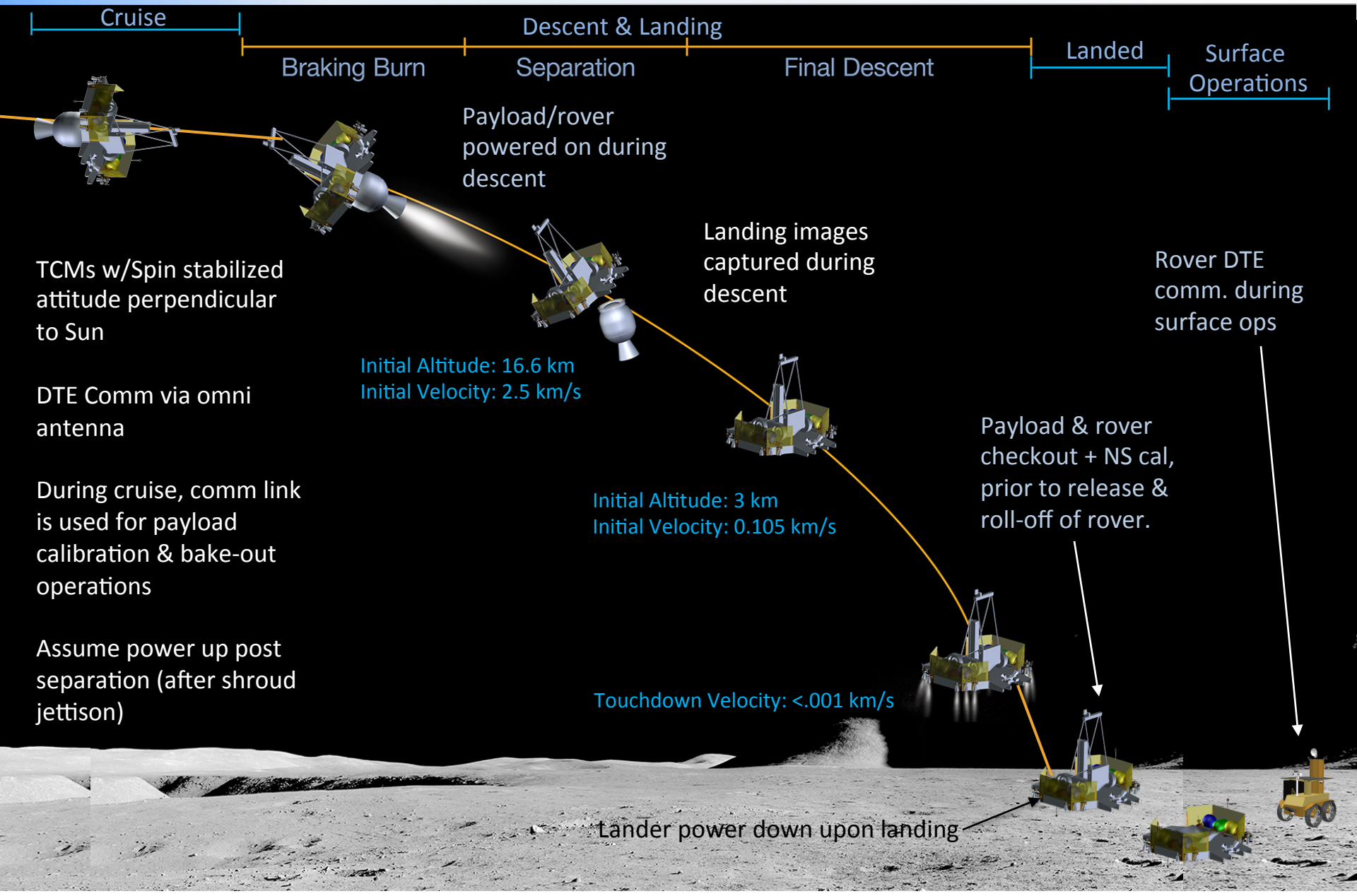
- **Super-heat soil** — Heat sample to reaction temps (150-900degC) using the OVEN Subsystem
- **Make water** — Flow H_2 through the heated soil to capture oxygen and make water using the OVEN Subsystem
- **Show me the water!** — Image and quantify the water created using the LAVA Subsystem

Getting there…

- Cruise Phase:
  - 5-day direct Earth to Moon transfer w/DSN S-band
  - Spin up to 1 rpm using Attitude Control System (post-TLI)
    - No de-spin during TCMs
  - Perform system checkout
  - Perform two TCMs (nom.)
  - Perform two Neutron Spec calibrations (nom.)
- Contingency / Off nominal
  - Allows for two (2) additional TCMs
  - Propellant margin for spin / de-spin for thermal anomalies



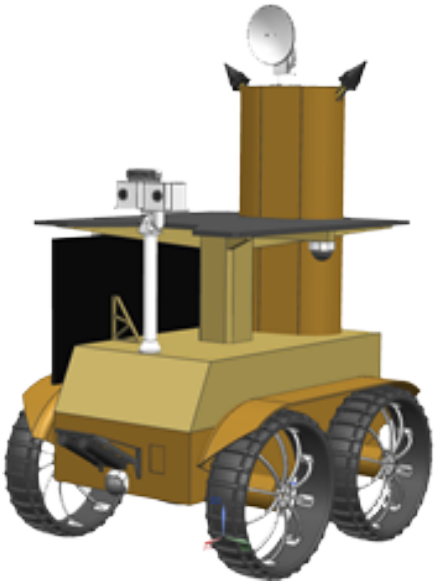
Landing there…



Resource Prospector – The Tool Box

Mobility

Rover
- Mobility system
- Cameras
- Surface interaction



Prospecting

Neutron Spectrometer System (NSS)
- Water-equivalent hydrogen > 0.5 wt% down to 1 meter depth

NIR Volatiles Spectrometer System (NIRVSS)
- Surface H2O/OH identification
- Near-subsurface sample characterization
- Drill site imaging
- Drill site temperatures

Sampling

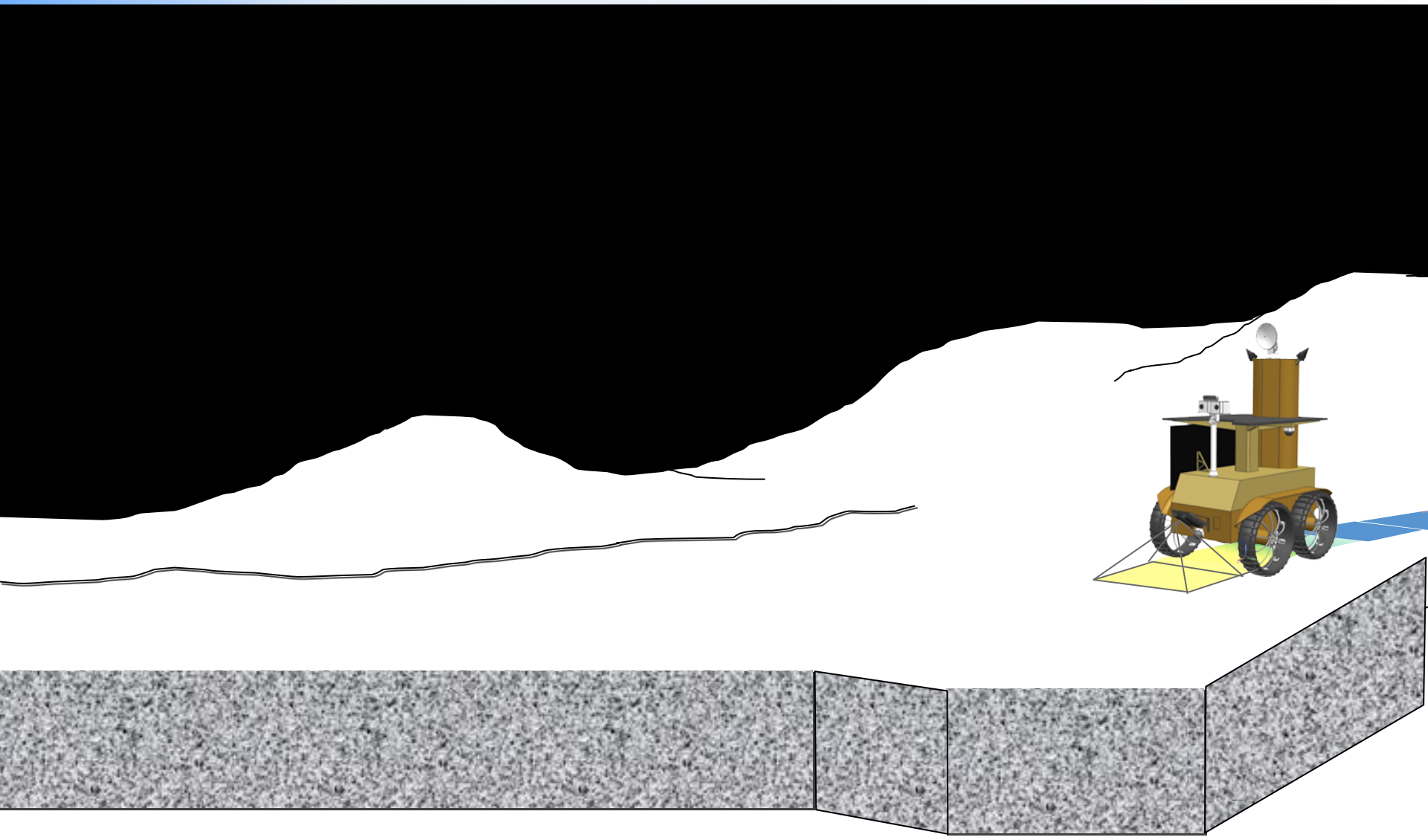
Auger / Core Drill
- Subsurface sample acquisition
- Auger for near-surface assay
- Core for detailed subsurface assay

Processing & Analysis

Oxygen & Volatile Extraction Node (OVEN)
- Volatile Content/Oxygen Extraction by warming
- Total sample mass

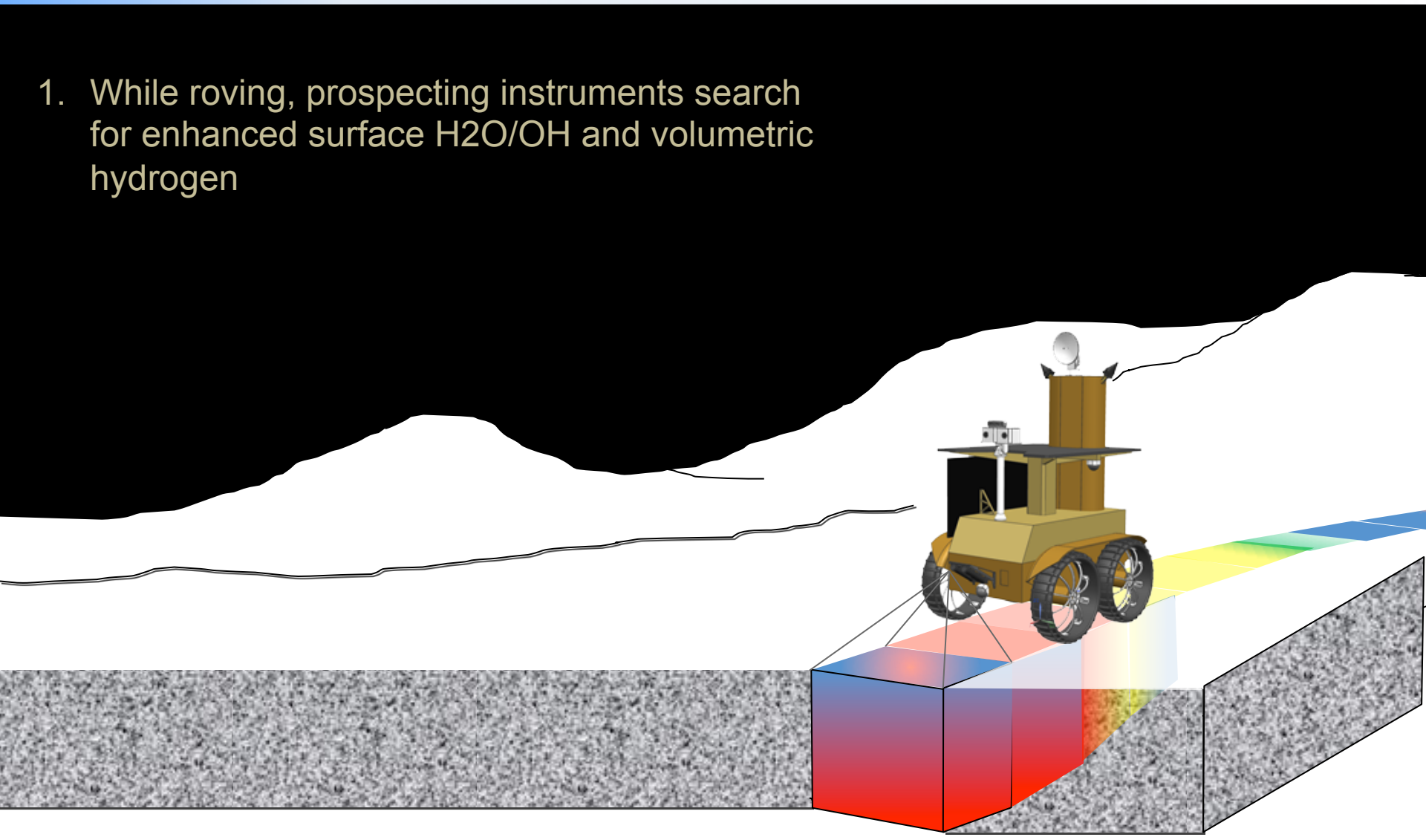
Lunar Advanced Volatile Analysis (LAVA)
- Analytical volatile identification and quantification in delivered sample with GC/MS
- Measure water content of regolith at 0.5% (weight) or greater
- Characterize volatiles of interest below 70 AMU

Prospecting…



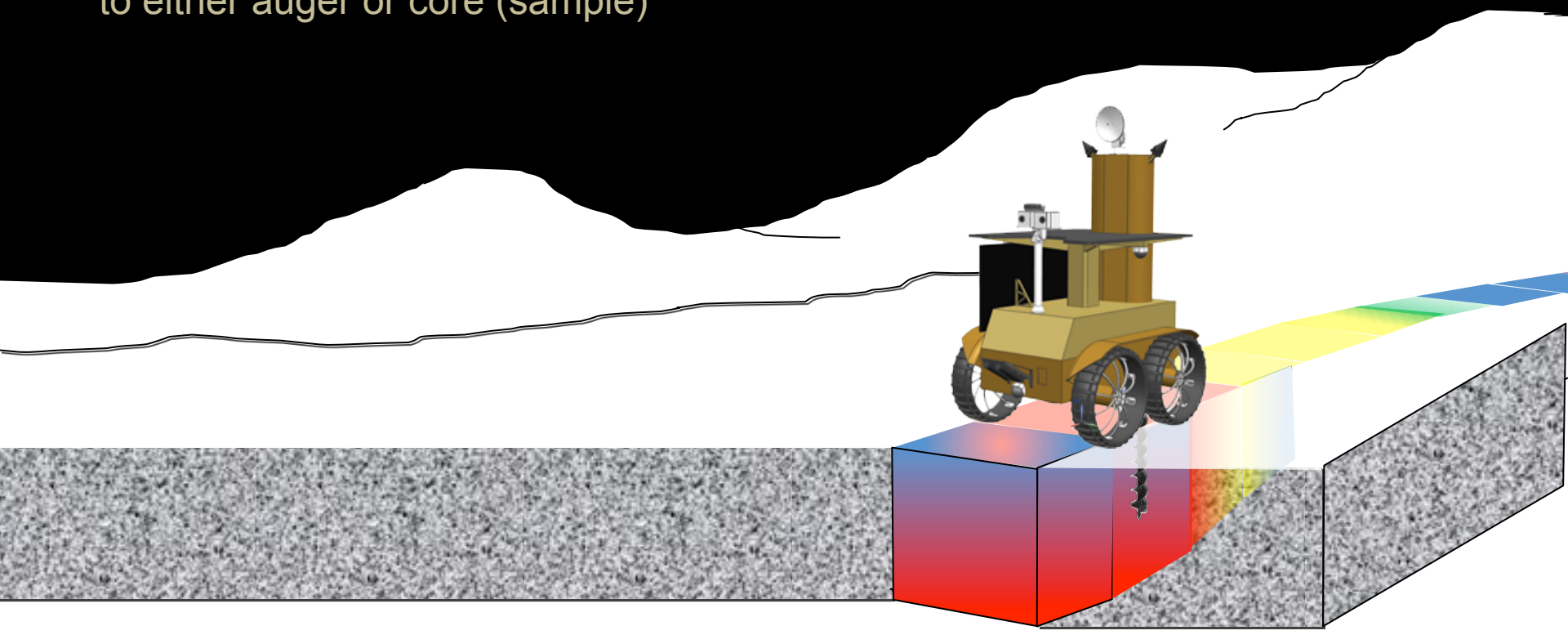
Prospecting…

1. While roving, prospecting instruments search for enhanced surface H2O/OH and volumetric hydrogen



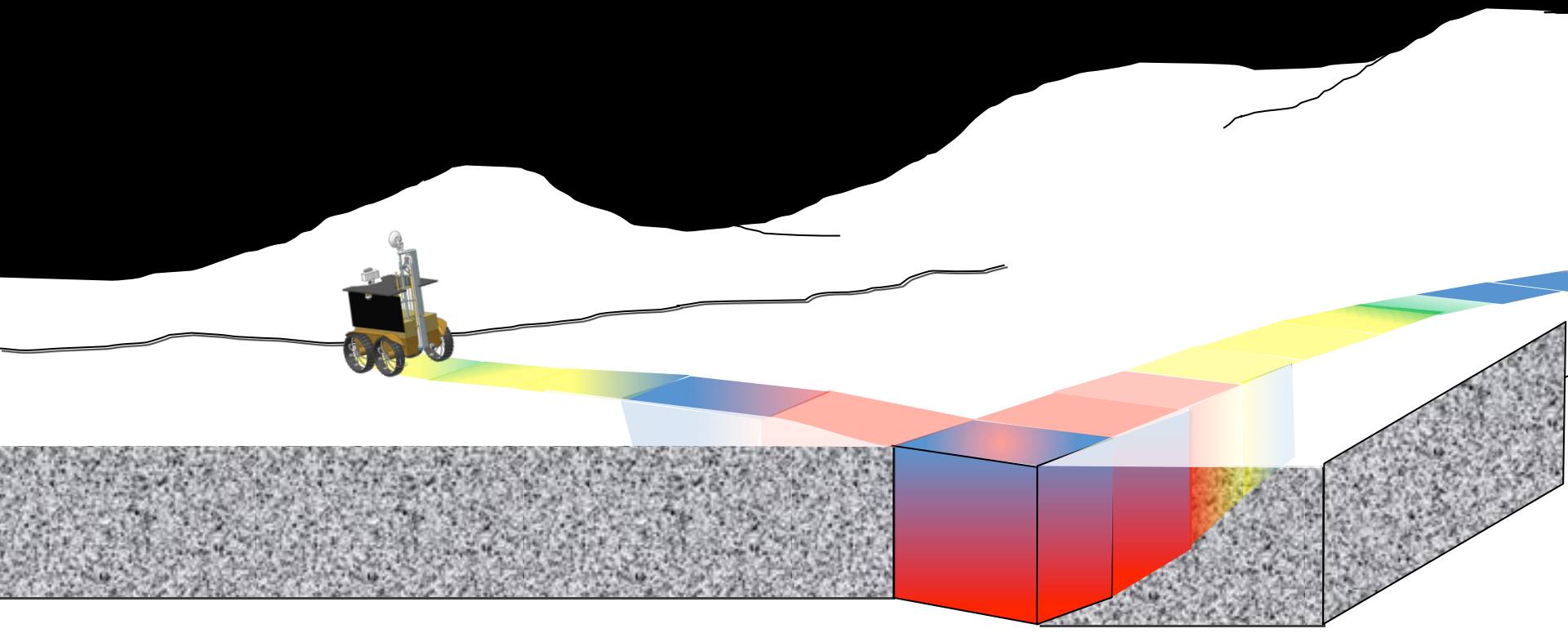
Excavating…

1. While roving, prospecting instruments search for enhanced surface H2O/OH and volumetric hydrogen
2. When enhancements are found decision made to either auger or core (sample)



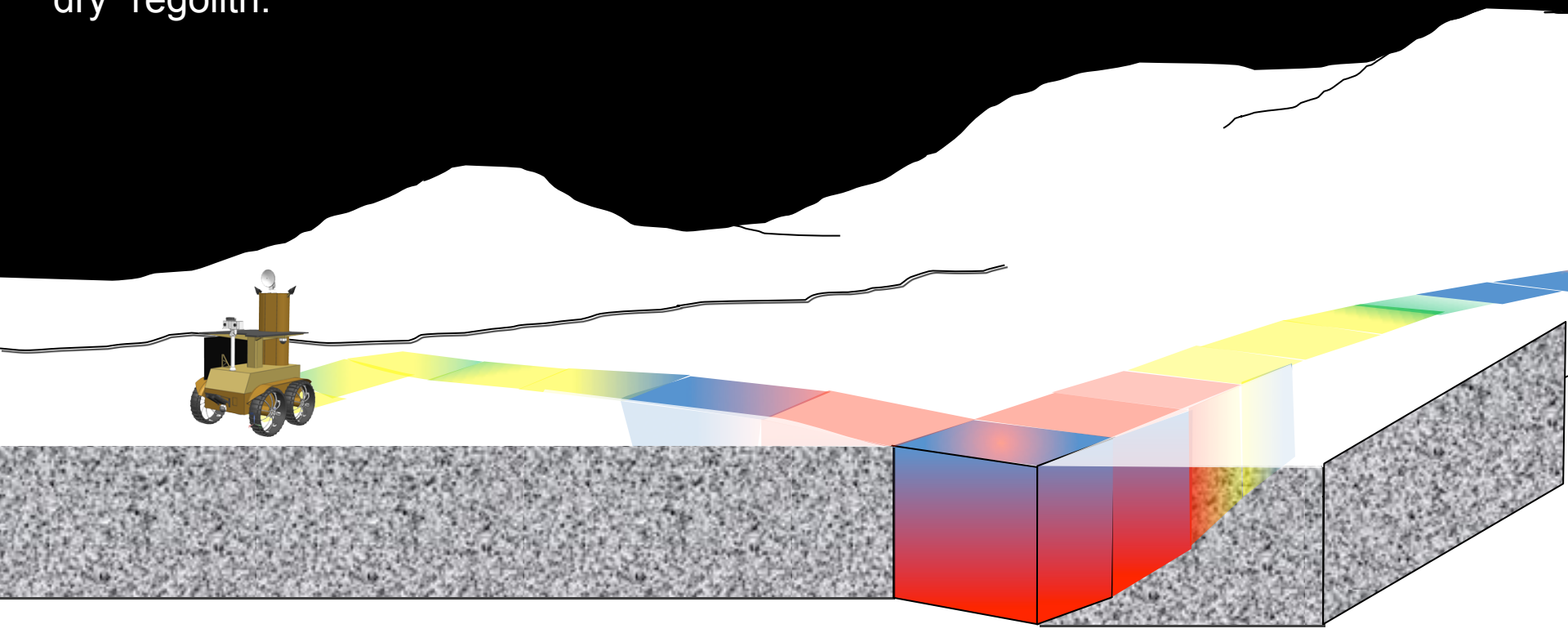
Mapping…

Mapping of volatiles and samples continues across a variety environments, testing theories of emplacement and retention, and constraining economics of extraction.



Demonstrating…

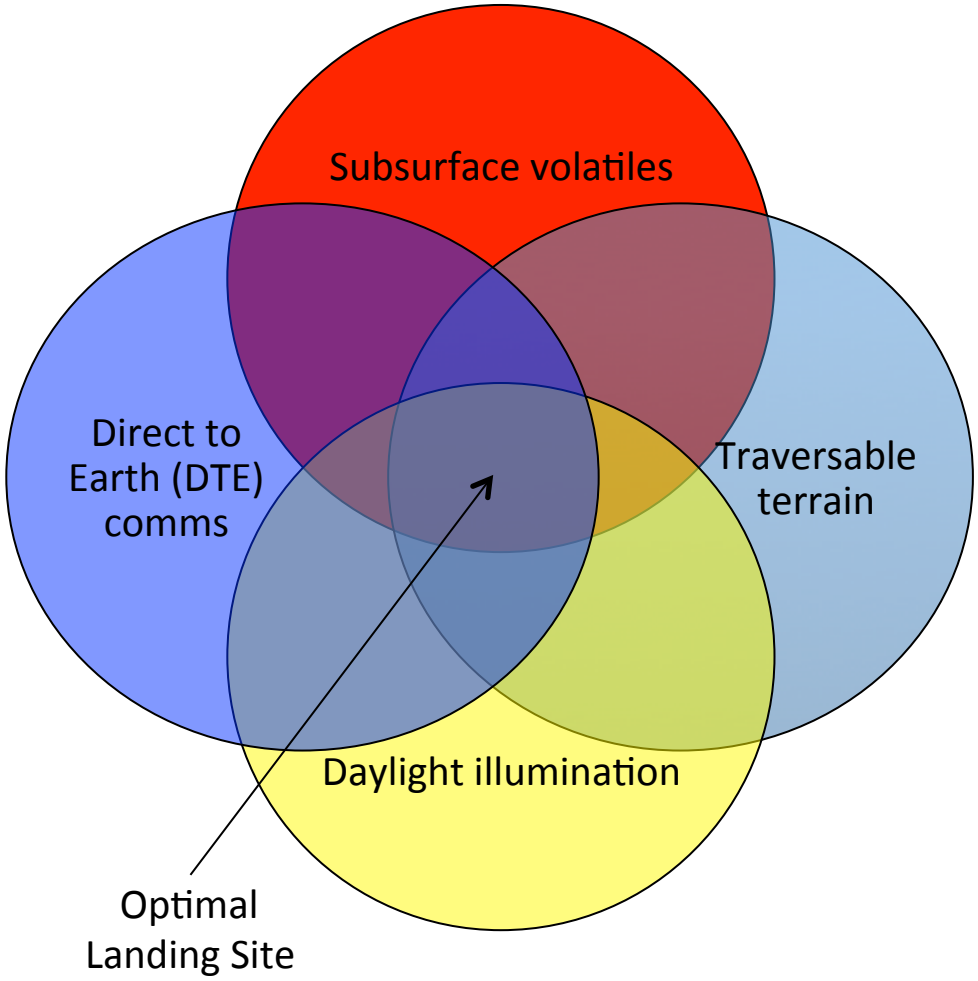
Concluding the primary mission, oxygen extraction from regolith with be demonstrated using hydrogen reduction, thus testing both possible ISRU pathways: local volatiles and water production from "dry" regolith.



Resource Prospector – Landing Site

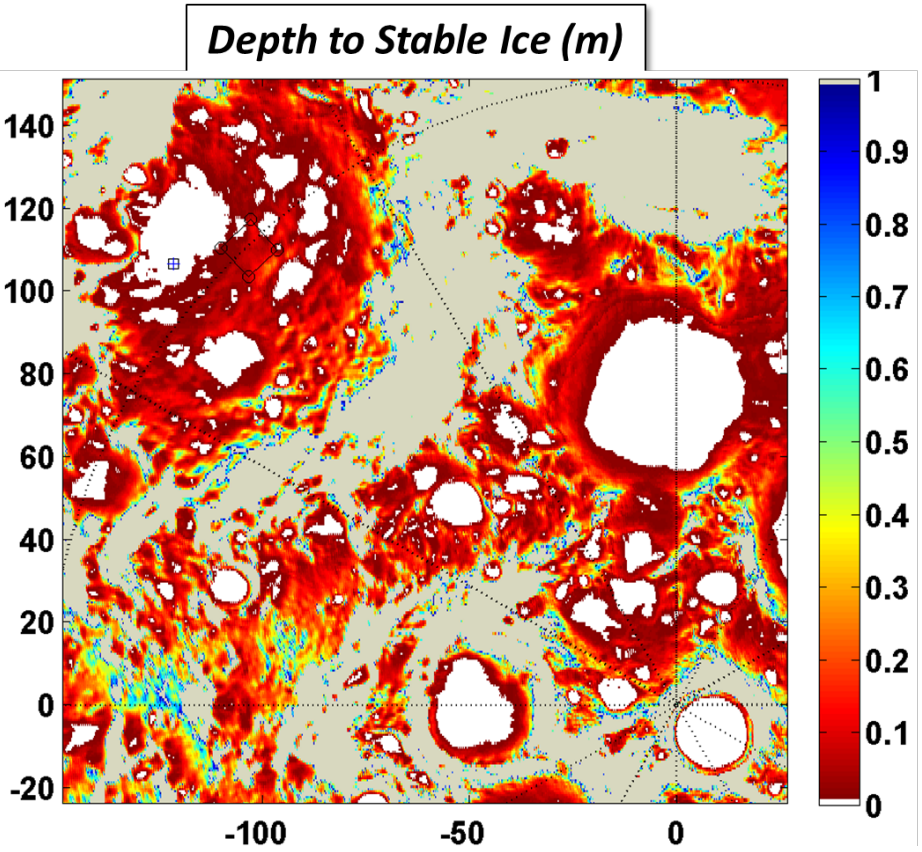
Where to go?
Site Selection Criteria

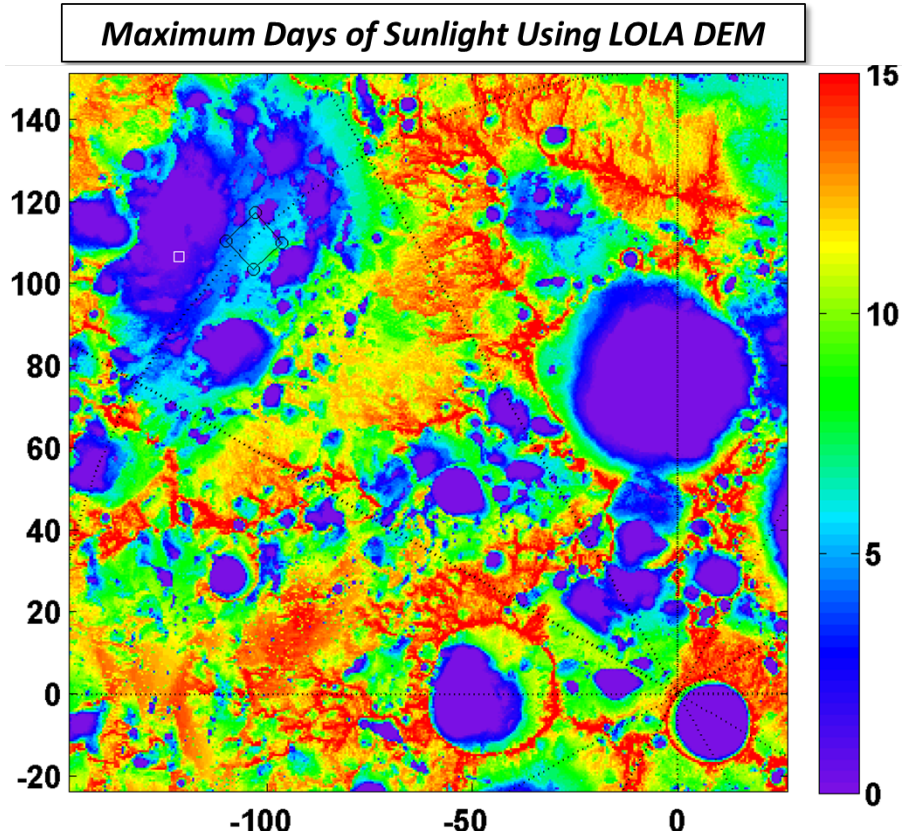
- Likely subsurface volatiles
  - Sustained low subsurface temperatures conducive to volatile retention
  - Orbital neutron spectrometer hydrogen signature
- Sufficient daylight illumination
  - More than 4 Earth days of solar power for rover operations
  - Clement surface temperature for rover survival
- Suitable for Direct to Earth (DTE) communication
  - DSN stations clear the horizon
- Traversable terrain
  - Slopes < 10 deg
  - Limited density of rocks



Resource Prospector – Site Selection

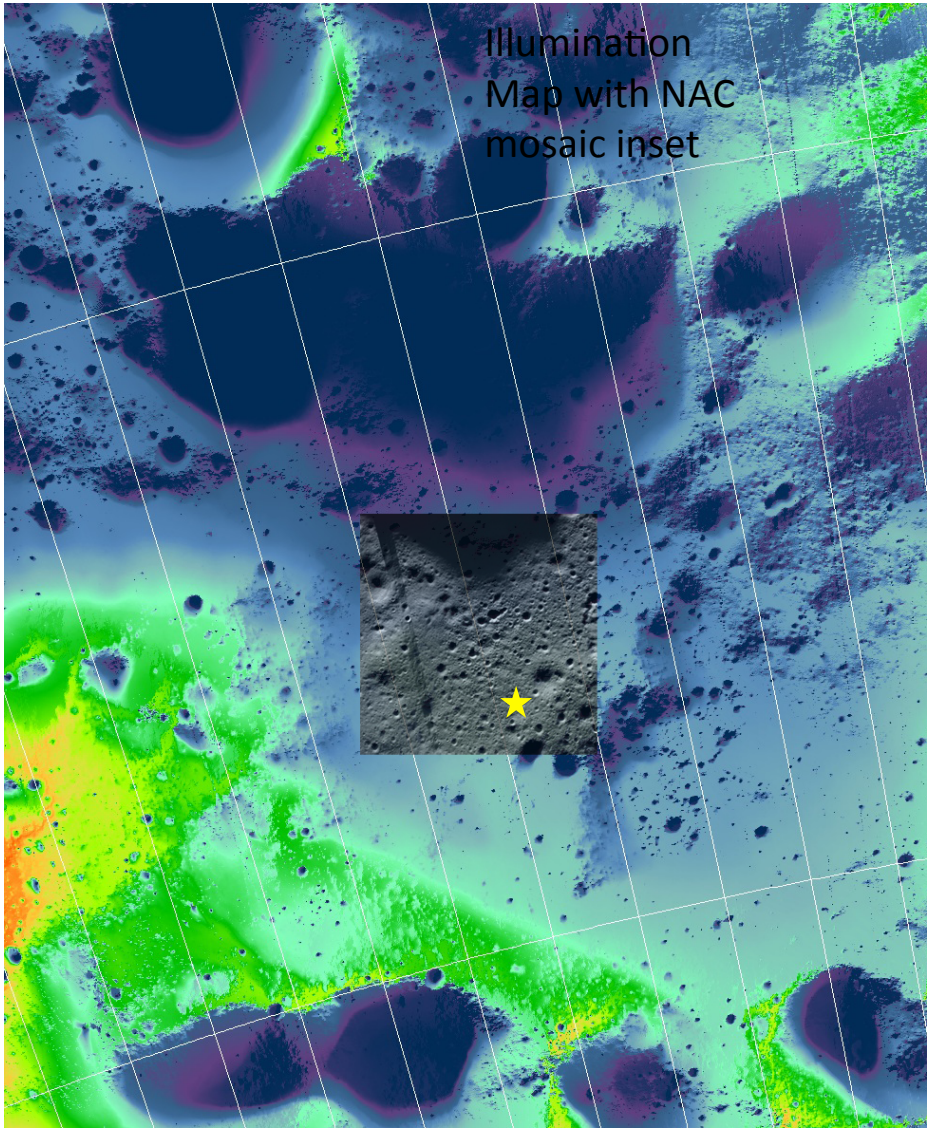
Landing Site analysis looking at near surface temperatures and days of solar illumination





Resource Prospector – Site Analysis Summary

- Have considered three sites in detail
  - Two SP and one NP
- Considered all criteria to the limits of existing data and data products
  - All meet RPM requirements
  - Preliminary hazard analysis for landing completed
- Have provided coordinates to LRO LROC Team to capture additional stereo image pairs
  - NAC stereo DEMs resolution down to ~5 meters
  - Additional site identification continues
- In Phase A and B would conduct site selection workshop to engage community



Resource Prospector – Notional Traverse

Current Travers plans are meant to:

- Validate the mission concept
- Identify areas in which additional stereo NAC imaging would be helpful
- Provide input to Mission systems for planning and design

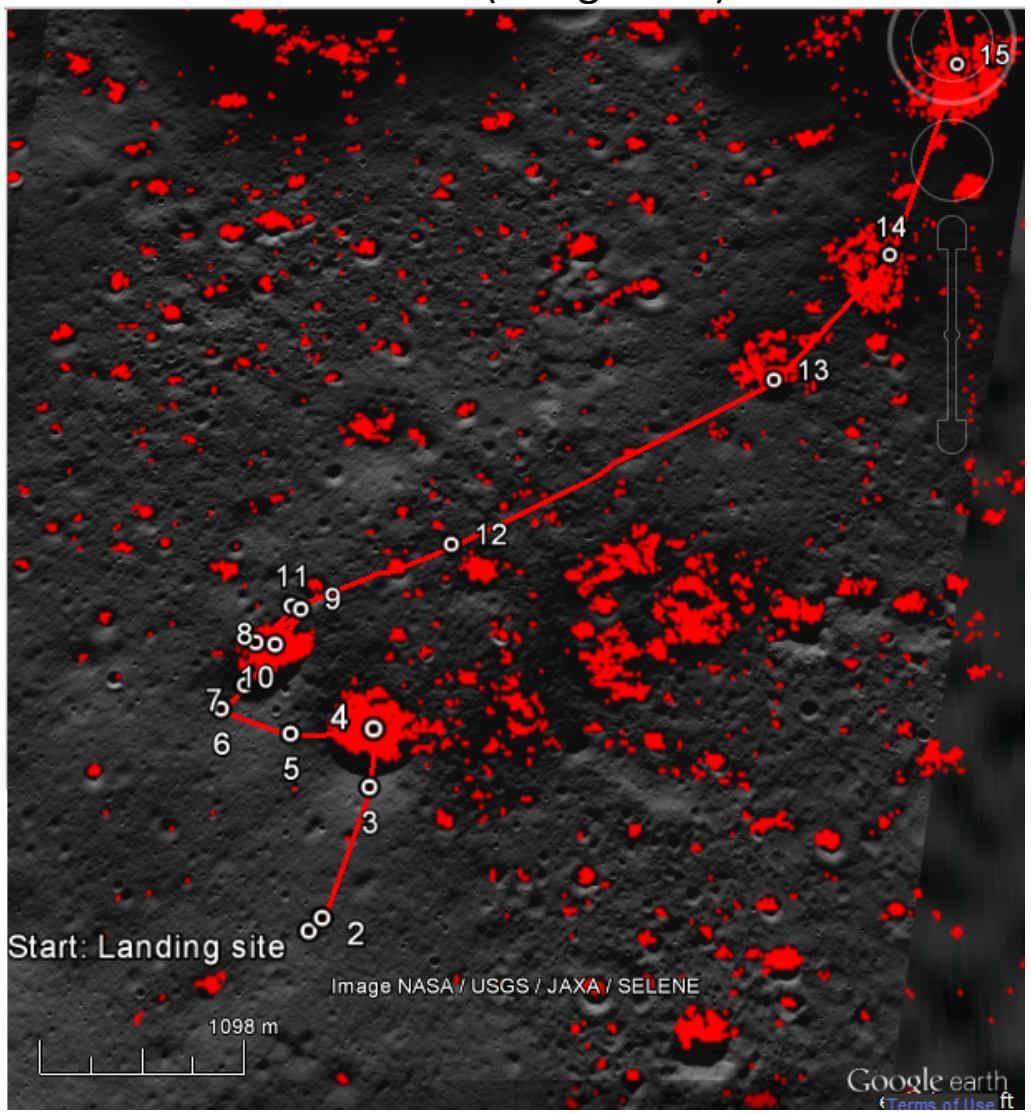
Measurement Team planning study traverse against requirements
Meet mission measurement goals

Activities fed to CONOPS team for mission profiling

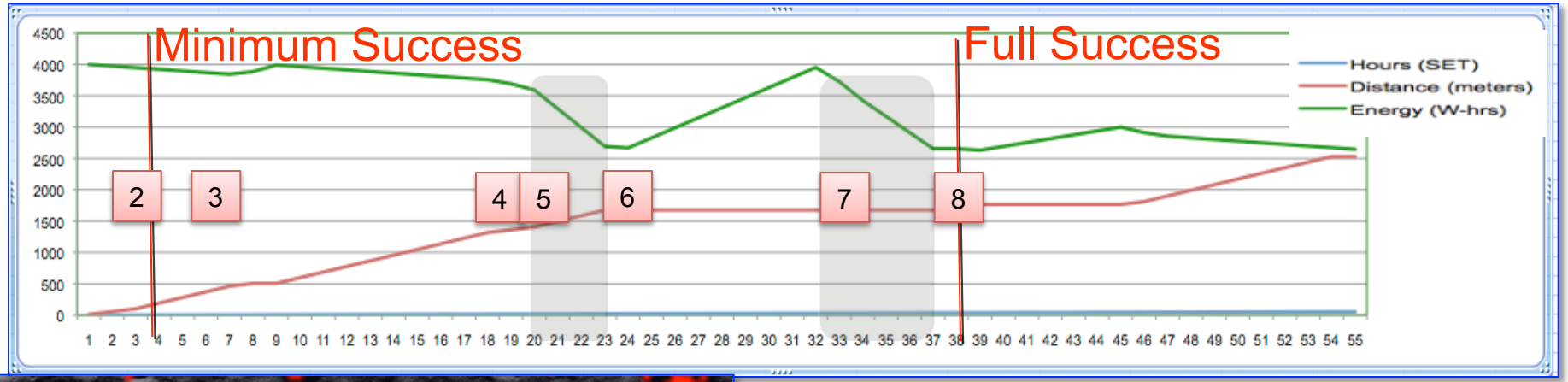
- Time, data, power

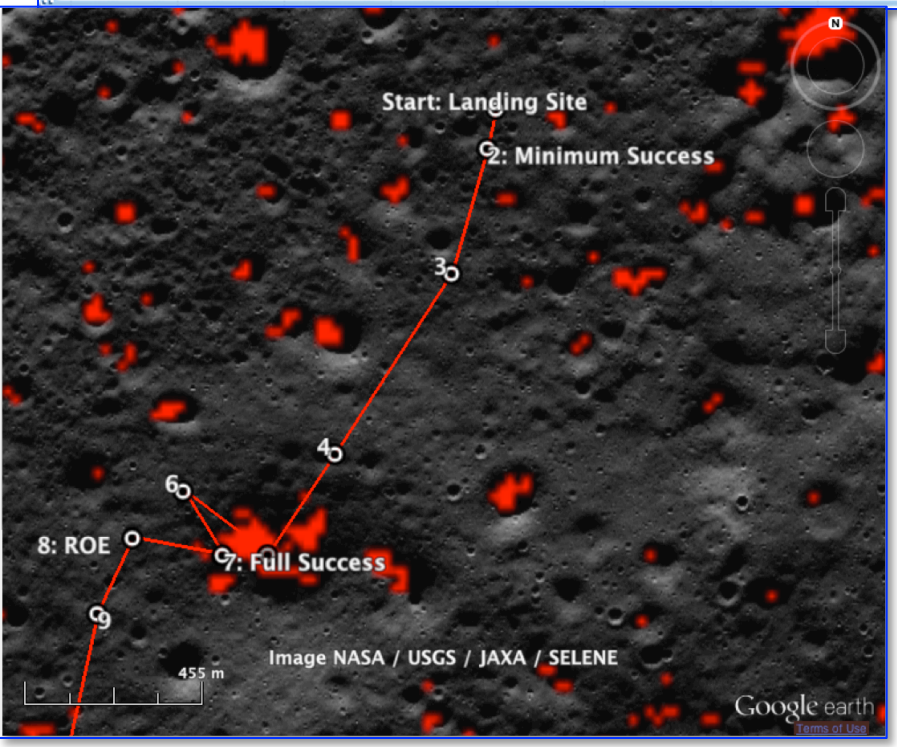
Red areas PSRs (McGovern & Bussey)
Overlaid on LRO LROC NAC

E.g. Traverse at Landing Study Site in NW of Haworth (using xGDS)



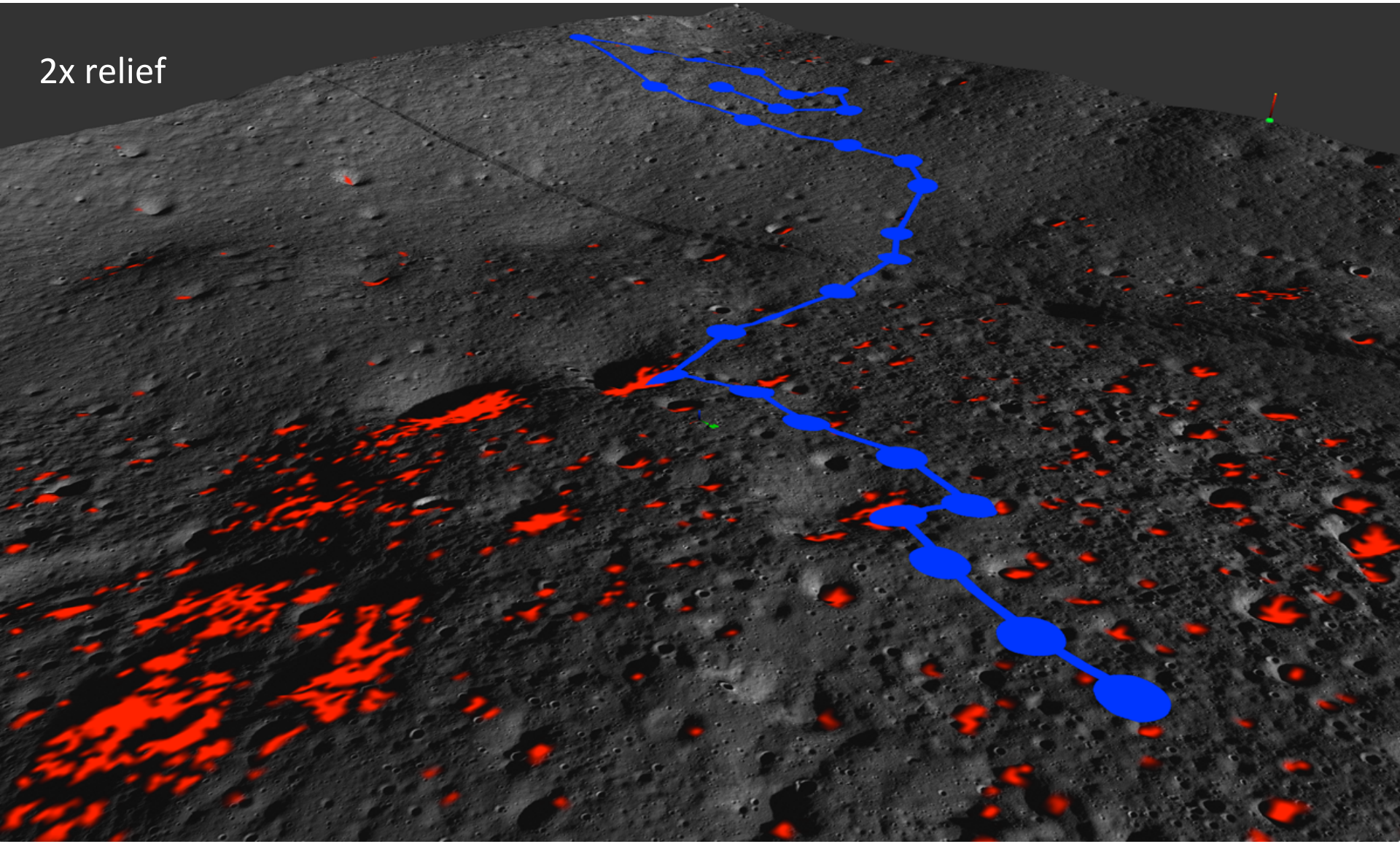
Surface Operations – Nominal Traverse





1. Landing Site & Check Out
2. Minimum Success achieved
3. Auger, Drive-Prospecting
4. Reach PSR, evaluate and checkout
5. Prospecting inside shadowed area
6. Evaluation of shadow data, plan next PSR campaign and recharge battery for next entry
7. Re-enter PSR, do detailed science evaluation, auger, core, samples
8. Depart PSR, do data evaluation, regolith oxygen extraction (ROE) test – Full Mission Success achieved
9. Stretch mission begins

Example Traverse – Perspective View



Paraphrased L2 Requirements

Minimum Success:

- Make measurements from two places separated by at least 100 meters
- Surface or subsurface measurements

Full Success:

- Measurements from two places separated by at least 1000 meters
- Surface and subsurface measurements (auger or core)
- Measurements in and sample acquired from shadowed area
- Demonstrate ROE

Stretch Goals:

- Make subsurface measurements (auger) at least eight (8) locations across 1000 m (point-to-point) distance
- Make subsurface measurements (core and process) at least four (4) locations across 1000 m (point-to-point) distance
- Provide geologic context

Resource Prospector – Summary

- RPM will address a multitude of HEOMD SKGs
- Has a robust payload
- A landing site selection process has been developed and a number of sites shown to meet mission requirements
- Mission traverse planning, tools and process, have been developed and show mission goals can be met
- Completed Mission Concept Review (Sep. 19, 2013); Moving into Phase A with SRR in October, 2014.

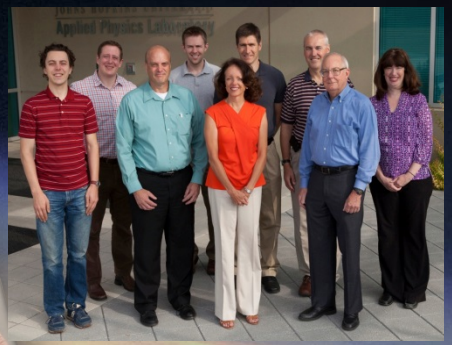
KSC Team

ARC Team

MSFC Team

Thank you,

From the RPM team!



APL Team

CSA Team

JSC Team

GRC Team

JPL Team