National Aeronautics and Space Administration

Resource Prospector Instrumentation for Lunar Volatiles Prospecting, Sample Acquisition and Processing

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What is Resource Prospector?

- Resource Prospector (RP) is a lunar mission that will land at one of the poles and search for volatiles, primarily water
- RP will map out the distribution of hydrogen bearing volatiles, both horizontal and vertical to 1 meter depth
- RP will also extract, handle, and quantify the amount of water ice in the lunar subsurface

SKGs and RP – Address at Least 22 Lunar SKGs

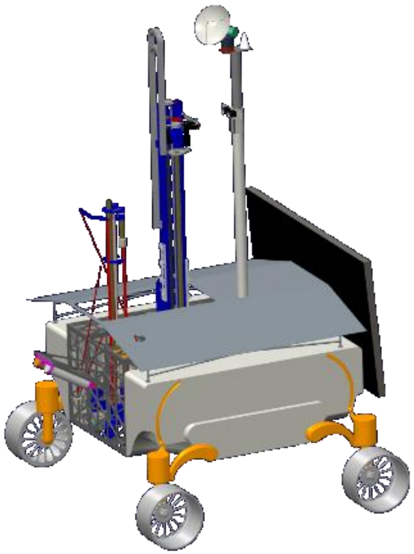
	Lunar Exploration Strategic Knowledge Gaps	Instrument or Activity	RPM Relevance
I. Understand the Lunar Resource Potential			
B-1	Regollith 2: Quality/quanity/distribution/form of H species and other volatiles in mare and highlands	NSS, NIRVSS, OVEN-LAVA	VH
D-3	Geotechnical characteristics of cold traps	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 – 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

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

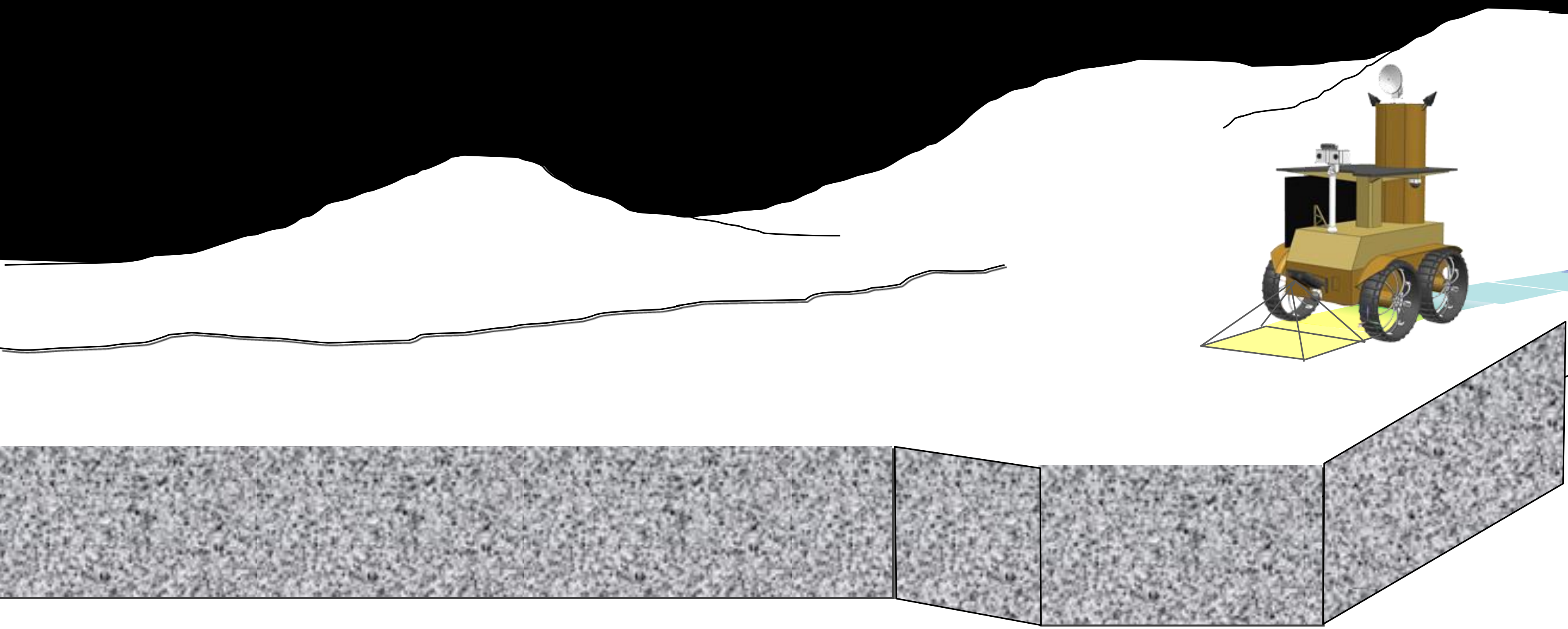
Processing & Analysis

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

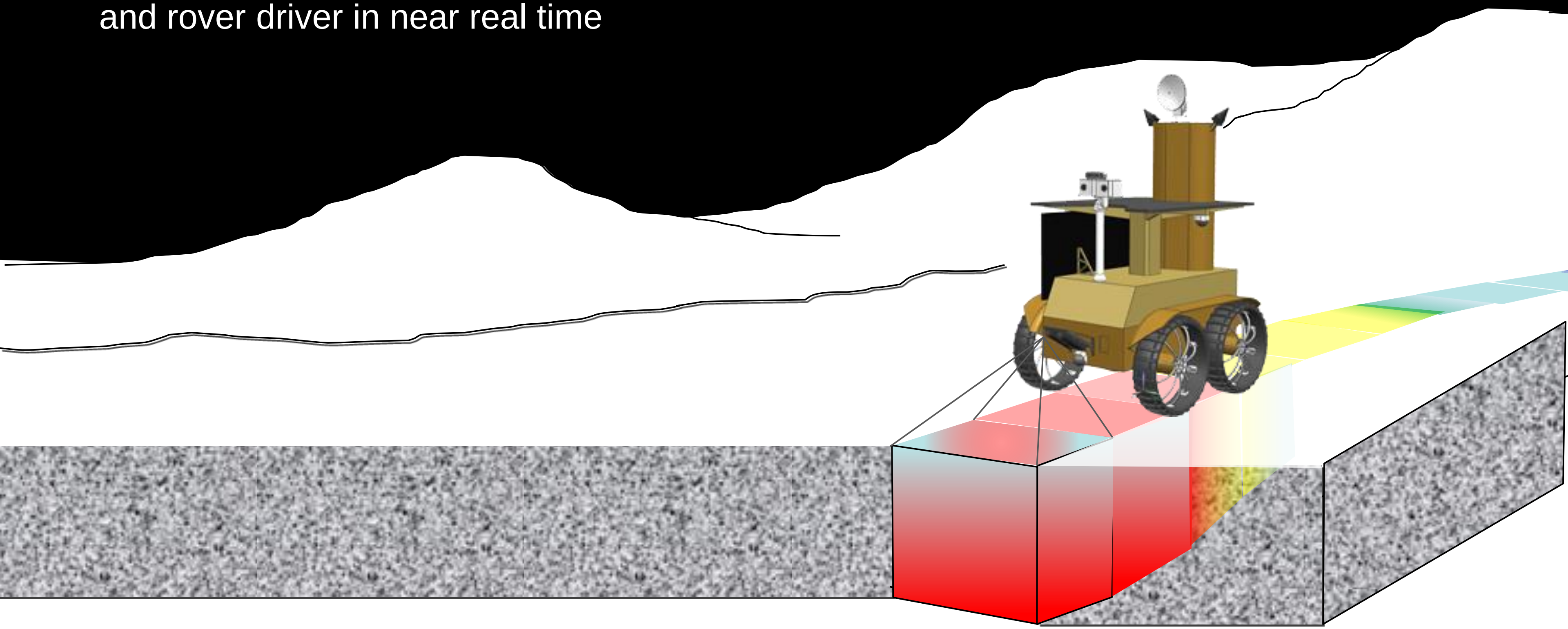
Prospecting… (NASA notional plan)

1. While roving, prospecting instruments (neutron spectrometer and near infrared spectrometer) search for enhanced surface H_2O/OH, other volatiles and volumetric hydrogen



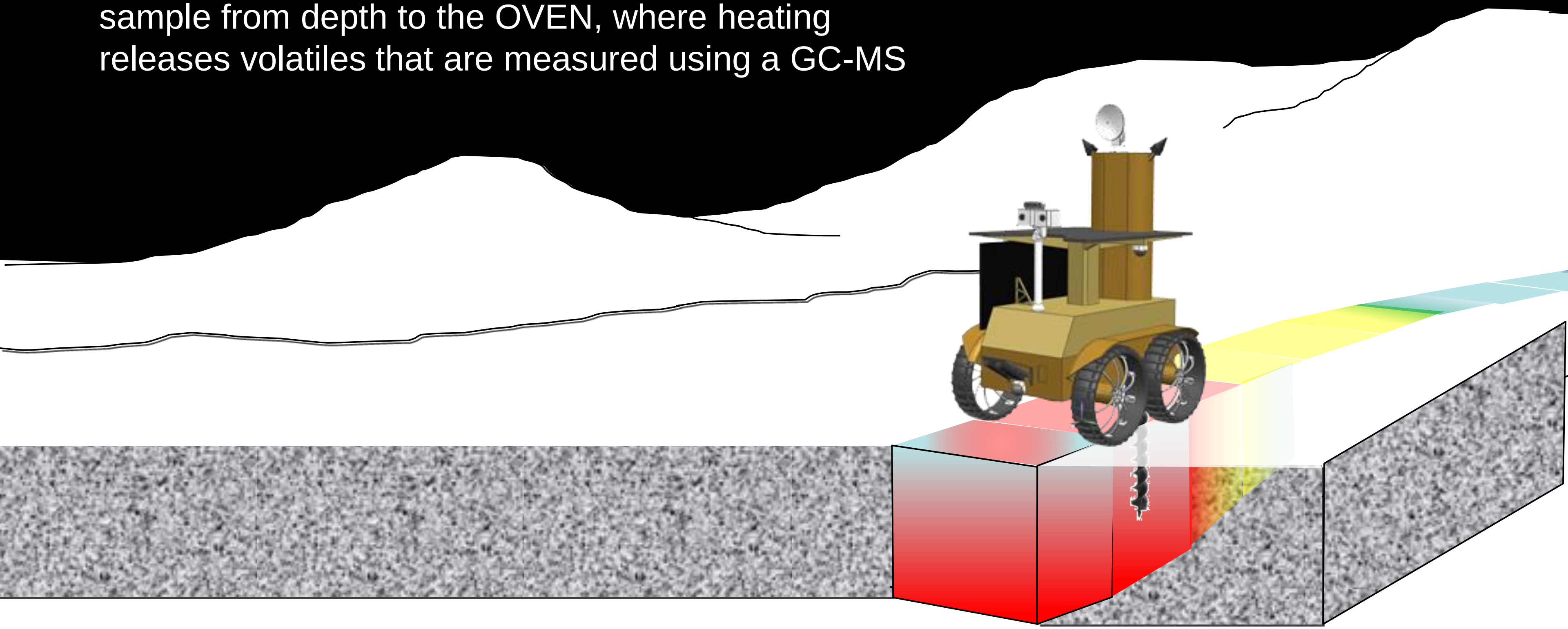
Prospecting… (NASA notional plan)

1. While roving, prospecting instruments search for enhanced surface H_2O/OH and volumetric hydrogen
2. When enhancements are found decision made to either auger or core (sample), this requires coordination between the scientists, instrument leads, and rover driver in near real time



Excavating… (NASA notional plan)

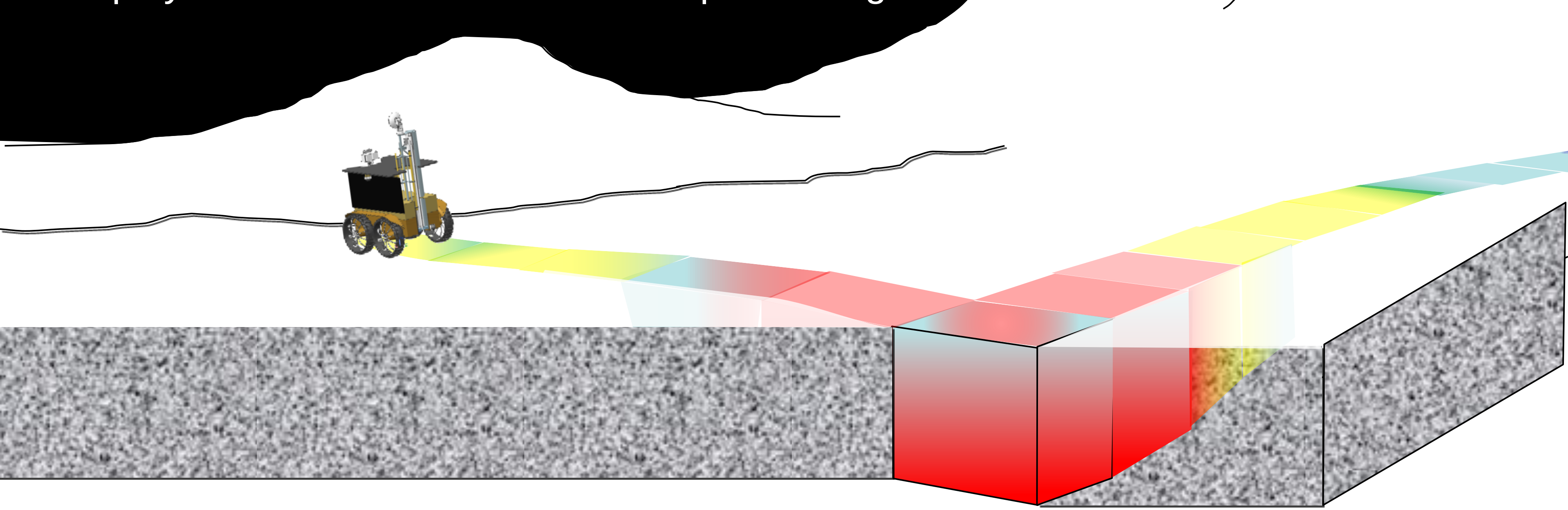
1. While roving, prospecting instruments search for enhanced surface H_2O/OH and volumetric hydrogen
2. When enhancements are found decision made to either auger or core (sample)
3. Samples are processed with the drill delivering regolith sample from depth to the OVEN, where heating releases volatiles that are measured using a GC-MS

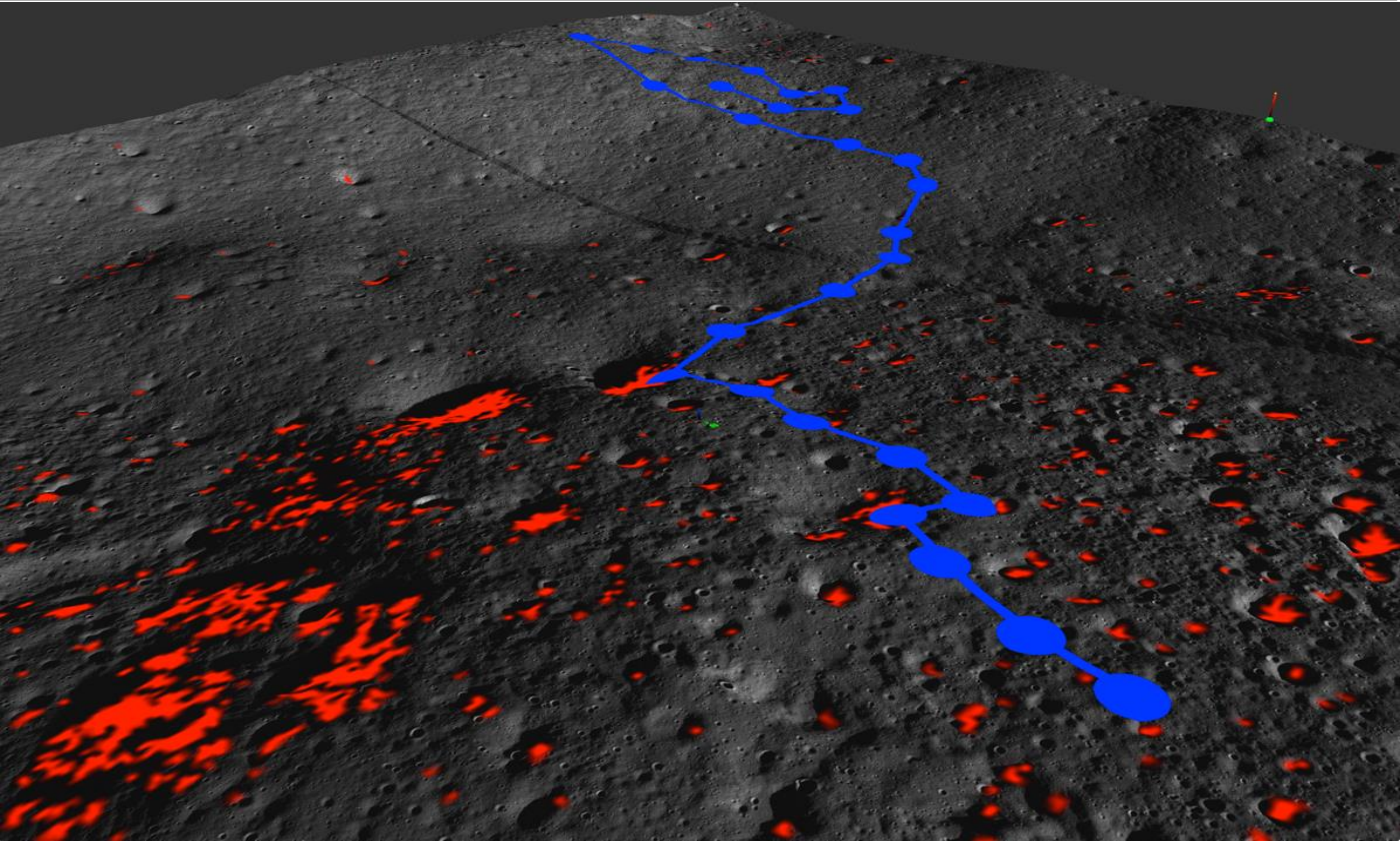


Mapping… (NASA notional plan)

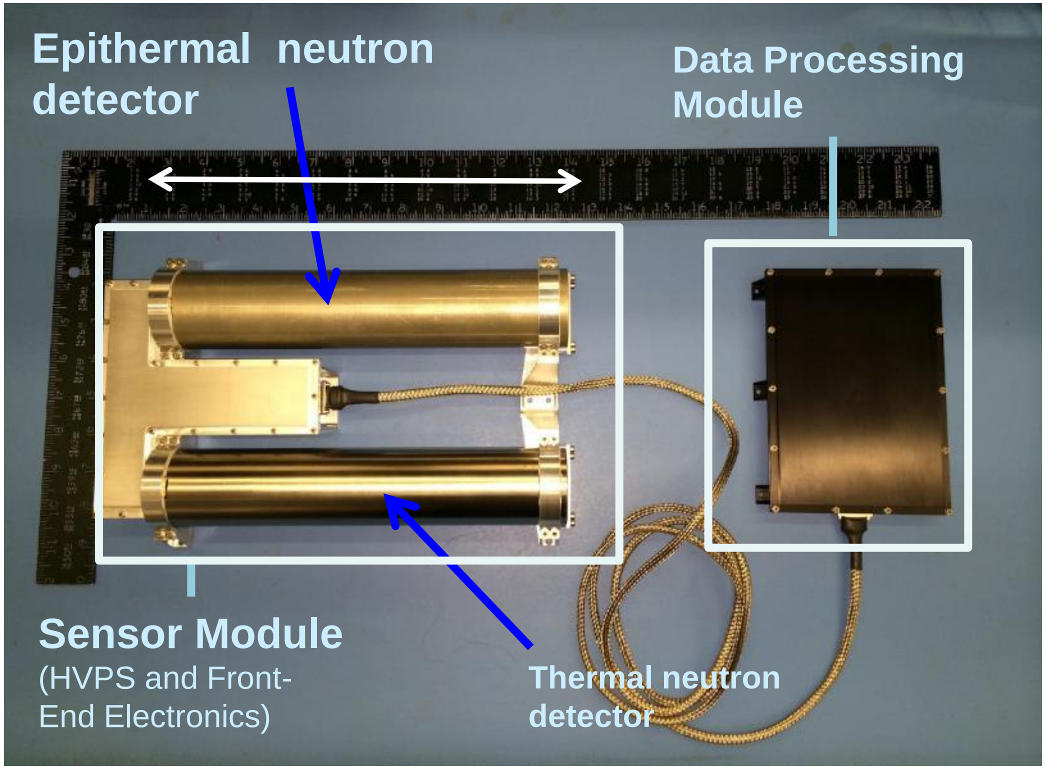
Mapping of volatiles and samples continue across a variety environments, testing theories of emplacement and retention, and constraining economics of extraction.

Coordination of science and mission operations required due to limitations of mission timeline and interplay of instrument data with rover positioning





Neutron Spectrometer Subsystem (NSS)



Instrument Type: Two channel neutron spectrometer.

Key Measurements: NSS assesses hydrogen and bulk composition in the top meter of regolith, with a footprint of 1-2 m

Heritage: Lunar Prospector (detectors); Resource Prospector (instrument)

Sensor Name	Neutron Spectrometer
Source	ARC / Lockheed Martin ATC
Heritage	Lunar Prospector, Resource Prospector
Instrument Type	Neutron Spectrometer
Sensing Element	Two ^{3}He gas proportional counter detectors
Mass [kg]	1.6
Dimensions [cm]	Sensor Module: 21.3 x 32.1 x 6.8 Data Processing Module: 13.9 x 18.0 x 3.0
Power [W], Peak/Avg	1.5/1.5
Range	0 – 511 counts/sec
Sensitivity	Area-efficiency product (@ 1 eV) = 80 cm^2
Accuracy	Absolute: 5-10% Relative: 1-2%
FOV/IFOV	4 pi steradians
Survival Temp Range [˚C]	SM = -40 to 60 DPM = -40 to 60
Operating Temp Range [˚C]	SM = -30 to 40 DPM = -30 to 50
Operating Voltage Range	28 ± 6 VDC
Interface	RS-422
Bits/Sample	712
Bits/Second	712
Samples/Second	1 (mapping)

Near InfraRed Volatile Spectrometer Subsystem

The NIRVSS NIR spectrometer observes the ground underneath the rover at the point where tailings pile from the drill are deposited. It obtains data continuously during roving or drilling activities which are continuously and immediately analyzed to assess the presence of volatiles in surface/sub-surface materials.

Main Components

NIR Spectrometer

- Modified COTS instrument with 2 fiber fed optical engines
- Acquires spectra between 1600-3400 nm with <15 nm resolution
- Identifies key volatiles (solid and gas) while both roving and drilling

IR Emitter (Lamp)

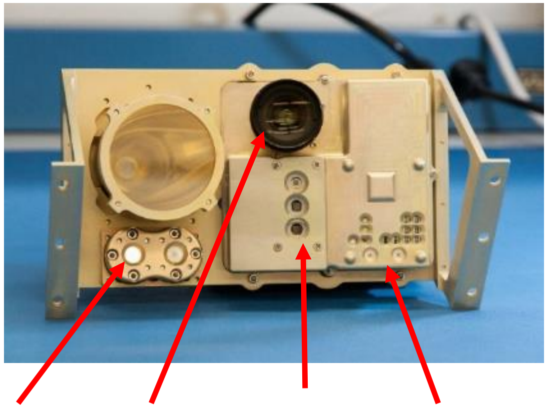
- Enables IR observations while roving and drilling, in lit and unlit terrain

Camera (DOC)

- Acquires images during roving and drilling
- Includes LEDs to illuminate the surface and provide compositional information

Longwave Calibration Sensors (LCS)

- Measures surface temperature.
- Used in determining concentrations of OH/H_2O



Drill

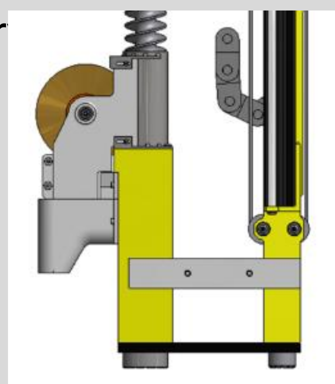
Hammer System

- 150 Watts
- 2 J/blow
- 1646 bpm max
- Max. Cont. Pwr: 153 W
- Integrated in 8 different planetary drill systems

Auger

- Hollow for temperature sensor wires
- Dual stage to enable sampling and auger cuttings to the surface. <25 mm dia

Sample Deliver



1. Brush directly into a cup/oven

Rotary System

- Speed: 209 RPM
- Max. Cont. Torque: 6.57 Nm
- Max. Cont. Pwr: 144 W
- Stall Torque: ~19 Nm

Slipring

- 4 channel
- Can support 1 RTD or 2 Thermocouples

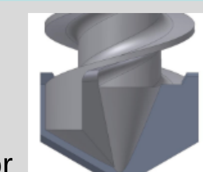
Z-Stage

- Allows 1 m penetration into subsurface
- Pulley based (dust tolerant, attenuates vibe)
- 1 m stroke (need ~1.1 m to clear auger tube)
- Max force: 523 N (any direction)
- Max linear speed: 21.3 mm/s
- Max cont. Power: 11.1 W

Deployment Stage

- Deploys and preloads drill against ground
- Pulley based
- 40 cm stroke (function of rover ground clearance)
- Max force: 523 N (any direction)
- Max linear speed: 21.3 mm/s
- Max cont. Power: 11.1 W

Bit



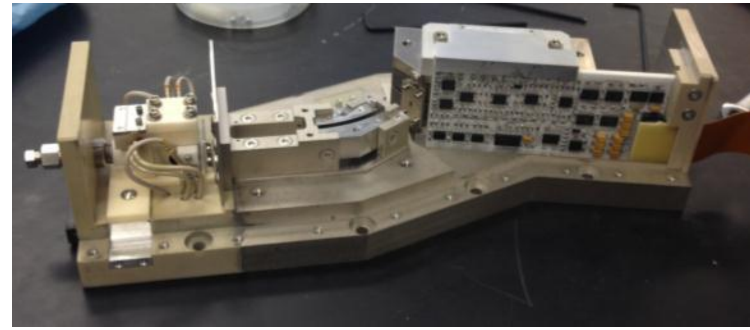
- Tungsten Carbide
- Potentially serrated blade
- Embedded temperature sensor

Oxygen and Volatile Extraction Node (OVEN)

- Accepts 12 cc of regolith from Drill
- Weighs the sample
- Seals sample in reactor
- Heats the sample to 150C, 350C, 450C
- Transfer gases evolved to LAVA
- Discards sample for crucible reuse
- Mass: ~12.5 kg
- Power: >50W steady state

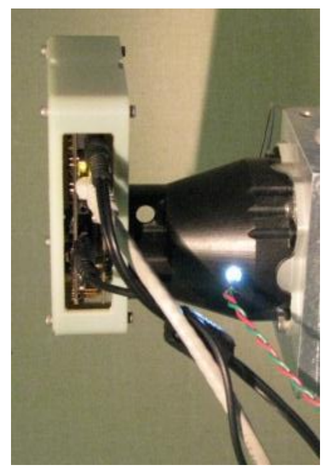
Lunar Advanced Volatile Analysis (LAVA)

- LAVA consist of a heated Fluid Subsystem, a Gas Chromatograph-Mass Spectrometer, Gas Supply System and a Water Droplet Demo

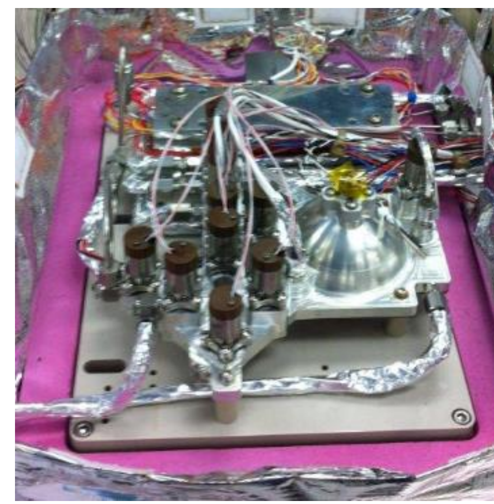


Mass Spectrometer with cover removed

- Gases evolved by OVEN from regolith samples will be identified and quantified by LAVA
  - Gases of interest are H_2O, CO, CO_2, H_2, H_2S, NH_3, SO_2, CH_4, C_2H_4
- Water that is evolved will be condensed and photographed



WDD



FSS Manifold

RP15 Field Test

- Payload (minus Drill and NSS) was integrated onto a Ground Interface Structure at KSC
  - Fully checked out and shipped on structure
- Accurate interface control
- Prefabrication of harnesses
- System characterization
- Physical integration practice
  - Hand access
  - Tool access and rotation
  - Etc.

Some Key Benefits of RP15

- Interfaces
  - Developed ICDs between all Payload subsystems and the Rover
  - Working across multiple NASA centers and contractors
- Process development
  - Utilized Work Order Authorizations and more formal Test Plans and Procedures for all I&T activities
- Mission simulations with a fully distributed team
  - Realistic simulations with a full Ground Data System, voice loop communications, and flight-like procedures and operations
- Operational practice
  - Better understanding of all the Payload subsystem interplay
  - Better understanding of the Rover-Payload interplay, especially during prospecting

Future Work

- Technology Development for instrumentation
  - Thermal vacuum testing
  - Vibration testing
  - Protoflight development plan
- Several trades ongoing
- International partnerships discussions ongoing
- Team is working towards SRR