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

## I. Understand the Lunar Resource Potential

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<th>Instrument or Activity</th>
<th>Relevance</th>
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## III. Understand how to work and live on the lunar surface

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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 $\text{H}_2\text{O}/\text{OH}$, other volatiles and volumetric hydrogen.
Prospecting… (NASA notional plan)

1. While roving, prospecting instruments search for enhanced surface H$_2$O/OH and volumetric hydrogen.
2. When enhancements are found, a decision is made to either auger or core (sample), which requires coordination between the scientists, instrument leads, and rover driver in near real time.
1. While roving, prospecting instruments search for enhanced surface H$_2$O/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 of 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)

**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)

**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)
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/subsurface 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/H2O
**Drill**

**Hammer System**
- 150 Watts
- 2 J/blow
- 1646 bpm max
- 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

**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

**Sample Delivery**
1. Brush directly into a cup/oven

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

- Gases evolved by OVEN from regolith samples will be identified and quantified by LAVA
  - Gases of interest are H$_2$O, CO, CO$_2$, H$_2$, H$_2$S, NH$_3$, SO$_2$, CH$_4$, C$_2$H$_4$

- Water that is evolved will be condensed and photographed
**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