Resource Prospector: Mission Goals, Relevance and Site Selection A. Colaprete[1], R. C. Elphic[1], D. Andrews[1], G. Sanders[2], A. McGovern[3], R. Vaughan[1], J. Heldmann[1], J. Trimble[1], [1]NASA Ames Research Center, Moffett Field, CA, [2]NASA Johnson Space Center, Houston, TX, [3]JHU/APL, Laurel, MD

Introduction: Over the last two decades a wealth of new observations of the moon have demonstrated a lunar water system dramatically more complex and rich than was deduced following the Apollo era. Observation from the Lunar Prospector Neutron Spectrometer (LPNS) revealed enhancements of hydrogen near the lunar poles. This observation has since been confirmed by the Lunar Reconnaissance Orbiter (LRO) Lunar Exploration Neutron Detector (LEND) instrument. The Lunar Crater Observation and Sensing Satellite (LCROSS) mission targeted a permanently shadowed, enhanced hydrogen location within the crater Cabeus. The LCROSS impact showed that at least some of the hydrogen enhancement is in the form of water ice and molecular hydrogen (H_2). Other volatiles were also observed in the LCROSS impact cloud, including CO_2, CO, an H_2S. These volatiles, and in particular water, have the potential to be a valuable or enabling resource for future exploration. In large part due to these new findings, the NASA Human Exploration and Operations Mission Directorate (HEOMD) have selected a lunar volatiles prospecting mission for a concept study and potential flight in CY2020. The mission includes a rover-borne payload that (1) can locate surface and near-subsurface volatiles, (2) excavate and analyze samples of the volatile-bearing regolith (up to 1 meter), and (3) demonstrate the form, extractability and usefulness of the materials.

Relevance and Goals: While it is now understood that lunar water and other volatiles have a much greater extent of distribution, possible forms, and concentrations than previously believed, to fully understand how viable these volatiles are as a resource, the distribution and form needs to be understood at a "human" scale. That is, the "ore body" must be better understood at the scales it would be worked before it can be evaluated as a potential architectural element within any evolvable lunar or Mars campaign. This next step in our evaluation of lunar resources has been captured as a list of Strategic Knowledge Gaps (SKGs). RP is meant to address several key Strategic Knowledge Gaps (Table 1) and provide the next step in evaluating the distribution and form of polar volatiles at scales that may be critical to robotic/human exploration (10s to 1000s of meters). RP's Level 2 mission requirements (paraphrased) are shown in Table 2.

Real-time Prospecting and Combined Instrument Measurements: Temperature models and orbital data suggest near surface volatile concentrations may exist at briefly lit lunar polar locations outside persistently shadowed regions. The Resource Prospector surface segment will be remotely operated at one of these locations based on lighting conditions and terrain navicability at relatively low cost.

Table 1 – Summary of key SKGs that RP will address

	Lunar Exploration Strategic Knowledge Gaps		Instrument or Activity	RP Relevance
I. Understand the Lunar Resource Potential				
	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 LM-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-LAVA, 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	
	F-4	Power Generation - Polar missions	Rover	M

Table 2 – Paraphrased Level 2 Measurement Requirements

Minimum Success:

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

Full Success (shalls):

- Measurements from two places separated by at least 1000 meters
- Surface and subsurface measurements
- Measurements in and sample acquired from shadowed area
- Demonstrate ISRU

Stretch Goals (shoulds):

- Make subsurface measurements in at least eight (8) locations across 1000 m (point-to-point) distance
- Process and analyze subsurface material in at least four (4) locations across 1000 m (point-to-point) distance
- Provide geologic and thermal context

Given the solar illumination and terrain environments in which this lunar mission is being designed, prospecting for sites of interest needs to occur in near real-time. The two instruments which are being used for prospecting are the Neutron Spectrometer System (NSS) and the NIR Volatile Spectrometer System (NIRVSS). NSS will sense hydrogen at concentrations as low as 0.5 wt% to a depth of approximately 80-100 cm. It is the principle instrument for identifying buried hydrogen-bearing materials. NIRVSS, which includes its own calibrated light source, radiometer (for thermal correction) and context camera, will look at surface reflectance for signatures of bound H_2O/OH and general mineralogy. Once an area of interest is identified by the prospecting instruments the option to map the area in more detail (an Area of Interest activity) and/or subsurface extraction via drilling is considered. The RP drill is an auger which can sample from discrete depths using "biting" flutes, deep flutes with shallow pitch which hold material as the drill is extracted. As the drill is extracted a brush deposits cuttings from the biting flutes to the surface in view of NIRVSS for a "quick assay" of the materials for water or volatiles. If this quick assay shows indications of water or other volatiles, a regolith sample may be identified and extracted for processing. Processing of the sample is performed by the Oxygen and Volatile Extraction Node (OVEN). OVEN will initially heat the sample to 150ºC, pause, and then continue to 450ºC. Any gases evolved from the sample are analyzed by the Lunar Advanced Volatile Analysis (LAVA) system which includes a Gas Chromatograph / Mass Spectrometer system.

Site Selection: A critical facet of the RP mission design is the selection of a landing site that meets several criteria:

1. Evidence of Surface/Subsurface Volatiles
2. Reasonable terrain for traverse
3. Direct view to Earth for communication
4. Sunlight for duration of mission for power

In addition to these four criteria, the overlap of all four must persist for a sufficient amount of time for the mission to accomplish its mission goals. The RP Site Analysis Team has evaluated several example "study sites" to determine if these four criteria can be met for the necessary periods of time. In a number of cases a "baseline" mission (up to 14 days) is evaluated, as well as an "extended" mission possibility in which the rover follows corridors of surface illumination to extend its mission life. In these study cases notional mission operation traverse timelines have been applied to evaluate the feasibility of these sites to meeting mission goals.

This talk will provide an overview of the RP mission goals, relevance to HEOMD goals, and review site analysis and traverse planning.

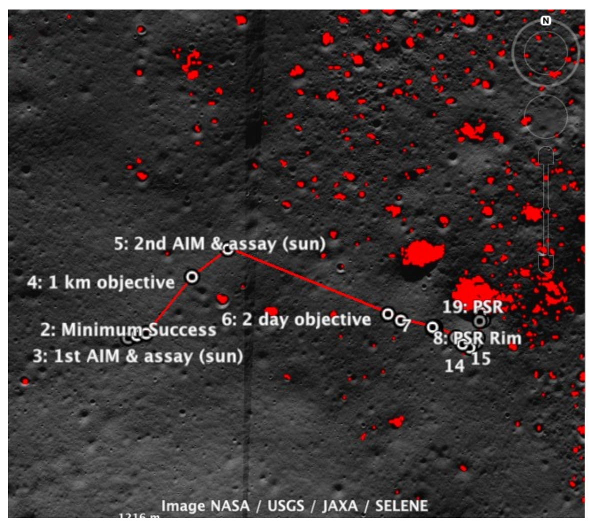

Figure 1. Example of a notional traverse plan evaluated for a study site north-west of the crater Haworth. Background is a LRO NAC image with the red areas being identified Permanently Shadowed Craters. Some of the key activities and mission accomplishments are called out.