Lunar Polar Volatile Strategy – Resource Prospector Mission and Beyond

Gerald B. Sanders[1], Anthony Colaprete[2], Jacqueline Quinn[3]

[1]NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX,
[2]NASA Ames Research Center, Moffett Field, CA
[3]NASA Kennedy Space Center, FL

From previous human and robotic lunar missions, especially the recent Lunar Crater Observation and Sensing Satellite (LCROSS) impactor and the on-going Lunar Reconnaissance Orbiter (LRO), we know water and hydrogen bearing compounds exist on the Moon. Measurements of the plume from the LCROSS impactor showed that significant amounts of volatiles may be present in permanently shadowed craters (15% or more by mass) at the lunar poles. Temperature models and orbital data also suggests that near surface volatile concentrations may exist at briefly lit lunar polar locations outside of persistently shadowed regions. Understanding the location, form, concentration, and distribution (spatially and subsurface) of lunar polar volatiles is important for both science and exploration. From a science perspective these volatiles provide important clues for both the evolution and history of the Moon and the solar system. From an exploration perspective, these volatiles may be important resources for propulsion, power, and life support systems to enhance or enable the human exploration of the Moon and beyond.

While past and on-going missions have provided evidence that water and other volatiles exist at and/or near the surface of the Moon, a lot more information is required before future missions will consider polar volatiles as a resource. Before these volatiles can be utilized in future human exploration and space commercialization efforts, four driving questions must be answered:

1. Where are the polar volatiles located? (Site Selection)
2. What is the form and distribution of polar volatile resources? (Prospecting)
3. Are long-term operations at the lunar poles feasible? (Mining Feasibility)
4. Is extraction of polar resources 'economical'? (Site Selection, Prospecting, and Mining Feasibility)

In 2011, the Lunar Exploration Analysis Group (LEAG) Robotic Campaign Analysis provided a list of mission goals for prospecting these resources for future exploration architectures. The mission goals were: i) Defining the composition, form, and extent of the resource; ii) Characterizing the environment in which the resources are found; iii) Defining the accessibility/extractability of the resources; iv) Quantifying the geotechnical properties of the lunar regolith in the areas where resources are found; v) Being able to traverse several kilometers and sample and determine lateral and vertical distribution on meter scales; and vi) Identifying resource-rich sites for targeting future missions. Since then, NASA and international space agencies involved in the International Space Exploration Coordination Group (ISECG) have also developed a list of Strategic Knowledge Gaps (SKGs) that need to be addressed and answered before long duration human exploration beyond Earth's orbit is possible.

To begin to address the first two driving questions associated with using polar volatiles in future missions, the NASA Advanced Exploration Systems (AES) Program, within the Human Exploration and Operations Mission Directorate (HEOMD), is spearheading a multi-center development effort aimed at flying a robotic precursor mission to the Moon called the Resource Prospector Mission (RPM). The mission's purpose is to 1) validate theories associated with polar volatile location and subsurface distribution through a comprehensive site selection process, and 2) explore the distribution and concentration of lunar volatiles for exploration and science, and demonstrate In-Situ Resource Utilization (ISRU). While RPM is aimed at addressing LEAG mission goals and NASA/ISECG SKGs for lunar polar volatile prospecting, to keep costs to a minimum, the Resource Prospector mission only has two Level 1 mission requirements: 1.1 RPM shall land at a lunar polar region to enable prospecting for volatiles, and 1.2 PRM shall be capable of obtaining knowledge about the lunar surface and subsurface volatiles and materials.

For the first mission purpose, NASA with external lunar science experts has initiated a site selection processes that considers both the near-term objective to minimize RPM cost as well as the long-term objective of mining and using polar volatiles if they can be 'economically' extracted. To meet both near-term prospecting and long-term mining objectives, the NASA site selection process includes the following 5 selection criteria:

1. Surface/subsurface volatiles are present
2. Reasonable terrain for landing and traversing

3. Direct view to Earth for communications
4. Sunlight for duration of mission for power generation
5. Hospitable environment/lighting nearby for mining and logistics infrastructure (may be excluded in RPM)

For the second mission purposes, RPM includes a solar-powered rover and science/resource prospecting payload called RESOLVE (Regolith and Environment Science and Oxygen & Lunar Volatile Extraction). While the minimum and full success criteria for the RPM are very broad, the RESOLVE payload currently provides a suite of instruments to address the much more detailed objectives of the NASA/ISECG SKGs. To help map and locate potential water/ice and hydrogen-bearing compounds, RESOLVE incorporates two analytical instruments: a neutron and a near infrared (NIR) spectrometer. The neutron spectrometer will be used to sense hydrogen down to concentrations as low as 0.5 wt.% to a depth of approximately 80 cm. The NIR spectrometer, which includes its own light source, will look at surface reflectance for signatures of bound H_2O/OH and general mineralogy, and can be used in concert with a camera and drilling auger. Once an area of interest is identified by the neutron and/or NIR spectrometers, the option to capture drill cuttings is considered. The auger drill can excavate samples to a depth of 100 cm. Captured samples are analyzed for volatile content using an oven to heat the sample and a gas chromatograph/mass spectrometer/NIR spectrometer system to determine composition and amount. An ISRU demonstration of hydrogen reduction is also planned, which has the ability to extract oxygen from iron oxide in the lunar regolith to produce water. Because RPM will utilize a solar-powered rover, the mission duration of only 4 to 15 days will be possible for lunar polar sites of interest. Within this mission duration, the goal of RPM is to traverse 1 to 3 km and perform subsurface sample evaluation at 4 to 8 locations.

This presentation will discuss a strategy for addressing the four driving questions that must be answered before polar volatiles can be utilized in future missions, the potential role of NASA's Resource Prospector mission in this strategy, and possible next steps in the utilization and commercialization of lunar volatile resources. The presentation is also aimed at obtaining input from the ISRU/mining community on the proposed polar volatile resource strategy and the Resource Prospector mission requirements, objectives, and RESOLVE instrument suite.