Brief Report
on
ISECG Lunar Polar Volatiles Virtual Workshop#2: Where to Explore, and How

On January 20, 2016 the ISECG held its second virtual workshop on exploring and using lunar polar volatiles. The workshop focused on understanding if there are preferred locations at the lunar poles (e.g., Regions of Interest) for exploration of lunar polar volatiles, and how near-term robotic missions are being planned to operate at the poles. Approximately 70 participants from various countries met online for a 2-hour session, representing not only space agencies, but industry and academia as well. The participants included planetary scientists, students, engineers, mining professionals, and other space professionals. NASA/Nantel Suzuki moderated presentations by seven expert panelists and addressed questions from attendees, while others participated simultaneously by exchanging text comments in an associated chat forum. All the presentation materials and a recording of the event were posted to the ISECG volatiles website (http://lunarvolatiles.nasa.gov).

Overarching questions:

1. Based on current knowledge, what are the most promising Regions of Interest for lunar polar volatile resource prospecting?

2. Given the unique polar environment (e.g. extreme temperatures; dynamic, low-angle sunlight and shadows; limited line-of-sight earth-communications, uncertain soil mechanics), how can lunar exploration systems and instrumentation be used to prospect, characterize, acquire, process, and utilize polar volatiles?

Panelists:

Dr. Angel Abbud-Madrid (Colorado School of Mines, USA) - President, Space Resources Roundtable
Mr. Dale Boucher (Deltian Innovations Ltd., Canada)
Dr. Tony Colaprete (NASA Ames Research Center, USA)
Dr. Jessica Flahaut (University of Lyon, France) - member, ESA Topical team on Exploitation of Local Planetary Materials
Ms. Myriam Lemelin (University of Hawaii, USA) - member, LEAG Polar Volatiles Special Action Team
Dr. Makiko Ohtake (JAXA/Institute of Space and Astronautical Science, Japan)
Dr. David Wettergreen (Carnegie Mellon University, USA)

Findings:

1. Three broad regions of interest (ROI) at the lunar poles have been identified based on a multi-parameter analysis. These include the Cabeus crater region; a region near Shoemaker, Faustini, and Nobile craters near the South Pole; and the Peary crater region near the North Pole. These ROI were identified based on

hydrogen abundance (>150 ppm), average annual temperature (<110 K), moderate topography (< 10° slopes), and solar illumination (landing/traverse locations outside of permanently shadowed craters). Complementary data that further defined the ROI included: direct-to-earth visibility for communications, percentage of solar illumination, and proximity to permanently shadowed regions (PSR). The Peary crater region has the best average earth visibility and solar illumination of the three ROI.

If the parameter space is enlarged (i.e., 100-150 ppm H, relaxing illumination or direct-to-earth and constraints), the identified ROI mostly remain the same, but the area within the ROIs and the number of potential landing sites increase. Additional ROIs that have been identified with this enlarged parameter space include: Amundsen crater, and plains west of de Gerlache crater near the South Pole, and the Plaskett/Rozodestvenskiy region near the north pole.

In addition to the polar volatile deposits, ROI at both poles contain interesting geological units that differ from those sampled by the Apollo and Luna programs, including geologically young surface units, and pure anorthosite (PAN) deposits that may be part of the original lunar crust. The ROI near the south pole may also contain South Pole-Aitken basin ejecta materials and impact melt.

2. In the prospecting phase, determining the 'grade' (quality) and 'tonnage' (quantity) is critical to understanding the potential feasibility and valuation of any polar volatile deposit. However, not all explored deposits will prove practical. In terrestrial mining of sulfide ore bodies (e.g. platinum, nickel), about 50% of prospected deposits transition to full-scale production. In the exploration for oil and gas, this number is more like 30%. Also, to understand the economic value of a deposit, the formation process of that deposit and the resulting 'geometry' of the deposit need to be understood. Drilling patterns for terrestrial mining of sulfide ore bodies to determine this geometry typically involve 50 meter spacing between drill locations.

3. Though our current understanding of the location of lunar polar volatile deposits is at the tens of kilometers scale, we don't understand where the polar volatiles come from or where they are going. Also, the location of polar volatile deposits on the Moon is not as well correlated with temperature and shadow as it is on Mercury. There is a lot of variability at all range of scales, and it is most important to understand the deposits at the robotic rover or human scale (meters to tens of meters to kilometers). To do this we need to get to the lunar surface.

Impact gardening is important to the distribution of water ice and other polar volatiles at the scale of a few meters, and to understand the resource potential of the polar volatiles on the moon, we need to understand how they are mixed laterally as well as with depth.

Solar-powered robotic missions to the polar regions of the Moon cannot be actively teleoperated (i.e., no 'joy-sticking') due to the constantly changing solar illumination and direct-to-earth communications. However, real-time monitoring of the missions will be required. These missions will be unlike any rover missions on Mars, as the rovers will need to utilize autonomous traverse planning.

The technologies needed to conduct long-distance, solar-powered robotic traverses at the lunar poles exist today. An example of this are the robotic rovers developed by Carnegie Mellon University that have explored the Atacama Desert in South America, investigating the presence of microorganisms, while using autonomously developed traverse paths, drill deployments, and sample collection.

Lunar solar-powered missions can be designed that last 3-4 months, using a moderate average speed of 1 cm/sec. These types of traverse missions typically include dwell times at sunlit locations lasting 15-20 earth days.

Candidate next steps that could improve the efficiency of lunar polar volatiles exploration include: hydrogen maps at 5 km per pixel spatial resolution; improved digital terrain models (DTMs) at the scale of a robotic rover mission; nuclear power units such as the advanced sterling radioisotope generator (ASRG) being developed by NASA; deep PSR access; and communication relays.