Regional Prospecting of Lunar Polar Water Resources Using the Polar Volatile Mapper Mission

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Introduction: Reliable identification of accessible water resources in lunar permanently shadowed regions (PSRs) is a critical prerequisite for deploying in-situ resource utilization (ISRU) systems that support sustained Artemis and commercial lunar operations. Water ice deposits can support life-support systems, oxygen production, and propellant generation, making them a key component of the exploration architecture being developed under NASA's Artemis program. However, a major challenge for deploying ISRU systems on the Moon is the lack of reliable regional-scale information describing the distribution, concentration, and accessibility of volatile deposits within polar cold traps.

Current datasets offer limited insights into resources. Orbital neutron spectrometer measurements have shown hydrogen enrichment in polar regions, but with resolutions of several kilometers, they can't identify specific mining sites or landing zones. NASA's VIPER mission will deliver detailed in situ measurements of volatile content and subsurface structure, but only in restricted geographic areas. Similarly, orbital missions such as Lunar Trailblazer could improve the spectral detection of surface water signatures but do not directly constrain subsurface structure or the accessibility of volatiles. This creates a significant gap between global reconnaissance measurements and localized surface observations.

This abstract proposes the Polar Volatile Mapper (PVM) mission concept, a low-altitude lunar polar orbiter designed to produce high-resolution maps of volatile resources in permanently shadowed regions near the lunar south pole. By combining neutron spectrometry, thermal infrared mapping, and ground-penetrating radar measurements, the mission produces a regional dataset describing hydrogen abundance, thermal stability environments, and subsurface layering associated with potential ice deposits.

Mission Concept: PVM operates in a ~30–50 km altitude polar orbit that repeatedly passes over key cold-trap craters, including Shackleton, Cabeus, Haworth, Shoemaker, and Faustini. Repeated observations allow measurements to be accumulated and averaged, improving signal-to-noise ratios and enabling higher-resolution mapping of volatile indicators. This approach is expected to produce volatile probability maps with spatial resolutions of approximately 100–300 m, significantly improving upon existing orbital measurements.

The mission is designed as a SmallSat-class lunar orbiter compatible with rideshare launch opportunities and cost frameworks similar to NASA SIMPLEx missions. Total mission costs are estimated at $70–130 M. The payload features multiple sensing systems. A neutron spectrometer detects hydrogen by suppressing epithermal neutron flux, aiming for sensitivities of about 0.1–0.3 wt% water-equivalent hydrogen [1]. A thermal infrared mapper measures surface temperatures with ≤5 K precision, helping identify environments that can preserve volatiles over time [2]. A ground-penetrating radar operates at decimeter wavelengths, offering subsurface sounding with depths of 5–15 m to detect potential buried ice deposits [3]. Lastly, a terrain imaging system provides high-resolution surface mapping for landing-site evaluation and interpretation of volatile measurements.

Value of the Data: PVM produces a regional lunar resource intelligence dataset that can identify and certify candidate ISRU sites at the lunar south pole. These data directly support landing site selection, surface mobility planning, and deployment of resource extraction systems. Like terrestrial geological survey programs that map subsurface resources before infrastructure investment, the dataset produced by PVM would provide foundational prospecting information for future Artemis missions and emerging commercial lunar resource activities.

References:

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