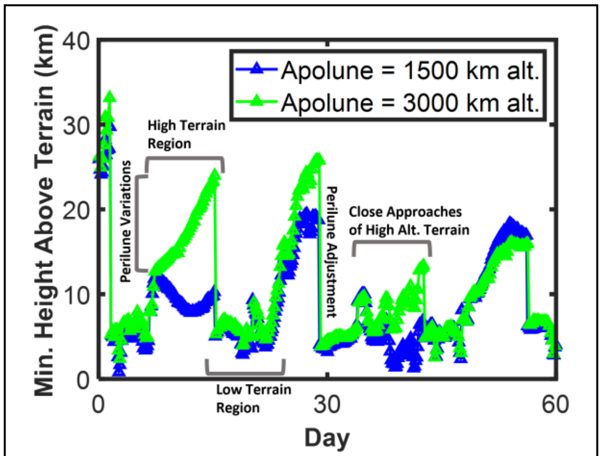
What We Don't Know about Water Ice on the Moon, and a Concept for How to Fix It. C. A. Hibbitts, M. N. Nord, J. Shannon, J. Berdis, K. Runyon, D. Smith. JHUAPL, 11100 Johns Hopkins Rd., Laurel, Md. 20723. Karl.hibbitts@jhuapl.edu

Introduction: Humans are going back to the Moon and doing so in a responsible and sustainable way that will require using in-situ resources instead of incurring the cost and waste of bringing the materials from Earth. In-Situ Resource Utilization (ISRU) includes using water-ice contained in the Permanent Shadowed craters at the poles for supporting human activities as well as providing the oxidizer and possibly fuel for rocket propellant. While we do know there is significant water ice in at least some PSRs [e.g. 1], especially at the lunar south pole, we do not have enough information to state definitively where to place an ISRU water-ice extraction plant.

We offer a specific approach (but we don't claim it is the only approach) to a campaign for resource evaluation to obtain the needed information. Understanding the nature of the resources on the Moon is one of 63 objectives of the newly released NASA Moon to Mars objectives [2]: AS-3 "Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions".

Concept: This resource evaluation campaign concept is composed of three elements to achieve the objective of locating and characterizing a water ice reserve in a lunar PSR for subsequent utilization. The first stage of the campaign is orbital reconnaissance. The objective of the orbital component is to identify the broad multi-kilometer locations in PSRs of possible water ice deposits that are also within a reasonable distance from potential Artemis landing sites [e.g. 3]. That report [3] proposes a distance of ~ 5km is reasonable from base camp on illuminated terrain near a ridge to water-ice extraction site in a PSR. This drives the desire to obtain a resolution as close to 5km as possible for orbital measurements of water ice abundance in PSRs in the general vicinity of potential Artemis basecamps. Current spatial resolution of near surface water ice, which is inferred from water equivalent hydrogen measurements derived from neutron spectroscopy measurements, is about 30 km/pixel [e.g. 4], which is insufficient to even constrain the signal to within most/all PSRs. It is also possible the upcoming LunaHMap observations will obtain much of the requisite information with its ~ 15 km perilune [5].



Predicted perilune altitudes for trajectories where the argument of periapsis is allowed to vary.

The second and third components of the campaign involve in-situ verification and detailed spatial and compositional characterization of terrain corresponding to any high WEH pixels that are also within exploration range of potential Artemis landing sites. This would involve a series of two robotic exploration efforts. First, a lander at the center of the most promising WEH detection would release a number of small rovers to prospect where in the 5+ km pixel the subsurface ice is concentrated using multiple small rovers equipped with neutron spectrometers; determining if the resource is wide-spread or is concentrated in one area as a reserve. Upon finding one or more locations of enhanced WEH, a single, more capable rover would be sent to characterize the composition and contaminants of the ice, the physical state of the ice, and to detail its spatial distribution.

Each component would only need to rely on currently available technologies. However, there are several implementation challenges in this concept including the thermal design of small rovers of sufficient operational duration to explore the limited PSR areas as well as ensuring communications between rovers and lander.

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References: [1] Colaprete et al., Science, 230, 2010. [2] Melroy, P., Moon to Mars Objectives, September 2022. [3] Kleinhenz, J. ASCEND, 2022. [4] Lawrence et al., JGR, E08001, 2006. [5] Hardgrove et al., LPSC 51, 2711, 2020.