THE CASE FOR A RETROREFLECTOR IN A LUNAR SOUTH POLAR SHADOWED REGION.

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Introduction: Two important recommendations of the Artemis III Science Definition Team Report [1] are: a) the prioritization and expansion of lunar geodetic monitoring capabilities; b) identification of surface frost composition and temporal variability at lunar permanently shadowed regions (PSR).

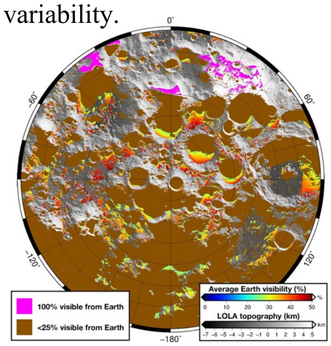
Apollo and Lunokhod lunar retroreflector arrays have demonstrated long-term geodetic monitoring capability and their interdisciplinary impact through the ongoing lunar laser ranging (LLR) experiment. However, their locations are limited primarily to the northern hemisphere, restricting the geometrical sensitivity of LLR observations to lunar interior structure parameters. Moreover, the high thermal diurnal variations of these retroreflectors over a lunar day have resulted in a non-uniform distribution of LLR observations *vs*. lunar phase due to reduced optical return at high operational temperatures. This also places practical engineering constraints on the size of a single corner cube retroreflector. We propose a possible solution to this problem. The lunar South Pole region is home to many low-temperature regions offering high Earth visibility over a lunar nodal cycle (18.6 years; see Fig. 1). Retroreflectors deployed within or near these regions would be subject to much smaller thermal diurnal variations compared to sunlit areas, simplifying retroreflector design requirements, and enabling the deployment of (very) large corner cube retroreflectors. Such large retroreflectors can improve the link margin by a factor of 100, enabling the expansion of LLR-capable Earth stations to the wider SLR network (>40 stations).

Some analytical/numerical models suggest oscillating horizontal lunar dust transport mechanisms caused by differences in electric potential between shadowed craters and their nearby sunlit regolith [2]. Close observations of such phenomena will enable an improved understanding of their dynamics. A hyper- or multispectral lidar ranging to the retroreflector within a PSR would enable unique *in situ* measurements of dust dynamics and distinguish it from frost layer formation on the optical surface of the retroreflector. With a single lidar wavelength, the knowledge of the pristine reflector optical gain would be used to track the degradation of lidar signal over time and could be correlated with events such as CLPS or Artemis landings to study the effects of surface operations on the polar environment. With a multispectral lidar operating near 3.1 μm, the presence of thin frost layers could be discriminated from dust by the increase in absorption (and reduction in optical gain) at that wavelength (λ). The high optical extinction coefficient of water ice at that λ means that a 10-nm frost layer results in a 3% reduction in signal from the retroreflector.

Landing Area(s): Some PSR areas have relatively high average Earth-visibility regions (*e.g.*, >40% in Shoemaker crater) and have some of the highest concentrations of neutrons and other volatiles as mapped by LEND (Fig. 2) and M3 observations (Fig. 4 in [3]) [4,5]; an opportunity to map/study at high resolution a PSR *in situ* while maintaining Earth-communication.

Science Objectives: a) To monitor the time variations on the lunar axial precession angle (~1.543°) to better than an arcsecond for the detection of a lunar solid inner core [1,6,7]; b) to detect the equatorial ellipticity of the lunar fluid core [1,8]; c) to improve the overall accuracy of lunar geodetic control points for the enhancement of the lunar coordinate reference frame [1]; d) to create a high-resolution spectro-temporal map of a PSR [1,9]; e) to characterize lunar dust dynamics [1].

Required Capabilities: Large retroreflector enabling sub-mm accuracies (solid/hollow); gimbal/robotic arm or rover for the accurate pointing of retroreflectors to within 1° of the mean-Earth direction; hyperspectral lidar or camera to map out compositional and temporal variability.



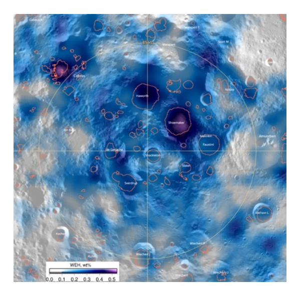


Fig. 1 (left): Stereographic lunar map (83-90°S); full (magenta) and poor (<25%, brown) Earth visibility. Other colored regions are cold (T_{max}<200K) with sufficient Earth visibility (25-50%) to support LLR objectives. **Fig. 2 (right)**: Map of the water equivalent Hydrogen (WEH) abundance (in wt.%) from LRO-LEND. Highest WEH abundances up to 0.5 wt.% are encoded by violet color.

References: [1] NASA (2020) Artemis III SDT Rep. (SP-20205009602); [2] Collier *et al*. (2013). *ASR*, *52*(2), 251–261; [3] Li *et al*. (2018). *PNAS*, *115*(36), 8907–8912; [4] Sanin *et al*. (2017). *Icarus*, *283*, 20–30; [4] Lemelin *et al*. (2021) *PSJ., 2*(3), 103; [5] Williams, J. G. (2007). *GRL*, *34*(3), 2–5; [6] Stys, C., & Dumberry, M. (2018). *JGR: Pla.*, *123*(11), 2868–2892; [7] Viswanathan *et al*. (2020). In *LPSC* (p. 2031); [8] Cremons *et al*. (2020). In *LSSW*. (Vol. 2241, p. 5068). **Acknowledgments:** The material is based upon work supported by NASA (award #80GSFC21M0002) and PSD's ISFM Research Program.