Seeing In The Shadows: M. S. Robinson[1], P. Mahanti[1], D. B. J. Bussey[2], L. M. Carter[3], B. W. Denevi[4], N. M. Estes[1], D. C. Humm[5], M. J. Kinczyk[4], S. Li[6], P. G. Lucey[6], E. Mazarico[7], M. A. Ravine[8], E. J. Speyerer[1], R. V. Wagner[1], J. P. Williams[9], [1]Arizona State University, Box 873603, Tempe, AZ 85287, robinson@ser.asu.edu, [2]Intuitive Machines, Houston TX, [4]Johns Hopkins University Applied Physics Laboratory, Columbia, MD, [4]University of Arizona, Tucson, AZ, [5]SPICACON, Annapolis MD, [6]University of Hawaii, Honolulu HI, [7]NASA Goddard Space Flight Center, Greenbelt, MD, [8]Malin Space Flight Center, San Diego, CA, [9]University of California Los Angeles, Los Angeles, CA.

Introduction: ShadowCam is a NASA Advanced Exploration Systems (AES) funded instrument hosted onboard the Korea Aerospace Research Institute (KARI) Korea Pathfinder Lunar Orbiter (KPLO) satellite (aka Danuri) [**1,2**]. ShadowCam is intended to acquire high-resolution (1.7-m pixel scale, S/N >100 on average) images of permanently shadowed regions (PSRs). The ShadowCam investigation was conceived to obtain measurements addressing three AES lunar volatile Strategic Knowledge Gaps (SKGs) [**3**], providing the rationale for the five ShadowCam science objectives.

Objective 1. *Map albedo patterns in PSRs and interpret their nature*. Albedo boundaries coincident with mercurian PSR boundaries provide evidence of volatile-rich deposits (**4,5**). However, no similar lunar albedo patterns were seen in low-resolution low-SNR LROC NAC images [**6**]. ShadowCam images of lunar PSRs have yet to reveal distinct albedo contrasts definitively attributable to the presence of volatiles. However, the large angle of secondary lighting with respect to the ground suppresses albedo contrasts, requiring contrasts >20% to be reliably detected [**7**].

Objective 2. *Investigate the origin of anomalous radar signatures associated with some polar craters*. Some of the most controversial results regarding volatile distribution in PSRs come from radar observations. A class of impact craters with high Circular Polarization Ratio (CPR) values found only within their interiors (not within the surrounding ejecta) was interpreted to indicate the presence of relatively pure ice [**8**]. An alternate hypothesis for these "radar anomalous" craters posits that the high CPR values are due to blocky interiors (>cm size blocks) [**9**]. ShadowCam images can detect blocks with diameters >2 m and roughness differences due to slumps, debris flows, and impact melt deposits that could produce increased CPR. Since block populations follow a fragmentation size frequency distribution, extrapolating to the radar-sensitive block size is not unreasonable [**10**]. A preliminary inspection of ShadowCam PSR anomalous craters is consistent with the blocky interior hypothesis in many cases.

Objective 3. *Document and interpret temporal changes of PSR reflectance units*. Due to various processes [see refs in **1, 6**], volatiles may migrate on diurnal or longer time scales, possibly resulting in surface reflectance variations. Newly formed impact craters could also cause reflectance changes due to the exposure of immature materials or sub-surface volatiles. Discovering temporal variations in PSR reflectance requires images acquired at different times; the likelihood of observing a change increases as the interval between images increases. For PSRs within 10° of the pole, at least one 5-m diameter crater should form in one year, and >1000 other surface changes (e.g., related to secondary ejecta) >=5-m width are predicted to form [**11**]. A significant ShadowCam temporal analysis will require at least one year of extended mission operations (through Jan. 2025).

Objective 4. *Map the morphology of PSRs to search for and characterize landforms that may indicate sub-surface volatiles*. Volatiles sequestered in the subsurface could affect regolith physical properties, resulting in diagnostic landforms (i.e., crater morphology, tree bark texture, slumps, creep, boulder tracks, collapse features, etc.). Work by Brown et al. [**6**] found only a few examples of landforms that may be consistent with ice-rich regolith (see their Fig. 2); they report ridges evocative of downslope creep within the Shoemaker PSR, with some examples on the rounded rim of Tooley crater (7-km diameter, located with the Shoemaker PSR).

To date, the ShadowCam team has debated the origin of many landforms within PSRs, and the most convincing example of a landform consistent with subsurface ice is a lobate-rimmed crater (LRC; 1200-m diameter) found on the floor of Faustini crater (**Fig. 1**). The LRC has a radar CPR signature consistent with a very young crater, and ultraviolet reflectance consistent with a young age [**12**]. Its steep inner slopes (>30°) and blocky rim are also consistent with recent formation. However, its depth-diameter ratio (d/D) is significantly lower (0.13) than expected for a young crater (>0.2) of that size, and its rim height above the surrounding terrain is 50% of the value expected for a fresh crater. Additionally, the LRC continuous ejecta is abruptly terminated within a 0.3 radius of the rim with a sharp topographic boundary (arrows **Fig. 1b**), a morphology consistent with viscous flow. Finally, the LRC floor is irregular, consistent with the impact event penetrating a strength discontinuity [**13**]. The LRC rim shape and shallow d/D are similar to the much larger Tooley crater (7 km diameter, **Fig. 1**), though Tooley crater does not have a robust boulder population on its rim. We have not found any other craters with morphologies as distinctive as these two examples, but some craters share similarities with the LRC found within the Faustini PSR and elsewhere [**14**]. These other craters may indicate a range of heterogeneity in subsurface properties (the Faustini LRC is an end-member example) or a distinctive degradation process. We note that no LRC-like craters are found near the LCROSS impact site.

Objective 5. *Provide hazard and trafficability information within PSRs for future landed elements.* To date (early Jan. 2024), ShadowCam has imaged >90% of PSRs within 8° of latitude of both poles (and a significant portion within 20°). These observations provide a cornerstone dataset for future PSR exploration. ShadowCam is also acquiring extensive stereo coverage enabling generation of digital terrain models (DTMs) with a ground sampling distance of 6 m [**15**], a dataset necessary for detailed mission planning.

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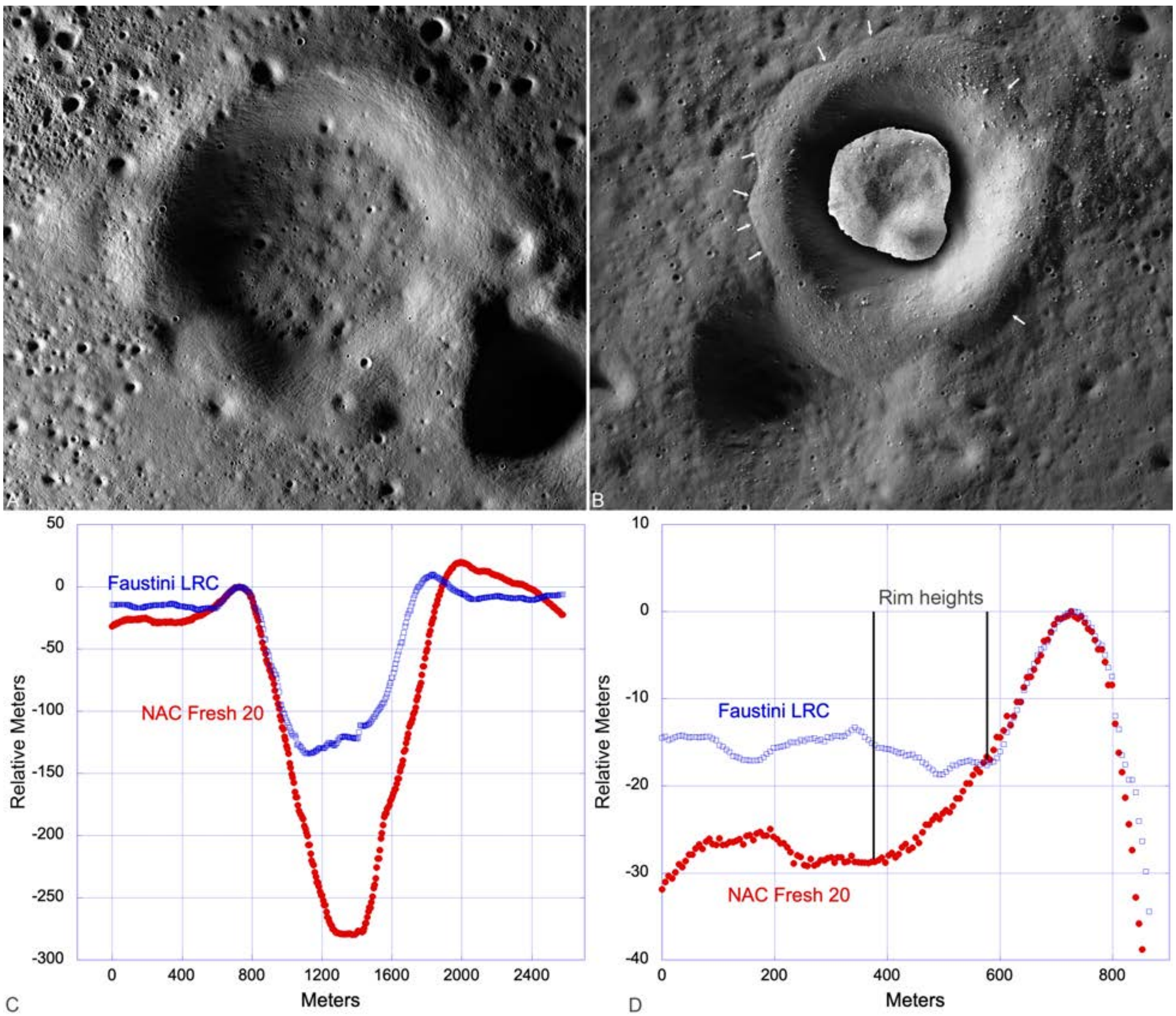

Fig. 1. A) Tooley crater (88.04°S, 51.31°E), ShadowCam mosaic 11,584 m wide. B) Faustini LRC (87.39°S, 82.31°E), ShadowCam mosaic 2462-m wide, central portion stretched to show details within the secondary-shadowed area. C) Topographic profile crossing left-to-right center over LRC from ShadowCam stereo DTM 6-m ground sampling distance (GSD), and a representative non-polar fresh crater (NAC Fresh 20, 3.03°S, 246.99°E) of similar diameter (1320 m), topography from NAC DTM 2-m GSD. D) Enlargement of profiles shown in C.