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ShadowCam – Seeing in the Dark

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Abstract

ShadowCam is designed to acquire high resolution, high signal-to-noise ratio (S/N) images within permanently shadowed regions (PSRs) on the Moon. The ShadowCam investigation has a single overarching goal: obtain measurements that directly address three of the four lunar volatile strategic knowledge gaps (SKGs) outlined in the NASA Korean Polar Lunar Orbiter (KPLO) instrument solicitation [**1**]. To this end we have five objectives: 1) identify albedo patterns in PSRs and interpret their nature, 2) investigate the origin of anomalous radar signatures associated with some polar craters, 3) document and interpret any temporal changes of PSR albedo, 4) map the morphology of PSRs to search for and characterize landforms that may be indicative of permafrost-like processes, 5) provide hazard and trafficability information within PSRs for future landed elements.

1. Introduction

ShadowCam has high heritage to the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) [**2**], which typically acquires images with 50 to 100 cm pixel scale and S/N >100 (for illuminated regions). ShadowCam will use a build-to-print copy of the LROC NAC optics; a 700 mm focal length, f/3.6 Ritchey-Chretien telescope with a composite metering structure and baffle. The electronics will be modified from LROC to use a time delay integration (TDI) charge coupled device (CCD) detector with larger pixels than LROC NAC to increase the effective photon collection per pixel to more than 800 times that of the LROC NAC. ShadowCam has a 17-µradian pixel scale and a swath width of 2.8°. The maximum downtrack dimension of a ShadowCam image is 81,920 lines (buffer limited), but typical observations will be less than 20,000 lines. From a nominal 100 km altitude, ShadowCam will provide a pixel scale of 1.7 m over a ~5 km wide swath. With the increased integration time enabled by the TDI detector, these images will have a S/N greater than 100 within most PSRs. This S/N estimate has been validated by images taken by the LROC NAC of PSRs (pixel scales of 10 to 40 m and S/N ~20). While these LROC images are inadequate to address the goals of the NASA Advanced Exploration Systems, they do provide key engineering data about illumination conditions within PSRs and thus required instrument sensitivity. These LROC NAC observations drove the design of ShadowCam, ensuring that the measurement objectives will be met. Development of uplink, downlink and archive operations and procedures will rely heavily on those already developed for the LROC NAC experiment.

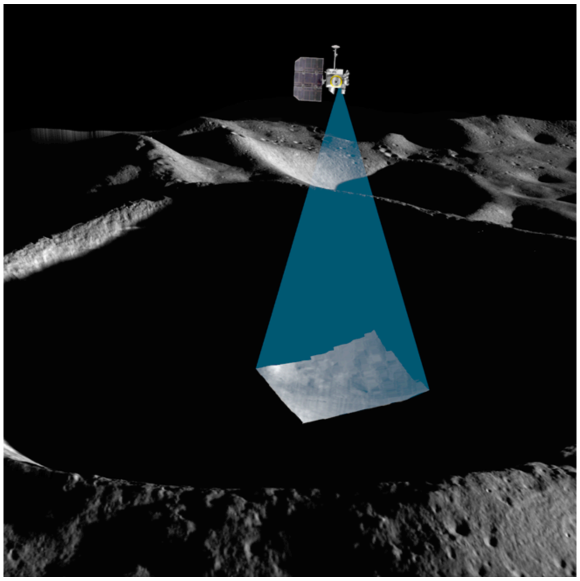

Figure 1. ShadowCam will image inside PSRs using secondary illumination reflected from nearby Sun-facing topographic facets.

2. Observations

ShadowCam will acquire complete coverage of PSRs poleward of 81°, which will enable mapping of landforms inside PSRs as well as the identification of any albedo signatures indicative of surface frost. During the respective "polar summer," when the Sun is highest along the horizon and the amount of scattered light into the PSRs is maximized, ShadowCam will obtain its highest S/N observations. During this period, geometric stereo observations can be collected (if allowed by the KPLO mission operations) to derive gridded topographic models at 6 m/pixel. For the opposite hemisphere in "winter" we will acquire observations of non-polar (< 81° N, S) PSRs greater than 10 km^2 and search for albedo changes with polar PSRs. As the mission progresses, ShadowCam will collect repeat observations of PSRs that can be compared to prior images to identify any large scale surface changes associated with the transport of volatiles. These repeat observations can also be compared to look for new impacts as well as secondary splotches indicative of churned regolith, giving insight to regolith properties and potentially the presence of ice [3,4].

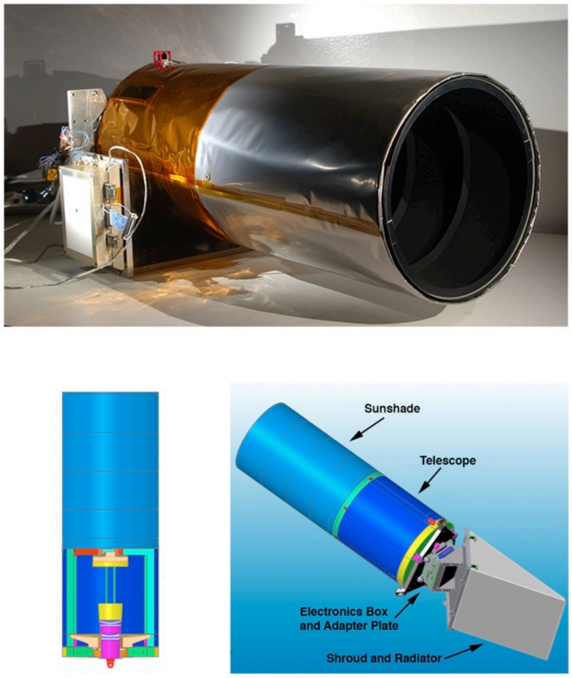

Figure 2. ShadowCam is based on the LROC NAC design shown above, and in engineering e-models (below).

ShadowCam can obtain complete coverage of the larger (>10 km^2) PSRs every month by imaging an average of 17,000 lines per orbit at the south pole and 10,000 lines per orbit at the north pole (assuming that at least 30% of each image contains not-previously-imaged PSR terrain; the rest is temporarily-shadowed terrain, illuminated terrain, or PSR terrain imaged on a previous orbit). Since the distribution of PSRs is not uniform, the number of lines needed per orbit varies, to a maximum of 78,000 lines on one pass over the south pole. The ShadowCam buffer can hold 256 MB (81,920 lines) before requiring a 35 m transfer to spacecraft memory, sufficient for 100% coverage of PSRs > 10 km^2 pole-ward of 81° for one orbit, and on an average orbit only 21% of the on-camera storage is needed. The remainder will be allocated for coverage of temporarily shadowed regions adjacent to PSRs for texture and albedo comparisons, for PSR or shadow observations at lower latitudes, for same-month repeat coverage of near-pole PSRs, and for calibration sequences, all subject to constraints on the total downlink volume.

While the NAC provides coverage of illuminated areas, ShadowCam will provide images of the shadowed areas. ShadowCam mosaics will be merged with the LROC NAC mosaics to make complete maps of the inside and outside of craters that host PSRs. These merged map products will put us one step closer to enabling landers and rovers to investigate the enigmatic lunar PSRs.

Acknowledgements

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References

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