SHADOWCAM: SEEING IN THE MOON'S SHADOWS. M. S. Robinson[1], P. Mahanti[1], S., S. M. Brylow[2], D. B. J. Bussey[3], L. M. Carter[4], M. J. Clark[2], B. W. Denevi[3], N. M. Estes[1], D. C. Humm[5], E. Mazarico[6], M. A. Ravine[2], J. A. Schaffner[2], E. J. Speyerer[1], R. V. Wagner[1], [1]Arizona State University, Box 873603, Tempe, AZ 85287, robinson@ser.asu.edu, [2]Malin Space Flight Center, San Diego, CA, [3]Johns Hopkins University Applied Physics Laboratory, Columbia, MD, [4]University of Arizona, Tucson, AZ, [5]SPICACON, Annapolis MD, [6]NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: ShadowCam is a NASA Advanced Exploration Systems instrument hosted onboard the Korean Aerospace Research Institute (KARI) Korean Pathfinder Lunar Orbiter (KPLO). The design of the instrument is based on the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC), but optimized for imaging of permanently shadowed regions (PSRs). PSRs never see direct sunlight and are illuminated only by light reflected from nearby topographic facets [**1–3**]. This secondary illumination is very dim, thus ShadowCam was designed to be over 200× more sensitive than the LROC NAC [**4**]. As a result, ShadowCam images will allow for unprecedented views into the shadows, but will saturate while imaging sunlit terrain.

Objectives: By collecting high-resolution images of lunar PSRs, ShadowCam will provide critical information about the distribution and accessibility of water ice and other volatiles at spatial scales (1.7 m/pixel from 100 km altitude) required to mitigate risks and maximize the results of future exploration activities. The ShadowCam investigation has five focused science and exploration objectives:

1. *Map albedo patterns in PSRs and interpret their nature*: ShadowCam will search for frost, ice, and lag deposits by mapping reflectance with resolution and signal-to-noise ratios comparable to LROC NAC images of illuminated terrain.

2. *Investigate the origin of anomalous radar signatures associated with some polar craters*: ShadowCam will determine whether high-purity ice or rocky deposits are present inside PSRs.

3. *Document and interpret temporal changes of PSR albedo units*: ShadowCam will search for seasonal changes in volatile abundance in PSRs by acquiring monthly observations.

4. *Provide hazard and trafficability information within PSRs for future landed elements*: ShadowCam will provide optimal terrain information necessary for polar exploration.

5. *Map the morphology of PSRs to search for and characterize landforms that may be indicative of permafrost-like processes*: ShadowCam will provide unprecedented images of PSR geomorphology at scales that enable detailed comparisons with terrain anywhere on the Moon.

Heritage: The ShadowCam design (**Table 1**) was inherited from the LROC NAC [**4**] with several modifications to optimize for the challenging lighting within PSRs and accommodation on the KPLO spacecraft. These modifications include: 1) increased baffling to reduce stray light, 2) redesign of the focal plane, and a 3) new passive radiator design.

Baffling. For smaller PSRs, rejecting stray light is the biggest challenge for obtaining high quality images. Thus the number of sunshade vanes was increased from six to twelve (**Fig. 1,2**), a secondary mirror inner baffle was added, two vanes were added to the primary mirror central baffle, and the field flattener lens diameters were increased by 0.150 in. to reduce edge scattering. These modifications increased stray light rejection by 5x.

Focal plane. To provide increased sensitivity, the LROC electronics were modified to use the Hamamatsu S10202-08-01 Time Delay Integration (TDI) Charge Coupled Device (CCD) detector with a custom mask to provide thirty two lines of TDI. Six of the outputs of the detector are digitized in parallel to 12-bits and then companded to 8-bits. Each of these outputs handles a 512 photoactive pixel section of the detector, for a total format of 3072 pixels.

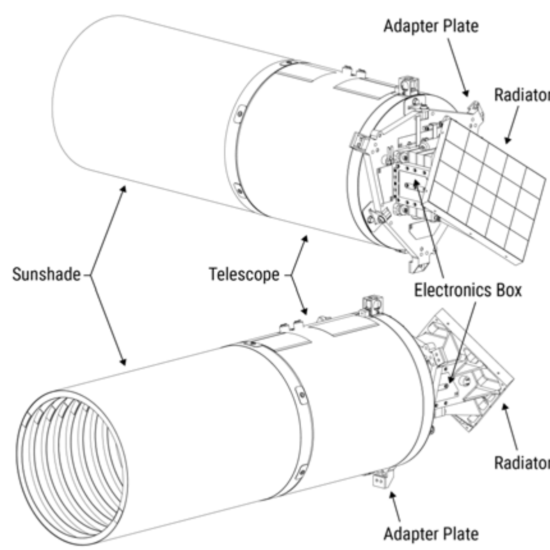

Fig. 1. Schematic views of ShadowCam. Total length of instrument is 118 cm (46 in).

Radiator. The radiating surface of the zenith-facing radiator will be exposed to the Sun, requiring that it have low solar absorptivity (α) while maximizing IR emissivity (ε). Optical solar reflector (OSR) material was used for this surface, (α = 0.1, ε=0.86), enabling the radiator to maintain the detector below 20° C even under the least favorable thermal conditions (**Fig. 1,2**).

Current Status: ShadowCam has been delivered to NASA/KARI and integrated into the KPLO spacecraft for launch in August of 2022.

Table 1. Key ShadowCam parameters

Sensor	Hamamatsu S10202-08-01 TDI CCD
FOV (cross track)	2.86°
Image Scale	1.7 m/pixel at 100 km
Signal-to-Noise Ratio	>90
Pixel Size	12 µm
Instantaneous FOV	17.1 µrad
Image Size	3144 (3072 sensing pixels cross track)
Image Footprint (100 km altitude)	5 km × ~140 km
Optics	f/3.6 Cassegrain (Ritchey-Chretien)
Focal Length	700 mm
MTF (@Nyquist)	>0.2
Aperture	194.4 mm
Effective TDI Lines	32
Sensitivity	>200× LROC NAC
Mass	8.753 kg
Volume	118 × 27 cm (w/radiator)
Peak, Standby Power	9.3, 4.5 W
Average Power	6.4 W

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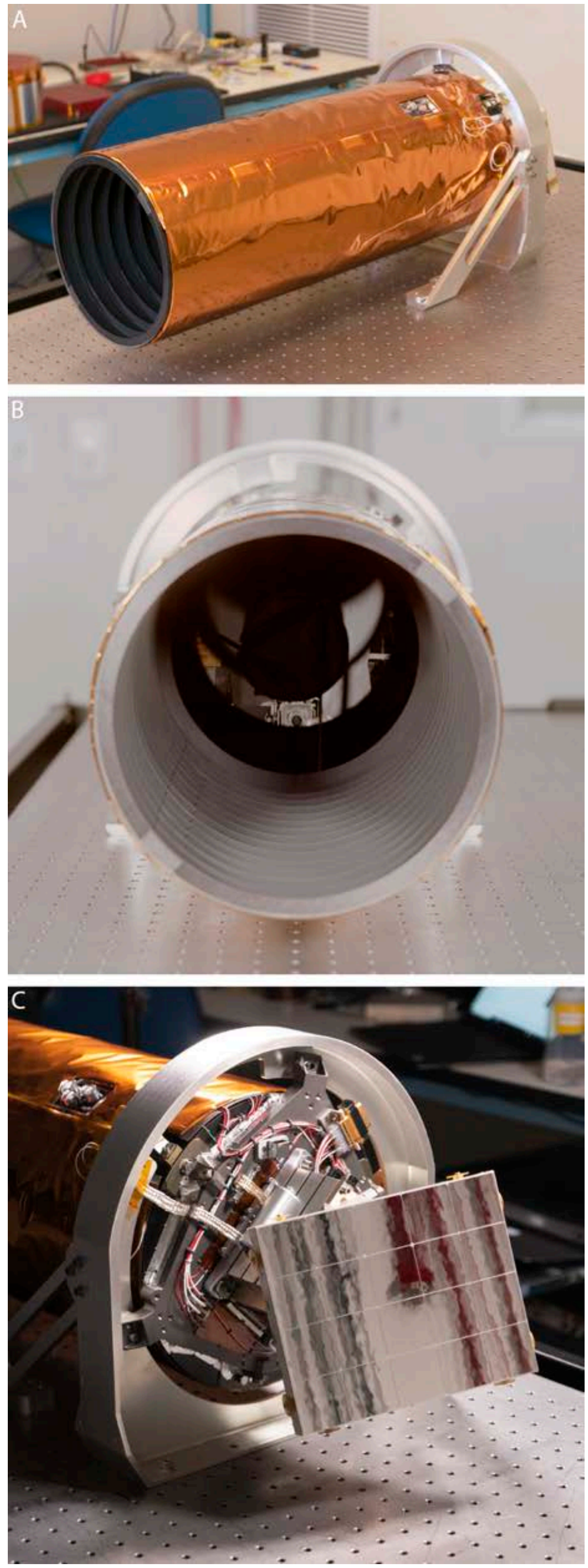

Fig. 2. A) ShadowCam instrument, B) view into telescope, note stray light baffles, baffle opening is 23.1 cm (9.1 in), C) radiator, exterior of electronics housing, and adapter plate.