Impact Flash Monitoring Facility on the Deep Space Gateway. D. H. Needham[1], D. E. Moser[1], R. M. Suggs[1], W. J. Cooke[1], D. A. Kring[2,3], C. R. Neal[4], C. I. Fassett[1]…[1]Marshall Space Flight Center, Huntsville, AL; [2]SSERVI Center for Lunar Science and Exploration, Lunar and Planetary Institute, Houston, TX, [3]Johnson Space Center, Houston, TX; [4]University of Notre Dame, Notre Dame, IN.

Science Objective: The Deep Space Gateway (DSG) will provide new opportunities for observing the contemporary impact flux to the inner Solar System by observing impact flashes on the lunar surface. Constraining this flux is critical for 1) understanding the population of meteoroids in our celestial neighborhood, 2) identifying sources for seismic signatures detected in future surface seismometer stations, and 3) assessing the hazards faced by astronauts living and working outside the protection of Earth's atmosphere. One approach is to observe flashes generated during impacts on the lunar surface (Fig. 1), then identify the resulting impact crater by analyzing time-sequenced images collected by LROC or an equivalent orbital camera

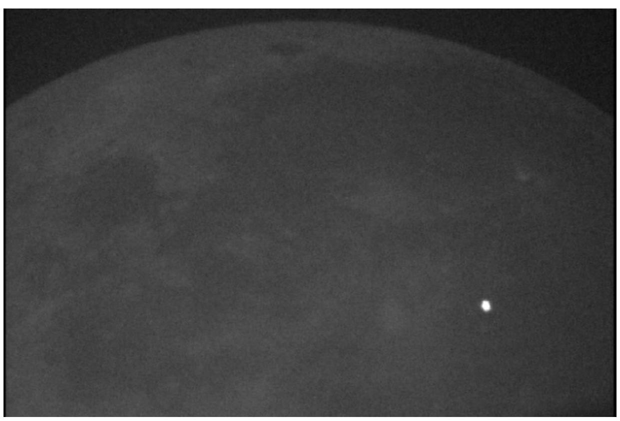

Figure 1: March 17, 2013 impact flash detected by the MSFC Meteoroid Environment Office Lunar Impact Monitoring Program from Earth. This impact event produced a flash >10 times brighter than ever detected before, and resulted in the formation of an 18 m diameter crater, later identified in LRO imagery [1].

(Fig. 2). Current Earth-bound observations of lunar impact flashes conducted by NASA Marshall Space Flight Center's Meteoroid Environment Office [2] are limited to the un-illuminated portion of the lunar nearside. Therefore, only about 15% of the lunar surface (~30% of the lunar nearside) is viewed. Installing a similar capability in cislunar space, ideally at Earth-Moon L2, will vastly improve the coverage of the measurements by exploiting continuous cloudless viewing conditions (non-illuminated surfaces are still required), increase the number of detected flash events, enable detection of much dimmer flash events (e.g., smaller, less energetic impacts), and improve our assessments of the impact flux, seismic sources, and hazards to crew in cislunar space. Although a similar facility is scheduled to fly on EM-1 (JAXA's DEtection camera for Lunar impact PHenomena IN 6U Spacecraft, DELPHINUS, a part of EQUilibriUm Lunar-Earth point 6U Spacecraft, EQUULEUS, 6 months operations), a facility on the DSG will be longer-lived, providing a prolonged capability for observing both sporadic impact events and seasonal meteor showers on the Moon.

Required Instrumentation: An impact flash monitoring facility requires two detectors mounted on the exterior of the DSG; the second detector is necessary to eliminate cosmic ray false detections (if a flash is observed in both detectors, an impact is confirmed). This could be accomplished with two independent optical systems or with one optical system with a beamsplitter feeding two cameras. A dichroic beamsplitter would also allow simultaneous measurements in two colors, yielding impact temperature information [3].

For the following mass, power, and volume estimates, the two-telescope option with commercial off-the-shelf (COTS) hardware was assumed. Actual specifications will vary depending on the materials and design used to construct the space-rated facility.

Optics: The optics for the cameras will depend on the chosen orbit. At a constant distance of 61,500 km (Earth-Moon L2), a camera would require a lens of ~60 mm diameter (focal length ~180 mm) to provide approximately the same sensitivity and field-of-view as the NASA Lunar Impact Monitoring Program on the Earth's surface. At the farthest distance of ~75,000 km (Near Rectilinear Halo Orbit), each camera would require a lens of ~70 mm diameter (focal length ~216 mm).

Mass: Together, the mass of each camera (~100 g) and lens (~1.3 kg) would be approximately 1.4 kg, for a total of 2.8 kg in camera mass. Larger diameter lenses rated for space operations would facilitate detection of fainter flashes at the expense of added weight.

Power: The power required to operate each

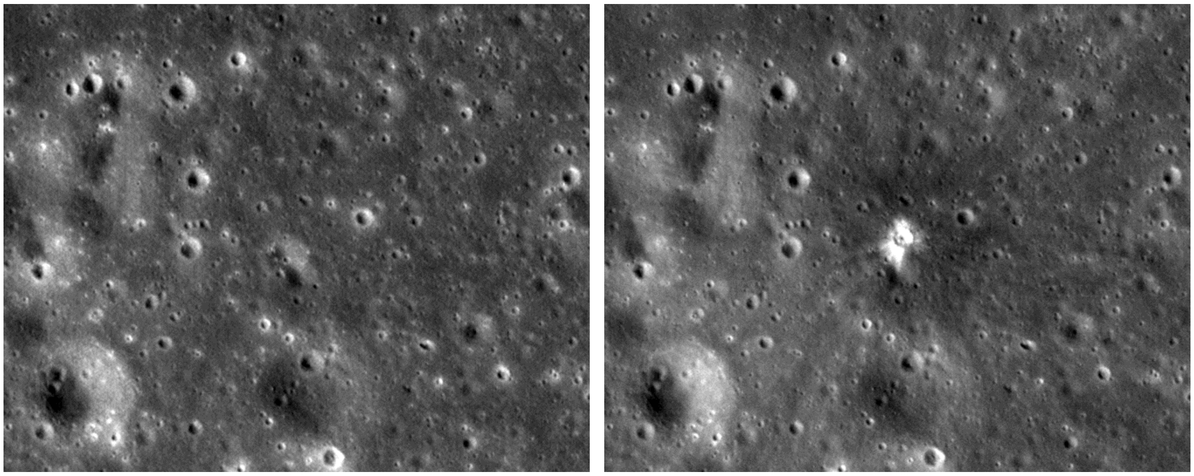

Figure 2: Before (February 12, 2012, M183689789L) and after (July 28, 2013, M1129645568L) images of the new crater formed during the impact flash event of March 17, 2013 [4].

camera is ~1.4 W from a DC+12V power supply, for a total of 2.8 W for camera operation. The on-board processor could consist of a fast general purpose computer, a field programmable gate array (FPGA) or a digital signal processor (DSP), subject to trades for cost and radiation tolerance. The on-board processing to find and correlate the impact flashes and prepare the video frames containing them for downlink is estimated to require ~10 W.

Temperature: Off-the-shelf cameras must be operated at temperatures ranging from -10ºC to +40ºC and stored at -30ºC to +70ºC. Custom space-rated cameras could have wider operating ranges.

Volume: Each camera is ~63mm x 34 mm x 34 mm, with lenses that are 200 mm in length and ~70 mm in diameter. The total volume of the optical system would, therefore, be ~150 mm x 234 mm x 70 mm, excluding the mounting platform.

Mounting Platform: In addition to the cameras and lenses, the impact flash monitoring facility will require a mounting platform capable of pointing the system for calibration and to keep the unilluminated Moon in the field of view. An articulated pointing system will be necessary since flight attitude will not necessarily be fixed relative to the line of sight to the Moon. Alternatively, while the DSG is uncrewed, the Gateway itself could be adjusted to provide line-of-sight from the Impact Flash Monitoring Facility to the Moon, if other instrumentation and system constraints permit.

Crew Interaction: Crew may be required to install and initiate the system. Ideally, this process would use an external robotic arm rather than a crew EVA. Once installed and running, this experiment should be self-sufficient and operate during both crewed and uncrewed DSG statuses.

Data Downlink: Although data is collected from the cameras at video rates, on-board processing would reduce the data to 1 to 10 image frames for each impact flash. MSFC impact detection rates are about 1 every 2 hours and assuming 10 frames of 720x480 pixels at 8 bits per pixel yields approximately 3.8 kbits per second on average assuming no compression. Higher resolution and greater bit depth cameras would require higher rates but lossless data compression would keep the data rate low.

References: [1] Robinson, M.S. et al., *Icarus, 252*, 229–235, 2015; [2] Suggs, R.M. et al., *Icarus, 238*, 23–36, 2014; [3] Bonanos, A. et al., *Proc. SPIE, 9911*, id. 991122, 2016; [4] Speyerer, E.J. et al., *Nature, 538*, 215–218, 2016.