Crew-based Micro-topographic Imaging of the Moon for Science, Exploration, and Safety

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SUMMARY: The topology of the lunar surface in the vicinity of the *Artemis III* south polar region landing site presents a unique opportunity for understanding small-scale regolith processes at scales inaccessible from orbital measurement systems (e.g, < 100 cm spatial scales). We suggest that crew-based imaging observations can be acquired in a specific and controlled manner to facilitate Structure-from-Motion (SfM) based computation of local scale relief at cm scales to fill in the gap below ~ 100 cm scales. Using crew-based EVA activities involving a simple array of flight-proven digital imaging systems mounted on a mast for ease of deployment, a control area 50 m x 50 m or larger could be imaged and processed into a 1 cm ground-scale distance digital elevation model (DEM) while the *Artemis III* crew are on the lunar surface. In effect, the crew can traverse a grid as if they were operating like a low-altitude commercial drone and produce the ensemble of nadir-viewing digital images with overlap necessary to produce a seamless DEM. Such a DEM could serve as a reference or boundary condition for models of lunar regolith formation, emplacement and modification, as well as a test-bed for future Artemis activities. Such a dataset could provide a civil-engineering reference dataset for deploying future systems to the Moon for ISRU, science, and controlled engineering experiments. The area of regard could be expanded to 100 x 100 m (one hectare) if time permits, providing a reference "pixel" for orbital remote sensing data acquired already by LRO and Kaguya, as well as that now being collected by ISRO's Chandrayan-2. Future systems, including hazards detection "imaging" lidars (HDL) and related descent imaging systems could expand the test area acquired during the initial Artemis activities by women and men on the Moon. Finally, the DEM produced by the simple digital in situ topographic imaging system suggested could be used as a calibration point (or training site) for next-generation in situ topographic mapping systems involving lidar, microwave, and other means. Crew-based deployment and processing while on the Moon or in transit back to Earth is a key part of this experiment and results could be used to improve engineering designs of future CLPS-based rovers or commercial mobile systems.

BASIC CONCEPT: Current space-rated digital imaging systems with wider fields-of-view are in production for lunar exploration, and are flying in low lunar orbit on the Lunar Reconnaissance Orbiter. Using modular multi-optical system cameras such as these, including those in flight on the OSIRIS-Rex mission to Bennu (e.g., MSSS NavCams), it will be possible to develop a crew-operated multi-camera system for "walkabout" imaging of the surface, ideally from a small camera extension "mast" not unlike that used in smartphone "selfies". One or two crew members on the lunar surface could operate such camera systems on a slow walking EVA to sample a simple grid at least 50 m x 50 m with the camera system extended about 2 m overhead to provide angular field of view coverage similar to a low-altitude camera drone on Earth. The digital camera system could be programmed to acquire data continuously in multi-frame mode until the crew command it to stop, writing the images into large flash buffers (32 Gb or more) for storage. In less than 1 hour of slow walking EVA, one crew member could sample a 50 x 50 m grid using a 2.5 m x 2.5 m moving camera FOV in a back-and-forth geometry. Other geometric configurations are also possible including an offsetting racetrack. Crew operation of the extended multi-headed camera will ensure frame-overlap is optimized for SfM processing to produce a point cloud that enables a 1 x 1 cm grid cell DEM to be assembled, with a vertical precision (locally) good to < 0.4 cm depending on frame density and quality of illumination. Should lighting be a problem, small illuminators (flash) could be built into the camera systems. There is ample room for optimizing the ultimate system for most flexible crew operation and utilization, and the same camera could be mounted on a low to the surface hand-cart with a few of the surface and pulled along for a much higher DEM sampling. The aim is to acquire a large number of overlapping frames in a controlled geometry to facility DEM computation using COTS SfM approaches that are now in use with commercial camera drones such as those by DJI, Parrot, and so forth.

GOALS: Crew-based imaging activities designed to quantify engineering and science-relevant characteristics of the regolith near current PSR's whose boundaries wander due to lunar librations over time scales of years to decades are relevant to sustaining a presence on the Moon for human activities. Given the importance of the PSR's, surveying the cm-scale topography of a reference patch adjacent to a PSR boundary at the *Artemis III* landing zone will be important. Of course the survey site will have to be undisturbed by HLS landing exhaust and evaluated by crew EVA before data acquisition. In the end, the resulting dataset will provide new boundary conditions for models and engineering solutions where micro-topography is a relevant parameter of interest, including for landing and roving systems.

CONCLUSION: Crew-based activities on early Artemis landings will necessarily require attention to safety and simplicity. The walkabout surface imaging experiment using flight-proven multi-headed camera systems deployed with a short extension "mast" is consistent with EVA flight rules and experience with Apollo missions. Given the capabilities of flight-proven modular camera systems (e.g., those by MSSS), developing a crew-based imaging system for topography at cm scales is both realistic and useful. We suggest that crew-operated activities such as this be evaluated in the context of concepts of human operations on Artemis III.

REFERENCES: SCEM (2007), V&V (2011), Bos et al (2017), and LEAG goals; Garvin *et al.* 2018, 2019 LPSC abstracts about descent imaging of topography (MSL's MARDI).