SCIENCE IMAGING LESSONS LEARNED FROM THE JETT3 ARTEMIS MISSION SIMULATION. J. M. Hurtado, Jr.[1], C. N. Achilles[2], E. R. Bell[2,3], A. W. Britton[4,5], B. A. Cohen[2], L. A. Edgar[6], A. L. Fagan[7], A. H. Garcia[4,5], W. B. Garry[2], T. G. Graff[4,5], S. R. Jacob[8], J. A. Richardson[2], M. J. Miller[4,5], M. J. Miller[9], S. K. Nawotniak[10], P. A. Reichert[4], J. A. Skinner, Jr.[6], C. M. Trainor[4,5], A. R. Yingst[11], K. E. Young[2]; [1]UTEP, El Paso, TX (jhurtado@utep.edu); [2]NASA GSFC; [3]UMCP, College Park, MD; [4]NASA JSC; [5]Jacobs, Houston, TX; [6]USGS Astrogeology, Flagstaff, AZ; [7]WCU, Cullowhee, NC; [8]ASU, Tempe, AZ; [9]NASA KSC; [10]ISU, Pocatello, ID; [11]PSI, Tucson, AZ.

Introduction: In Oct. 2022, the Joint Extravehicular Activity (EVA) & Human Surface Mobility Test Team (JETT) conducted the JETT3 Artemis EVA simulation [1]. As expected for Artemis, the JETT3 EVAs included cameras for situational awareness and to document science activities. One goal is to assess camera performance, and utility of the resulting images, under challenging lighting conditions and in a realistic operational context including a Science Evaluation Room (SER) [2]. To simulate lunar south pole illumination, JETT3 EVAs were conducted at night with artificial light sources [3]. Here we discuss JETT3 Science Team (ST) imaging lessons learned.

EVA Cameras and Procedures: JETT3 EVA crewmembers were equipped with a pair of cameras. One, a high-definition video camera with a wide-angle (100° field-of-view, FOV) lens [4], was affixed to the left side of the EMU (extravehicular activity unit) helmet, with the camera pointing slightly downward. The video camera transmitted high-resolution color footage in real-time with synchronized voice loop audio. The second camera was a digital, full-frame (~46 Mpixel), mirrorless handheld camera with a 28-mm lens [5]. Although capable, it was not used to shoot video and was only used as a still camera. The still camera was configured to auto-focus and acquire three bracketed-exposure images each time the shutter release was pressed. The still camera automatically adjusted shutter speed, aperture, and ISO based on the built-in light meter (*i.e.* Programmed Auto and Auto ISO modes).

The crew was trained to use both cameras. The video camera required no user input. Training included understanding how crewmember pose and orientation affect the video FOV. The pre-configured exposure and focus settings for the still camera were fixed and were note changed by the crew during an EVA. Training focused on framing shots to capture science targets, operating the shutter, and procedures for obtaining panoramas and documenting outcrops and samples. The ST was briefed on general aspects of the cameras and included imagery requests in the Science Traceability Matrix and cuff checklists [6] but did not consider detailed camera capabilities in EVA planning.

Real-Time Image Data: Still images were not available to the ST in real time, consistent with early Artemis mission expectations. The entire ST did have access to the real-time video feed via a large video display in the SER [2] as a primary means for tracking EVA activities, along with the EVA voice loop. Selected SER positions also had direct access to the video from their workstations from which screenshots were pulled for documentation purposes [2]. Video quality was sufficient for discerning details and activity within the relatively small, illuminated area immediately around the crewmembers, but some issues need improvement, *e.g.*: (a) the downward pointing angle of the video camera prevented the horizon from being visible in the FOV, making crew orientation and position difficult to track; and (b) there was no capability to replay/review video during or after EVAs.

Post-EVA Image Data: Still images were uploaded to a shared drive for the ST to access after each EVA, first (within a few hours) as JPEG-format files and later (after the end of the mission) as RAW-format files. The ST reviewed still images between EVAs to provide feedback on image quality to the crew and to personnel managing the cameras. The following was also done to facilitate further work: (1) correlation of photographs to specific stations and EVA events, a laborious, manual process done without benefit of geolocation or timestamp metadata; (2) organization of image files, *i.e.* grouping of sample images, panoramic photo sets, and candidate 3D image sets, again without timestamps to link image files to EVA tasks; and (3) grouping triads of bracketed-exposure images for HDR (high dynamic range) processing. With these tasks complete, the ST conducted some higher-level image processing on the still images as proofs-of-concept (see below).

HDR Stacking. Bracketed-exposure still images were used to produce enhanced composite images in which all parts of the scene were optimally exposed (Fig. 1a). While the preliminary results are good, the procedure could be automated and optimized (*i.e.*, improved camera settings and algorithm parameters).

Panoramas. At most EVA stations, the crew obtained multiple, overlapping still images which were mosaicked to produce high-resolution panoramas (Fig. 2b). Crew procedures were well executed, and the resulting panoramas are high quality. Issues to resolve include streamlining grouping of panoramic photos (*i.e.*, automatically tagging which photos belong), and illumination (*i.e.*, panoramas were more successful for close range subjects, *e.g.*, sample localities, rather than for distant targets, *e.g.*, landscape context shots).

3D Models. In several cases, the crew obtained still image sets amenable for photogrammetric construction of point clouds and derived 3D products [7,8]. Excellent 3D models resulted (Fig. 1c), even though the crew was not explicitly directed or trained to take images for this purpose. The results could be even better if images were taken more deliberately. It should also be possible to produce 3D models from extracted video frames [7,8].

Z-Stacking. Because of the illumination, exposure and focus settings, and lens choice, the still images have shallow depth-of-field (DOF). Using multi-focus still frames, one can produce composite images with wide DOF. We did not implement Z-stacking for JETT3, but future tests should include methods for doing so, particularly for photography of small details in samples.

Still Camera for Crew Navigation: The crew used the still camera as a low-light imaging device. The camera's viewfinder preview image was able, even in very dark conditions, to show the surrounding terrain with sufficient detail to enable the crew to have more confidence in navigation and positioning. This use case demonstrates the value of having a comparable capability for EVAs in challenging lighting conditions.

Assessment of JETT3 EVA Imaging: An issue in communicating between the SER and the crew was perception of color/brightness in pre-mission remotely-sensed data vs. crew field observations vs. field video/still images [3]. Artemis EVA planning and execution will need to consider differences in human perception of color/brightness vs. what is seen in images, including assessment of camera performance in relevant, high-fidelity lighting conditions.

The video feed was vital for maintaining situational awareness in the SER. When communications drop-outs prevented the ST from seeing the video or caused the video to lose synchronization with EVA audio, it was difficult for the ST to accurately follow EVA events.

Given the EVA schedule and the time to obtain still images from the field, it was not possible to extensively work with the images for science analysis or EVA replanning. The images are of sufficient quality to enable science activities, including sample documentation and curation, sample and station reconstruction (including in 3D), etc. Illumination conditions remain a challenge, and, because of the relatively small illuminated area and without the context provided by having the horizon and distant objects in the FOV, exploring the EVA site though the images is much like "viewing the site through a soda straw."

Recommendations: (1) Metadata tags are needed to correlate still image files to locations (*e.g.*, geospatial coordinates, traverse path, station), EVA events (*e.g.*, mission-elapsed time, task), and purpose (*e.g.*, sample, panorama, 3D). Methods are also needed for attaching searchable notes and descriptions to photos. (2) Video needs to be of the highest quality possible (especially resolution and low-light capability), should always be synced to audio, and needs to be recorded so that the ST can replay it on demand during and after EVAs. (3) At least thumbnail quality stills should be provided to the ST in real-time. Alternatively, high-resolution/lower frame rate video from which stills could be pulled would be beneficial [11]. (4) Many downlink and processing tasks can be automated. Similarly, video frame capture for documentation can be automated. (5) 3D modelling and HDR and Z-stack processing should be standard parts of the image pipeline. (6) Low-light camera capabilities, including for real-time crew use, should be further developed. (7) Annotated images are a powerful, information-dense way of communicating. Annotation and sharing images within the SER, between the SER and other parts of mission control, and between mission control and the crew will be important capabilities.

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References: [1] Caswell et al. (2023) *LPSC 54*. [2] Bell et al. (2023) *LPSC 54*. [3] Edgar et al. (2023) *LPSC 54*. [4] https://marshall-usa.com/cameras/CV503-WP/. [5] https://www.nikonusa.com/en/nikon-products/product/mirrorless-cameras/z-9.html. [6] Fagan et al (2023) *LPSC 54*. [7] Hurtado (2020) *LSSW 1*. [8] Hurtado (2021) *LSSW 8*. [9] https://www.hdrsoft.com.[10]https://www.agisoft.com. [11] Nawotniak et al. (2019) *Astrobio.*, v.19, n.3.

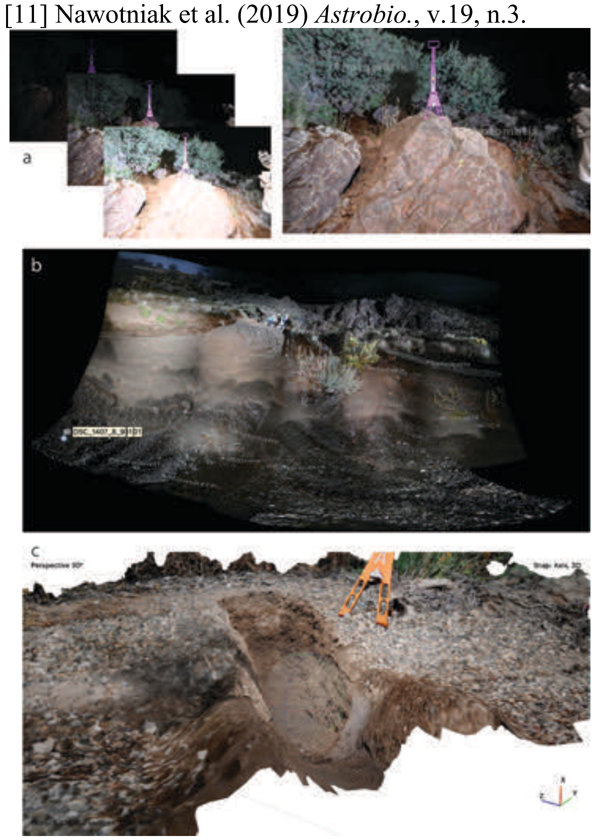

Fig. 1. *(a) HDR stack of a sample site from EVA 2 made with [9]. (b) Panoramic mosaic (EVA 3, 19 photos) made with [10]. (c) 3D model of a trench (EVA 4, 22 photos; 32M points, 3.9M faces) made with [10].*