

## Applied Science with the Artemis Baseline Camera (Nikon Z9) in Analog Field and Laboratory Investigations.

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**Introduction:** When astronauts explore the South Pole region of the Moon for the first time during Artemis III, they will capture photos with the Handheld Universal Lunar Camera (HULC). The images from the HULC will contribute to the three pillars of the Artemis program: (1) National Posture; (2) Inspiration; and (3) Science. The Nikon Z9, a 48MP mirrorless camera, was selected as the basis for the HULC, and an agreement between NASA and Nikon outlines development of the HULC for use in the harsh lunar environment (e.g. thermal blanket cover, modified grip and buttons, etc).

Testing the Nikon Z9 in multiple analog settings will increase science return from Artemis by directly addressing the needs outlined in the Artemis Science Definition Team Report [1] and the Analog Objectives for Artemis Specific Action Team Report [2]. These documents describe the need for well-choreographed in situ measurements and encourages continued efforts to exercise the capabilities of cameras like those baselined for Artemis in a range of lighting conditions, especially low-light conditions similar to the South Pole.

During 2024, we have used the Nikon Z9 paired with a NIKKOR 28mm wide-angle lens in multiple analog environments, focusing our testing efforts on science applications of the camera and associated operational considerations. Here we describe analog testing we conducted at the RISE2 [3] field site in Kilbourne Hole, NM; during the JETT5 test in Flagstaff, AZ [4]; in a cryolithology freezer study at NASA Goddard [5]; and during the ARDVARC test in Flagstaff, AZ [6].

**RISE2:** Theme 2 of the Remote, In Situ, and Synchrotron Studies for Science and Exploration 2 (RISE2) team conducted a series of field deployments to Kilbourne Hole, a volcanic maar crater in the Potrillo Volcanic Field in southern New Mexico to assess the integration of portable and handheld field instruments into analog lunar surface EVAs [3]. During the February 2024 deployment we assessed the use of handheld and suit-mounted cameras as scientific instruments during analog EVA scenarios. The team tested the Nikon Z9 to: (1) collect images that support science across a diverse range of geologic targets and lighting conditions; (2) exercise Artemis III-like operational constraints to understand and improve science return; and (3) maximize efficiency with respect to EVA time and data volume. We conducted photogrammetry tests of multiple objects (e.g. ash bed outcrops, large boulders) to test data coverage vs. collection time. Additionally, short walking traverses were conducted to compare

photogrammetrically-generated digital terrain models derived from Nikon Z9 images to those derived from suit camera video footage.

**JETT5:** The Joint EVA and Human Surface Mobility Test Team (JETT) develops, integrates, and executes human-in-the-loop tests and analog missions to prepare crew member, mission operations personnel, and science support teams for Artemis lunar surface operations. During JETT5 in May 2024, astronauts performed a series of simulated moonwalks in the San Francisco Volcanic Field near Flagstaff, Arizona, while flight controllers and scientists at NASA's Johnson Space Center in Houston, Texas guided and provided feedback on their progress [4].



*Fig. 1. Discussions around HULC images displayed in the JETT5 SER. Mosaics of HULC images were rapidly produced for display. These images revealed that the crew had encountered and sampled different materials, and this realization informed the sample collection strategy. (Photo Credit: Scott Wray)*

The astronauts utilized the HULC camera during the 4 planned EVAs, and during EVAs 3 and 4 a subset of images from the HULC were downlinked for evaluation by the Science Evaluation Room (SER; Fig. 1). Science observations, discussions, decisions, and engagement were all improved when HULC images were returned during EVAs on tactically relevant timescales. The entire SER focused on the HULC images because they were more stable, in-focus, and higher resolution than the suit camera video and acquired with scientific intent. The HULC images were a conversation starter for future observations and formed the basis for certain decisions made in the SER, including comparing sample images to those previously collected. This informed future sampling needs and refined mass estimations.

**Cryolithology Study:** The optical properties of ice can make it difficult to image, especially under low-light conditions [5]. To better understand the reflectance and absorption properties of ice and simulated regolith mixtures, we used the Nikon Z9 to conduct imaging tests of ice bearing lunar simulant in various forms in a freezer laboratory with controlled lighting. The variety of lunar simulant and ice forms we investigated is analogous to some of the potential ways that water ice might exist in the regolith of the Moon's Permanently Shadowed Regions (PSRs) [7,8,9].

We prepared icy regolith simulants with various concentrations of water (3, 5.3, 6, and 12wt%; weight percent) in dark colored pans to prevent light reflection. We also included a dry regolith sample (0wt% water), a clear distilled water ice sample, a “dark” ice sample, and a “mixed” sample. The mixed sample contained icy regolith (~20wt%) along with clasts of olivine, lava, and basaltic glass with dry regolith covering the top of half of the surface. For the dark ice sample, JSC-1A lunar mare simulant was mixed with water in a 50/50 ratio and frozen. For all the remaining samples, OB1A lunar highlands simulant was used as a proxy for the expected dominant material at the lunar South Pole. Samples were mixed using the procedures outlined in [10] wherein distilled water and simulant were homogenized before being frozen.

Images were collected in a sequence of three bracketed exposure shots: one metered exposure, one +3 exposure value (EV), and one -3 EV. This technique is similar to that used during the JETT5 [4] analog tests and planned for Artemis III surface EVAs to capture the scene’s full dynamic range. Images were taken from multiple distances and view angles with two lighting configurations: (1) oblique low-level lighting similar to the South Pole; and (2) diffuse overhead lighting.

**ARDVARC:** Augmented Reality Data Visualization Analog Research Campaign (ARDVARC) is testing a multi-phased approach to exploring a remote field site in preparation for future lunar missions [6]. The October 2024 field campaign took place at the Cinder Lakes Crater Field in Flagstaff, AZ and involved rover analog operations conducted at night with an artificial lighting system to best approximate the illumination conditions of landings sites near the lunar south pole. While supporting the ARDVARC campaign, the Nikon Z9 was utilized to image the terrain. We completed imaging tests in multiple configurations (e.g. straight down, angled, and with multiple angles with respect to sun direction). We utilized the JETT5 camera configuration and photography procedures.

**Lessons Learned and Future Plans:** Apollo astronauts completed camera training to ensure the photographs they took on the Moon were scientifically and operationally useful. To this end, photographs taken by the astronauts during their training were processed and reviewed with the crew for follow-up and feedback [11]. We recommend that this same training strategy be employed for the Artemis astronauts in preparation for lunar EVAs. Systematic HULC imaging plans will ensure consistent imaging across multiple targets and allow for pre-planned approaches to different targets (e.g. walls, boulders, ice, hardware, etc.).

From a geologic perspective, the Nikon Z9 is a capable camera for in situ science and documentation.

Pairing it with a zoom lens would be useful where astronaut mobility is limited i.e., bending down for close-up images of the surface or imaging distant targets that cannot be reached given EVA traverse constraints. Lens choice will also need to consider the depth-of-field and minimum focus distance of the camera. Our experiments in the field and cold laboratory, revealed there were imaging conditions and exposure settings where the Nikon Z9 paired with the 28-mm lens had a narrow depth-of-field, making photography of close-range (~1.5m distance) targets like samples difficult. To ensure images of samples with optimal focus, we suggest experimenting with focus-stacking, like what is utilized by Mars rover cameras [12]. In our experiments, we found that photogrammetric processing of stereo pairs and multiview stereo sequences yielded 3D products (visualizations, 3D models, etc.) that were extremely useful for making measurements and analyzing surface textures of geologic targets for relatively short time cost during EVAs.

Our cryolitholgy study results suggest that it will be difficult to determine the wt% of water in icy regolith samples with the current imaging plan. While differences in surface textures are possible to capture in images, those differences could be related to water interaction with the regolith as well as other factors, including sample preparation methods. In addition to the narrow depth-of-field issue, we found that in images taken from 1.5m distance (approx. astronaut standing height), it was difficult to resolve individual regolith and ice grains. Lens choice should consider the spatial resolution required for various science objectives.

We plan to continue to test the Nikon Z9 during more analog tests and mission simulation activities, especially under low light conditions and in Artemis operations scenarios. As the Artemis team continues to adjust HULC camera settings, lens configurations, and imaging procedures, we hope to similarly adjust our system for future imaging campaigns.

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