Analog fieldwork at Kilbourne Hole: a concept of operations for low altitude lunar remote sensing by astronauts.

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Introduction: Kilbourne Hole (KH) in the Portillo Volcanic Field in southern New Mexico is a large, Pleistocene-aged maar volcano created by explosive eruptions that distributed fine ash to large, fractured basalt fragments [1]. The Remote, In Situ, and Synchrotron Studies for Science and Exploration (RIS4E/RISE2) team has conducted a series of analog campaigns at KH during 2017-2024, focusing on the integration and collection of data using portable handheld field instruments in the context of planetary surface exploration [2]. A wide range of geological and geophysical measurements was made relevant to priorities described in the Artemis 3 Science Definition Team report [3].

The science at KH is focused on the rim and utilized orbital and aerial remote sensing image and topographic data for full coverage of the field site [4]. However, the resolution of data is not sufficient to support all surface activities and science. LiDAR instruments used on the surface obtained higher resolution data, which were useful for operational tasks such as identification of traverse hazards [5] and optimal for science tasks such as tephrastratigraphy [6]. However, a gap in data coverage and resolution exists between remote sensing and outcrop scale images and measurements of topography.

Methods: The gap was bridged using highly accurate cm-scale digital elevation models (DEMs) and image data, derived from using stereophotogrammetry of Unmanned Aerial System (UAS) camera data. UAS image data were collected at KH during previous RISE2 simulated EVA activities, meeting the project's initial need of local reconnaissance, site mapping, and site context. Broader mapping was originally proposed in RIS4E, but it was nearly phased out due to the large size of KH and smaller scope of executed field activities. The utility of UAS-derived data products was demonstrated during the 2023 RISE2 deployment [2], especially for derived map products for navigation and emerging science questions and themes, such as an analysis of block distribution and Afton basalt thickness.

At the 2024 RISE2 campaign, the UAS team developed and utilized an efficient concept-of-operations (CONOP) for GPS and UAS image surveys consisting of a mobile ground team of two operators. One operator did initial flight planning using the UAS system and third-party software. The second operator traveled by foot down range within the area of planned image acquisition, placing and surveying ground control point (GCP) targets using cm-accurate GPS for later data georegistration. One operator assumed the remote pilot responsibilities, launched the UAS and monitored image-acquiring flights. While the operators traverse down range with the UAS, battery changes were conducted from a mobile home point. GCPs were retrieved as operators exited a completed flight area. The operators worked in tandem to cover remote pilot, visual observer, and ground observation responsibilities.

Results: The CONOP allowed near continuous and efficient operation of the UAS, acquisition of broad coverage of the maar rim, and visual reach of difficult-to-access science targets in hazardous terrain. In four days, the UAS team collected ~6,000 strategic images for DEM production. The 2024 campaign resulted in cm-scale orthoimagery and topography, totaling 8 linear km, completing high resolution imaging for the full circumference of KH for detailed geologic analyses.

Discussion and Conclusion: Several efforts are underway for lunar missions to predict and minimize scientific and operational risks from topographic hazards, such as careful mission planning, hardware and software development for sensing hazards, and synthetic realistic terrain generation for surface operation simulations that predict a range of responses to hazards [7-9]. The ideal solution is complete knowledge of the terrain, its properties, and the potential interactions with mission assets. The 2024 RISE2 field campaign presented a similar challenge that was addressed effectively using a UAS CONOP that is a model for bridging the gap between orbital and outcrop scale data. The lunar surface introduces unknown operational limits that highlight the opportunity costs to potential science, and Artemis missions will be faced with a similar data gap, but will not have conventional UAS capability. This problem could be solved with development of a Lunar Overhead Imagery System (LOIS) combined with the lunar relevant CONOP developed here. This would provide advantages to both operations and science tasks, most importantly a significant gain in knowledge of the proximal and distal operations area on the lunar surface.

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