GEOLOGIC EXPLORATION ENABLED BY OPTIMIZED SCIENCE OPERATIONS ON THE LUNAR SURFACE. J.L. Heldmann[1], D.S.S. Lim[1,2], A. Colaprete[1], W.B. Garry[3], S.S. Hughes[4], S. Kobs Nawotniak[4], A. Sehlke[1], C. Neish[6], G.R. Osinski[6], K. Hodges[7], A. Abercromby[8], B.A. Cohen[3], A. Cook[1,5], R. Elphic[1], H. Mallonee[4], A. Matiella Novak[8], E. Rader[1], D. Sears[1,2], H. Sears[1,2] and the FINESSE and BASALT teams. [1]NASA Ames Research Center Moffett Field, CA, [2]Bay Area Environmental Research Institute, Petaluma, CA, [3]NASA Goddard Space Flight Center, Greenbelt, MD, [4] Idaho State University, Pocatello, ID, [5]Millennium Engineering, Moffett Field, CA, [6]Western University, London, Ontario, Canada, [7]Arizona State University, Tempe, AZ, [8]Johns Hopkins University / Applied Physics Lab, Laurel, MD.

Introduction: Humanity's return to the lunar surface will enable unprecedented studies of science on, of, and from the Moon. Of great interest are in situ studies with human and robotic explorers of volcanism and impacts as the dominant planetary processes shaping the Moon. We've conducted such research in terrestrial analog environments, and both the science and exploration research is placed in the context of optimizing the scientific return from upcoming lunar surface missions. This paper presents detailed geologic field studies that can best be accomplished through in situ investigations, and the associated recommendations for human and robotic mission capabilities and concepts of operations for lunar surface missions.

To this end, NASA's FINESSE (Field Investigations to Enable Solar System Science and Exploration), partnered with NASA's BASALT project has conducted numerous field campaigns to field sites as lunar analogs. The scientific investigations are directly correlated to the related science applicable to the Moon, and the concepts of operations and capabilities required to conduct these investigations are tested, validated, and used to inform human architecture planning through NASA's human spaceflight program.

Field Sites: Our work is focused at three locations.

Craters of the Moon (COTM) National Monument and Preserve. COTM is a dominantly basaltic volcanic system with a variety of well-exposed analogs to volcanic formations on the Moon [1]. Field research topics include, but are not limited to, comparative planetology to understand the geologic history of volcanic landforms (e.g., cinder cones, lava tubes, different lava flow types, rilles and vent structures) similar to features within the Marius Hills region [2], measuring surface roughness with implications for emplacement of lava flows and impact melt [3], understanding phreatic craters and ballistic ejecta field formation [4], and testing various techniques such as thermoluminescence for age dating volcanic flows [5].

West Clearwater Impact Structure (WCIS). WCIS is located in northern Quebec, Canada and possesses one of the best records of impact melt rocks and breccias among impact craters on Earth. Science research at WCIS includes constraining the age of the impact through geochronology [6], assessing shock metamorphism and complex crater collapse [7], studying impact induced geothermal activity, and characterizing unique impact features such as lineaments and melt veins [8].

Kilauea Volcano, Hawai'i. Kīlauea presents a basaltic terrain with a variety of surficial features analogous to lunar features. The historically active volcanoes enable the investigation of relatively sterile, recently-erupted lava as well as basaltic substrates and fumaroles. Hawai'i has also served as a key field site for past and current surface exploration research.

Exploration Investigations: Exploration research is conducted within the context of enabling bona fide scientific investigations. This research focuses on operational concepts such as the structure and functions of extra-vehicular activity, intra-vehicular activity, mission control and science backroom teams [9]. New technologies are incorporated into the deployments and evaluated for efficiency and utility including, but not limited to, portable field instrumentation (VIS-NIR spectrometer, portable XRF, portable LIBS, FLIR cameras, LiDAR, UAV systems, etc.) to identify capability requirements for future instrument development, comparison of lab versus field data, ergonomics and instrument use considerations for science output and decision making pathways [10]. We have also assessed science training required for astronaut explorers and provide recommendations regarding subject matter, approaches, instrumentation, and follow-up laboratory work in conjunction with active duty astronaut participation [11].

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