FIELD GEOLOGY BOOT CAMP FOR NASA ENGINEERS AND MANAGERS. C. A. Evans[1], T. G. Graff[2], K. E. Young[3], J. E. Bleacher[3], J. M. Hurtado[4], L. A. Edgar[5], J. A. Skinner[5], [1]NASA Johnson Space Center, 2101 NASA Pkwy, Houston TX 77058, cindy.evans-1@nasa.gov, [2]Jacobs Engineering, NASA Johnson Space Center, Houston TX 77058, [3] NASA GSFC, Greenbelt MD, [4] Univ. Texas, El Paso, El Paso TX, [5] USGS Astrogeology Center, Flagstaff AZ.

Introduction: With planning efforts for Artemis missions to the Moon in full swing, including plans for operations and EVAs (extra-vehicular activities or space walks) focused on planetary surface exploration, a team of geologists from NASA, the USGS, and academia have been working together to provide training to the NASA engineering and management community.

The lunar science community has long studied the benefits of field training for astronauts and has drafted recommendations for field training for future Artemis astronauts [e.g., 1, 2]. Further, a team from across NASA, the USGS, and the academic community has been providing intensive field training to new astronaut classes since 2009 [3-7]. But to ensure mission planning and hardware engineering success, it is also beneficial for those who are developing Artemis plans, hardware, and operations (e.g., NASA flight controllers, hardware engineers, and managers) to develop some knowledge of the lunar exploration environment by learning introductory geology, field principles, and operations. To address this need, we have developed and refined the class "Field Geology Boot Camp for NASA Engineers and Managers".

The idea for broader community training in the field sciences was initiated in the late 2000s, during the NASA Constellation era, with the purpose of providing students hands-on experience with the some of the complexities of surface field operations. Adopting best practices from Apollo, including training with the flight control team and mission managers [2], scientists at the Johnson Space Center conducted an Engineer-Manager trip in 2009 that included a group of ~10 engineers from across NASA. These students were assigned to small teams, each with a field instructor, and were tasked with building a geologic map of a small field area [3]. The first classes, through 2015, were held in an area near Los Alamos, New Mexico.

Discussion: In recent years, our team has revised the class and have developed a field area north of Flagstaff, AZ in the San Francisco Volcanic Field near SP Mountain. In partnership with scientists at the USGS Astrogeology Science Center and with other academic collaborators, we have standardized the pre-field lectures and activities and worked closely with programs and organizations within NASA's human exploration mission directorates to understand their needs and requirements. Currently, we aim to conduct the training with at least 2 classes a year, targeting 16-20 students per class, including members of Artemis flight control teams and NASA's engineering community.

We designed the class, exclusive of travel, to include an introduction and preparatory evening class, followed by 2 field days. We divide the participants into mapping teams that include 3-4 students from different areas of expertise to enable cross-disciplinary discussions. Each group is assigned 1-2 instructors who are experienced field geologists.

The fundamental attributes of the class include: (1) instructor-provided background on surface operations and planetary exploration; (2) instruction on individual and team field tools – maps, clipboards, hand lenses, eye protection for each student, and shared field equipment for each team (e.g., geologic hammer and chisel, first aid kit, binoculars, radio, GPS receiver, and sample bags); (3) team development of a pre-field planning map based on remotely sensed imagery and topographic information to guide each team's fieldwork, to be modified in the field as they collect observations; (4) facilitated field guidance by instructors, to include a mix of field geology science, observational techniques, and operational considerations with focus on the development and testing of multiple working hypotheses, documentation of field observations, and the flexible execution of traverse plans; (5) finalized geologic maps from each team and a presentation to the other teams about their map, their inferred geologic history, their map-making process and traverse strategy, their representative hand samples from each geologic unit, and any remaining unknowns; and (6) after each team has discussed their results and experiences, we have a group discussion about the training take-aways and how they can be applied to each student's "day job".

Results: Since 2015, our team has trained 63 engineers and managers from across NASA. There has been a particular emphasis on engineers from the EVA office; engineers designing space suits, geological tools, and new software elements to aid EVAs; mission planners; flight operations personnel; and EVA training engineers. The students have also included robotics specialists and managers of planetary science operations.

With the overarching goal of beginning to build a common language and base of experience across the science-engineering-operations-management

community, some of the critical take-aways from the training include: (1) the benefit of understanding complexities of terrain; (2) the importance of lighting; (3) the complementary value of broad observations about the landscape (landscape scale morphologies), together with smaller-scale (outcrop or local) observations of mineralogy, the presence or absence of different kinds of rocks in outcrop or as surface float, changes in surface color, etc.; (4) the inevitability of adjusting plans because the landscape tells a story different from the remote sensing imagery used to build the initial plan; (5) the benefit of working with team mates from different areas of expertise and different skill sets and perspectives; and (6) the implications for designing complex operations in a real planetary setting.

Going forward, our team is working closely with Artemis managers and flight controllers to ensure that critical staff receive this training as Artemis mission architectures and operations plans are developed and translated into integrated mission training, simulations, and execution.

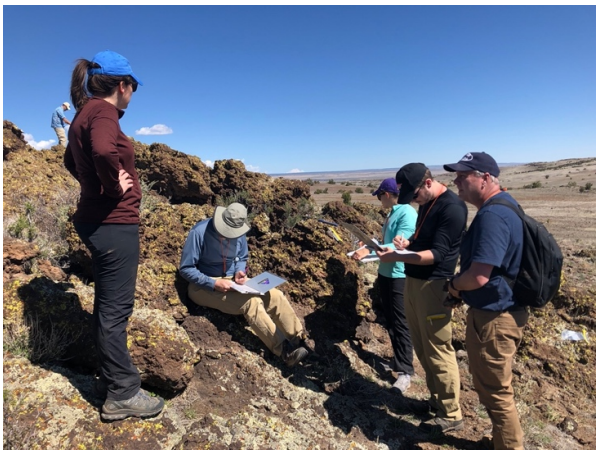

Figure 1. NASA engineers making field observations and creating geologic maps.

References: [1] LEAG Geologic Astronaut Training Strategic Action Team (GAT-SAT), https://www.lpi.usra.edu/leag/reports/; [2] Phinney, W., (2015), NASA/SP-2015-626; [3] Eppler, et al, 2016, GSA Today, v. 26, no. 8, doi: 10.1130/GSATG295GW.1; [4] Evans C. A. et al. (2018) AGU, P31H-3798; [5] Graff T. G. et al. (2018) 49th LPSC, 2547; [6] Graff T. G. et al. (2019) 50th LPSC, 2139; [7]Graff, et al, (2020), 51st LPSC, 1787.