LUNAR SURFACE GEOSCIENCE TRAINING FOR ASTRONAUTS. T. G. Graff[1], K. E. Young[2,3], C. A. Evans[2], J. E. Bleacher[3,4], A. D. Kanelakos[2], and S. J. Wray[5], [1]Jacobs, NASA/JSC, Houston, TX 77058 (*trevor.g.graff@nasa.gov*), [2]NASA/JSC, [3]NASA/GSFC, [4]NASA/HQ, [5]KBR.

Introduction: Geoscientists have been training and preparing astronauts to observe the Earth from space and explore other planetary surfaces with a legacy that reaches back to the early days of the space program [1-8]. Continuing this legacy and critical function, a core NASA team has been closely coordinating with the Johnson Space Center (JSC) Flight Operations Directorate (FOD) as well as academic, research institutions, and other governmental partners to conduct a comprehensive geoscience training program that ranges from initial astronaut candidate training [9-13] to preparing assigned crew for future lunar surface missions. Described below are the three program training phases (summarized in Figure 1), along with recent program highlights and forward planning. Given NASA's increased planning and development efforts regarding near-term lunar surface science activities, we welcome ideas, concepts, capabilities, collaborations, and innovations to this astronaut training program.

Phase 1 - Initial Training: The initial training, or Phase 1, of the program is conducted during the intensive ~two-year astronaut candidacy period. This phase has been iteratively developed based on feedback from the Group 20 (2009) and Group 21 (2013) astronaut classes, input from the Lunar Exploration Analysis Group (LEAG), and findings from a NASA HQ commissioned Strategic Action Team on Geologic Astronaut Training. Approved by the NASA Astronaut Office and the FOD Astronaut Candidate Training Working Group, Phase 1 content is currently comprised of a comprehensive 4-week training curriculum that includes classroom and field components. Classroom training modules include Geoscience Fundamentals (tectonics, structural geology, remote sensing, geomorphology, and volcanism), Earth Systems (land cover/land use, atmospheric and climate sciences), and Planetary Science and Exploration Missions (Moon, Mars, small bodies, and astrobiology). Field training activities include expeditions to geologically-relevant locations that are particularly well-suited to introductory geoscience training, sampling, and mapping activities. In addition, these field activities serve as a mechanism for expeditionary skill set development by providing a platform for operational, team, and leadership experiences.

Group 22 (the NASA and Canadian Space Agency class selected in 2017 nicknamed "The Turtles") was the most recent group of astronaut candidates to complete Phase 1 of the geoscience training program. The overall training curriculum for Group 22 is detailed in [11], with their specific 2018 and 2019 geoscience training activities highlighted in [12] and [13] respectively. Initial planning for the selection and training of Group 23 is already underway.

Geoscience training for NASA engineers, flight operations, mission planning, and managers has also been a successful component of Phase 1. Leveraging the astronaut candidacy curriculum, this program has developed and provided a field-based geoscience training short course to members of the NASA community that are currently working on lunar and planetary surface exploration initiatives. Providing real geologic fieldwork exposure and a unique cross-organizational training experience to those planning missions, developing operations, and building flight hardware has proven extremely valuable.

Phase 2 – Proficiency Training: Phase 2 of this program strives to build upon the foundational knowledge gained during the initial phase. This astronaut training takes place post candidacy and prior to flight assignment. Phase 2 geoscience training includes Crew Earth Observations (conducted by JSC Earth Science and Remote Sensing experts in preparation for flight on the International Space Station), slots for crewmembers in high-fidelity operational mission analogs (like the undersea NASA Extreme Environment Mission Operations (NEEMO) or the Desert Research and Technology Studies (Desert RATS) projects), and opportunities to accompany field scientists on expeditions to accomplish cutting-edge science objectives. These opportunities give astronauts a chance to maintain and develop the knowledge built during Phase 1, as well as deploy that knowledge in operationally relevant settings. These unique field and analog mission opportunities also give crewmembers the opportunity to build upon critical team and leadership skills.

In addition to the field-based activities, Phase 2 also includes numerous JSC facilities currently under development to simulate lunar and planetary surface conditions for crew training, operational testing, physiological assessments, and hardware evaluations. These facilities include the Active Response Gravity Offload System (ARGOS), the Neutral Buoyancy Laboratory (NBL), the JSC Rock Yard, the Physical And Cognitive Exploration Simulations (PACES) lab, as well as numerous mixed reality facilities. Science content and planning considerations have been closely integrated into the development of these training facilities in the form of appropriate simulant materials, science operations, terrain modeling, sampling methods, scientific

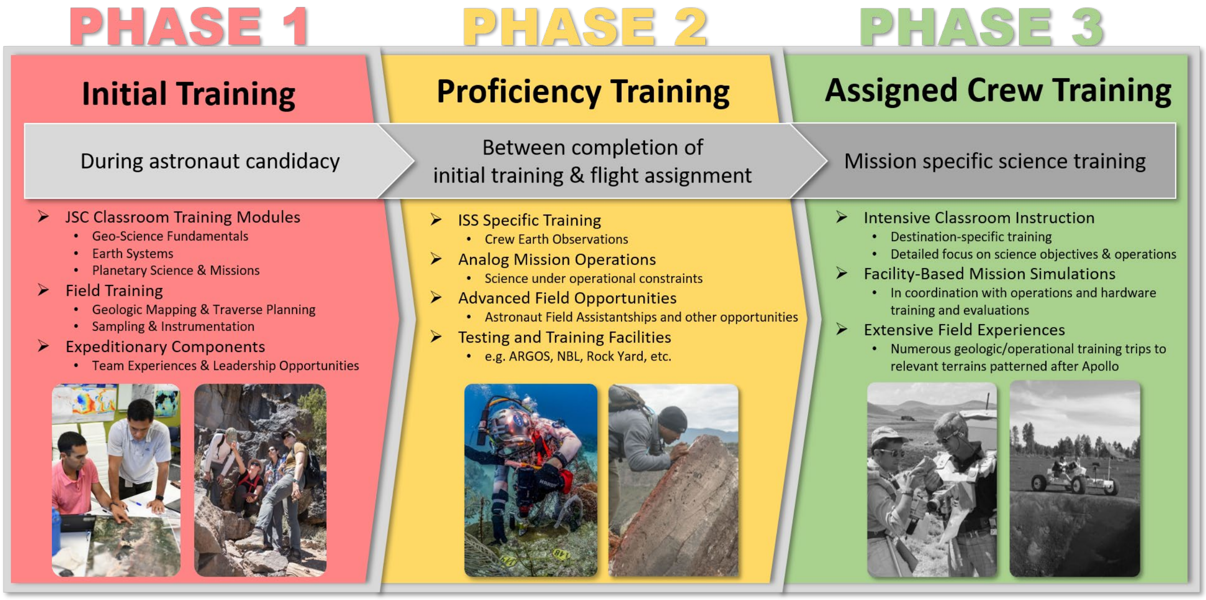

Figure 1: Schematic demonstrating the three phases of astronaut training, starting from candidacy and moving through mission specific training.

instrumentation, mobility considerations, tool development, and traverse planning.

Phase 3 – Assigned Crew Training: Planning is currently underway for Phase 3, the intensified training that will take place once a crew is assigned and a landing site is selected for a specific lunar or planetary exploration mission. Phase 3 training will include additional geoscience classroom instruction and extensive fieldwork geared towards the science objectives of the mission, as well as detailed science operations incorporated into facility-based simulations (e.g. ARGOS, NBL, etc.) using flight-like hardware (space suits, landers, rovers, tools, instruments, etc.). This phase of geoscience training will be highly integrated with JSC's FOD and a strong partnership is already established.

Phase 3 components that are currently underway include the selection of field training locations, science operational planning, and lunar surface tool development. Initial evaluations and reconnaissance of potential geoscience field and operational training locations for a lunar south pole mission are in progress. Current progress on science operational planning and the development of Artemis sampling tools are reported by [14] and [15] respectively.

Conclusions: A comprehensive multi-phased geoscience training program is well-established for training astronauts from initial candidates all the way to selected crew for lunar or planetary missions. A successful Phase 1 of this training program was recently completed training the Group 22 Astronaut class. Phase 2 training opportunities have been given to a number of crewmembers over the last several years through field assistantships, crew slots on analog missions, facility testing, and classroom training in Crew Earth Observations. As NASA moves forward with the Artemis program, Phase 3 development is underway and will include extensive classroom instruction, facility simulations, and field experiences. We welcome ideas, concepts, capabilities, collaborations, and innovations to this training program.

Acknowledgments: We would like to acknowledge the contributions, hard work, and dedication of all the individuals and organizations that have made this program possible and successful. Collaborations across universities, research institutions, other governmental agencies, JSC organizations, and NASA centers is critical to the success of this program and will ultimately maximize the scientific return from future missions to the lunar surface.

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