NASA'S GEOSCIENCE TRAINING PROGRAM FOR ASTRONAUTS. T. G. Graff [1], K. E. Young[2,3], C. A. Evans[2], J. E. Bleacher[3,4], [1]Jacobs, NASA/JSC, Houston, TX 77058 (*trevor.g.graff@nasa.gov*), [2]NASA/JSC, [3]NASA/GSFC, [4]NASA/HQ.

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, institute, and other governmental partners to conduct a comprehensive geoscience training program that ranges from initial astronaut candidate training [9-12] to preparing crew for Artemis missions. Described below are the three program training phases (summarized in Figure 1), along with recent program highlights and forward planning.

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 of the training program has been developed based on feedback from the 2009 and 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 Astronaut Candidate Training Working Group, the Phase 1 content is 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 and land use, atmospheric and climate sciences), and Planetary Science and Missions (Moon, Mars, and small bodies, as well as astrobiology). Field training activities include expeditions to geologically-relevant locations that are particularly well-suited to introductory geoscience training and mapping activities. In addition, these field activities serve as a mechanism for expeditionary skill set development by providing a platform for operations, team, and leadership experiences.

Group 22 (the NASA and Canadian Space Agency class selected in 2017 and 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] and their 2018 geoscience training activities are highlighted in [12]. Their 2019 activities included a classroom training week that took place September 9th to 13th at JSC. This week featured prominent instructors from several university, institute, other governmental, and NASA scientists covering fundamental topics in atmosphere and climate science, land cover/use, remote sensing, and cratering. Additionally, this week covered the planetary science and missions training modules including small planetary bodies, Mars, astrobiology, and an extensive module on Earth's moon. To reinforce and apply their new geoscience and planetary fundamental knowledge, the astronaut class completed a capstone exercise focusing on two case study regions. Teams analyzed volcanic, structural, impact cratering, and surface features at two key locations on the Moon (Aristarchus Plateau) and Mars (Jezero Crater) and addressed the questions of *what's there*, *what happened*, *when*, and *why*. Teams presented their regional analyses and rationale to the rest of the class and to instructors at the conclusion of the capstone. The remainder of the 2019 classroom training consisted of a block of instruction covering field instrumentation, tools, and sampling techniques, as well as a pre-fieldwork mapping exercise that prepared them for their field activities.

The 2019 field training took place from September 15th to 20th, immediately following the classroom training. Basecamp was established near Flagstaff, Arizona, with logistics support provided by the New Mexico Bureau of Geology and Mineral Resources and local area expertise by the USGS Astrogeology Science Center. The field mapping area was located in the San Francisco Volcanic Field (SP Crater region) north of Flagstaff. This region was selected based on a number of training objectives and has a long history of NASA training and operational activities. For the three days of mapping activities, the class was divided into three teams with field objectives to 1) observe and apply classroom geoscience fundamental concepts, 2) construct a geologic map and cross section, 3) conduct detailed traverse planning/re-planning, 4) collect a representative sample suite using a set of planetary exploration-relevant sample collection tools, and 5) present their finished products and interpretations of geologic history at the conclusion of the field mapping exercise. After the field mapping days, the class visited Barringer Meteorite Crater for a day of guided instruction and activities in the processes and products of impact cratering. The class concluded the field week with a guided instructional hike into the Grand Canyon along a portion of the Grandview Trail.

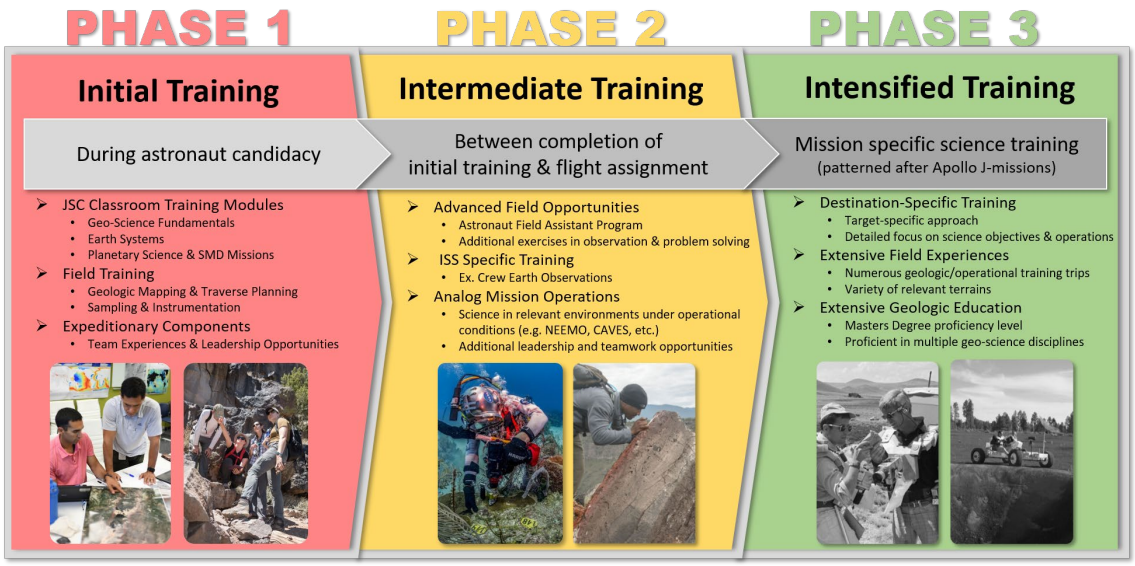

Figure 1 (above): Schematic demonstrating the three phases of Astronaut training, starting from candidacy and moving through mission specific training.

Phase 2 - Intermediate Training: Phase 2 of this program strives to build upon the foundational knowledge gained during Phase 1. This training takes place post candidacy and prior to flight assignment and consists of a variety of training opportunities. These include training for flight on the International Space Station in Crew Earth Observations (conducted by JSC Earth Science and Remote Sensing experts), slots for crewmembers in high-fidelity operational mission analogs (like the undersea NASA Extreme Environment Mission Operations – NEEMO project), and opportunities to accompany field scientists on expeditions to accomplish cutting-edge science objectives. These opportunities give crew a chance to maintain and develop the knowledge built during Phase 1 training as well as deploy that knowledge in operationally relevant settings. These field and analog mission opportunities also give crewmembers that opportunity to develop team skills while conducting science operations.

Phase 3 - Intensified Training: Planning is currently underway for Phase 3, or training that will take place once a crew is assigned for a planetary exploration mission. Similar to the training that the Apollo astronauts received prior to their lunar surface missions, future astronauts, once assigned to a mission, will receive destination-specific training once a landing site has been selected. Training will also include additional classroom training as well as extensive fieldwork geared toward processes relevant to their future missions, including operationally-relevant scenarios and science training.

Conclusions: A comprehensive multi-phased geoscience training program is well-established for training astronauts from initial candidates all the way to selected crew for 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, and classroom training in Crew Earth Observations. As NASA moves forward with an eye on the Artemis program, Phase 3 development is underway that will include extensive destination-specific, field, and classroom training.

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