

**ASTRONAUT GEOLOGY TRAINING: BACK TO THE FUTURE, OR DEJÁ VU ALL OVER AGAIN...**

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**Introduction:** The scientific success of the Apollo Missions is a testament to the scientists, engineers and managers who developed the exploration architecture that accomplished their goals. There will be numerous differences between the Apollo Program and HEOMD approaches to surface science during future human exploration of the Solar System. However, many similarities will likely exist. The Apollo Program approach to preparation for science operations included extensive geology training, including over 1000 hours per crew member during the J-Missions [1]. Fielding well-trained crew members, particularly for those who do not possess a science background, was considered a major influence on the science success of those missions [1-4]. Although the Apollo geologic training program was discontinued in 1972, Space Shuttle crewmembers received 40-50 hours of limited training in Earth observations prior to their flights [5]. In 2008, it was decided to revamp the geologic training curriculum to include more thorough classroom work and geologic mapping to improve the astronaut's observations skills and understanding of basic geological concepts. The two most recent astronaut candidate classes (2009 and 2013) received this improved geology training, and the Astronaut Office has also involved senior members in short field geology mapping courses and field assistant programs. Here we discuss the current status of astronaut geology training and plans for the future.

**Background:** Geology training for the Apollo Program was conducted in an atmosphere of known targets and defined science objectives. The current environment within NASA involves development of hardware to carry humans to a series of possible destinations, with a long range vision of humans at Mars. As such, geology training at this time is primarily focused on basic geologic concepts as a means of enhancing observations and science that might be conducted from the ISS. The goal is not to train astronauts in lunar, asteroid or Mars science, but to begin training the mindset that all astronauts should know the scientific value of, and routinely consider the observations they can make from their unique vantage point. We plan to help develop a Crew Office within which consideration for science operations is the norm for all decision making steps during the development of the human exploration architecture.

**Geology Training:** Geology training for the astronauts can be generally divided among three main approaches, including: 1) class room teaching and field exercises, 2) a field assistant program, and 3) integrated analog field tests. Classroom and field exercises incorporate an "outcrop to orbit" perspective; whether the subject is structural geology or volcanology, all topical training integrates orbital observations. The field component of geology training is also integrated with a Crew Office requirement to routinely provide expeditionary training and team building experiences.

**Classroom & Field Exercises:** Classroom training and field exercises are the primary mechanism for training during astronaut candidacy. The curriculum includes input from > 30 geologists both within and outside of NASA. Classroom training is focused on basic field geology concepts and for the 2013 class involved three weeks of classroom activities. Discussion of target specific science was provided in an historical context with respect past or currently active missions, such as Apollo, MER and MSL.

The approach to classroom training involves a daily focus on a single geologic discipline. Typically the crew were presented with a perspective of what they can expect to see from ISS, essentially a regional to global perspective from orbit. Lectures and activities become more focused on details within each discipline. The details are not presented as material to be memorized and retained but in a manner that enables the crew to understand why the observations they can make from ISS are important to scientists on the ground. For example, the crew are trained not to necessarily interpret that a volcano is rhyolitic but to explain that they see a volcano with steep flanks and a dark colored plume that extends nearly 3 volcano diameters away from the vent. The goal is to train scientific observational skills and an understanding of the value of those observations.

During classroom training each crew member constructs a preliminary geologic map of the field exercise area, a volcanic region of about 140 km<sup>2</sup>, from remote sensing data. Most days are concluded by revisiting and revising the map on the basis of the geologic lessons that day. The end result is a well constructed remote sensing map from which they develop field-testable hypotheses and plan their field activities.

Shortly after completion of classroom training the crew are taken into the field. Although the primary

objectives are geological, living and working outdoors also provides opportunities for expeditionary training. With preselected field targets and their preliminary maps in hand, crew member pairs and a field geologist conduct geologic mapping, sample characterization and collection, and data collection with a range of geologic instruments. A geologic map and cross section that integrates both remote sensing and field observations are the final team products of these efforts. Results are later compared with published interpretation(s) for the site. Upon requests from the Crew Office, a similar approach has been adopted for senior members who joined the Astronaut Corp prior to the 2009 class. Field training exercises for this purpose have been conducted several times in the last few years with the intent of providing a baseline level of geologic training and experience for the entire Crew Office.

**Field Assistants:** Classroom training and field exercises provide a large group with a basic level of geologic knowledge. However, basic field exercises can lack a sense of “doing new science”. To address this the field assistant program was developed. In this program geology trainers inform the Crew Office of opportunities for astronauts to take part in current research projects. As field assistants the crew members are given an opportunity to experience the reality of testing multiple working hypotheses and dealing with the real-life difficulties of doing so. The participants are exposed to situations where field geologists disagree while discussing their observations in the field. This provides the field assistants with a realistic view of how geologists communicate and present their observations and testable hypotheses. The emphasis complements the goals of the classroom/field activities in which training observational capabilities is the goal. We consistently find the field assistant program to benefit the geologists as well. Astronauts often approach field science from well outside the geologist’s “box” of thinking. By challenging the team’s conventional thinking the assistants help push the research in new directions. Because many of these projects are related to planetary analogs, the astronauts who participate are also given a chance to gain relevant planetary science knowledge, which they typically present to the Crew Office through briefings. Perhaps the best testament to the quality of the students in the training is the recognition that astronauts have often made observations that the professionals have missed.

**Developing Future Approaches and Practices:** The program described above has been in place informally since 2008, and has trained two successive classes of astronauts, as well as having exposed engineers and managers to geologic field work. Although it has proceeded unofficially, the success of the program has

prompted a detailed review, using the “LEAG SAT” (Lunar Exploration Analysis Group, Special Action Team) process, to prepare for the 2017 Astronaut Candidate Class and to move into the future. Besides evaluating the curriculum presented to the previous classes, this Geology Astronaut Training (GAT) SAT will develop an updated training program for the 2017 class, and design a field assistant program that has a more consistent investigator team, with predictable funding and regular schedule. In addition, conducting geologic investigations in situations that continues to develop teamwork and management skills in outdoor settings serves to improve skills in both areas. The popularity and success of this program supports the notion that geologic astronaut training be formally included in the astronaut training program. This is especially critical as a number of key members of the current training experts are nearing retirement age. Introducing more management planning into the execution of this program will ensure that new trainers are brought into the program to take the place of those individuals of conceived of, and executed this modern incarnation of an old Apollo success story.

**Conclusions:** Field geology training was a fundamental aspect of the success of the Apollo Program. Astronauts of the Shuttle Program era received roughly one week of training related to orbital observations of the Earth. LEAG and CAPTEM recently recommended an increase in this training and the development of an official geology training program to ensure the science success of future human exploration programs; the GAT-SAT will address those recommendations. Geology training that was developed and implemented within NASA for the 2009 and 2013 astronaut classes included NASA personnel, US and State Geological Surveys and participants from academia. This effort builds upon the Apollo geology training, is reestablishing the links between NASA and professional geologists outside of NASA, and has exposed several early career participants to the institutional Apollo knowledge base that is now retired or might be retired over the next decade. The goals of the training program are to develop a Crew Office with a healthy understanding of how science fits within human exploration of the Solar System and to put in place and provide experience for the next generation of astronaut geology trainers.

**References:** [1] Lofgren, Horz, Eppler (2011) GSA SP483, 33-48. [2] Schmitt et al., (2011) GSA SP483, 1-16. [3] Hodges, K. & Schmitt, H. (2011) GSA SP483, 17-32. [4] El-Baz, (2011) GSA SP483, 49-66. [5] Evans, Wilkinson, Stefanov, Willis, (2011) GSA SP483, 67-74.