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Scientific field training for human planetary exploration

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ABSTRACT

Forthcoming human planetary exploration will require increased scientific return (both in real time and post-mission), longer surface stays, greater geographical coverage, longer and more frequent EVAs, and more operational complexities than during the Apollo missions. As such, there is a need to shift the nature of astronauts' scientific capabilities to something akin to an experienced terrestrial field scientist. To achieve this aim, the authors present a case that astronaut training should include an Apollo-style curriculum based on traditional field school experiences, as well as full immersion in field science programs. Herein we propose four Learning Design Principles (LDPs) focused on optimizing astronaut learning in field science settings. The LDPs are as follows:

(1) LDP#1: Provide multiple experiences: varied field science activities will hone astronauts' abilities to adapt to novel scientific opportunities
(2) LDP#2: Focus on the learner: fostering intrinsic motivation will orient astronauts towards continuous informal learning and a quest for mastery
(3) LDP#3: Provide a relevant experience—the field site: field sites that share features with future planetary missions will increase the likelihood that astronauts will successfully transfer learning
(4) LDP#4: Provide a social learning experience—the field science team and their activities: ensuring the field team includes members of varying levels of experience engaged in opportunities for discourse and joint problem solving will facilitate astronauts' abilities to think and perform like a field scientist.

The proposed training program focuses on the intellectual and technical aspects of field science, as well as the cognitive manner in which field scientists experience, observe and synthesize their environment. The goal of the latter is to help astronauts develop the thought patterns and mechanics of

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an effective field scientist, thereby providing a broader base of experience and expertise than could be achieved from field school alone. This will enhance their ability to execute, explore and adapt as in-field situations require.

1. Introduction

Gene Shoemaker[1] advocated astronauts be "instruments of scientific discovery". His opinion was formed during the Apollo era, which focused on proofing technologies, as well as collecting lunar rocks and visual data for post-mission scientific analyses. Apollo Moon missions were characterized by short stays and geographically restricted extra-vehicular activities (EVAs). As such, scientific training efforts were designed to ensure that Apollo astronauts were versed in geological methods, terminology and techniques relevant to their exploration of the Moon (see Wilhelms, 1993 for overview). Training evolved as the Apollo program moved from the G to the J class missions, which involved longer, more complex EVAs, and an increased emphasis on scientific return. Instruction to prepare the astronauts included both classroom and field activities, the latter of which took them to locales around North America such as Meteor Crater in Arizona, Kilauea Volcano in Hawaii, and the Sudbury Impact Crater in Ontario, Canada. These sites were chosen for their relevance as lunar analogs where astronauts could enhance their scientific knowledge, and ultimately possess the ability to act as proxy scientists on the Moon. The training efforts were deemed a success. Indeed, NASA's Apollo era astronauts demonstrated a high degree of sophistication in real-time and post-mission scientific activities.

Shoemaker's philosophy still resonates today as we enter a new era of human space exploration. It is reasonably anticipated that NASA's Exploration Architecture for the next round of human planetary exploration will include increased demand for scientific return both during and after the mission, longer surface stays, greater geographical coverage, more frequent and lengthy EVAs, and more operational complexities to test and ground truth preliminary conclusions reached from remote-sensing experiments, and to explore previously unsurveyed regions.

These factors will allow for and demand a greater degree of intellectual, physical and operational autonomy for the astronauts relative to what occurred during the Apollo missions. Harrison "Jack" Schmitt was the only formally trained field scientist to take part in the Apollo missions. In the future, predominantly selecting experienced field scientists as astronauts would be one mechanism to ensuring a high degree of scientific return, innovation and discovery on the Moon, Mars, and other targets such as Near Earth Objects (NEOs). Realistically, however, astronauts will be chosen from a variety of backgrounds, both scientific and non-scientific, and crews will comprise a mixture of expertise. This creates both an opportunity and a need to shift the nature of astronauts' scientific capabilities to something akin to an experienced terrestrial field scientist. A summary of past and present scientific exploration circumstances is summarized in Table 1.

To achieve this aim, we propose that training include an Apollo-style curriculum based on traditional field school experiences, as well as full immersion in field science programs. Herein we propose four Learning Design Principles (LDPs) focused on optimizing astronaut learning in field science settings. The proposed training program would focus on the intellectual and technical aspects of field science, as well as the cognitive manner in which field scientists experience, observe and synthesize their environment. The goal of the latter is to help astronauts develop the thought patterns and mechanics of an effective field scientist. This will offer them a broader base of experience and expertise to draw upon in order to hone their ability to execute, explore and adapt as the situation requires. This field science training could be used to train both individual astronauts and pre-determined teams of astronauts.

In effect, astronauts can become both *instruments* and *innovators* of scientific discovery, and we expect large scientific gains to result. A recent Field Exploration Analysis Team (FEAT) white paper (Schmitt et al., in review) describes the need to develop astronauts with the field science know-how to be able to "interpret the unexpected," or at least collect the data that can eventually be used to interpret the "unexpected." The purpose of this paper is to present ideas on how to connect on-going and future exploration and science activities, and to use this synergy to prepare astronauts so that they can face the unforeseen, unexpected scientific circumstances that are commonly encountered by terrestrial field scientists, and which will undoubtedly be encountered on a variety of planetary settings.

Table 1
Comparison of Apollo era versus future human planetary exploration opportunities and astronaut training needs. The additional opportunities and training needs for future missions are in BOLD.

Apollo	Future human planetary exploration activities
Opportunity: Proofing of technological innovations on the Moon and the application of well-established field methods in geology and geophysics to the collection of rock and visual data for post-mission scientific analyses by extended (terrestrial) science team	Opportunity: Proofing of technological innovations on the Moon/**Mars/other planetary bodies** and the application of well-established field methods in geology and geophysics to the collection of rock and other data for **real-time** and post-mission scientific analyses by **immediate (astronaut)** and extended (terrestrial) science team **More in-depth scientific discovery and innovation while conducting on-site planetary exploration**
Astronaut science training requirements: Grounding in relevant geological and field techniques, including data collection, nomenclature, and sample triage	Astronaut science training requirements: Grounding in relevant geological and field techniques, including data collection, nomenclature, and sample triage **Experience and expertise in field science techniques, including cognitive, operational, and team science components of field science**
Training method: *Field school*—Classical geological field school activities, including classroom and field learning	Training method: *Field School*—Classical geological/biological field school activities, including classroom and field learning ***Field science*—immersion in real field science activities**

[1] Eugene M. Shoemaker created the research field of planetary science, and was affiliated with the US Geological Survey and the California Institute of Technology (Caltech). Among many legendary accomplishments, he was also involved with Apollo astronaut field training. More information about Dr. Shoemaker can be found at http://astrogeology.usgs.gov/About/People/GeneShoemaker/.