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Tools and technologies needed for conducting planetary field geology while on EVA: Insights from the 2010 Desert RATS geologist crewmembers

Kelsey Young [a,*], José M. Hurtado Jr. [b], Jacob E. Bleacher [c], W. Brent Garry [d], Scott Bleisath [e], Jesse Buffington [f], James W. Rice Jr. [c]

[a] Arizona State University, School of Earth and Space Exploration, Bateman Physical Sciences Center F-wing, Room 686, Tempe, AZ 85287-1404, United States
[b] University of Texas at El Paso, Department of Geological Sciences, 500 West University Avenue, El Paso, TX 79968-05555, United States
[c] Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD 20771, United States
[d] Planetary Science Institute, 1700 East Fort Lowell, Suite 106, Tucson, AZ 85719, United States
[e] NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135, United States
[f] EVA Hardware Development Tools and Equipment Branch (EC7), NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058, United States

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ABSTRACT

The tools used by crews while on extravehicular activity during future missions to other bodies in the Solar System will be a combination of traditional geologic field tools (e.g. hammers, rakes, sample bags) and state-of-the-art technologies (e.g. high definition cameras, digital situational awareness devices, and new geologic tools). In the 2010 Desert Research and Technology Studies (RATS) field test, four crews, each consisting of an astronaut/engineer and field geologist, tested and evaluated various technologies during two weeks of simulated spacewalks in the San Francisco volcanic field, Arizona. These tools consisted of both Apollo-style field geology tools and modern technological equipment not used during the six Apollo lunar landings. The underlying exploration driver for this field test was to establish the protocols and technology needed for an eventual manned mission to an asteroid, the Moon, or Mars. The authors of this paper represent Desert RATS geologist crewmembers as well as two engineers who worked on technology development. Here we present an evaluation and assessment of these tools and technologies based on our first-hand experience of using them during the analog field test. We intend this to serve as a basis for continued development of technologies and protocols used for conducting planetary field geology as the Solar System exploration community moves forward into the next generation of planetary surface exploration.

1. Introduction—overview of the Desert RATS 2010 operation

The 2010 Desert Research and Technology Studies (RATS) field test consisted of two seven-day traverses of two small, pressurized rover prototypes. All fourteen days of the mission were conducted with both vehicles operating simultaneously, moving through a pre-determined traverse plan, with a crew

Abbreviations: CFN, Crew Field Note; COTS, commercial off-the-shelf; DSB, Documented Sample Bag; DVR, digital video recorder; EVA, Extravehicular Activity; EVAIS, Extravehicular Activity Information System; GIS, Geographic Information System; GPS, global positioning system; HCl, hydrochloric acid; HD, high definition; IVA, Intravehicular Activity; LEM, lunar excursion module; LiDAR, Light Detection and Ranging; LRV, Lunar Roving Vehicle; NASA, National Aeronautics and Space Administration; RATS, Research and Technology Studies; RFID, radio-frequency identification; SEV, Space Exploration Vehicle; XRF, X-ray fluorescence

* Corresponding author. Tel.: +1 703 577 6562.
E-mail address: Kelsey.E.Young@asu.edu (K. Young).

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change on day seven. A crew of two, one commander/engineer and one geologist with extensive field experience, operated each SEV (Space Exploration Vehicle). Three out of four commanders were experienced National Aeronautics and Space Administration (NASA) astronauts with at least one Space Shuttle flight. The geologists were selected from various NASA centers and academic institutions based on their familiarity with working in the field. Each crew therefore had the range of skills necessary to deal with both mission operations and science activities. Another benefit of the 2010 crew structure and mission duration was that a total of eight crewmembers (four each week) were able to test the technology and protocols, providing more input to the engineering teams. For a complete description of both the 2010 Desert RATS field test and preceding tests, see Kosmo et al. (this issue) [1].

Each traverse day was marked by several (1–4) extravehicular activities (EVAs) of varying duration, where each crew egressed from their rover for "boots-on-the-ground" scientific data collection. The crews collected samples and recorded their observations using a suite of equipment mounted on both the aft deck of the SEV (Fig. 1) and the mock-up spacesuits (Fig. 2; for details on protocols and procedures while on EVA, see Hurtado et al. (this issue) [2]). These ranged from the simple hand tools used in sample collection to prototype imaging and computing technologies designed to document crew observations while on EVA. This paper seeks to describe these tools and technologies and put forth our experiences with their utility. The authors of this paper represent Desert RATS geologist crewmembers as well as two engineers who developed the technologies described here. We focus on the technology used in the 2010 Desert RATS test, present lessons learned from the 2010 simulated mission, and offer suggestions for future tests and real mission scenarios.

2. History of planetary field geology

The only example of humans conducting field geology on another planetary surface is the Apollo program

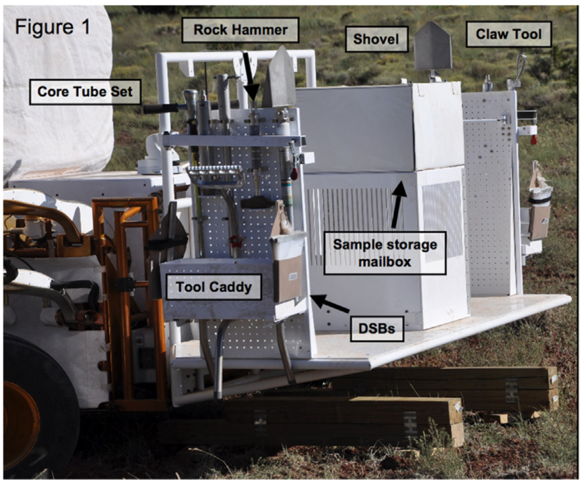

Fig. 1. The aft deck of the SEVs held a variety of tools used by the crew on EVA. Tool functions are described in Section 3.1.

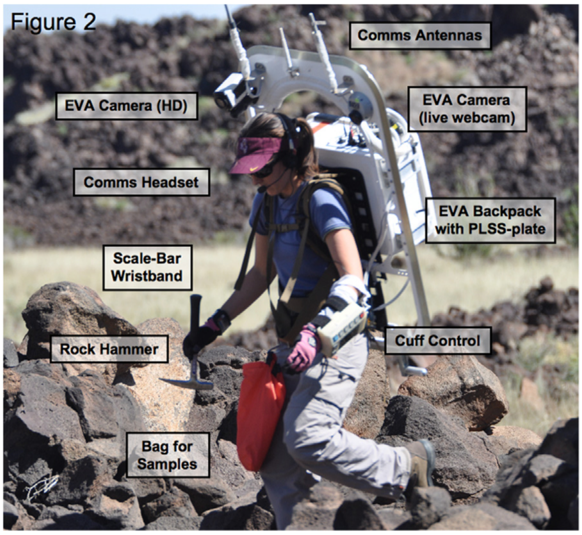

Fig. 2. A 2010 Desert RATS geologist crewmember traverses over a lava flow while on an EVA. Some of the tools available for EVA are shown here. The PLSS (portable life support system) plate is the large rectangular metal outline that allows the pack to fit into the suitports on the SEV, allowing for a safe and relatively quick ingress into the pressurized rover.

(1969–1972). During these six surface missions, twelve astronauts conducted a series of EVAs on the Moon, collecting samples and making scientific observations that have revolutionized our understanding of lunar geology and left us with a wealth of lessons learned about developing technology for planetary field geology. This is, however, our only data point in conducting manned science operations on another planetary surface. Combining these lessons learned during Apollo into equipment that reflects the technological advancements that have occurred since the early 1970s will give us the best chance of increasing the efficiency of scientific data collection on other planetary bodies.

2.1. Apollo era field geology

Due to the short time each crew was able to spend on the lunar surface during the six Apollo missions (ranging from 2 h, 14 min during Apollo 11 to roughly 22 h during Apollo 17) [3], EVA activities were tightly scheduled. Each Apollo mission had very specific mission objectives, and EVA tasks were limited to only those addressing the predetermined objectives. Science teams worked in advance to develop traverse plans for each landing site, and the astronauts were instructed to follow these plans extremely carefully. As a result, there was little flexibility for modifying or improvising plans while on EVA [4].

In order to assist the astronauts in collecting samples, installing experiments, and operating on the lunar surface, engineering teams designed a suite of tools for the Apollo missions [5]. EVA sample collection tools included tongs, a scoop, a rake, and a hammer, all made to assist the astronaut in isolating a sample for bagging and returning it to Earth. Core tubes and an electric drill (only deployed on Apollo 15–17, also known as the J-missions), were used to sample material from beneath the surface. Samples were stored in individual bags and containers