LESSONS LEARNED IN SCIENCE OPERATIONS FOR PLANETARY SURFACE EXPLORATION

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The six Apollo lunar surface missions represent the only occasions where we have conducted scientific operations on another planetary surface. While these six missions were successful in bringing back valuable geologic samples, technology advances in the subsequent forty years have enabled much higher resolution scientific activity *in situ.* Regardless of where astronauts next visit (whether it be back to the Moon or to Mars or a Near Earth Object), the science operations procedures completed during this mission will need to be refined and updated to reflect these advances. We have undertaken a series of operational tests in relevant field environments to understand how best to develop the new generation of science operations procedures for planetary surface exploration.

RESEARCH AND TECHNOLOGY STUDIES (RATS) OPERATIONAL FIELD TESTS

The Research and Technology Studies (RATS) operational field tests were conducted over several years, first in the San Francisco Volcanic Field (SFVF), Arizona, and then in the Space Vehicle Mockup Facility (SVMF) at the NASA Johnson Space Center. RATS testing enabled rapid technology development (centering on rovers, spacesuits, and other exploration-enabling assets) but also providing a robust testing platform for science operations testing. Lessons learned include tool development necessary for planetary field geology, sampling and data collection procedure development, use of an intravehicular (IV) crewmember, operational implications of varying time delays and backroom support structures, and many more [1, 2, 3]. SFVF field testing simulated longer traverses in a relevant analog environment while SVMF testing simulated operations in lower gravity environments using the Active Response Gravity Offload System (ARGOS).

NEEMO

The NASA Extreme Environments Mission Operations (NEEMO) missions are conducted in the Aquarius habitat off the coast of Key Largo, Florida. Crewmembers live in this underwater habitat, conducting IV and extravehicular (EV) activities, and each mission serves as a unique chance to develop and answer questions about the science, science operations, and technology needed for future planetary surface exploration. Science operations objectives investigated at the most recent mission (NEEMO 21, run in July – August 2016) included how to conduct integrated EVA science operations over a long communications latency and included real-time interactions between EV and IV crewmembers, Mission Control, and a Science Team that were working to answer authentic science questions through a flexible execution methodology.

FIELD PORTABLE INSTRUMENTATION

While technology deployed during Apollo focused on sampling and curation tasks, new technology development has made it possible to examine chemistry, mineralogy, and physical properties of samples *in situ*, something that is just beginning to be implemented in terrestrial field geology. Future planetary surface exploration will include these field portable instruments, but it is not yet understood how this integration will be reflected in science operations procedures and traverse planning strategies. The Remote, In Situ and Synchrotron Studies for Science and Exploration (RIS^{4}E) Solar System Exploration Research Virtual Institute (SSERVI) team is investigating how integrating field portable instruments into EVA planning will affect timelines and operational planning [4].

MOVING FORWARD

While all of the efforts discussed above are making large strides into developing the new operational concepts for advanced science operations, more work is needed to converge on a robust and flexible testing methodology. This submission will discuss the integration of past and current operational field tests, as well as discuss a strategy for moving forward in the development of science operations testing.

REFERENCES

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