

SCIENCE OPERATIONS DEVELOPMENT FOR FIELD ANALOGS: LESSONS LEARNED FROM THE 2010 DESERT RATS TEST. D. B. Eppler¹, and D. W. Ming² and the Desert RATS Science Operations Team, ^{1,2}Exploration Sciences Office, Mail Code KX, NASA-Johnson Space Center, 2101 NASA Parkway, Houston, TX, 77058, dean.b.eppler@nasa.gov, ²doug.w.ming@nasa.gov.

Introduction: Desert Research and Technology Studies (Desert RATS) is a multi-year series of hardware and operations tests carried out annually in the high desert of Arizona on the San Francisco Volcanic Field. Conducted since 1997, these activities are designed to exercise planetary surface hardware and operations in conditions where long-distance, multi-day roving is achievable. Such activities not only test vehicle subsystems through extended rough-terrain driving, they also stress communications and operations systems and allow testing of science operations approaches to advance human and robotic surface capabilities.

Desert RATS 2010 tested two crewed rovers designed as first generation prototypes of small pressurized vehicles. Each rover provided the internal volume necessary for crewmembers to live and work for periods up to 14 days, as well as allowing for extravehicular activities (EVAs) through the use of rear-mounted suit ports. The 2010 test was designed to simulate geologic science traverses over a 14-day period through a terrain of cinder cones, lava flows and underlying sedimentary units. Conduct of the actual test took place between 31 August and 13 September 2010. Two crewmembers lived in and drove each rover for a single week with a “shift change” on day 7, resulting in a total of eight test subjects for the two week period. Each crew consisted of an engineer/commander and an experienced field geologist. Three of the engineer/commanders were experienced astronauts with at least one Space Shuttle flight. The field geologists were drawn from the academic community. Three of the crews were male, with the fourth crew being female.

Operations were tested with different communication states and rover deployment conditions. Three days of each week operated under continuous communications with mission operations team, and three days the rovers were operated with communications only for ≈ 1 hour in the morning and ≈ 1 hour at the end of the traverse day. In addition, portions of the traverses were conducted with the two rovers in mutual support, largely operating as a single entity, while during other periods, the rovers operated out of line-of-site of each other, pursuing independent science objectives.

Science Operations Management Approach:

Past experience has shown that overseeing manned operations of multiple vehicles requires a separate control room for each (e.g., Space Shuttle and ISS operations prior to docking of the orbiter to ISS or after undocking). Consequently, each rover worked directly with a Tactical Science Operations Team (TSOT) responsible for managing real-time science operations while each crew was conducting “boots on the ground” geologic field operations. In addition to the TSOT, independent test operations with two rovers required an integration team, termed the Strategic Science Operations Team (SSOT). The SSOT would analyze the results of daily sciences operations from each rover crew after completion of the crew day and evaluate those operations within the larger objectives of the field traverse plans. In particular, a major function of the SSOT was to evaluate the completion status of a particular day’s objectives and, if necessary, recommend to the Mission Manager variations in the following days’ operations in response to missed objectives or important, serendipitous discoveries.

Major Science Operations Lessons Learned:

Ultimately, the most critical lesson for successful surface operations concerns both science team makeup and crew background. Effective science operations and the best science accomplishments will happen when the science operations team and the crewmembers on the surface have a background in the science mission being executed, in this case, geology. During this year’s operation, we had a highly experienced science operations team (>400 years combined experience as scientists, >35 years experience in field geology) and accomplished field geologists in each rover. This level of expertise was unprecedented, and it served to both improve the quality of operations in real-time as well as greatly inform the lessons learned. However, we found that many of the problems experienced, both in the science support rooms and the field, could be tracked to the training of the science personnel in the specific operations they were undertaking, in procedures being executed and in the hardware being used. Both the science operations team and the crews in the field improved as the 2-week test proceeded, and this argues that future science operations teams must be well trained in the activities they will be executing prior to mission start.

One of the critical issues for future planetary surface operations is the level of communications infrastructure that will be available, and whether real-time discussions with crewmembers will be the norm. This year's test had a number of significant findings relative to operations under continuous communications vs. twice daily (2-A-Day) communications. The science operations teams found that when working in a continuous communications state and with stable, high fidelity communications, the science return is exceptional. In particular, the interaction between the crews and the science support rooms led to detailed discussions that greatly improved the TSOT's understanding of the geology of the field area. In contrast, when communications were down or intermittent during continuous communications, science return was limited and led to a loss of critical science data, such as sample documentation and geologic context. If communications are predicted to be poor at a given station, however, an aggressive tactical team and a scientifically competent crew can work out the operational details of the science to be performed prior to communications becoming degraded and still achieve substantive science return. A related "corollary" is that if the crew is operating in challenging terrain with constrained communications and flight rules that require constant contact with the ground, EVAs may be driven to operations in locations that provide poor science return. In short, mission planning may drive the crew to a mediocre or poor site because the best site results in loss of communications.

Relative to 2-A-Day communications, the quality of the science return is directly related to both the quality of the crews' science training and their ability to review acquired data prior to leaving a particular geologic station. With well-trained field geologists and well-executed field procedures, the science return is still high, although the absence of interaction between the crew and the ground science team will limit the science discussions that improve science return on during continuous communications. In addition, the crew must have the ability to review acquired data prior to leaving a particular site, particularly image data. Otherwise, poor images will deprive the ground of a critical data set for both documentation and interpretation of science operations at a given locality.

Tactical and Strategic Science Operations Teams were deployed this year at a level not previously tested on RATS. In the case of the Tactical Science Operations Team (TSOT), it was found that a critical part of improved science return was the interaction

between the scientists during EVAs. This allowed hypotheses to be considered that would account for crew descriptions and discussion and, where it was possible to interact with the crew, hypotheses could be tested in real-time. However, even with delayed communications, as will be experienced on either NEO or Mars missions, the internal interaction of the tactical science team as it watches an EVA proceed will still be a critical part of science data gathering, even when the team cannot interact with the crew. In short, delayed communications will still benefit from real-time science analysis by a competent tactical team.

Relative to SSOT operations, it was found that the quantity of data from four crewmembers and multiple imaging systems posed a significant obstacle to analysis, integration and interpretation of a given day's data set within the 8-hour shift allowed. One of the biggest problems was analysis and interpretation of verbal communications. Transcripts were not available, requiring team members collecting data from verbal descriptions of geologic context and sample to listen, in real-time, to a complete verbal exchange. In short, it is not possible to "speed listen" the way it would be possible to skim a written transcript and glean the pertinent data. Largely, managing data by the SSOT was an issue data access that will be improved with good data system design that is based on the SSOT's experience in RATS 2010.

The 2010 RATS Science Operations Test was extremely successful, testing a variety of old and new operations approaches to managing science data and crew operations on planetary surfaces. The lessons learned in 2010 are already being applied to the planning for the RATS 2011 operation. In addition to substantive lessons learned that will be discussed other abstracts (e.g., [1]), the test served to begin training a new generation of scientists in the demands of planetary surface science operations.

References: [1] J. Hurtado, et. al., (2011), *LPSC XLII*, Abstract this meeting.