SCIENCE OPERATIONS DEVELOPMENT FOR FIELD ANALOGS: LESSONS LEARNED FROM THE 2010 DESERT RESEARCH AND TECHNOLOGY TEST.

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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 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 2-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 terrane of cinder cones, lava flows and underlying sedimentary units. Conduct of the 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, with 3 of the engineer/commanders having at least one Space Shuttle flight.

Operations were tested with different communication states and rover deployment conditions. Three days of each week the rovers operated under continuous communications with mission operations team, and 3 days allowed communications between the rover and the operations team for only ≈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 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 operations of multiple crewed vehicles requires a separate control room for each (e.g., Space Shuttle and ISS operations). Consequently, each rover worked directly with dedicated 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 at night and evaluate those operations within the larger objectives of the field traverse plans. 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. Details for the 2010 Desert RATS science operations are provided in [Eppler, et. al., 2011 LPSC].

Major Science Operations Lessons Learned - Team Member Background and Mission-Specific Training: Ultimately, the most critical lesson for successful surface operations concerns both science team makeup and crew background. The most effective science operations and the best science return will happen when the science operations team and the crewmembers on the surface have a professional background in the science mission being executed (in this case, field geology) and extensive training in the mission operations to be executed. During this year's operation, the science operations team was highly experienced (>400 years combined experience as scientists, >35 years experience of conducting geologic field projects), and each rover team included an accomplished field geologists. This level of expertise was unprecedented, and it served to improve the quality of operations in real-time over previous Desert RATS exercises. However, many of the problems experienced, both in the science support rooms and in the field, could be tracked to the abbreviated training of the science personnel in the specific operations and procedures being executed, and in the hardware being tested. Both the science operations team and the crews in the field improved as the 2-week test proceeded as the teams' familiarization with the operation improved. This argues that future science operations teams and surface crews must be well trained in the activities they will be executing prior to mission start.

Major Science Operations Lessons Learned - Communications: 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 under working in a continuous communications state and with stable, high fidelity communications, the science return was exceptional. In particular, the interaction between the crews and the science support rooms led to detailed discussions that greatly improved the TSOTs understanding of the geology of the field area. In contrast, when communications were down or intermittent during periods that were planned for continuous communications, science return was limited and led to a loss of critical science data, such as sample documentation and geologic context. This was mitigated somewhat if communications were predicted to be poor at a given station and an aggressive tactical team and a scientifically competent crew worked out the operational details of the science to be performed prior to communications becoming degraded. In this case, the teams still achieved substantive science return. A related "corollary" was that if the crew was operating in challenging terrain with constrained communications and flight rules that required constant contact with the ground, operations were often driven to traverse stations that had limited science return met the communications requirements. This suggests that mission planning under constrained communications in the future may drive the crew to mediocre localities because the best site would result 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. Well-trained field geologists and well-executed field procedures ensured that the science return under these communications constraints was still substantive, although the absence of interaction between the crew and the ground science team will limit the interactions between operations team and crew that improved science return during continuous communications. Further, the crew must have the ability to review acquired data prior to leaving a particular site, particularly image data, so as to correct poor images while still at the site. Otherwise, lack of quality images will deprive the ground of a critical data set for both documentation and interpretation of science operations at a given locality.

Major Science Operations Lessons Learned - Operations Team Approach: Science Operations Teams were deployed this year at a level not previously tested on Desert RATS. In the case of the TSOT, it was found that a critical part of improved science return was the science interaction between the TSOT members 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 volume of the datasets produced by 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 available. One of the biggest problems was analysis and interpretation of verbal communications. Written transcripts were not available, requiring team members collecting data from the verbal descriptions of geologic context and sample to listen, in real-time, to the complete communications file. 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 of data access and selection that can be improved with good data system design, based on the SSOT's experience in RATS 2010.

Conclusions: The 2010 RATS Science Operations Test was extremely successful, testing a variety of old and new operations approaches to managing crew operations and science data 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., [Hurtado et al. 2011 LPSC]), the test served to begin training a new generation of scientists in the demands of planetary surface science operations.

References: [1] Eppler, et. al.. (2011), *LPSC XLII,* Abstract this meeting, [2]. J. Hurtado, et. al., (2011), *LPSC XLII,* Abstract this meeting