DESERT RATS 2010 OPERATIONS TESTS: INSIGHTS FROM THE GEOLOGY CREW MEMBERS.

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Introduction: Desert Research and Technology Studies (Desert RATS) is a multi-year series of tests of NASA hardware and operations deployed in the high desert of Arizona. Conducted annually since 1997, these activities exercise planetary surface hardware and operations in relatively harsh conditions where long-distance, multi-day roving is achievable. Such activities not only test vehicle subsystems, they also stress communications and operations systems and enable testing of science operations approaches that advance human and robotic surface exploration capabilities.

Desert RATS 2010 tested two crewed rovers designed as first-generation prototypes of small pressurized vehicles, consistent with exploration architecture designs [1]. 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 [2,3]. The 2010 test was designed to simulate geologic science traverses over a 14-day period through a volcanic field that is analogous to volcanic terrains observed throughout the Solar System.

The test was conducted between 31 August and 13 September 2010. Two crewmembers lived in and operated each rover for a 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 scientific community, based on funded and published field expertise.

Methods: The 2010 test met NASA architecture requirements for synchronous use of two rovers. Within this framework the team tested different communications and operations modes. Three days of each week were tested with the rovers in continuous communications (CC) with mission operations and science backroom teams. Another three days were tested with communications for ≈1 hour in the morning and ≈1 hour at the end of the traverse, called twice-a-day communications (2XD). During 2XD rovers were to generally remain in line of sight and communication with each other. Separation distance was < 500 m. Using two rovers also enabled the testing of different operations modes. We tested an exploration strategy in which the two rovers executed unique traverses, called divide-and-conquer (DC). The second mode of operation had the rovers follow one another on the same traverse, called lead-and-follow (LF). Matrices were designed to measure the science productivity of different combinations of these operations modes, and suggested that no mode was consistently preferable. Here we report the opinions of the geologist crewmembers as to which aspects of each mode were considered advantages and disadvantages from the perspective of testing scientific hypotheses during human exploration of the Solar System.

Results: The 2010 Desert RATS field campaign tested combined two operations modes, CC & DC and 2XD & LF. Each combination demonstrated unique results within the test, which also have unique relevance to different styles of missions and scientific data collection. For instance, missions to Mars or asteroids are unlikely to experience CC, therefore preparation for dealing with limited communications is critical [4].

CC & DC: During this portion of the test the operations enabled the rovers to spread out and cover more ground. This capability supported the exploration of and collection of samples from a more diverse set of geologic units. Furthermore, CC enabled us to continuously develop testable hypotheses in the field with additional real-time input from the backroom [5]. The backroom was also able to provide support to the crew by indicating when the image data or sample description information was not adequate, thereby enabling the crew to take corrective measures. CC also allowed for the backroom to operate rover mounted instruments during crew EVAs. Although we found the communications with a backroom to be beneficial, we did identify some drawbacks. To reduce the overlap in communications between two rovers and science backrooms, the Desert RATS team placed each rover on unique communications loops with their backrooms. As a result we found that our communications with the other rover during the CC traverses were limited. We made up for this deficiency by holding unscheduled 30-60 minute rover-to-rover debriefs daily during crew personal time. However, this limited the potential advantage of each crew being aware of the other’s results in real-time, which would have been scientifically and operationally advantageous during daily activities.

2XD & LF: LF rover crews were able to provide better situational awareness feedback for each other. This was advantageous when crossing rough terrain such as gullies. LF operations often led to repetitive sampling of the same geologic units as the traverse stations regularly restricted the crew to the same area. This could be viewed as a disadvantage in that we covered less ground and explored fewer units. Conversely we found that while working with the other rover we were able to collect more detailed process-related insights [4]. An example involved a gully that had eroded into the base of a cone. During EVA the two crews crossed the gully at ~ 300 m separation and were able to determine the amount of incision over that distance. A stop at the same location during DC would have collected one set of the same samples but provided little input on the erosion process other than that it had occurred.

During 2XD we communicated nearly continuously between rovers. Although CC interaction with a backroom enabled more experienced minds to work on a science problem, having two sets of trained eyes on the same terrain also provided advantages. For example, often the geologist in the rover ahead would scout for the best sites for the rovers in preparation for EVAs and acquisition of imagery. This sort of real-time traverse refinement informed by first-hand analysis in the field is not possible with a remote science team and was a benefit to making practically efficient and scientifically effective EVAs. Similarly, during EVAs the geologists could, when practical, convene on the outcrop in order to compare samples and observations, an effective way of synthesizing geologic understanding while still in a position to make additional observations. Having communicated throughout the day's traverse reduced the amount of time spent discussing work during crew personal time at the end of the day. However, during 2XD we found that the scheduled ~60 min science debriefs at the end of the day were not adequate to convey our daily observations and hypotheses to the science team. This could essentially represent a loss of data between crew and backroom at some points, which highlights the need for effective data flow between all parties.

Conclusions & Recommendations: Early in the test the morning science briefings focused heavily on sample collection objectives. We feel that it is critical for the backrooms to present the crew with the geologic hypotheses that drive the sample requirements. This is something that did improve throughout the test.

We note here that although the test included CC scenarios, at no point did we truly reach continuous communications with mission control and science backrooms due to difficulties in deploying test assets to maintain communications in a terrain with significant relief. Furthermore, we find it easier to operate when planning for intermittent communications than to prepare for CC but in reality experience intermittent communications. As a result, we recommend that a series of fallback communications operations protocols should be established to deal with loss of signal situations.

Based on the communications tests the crew feels that the best real-time science was achieved when more brains were working on the science problems. Ideally we prefer regular communications with a backroom to help develop competing hypotheses and field tests to differentiate between them. When not in regular communications with a backroom the crew relied heavily upon inter-rover discussions to increase the value of our science results. However, if near-continuous communications are achievable, we recommend that the crews should be provided time in the schedule to communicate to each other during a traverse. As mentioned earlier, having multiple personnel working in a backroom is beneficial, but so is having a second set of eyes on the ground. Neither completely replaces the value of the other and the advantages of both should be preserved even when operating in near-continuous communications with a science team.

To ensure flow of information between rovers (and backrooms) the concept of a single Science PI, with oversight of both rover teams, should be explored. This person would be responsible for developing the overall science story so that no team is working in isolation as a consequence of trying to reduce the impact of too many voices speaking simultaneously on communications loops. Furthermore, we recommend that a geology-trained crew member should be identified as a Field Science PI in much the same way that an overall crew commander is identified with final decision making authority on the ground. The Field Science PI would be most important when communications are limited to several times per day opposed to CC. Although we did not encounter a problem in this aspect of the test during 2XD, it is obvious that somebody should have overall science decision-making authority on the ground.

The data flow framework must be clearly understood between the rovers and backrooms. In some instances confusion arose between the rovers and backrooms because it was not clear what data were transferred and included in briefing discussions. A data manager position should be filled with oversight into this issue. Furthermore, data should be easily transferred between rovers and the crews should have access to the data that they collected during their traverse.

Regardless of the operations mode for a mission, traverse design should be led by a science PI who will be in the backroom during its execution. It is critical that the Science PI have an intimate understanding of the traverse for real-time decision making based on the collection of new data. Furthermore, it is critical that the crew and the daily brief/debrief leads also have an intimate understanding of the daily traverse plans, which is most easily established through involvement in traverse development.

References: [1] NRC Report (2007) Scientific Context for Exploration of the Moon. [2] Garry and Bleacher (2010), LPSC, abstract #1533. [3] Garry et al., (2009) LPSC, abstract1649. [4] Hurtado et al. (2011), this issue. [5] Young et al. (2011), this issue.