COMPARING APOLLO AND MARS EXPLORATION ROVER (MER) OPERATIONS PARADIGMS FOR HUMAN EXPLORATION DURING NASA DESERT-RATS SCIENCE OPERATIONS. R. A. Yingst[1], B. A. Cohen[2], D. W. Ming[3], and D.B. Eppler[3], [1]Planetary Science Institute, 1700 E. Ft. Lowell, Suite 106, Tucson, AZ 85719 (yingst@psi.edu), [2]NASA Marshall Space Flight Center, VP62, 320 Sparkman Dr., Huntsville AL 35805, [3]NASA Johnson Spaceflight Center, KX, 2101 NASA Parkway, Houston, TX 77058.

Introduction: NASA's Desert Research and Technology Studies (D-RATS) field test is one of several analog tests that NASA conducts each year to combine operations development, technology advances and science under planetary surface conditions [1]. The D-RATS focus is testing preliminary operational concepts for extravehicular activity (EVA) systems in the field using simulated surface operations and EVA hardware and procedures. For 2010 hardware included the Space Exploration Vehicles, Habitat Demonstration Units, Tri-ATHLETE, and a suite of new geology sample collection tools, including a self-contained GeoLab glove box for conducting in-field analysis of various collected rock samples. The D-RATS activities develop technical skills and experience for the engineers, scientists, technicians, and astronauts responsible for realizing the goals of exploring planetary surfaces.

The science community has had success with two distinctly different models for human-in-the-loop remote field experience. On one hand is the Apollo back-room experience, where trained geologists were required to rapidly assimilate data and communicate real-time instructions to astronauts interacting with the geological environment. In this environment, the back room decisions had immediate implications. The scientists involved in this process also had the benefit of knowing that tens to hundreds of kilograms of rock samples were to be returned to round out the in situ observations. At the other extreme, the MER mission has been conducted entirely robotically with significant time delays. Similarities to Apollo include the fact that only a single individual conveys the instructions to the rovers, and prior to that only a small subset of the team interacts to create the observational plan for a specific period of time. Unlike Apollo, this small team changes daily, but familiarity among team members and with the rovers eventually paralleled the Apollo experience [2]. In addition, significant field methodology differences were developed for MER because the data are relayed to the science team once per day and they have many hours or even days to pore over the data and decide on a plan of action.

Going forward, it is logical to assume that future remote field protocols will use elements from both experiences. For long-duration and outpost-type lunar missions, some degree of crew autonomy will have to be the case, where ground crew may only be in the loop once per day. At the same time, the opportunity to have a remote team of experts involved in real time science decisions provides significant benefits. There will probably be returned samples, but given surface stay and EVA durations greater than Apollo, the mass returned will likely be less than can be collected by the crew, so sampling decisions may be crucial. Our current knowledge of robotic traversing is the baseline that provides realistic expectations for future sample characterization and return, which may well be more limited than our Apollo experience. In every case, human EVA time is a critical resource that must be effectively planned.

The Apollo Model: In 2008, D-RATS invited a science team to integrate science operations into field tests. The science team provided geological context and traverse protocols for the surface activities. The role of science was expanded in the D-RATS 2009 analog exercise, significantly advancing science operations concepts using a science team, or backroom, based on the Apollo model. The science backroom role was to understand and support traverse activities in real time, using suit-mounted and rover-based video streams and data. This model emphasized the need for scientists to analyze and interpret information on timescales that are unusually short (seconds to minutes) by remote sensing or robotic mission standards. This posed significant challenges for the science team, who struggled to keep up with the tactical operations of the crew and had little time to think strategically about the data being collected. Nonetheless, test metrics showed that real-time data return to the backroom allowed for both greatly improved field operations and scientific return.

The MER Model: In 2010, the science backroom was significantly expanded and constructed on the Mars Exploration Rover (MER) model. The backroom was divided into a Tactical Science Operations Team (TSOT) and a Strategic Science Operations Team (SSOT). The TSOT worked with the D-RATS field crew in real time during the day, then data and notes were "downlinked" to the SSOT in the evening. The SSOT reviewed the science data acquired during the tactical process and re-planned based on the resulting science discussions. This model thus split the duties of data collection and data integration, which proved challenging in the 2009 test. Instead, the TSOT assisted the crew in collecting data and provided crew support, then made recommendations to the SSOT on what was likely to be important data. The strategic team interpreted the day's activities in the context of overarching hypotheses for the geology of the region, identified areas of progress or outstanding questions, and re-planned subsequent day's activities to converge on answers. This model had significant advantages in that it decreased individual workloads and increased the scientists' ability to evaluate specific scientific hypotheses. However, this mode suffered at each point where data and knowledge needed to be transferred, requiring significantly more data infrastructure (databases, notes, etc.) to function smoothly.

Discussion: Two significant findings based on science backroom activities in both the Apollo-style (2009) and MER-style (2010) model involved (1) data management and flow; and (2) the significance of communication.

Data management and flow. In the modern era of rapid data sharing and virtual presence, large science backroom operations with physically co-located personnel may be unnecessary. However, the large amount of real time data being generated to support the scientists needs an efficient and intuitive data plan that streamlines data flow. The MER database took years and many tools to develop. All spacecraft budget large sums for data pipelining for tactical use and for long-term storage on the PDS, whereas Apollo did not. A real time mission with human involvement will produce significant amounts of data, and new types of data such as voice transcripts also will need to be ingested and made available.

One significant tension in both operational models occurs where the timescale of data acquisition is out of sync with the timescale for scientific understanding [e.g. 4]. There is a need to discuss strategic goals outside of the tactical timeline in order to evaluate accomplishments, identify outstanding questions, and re-plan activities. The lack of ability to pause the process was a significant issue during both models, though for different reasons. In the Apollo-style test, the backroom seats were usually overwhelmed trying to capture real time data from cameras and narrative. Breaks were, by necessity, short and staggered. Observations along the drive path between stations were crucial for establishing geologic setting and so were not appropriate times for intense discussion. There was no time during the traverse when all the science backroom stations were simultaneously free to discuss the traverse science.

In the MER-style test, the SSOT spent significant time reviewing and piecing together data due to breakdowns in communication during the tactical process (discussed below). Additionally, the strategic science was conducted overnight, so that fatigue became a crucial factor in science efficiency. However, the SSOT did succeed in its goal to discuss science objectives in greater detail than was possible during the Apollo-style tactical-only mode. A future improvement might include providing a mini-backroom to each tactical station, helping capture the data and discussing it during that station's natural breaks. That station would be armed with the consensus information for the benefit of the mission science lead.

Communications. In both models, the science team relied on clear and complete communications from the crew, but fragmented communications was a serious tension point. The necessity of asking the crew to repeat lost information or hold still for another camera shot frequently annoyed the crew who perceived it as wasting their time. This tension point may be alleviated by aligning the actual communications ability with training of the crew and backroom to be comfortable within these data limits. Communications will also be streamlined with training of both crew and backroom [1]. Such training leads to smoother communications, competency and trust. Significant crew and backroom training has not been accomplishable within the limits of the D-RATS activity, but obviously intense geologic training of both crew and backroom will be necessary. Such training will allow the crew to be much more efficient in the field and drastically cut the desire for backroom coaching, freeing up time for evaluation.

Lessons Learned: Lessons learned from both MER and Apollo models emphasize several common themes. Stable, high-fidelity communication and streamlined information access should be the standard for planetary geologic exploration, which requires investment in information tools and databases, and likely orbital communication satellites rather than relying on line-of-sight architectures. Having well-trained geologists on the crew and on the science operations teams is probably the most important factor determining science return, but scientists in the backroom and on the ground must have tools and an architecture that allows sufficient time for scientific understanding. Finally, the continued collaboration between science, engineering and operations is crucial for future expeditions.

References: [1] Eppler, D.B., et al., this volume. [2] Tollinger, J. V., C. D. Schunn, and A. H. Vera (2006) *Proc. Conf. Cognitive Science Society, 28th*, pp. 840-845. [3] OSEWG (2009) "Workshop on Architecture Issues Associated with Sampling" Final Report. http://www.lpi.usra.edu/osewg/products/presentations/samplingWorkshopReport.pdf. [4] Yingst, R.A. et al. (2010) *GSA Annual Mtg*, Abstract #176149.