OUT OF THE LAB AND INTO THE FIELD: A HISTORY OF DESERT RATS ADVANCED EVA AND SURFACE MOBILITY FIELD TESTING.

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Introduction: By the time humans step onto the Moon again, it will be 5 decades and 2 generations since the last Apollo mission. In the years since Apollo, NASAs experience with astronaut operations external to a spacecraft (EVA) has concentrated on orbital operations for Shuttle and the International Space Station. Orbital EVA operations are fundamentally different than planetary surface operations; in fact, with the exception that both operations involve crewmembers in space suits, much of the similarity between these operations ends there. Development of advanced EVA and crew mobility systems for planetary surface operations involves a range of engineering design and logistics considerations that differ radically from our present EVA approach. To that end, NASA began conducting field testing of advanced EVA and surface mobility technologies in 1997 in order to tease out critical information that will be used for developing the next generation of planetary EVA and surface mobility systems.

Desert RATS Overview: Desert "RATS" (Research and Technology Studies) is a combined group of inter-NASA center scientists and engineers, collaborating with representatives of industry and academia, for the purpose of conducting remote field exercises. These exercises provide the capability to validate experimental hardware/software, mission operational techniques & identify & establish technical requirements applicable for future planetary exploration. Currently, D-RATS remote field testing is conducted in high desert areas adjacent to Flagstaff, Arizona, along with dry-run tests conducted at JSC. The testing takes advantage of terrain conditions are representative of both Moon and Mars: strewn rock and volcanic ash fields, meteorite crater ejecta blankets, rolling plains, hills, gullies, slopes and outcrops. In addition, Flagstaff is the location of USGS/Astrogeology Branch, which historically supported Apollo astronaut geologic training. The USGS facilities provide host-accommodations by joint agreement with NASA, including acquisition of land use permits, use of USGS facilities and equipment to support real-time operations, and the availability of extensive planetary geology reference sources. In addition, and equally important, the Flagstaff area provides substantial logistics support, including local medical facilities, breathing air and liquid nitrogen to operate life support systems, commercial outlets for hardware/electrical equipment supplies, and adequate food and lodging accommodations to take care of team members during long hours of field operations.

RATS History: A brief summary of the accomplisments of each is provided below:

1997: Death Valley, CA. The first year's activity was undertaken to prove out technology of shirtsleeve geologic exploration activity ergonomic motion capture, and to investigate the activities undertaken by a field geologist during nominal exploration traverses.

1998: Flagstaff, AZ area. The first year of suited activity compared unsuited and suited comparison of geologic tasks undertaken during a nominal exploration traverse, and during simulated deployment of a mockup surface geophysical package.

1999: Silver Lake, CA. The Astronaut/Rover (ASRO)Project was a study of human/robot interactive tests and an investigation of the division of labor between humans and robots for planetary EVA exploration operations, using a Marsakhod robot provided by the Ames Research Center. A deployment of the mock-up surface geophysical package was also performed.

2000: Flagstaff, AZ area. Testing concentrated on EVA deployment of surface power systems (e.g. solar panels and power cables). This test continued the study of human-robotic interaction utilizing the JSC EVA Robotic Assistant (ERA) vehicle as the deployment vehicle, with astronaut oversight and management of the deployment activities. Testing activities also included drilling core samples using a commercial off-the-shelf core drilling rig.

2002: Flagstaff, AZ area. This test continued testing of EVA scientific traverse and human-robotic interactive tasks. Enhancements over the earlier traverse activities included a science trailer for geochemical sample analysis to evaluate the conduct of in-situ chemical analysis, an EVA informatics pack that provided information on crewmember position and life support system status, the deployment of geophone packages both robotically and by a human crewmember, night EVA operations, and the first activity with direct link to Johnson Space Center mission operations center using a satellite link up.

2003: Flagstaff, AZ area. This test conducted the first manned rover testing, using the USGS 1-g Lunar Rover Training Vehicle originally used during Apollo, conducting shirt sleeve and suited driving tests. Testing also included suited geologic traverses using a second-generation science trailer and informatics pack, additional night testing, and improved satellite communications.

2004: Flagstaff, AZ area. The testing included an assessment of an electric tractor and "Chariot" human rover to assess functional performance characteristics of an untested rover design, further use of the science trailer during simulated surface EVA traverses, and further evaluation of human/robot system evaluation of EVA informatics technologies and user interfaces.

2005: Flagstaff, AZ area. We expanded testing with simultaneous 2 suit operations, including in-suit recharge of backpack life support, 2-person EVA traversing, and large mass transport & handling. In addition, this was the first field test of the SCOUT crew and robotic rover, a rover test-bed based, in part, on the 2003 tests with the Apollo 1-g LRV training vehicle. A next-generation suit informatics pack (the Communications, Avionics & Informatics pack (CAI-pack) system) was evaluated, including EVA traverse planning from map generation using LIDAR. Lastly, geologic & biologic sample collection & curatorial procedures with emphasis on planetary protection techniques was demonstrated.

2006: Flagstaff, AZ area. Testing included lunar surface operations concept development, including evaluation of mission scenarios to collect time-line data for Lander/Airlock EVA preparation, egress, and return, field geological exploration, deployment of instrument packages, digging and mapping regolith trench walls, and experimenting with regolith excavation and handling techniques for radiation protection and resource extraction. In addition, suited crewmembers gathered data to aid in planetary protection requirements development (biological sample collection). Several test activities took place with a variety of rovers, including demonstrating combined robot operations and two suited crewmember planetary activities, testing the SCOUT vehicle while being driven by an onboard operator, a tele-operator at a remote location and an autonomous driving system and evalutation of SCOUT cockpit design, on-board life support system recharge, and further testing with the CAI-pack systems.

RATS Lessons Learned: Numerous lessons have been learned on Desert RATS, which are briefly summarized here.

General. All items must be tested and demonstrate a level of readiness prior to the field test to maximize test time and to minimize down time.

Test Management & Organization. A clear leadership organization is necessary (define who is in charge and able to make real-time field decisions). Pre-test briefings are vital, and all team members need to be briefed on changes or modifications to test activities.

Operations. Time needs to be scheduled for on-site post-ship hardware checkout and repair.

Field Test Maintenance and Support. Carry adequate spares and hardware components for a wide variety of anticipated and unanticipated repair or replacement operations (expect the unexpected!). Easy access should be provided for all equipment for on-site, real-time trouble-shooting and repair.

Logistics. All perspective and alternate test sites need to be scouted out and reconnoitered.

Weather and the Local Environment. The desert is a harsh place; hardware needs to withstand severe wind and dust conditions. Wind-blown dust is abrasive and can damage computers, suits, connectors, etc. Also, a plan must be in place in the event of severe weather conditions (rain, lightning, hail).

Communications. Communications is one of the most critical aspects of a successful test. However, communications infrastructure must be set up and checked out before the test.

Computer Networks. The networks need to be carefully planned and IP addresses assigned before testing begins, and the network needs to be protected from attacks from hackers.

Operations. In-use suit recharge is essential both for safety on the lunar surface, in the event of a walk back, and to maximize the crewmember's time to complete tasks. However, backpack recharge needs to occur while the crewmembers are seated on a rover.

Rover Operations. Use of a rover reduces crewmember fatigue and increases both the duration and quality of any test operation or EVA. Rovers, however, must be simple, turn-key vehicles with limited requirements for maintenance or technological/operational complexity.

Human-Robotic Interaction. We need to better define the tasks that humans and robots should do (proper mix of rover autonomy and crew control). Robots excel at large mass handling, regolith excavation, deployment of communication repeaters & recharge way-stations, etc., while humans are most adept at science sample collection, rover control and activities requiring creative thought and integration of disparate data sources.