SCIENCE OPERATIONS ON THE LUNAR SURFACE – UNDERSTANDING THE PAST, TESTING IN THE PRESENT, CONSIDERING THE FUTURE. Dean B. Eppler, Astromaterial Research and Exploration Sciences Directorate, NASA-Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058; dean.b.eppler@nasa.gov and a decade of dedicated Desert RATS Team Members.

Introduction: The scientific success of any future human lunar exploration mission will be strongly dependent on design of both the systems and operations practices that underpin crew operations on the lunar surface. Inept surface mission preparation and design will either ensure poor science return, or will make achieving quality science operation unacceptably difficult for the crew and the mission operations and science teams. In particular, ensuring a robust system for managing real-time science information flow during surface operations, and ensuring the crews receive extensive field training in geological sciences, are as critical to mission success as reliable spacecraft and a competent operations team.

Apollo: The scientific success of the Apollo J-missions rested in part on the strong relationship between the crewmembers, the scientists involved in planning the mission and training the crew, the mission operators and NASA management. This team was responsible for integrating science objectives into the landing site selection, flight and surface science operations development, crew geologic training, and the mission management practices that allowed the crew to rove significant distances from the LM with the skills to perform as competent scientific explorers. Pertinent examples include the willingness of the mission designers on Apollo 17 to fit the landing site ellipse into the Taurus-Littrow Valley, writing mission rules to allow roving distances of up to 10 km, and providing >1000 hours of scientific training (including >500 hours of geologic field training) to the J-mission crews. Even when the projected site geology turned out to be radically different from what was expected (e.g., during Apollo 16), the crewmembers' training enabled them to recover from the unexpected findings and produce scientifically competent field observations and samples that changed our view of the Moon.

Desert RATS: Since 1997, JSC has conducted extensive field testing of EVA systems, prototype unpressurized and pressurized rovers, habitats, information systems and mission operations approaches, including extensive science operations teams. The majority of this testing has been carried out in the San Francisco Volcanic Field near Flagstaff, AZ. The complexity of the missions tested has increased from 2 researches and 1 test subject (1997) to well over 200 team members and 17 different teams (2010) [1]. The most extensive RATS exercise was in 2010, where the team simulated a 24-7, two-week long traverse on the lunar surface using 2 pressurized rovers, 4 crewmembers and an extensive science operations team with 2 tactical science teams and a single strategic science operations team. The critical lessons learned include 1) a well-trained crew, patterned after the Apollo 17 model of 1 pilot/engineer and 1 geologist, can conduct cutting edge geologic research on the lunar surface, provided they have the mobility systems to safely range 10s of km from a landing site and the operations practices to allow wide ranging exploration; 2) the volume science data coming out of this kind of mission is extensive and can swamp the ability of a science operations team to assimilate and evaluate the data and manage crew science operations in a given 24 hour period; 3) crew interaction with ground science teams can be extremely cumbersome unless all parties involve recognize that the ground science team is the "brain trust" that helps the crew understand science results and can assist the crew's science operations by doing science planning; and 4) managing long-duration (probably >5 days) human planetary exploration in a manner similar to Apollo is probably not workable in terms of cost, stress, fatigue and morale [2], [3], [4], [5].

Future Surface Operations Recommendations: 1) we are well along to having the appropriate EVA and rover systems to enable extensive science exploration of the Moon. Although developments need to be made in building new hardware and scaling up test approaches from low TRL levels to flight readiness, the engineering community has made great strides in getting these systems ready; 2) the spaceflight community needs to realize that extensive (>1000 hours) field-based, *not* computer-based, scientific training of future lunar crews is *the* key to scientific success, without which all the engineering accomplishments comes to naught; 3) we need extensive work on IT systems to manage the volume of science information (HD still/video, voice), including the ability to turn verbal crew science observations into "skimmable" written transcripts, so science data can be useful to science mission planners immediately, not months after the surface mission is over.

References: [1] Ross A. et al. (2013) *Act. Astronaut., 90,* 182-202. [2] Eppler D. B. et al. (2013) *Act. Astronaut., 90, 224-241*. [3] Hurtado J. M. et al (2013) *Act. Astronaut., 90, 344-355*. [4] Bleacher J. et al (2013) *Act. Astronaut., 90, 356-366*. [5] Bell E. et al (2013) *Act. Astronaut., 90, 215-223*.