**SCIENCE-DRIVEN STRATEGIES FOR SEMI-AUTONOMOUS ROVERS ON THE MOON: FIELD TEST AT AN ICE-BEARING REGOLITH ANALOG.** R. A. Yingst[1], B. A. Cohen[2], B.M. Hynek[3], J.B. Johnson[4], M. E. Schmidt[5] and C.M. Schrader[2], [1]Planetary Science Institute, 1700 E. Ft. Lowell, Suite 106, Tucson, Arizona, 85719 (yingst@psi.edu), [2]NASA Marshall Space Flight Center, Huntsville, Alabama, USA, [3]University of Colorado, Boulder, Colorado, USA, [4]University of Alaska-Fairbanks, Fairbanks, Alaska, USA, [5]Brock University, St. Catharines, Ontario, Canada.

**Introduction:** The Mars Exploration Rovers (MER) mission represents our most extensive experience to date in conducting field geology remotely on another terrestrial body with a semi-autonomous rover. We have been analyzing science operational strategies used for MER on Mars in order to determine best practices suitable for conducting remote semi-autonomous rover geology on the Moon [1] (science operational strategies are defined here as how, when and in what order measurements or observations are taken). As part of this effort, we conducted field tests at two glacial moraines, as analogs for a potentially ice-bearing lunar regolith. For these field tests, we defined two hypotheses for testing: (1) the science methodology that informed the MER operations is sufficient to locate, identify and characterize important geologic materials, and specifically subsurface water ice; and (2) regolith-like material (an amalgamation of poorly-sorted and lithologically diverse rocks and soils) can be used to determine a region's geology using MER-inspired rover strategies.

**Approach:** For this test, we assessed the performance of science-driven operational strategies alone in facilitating and optimizing science return, rather than use an outfitted rover mock-up with an engineering or "astronaut" team in the field and a "blind" offsite science team [e.g., 2-12]. Commercial, off-the-shelf instruments that provided similar information to that produced by flight-ready instruments were used to acquire data; humans were utilized for mobility. Results regarding whether and how MER-informed operational strategies were suitable for lunar rover activities were thus independent of technical issues that might have been introduced by equipment failure, problems with traversibility, or environmental concerns such as weather. Also, results were not specific to any one instrument, but could be generalized to common instrument types (e.g. imagers, spectroscopic imagers. Finally, this approach models traditional terrestrial geologic fieldwork in that it is heuristic; that is, problem-solving takes place through experimentation, knowledge is gained by experience.

**Field Site:** Given the initial hypotheses of this field test, we required an appropriate site to be dominated by a relatively fresh regolith analog (that is, unconsolidated, fine-grained material sourced and transported from the surrounding region) that had the potential of bearing sub-surface ice. We thus chose a glacial moraine, specifically one that (a) showed little encroachment by vegetation; (b) was associated with an active glacier to increase probability of the presence of subsurface ice; and (c) was formed by a glacier that sampled a wide variety of geologic materials upstream. The field sites also had to be relatively accessible. We chose the Gulkana and Matanuska glacial moraines in central Alaska. Here, we report on our work at Gulkana.

**Methodology:** At each site a rover science team broke down observational "days" into detailed analyses of targets of interest. In previous field tests [1], we defined a "traverse methodology," based on MER campaigns in which the primary objective was to drive to another location and secondarily to acquire targets of interest along the way. Because the goal of this test was to locate and identify a specific material, we designed the "survey mode" based on MER activities where the science objective was to make a detailed assessment of a specific feature, target or location; thus, the number and frequency of observations is higher and more systematic.

Images simulating a high-resolution stereo imager and a hand lens-scale imager were taken using a professional SLR digital camera with interchangeable lens capability and megapixel imaging. To mimic the acquisition of basic mineralogical data, we utilized a portable ALTA II, a multiband photometer that measures reflectances in separate, non-overlapping ranges of wavelength sensitive to many Fe-bearing species. While the rover team collected and analyzed data on a simulated tactical timeline, a team using traditional terrestrial field methods examined each site as well. This allowed us to compare directly what was revealed by human versus rover-inspired methods.

**Observations:** The rover and field teams spent two days at the Gulkana moraine. On day 1 the rover team focused on overall assessment of the site and on finding targets that could potentially contain subsurface water ice (for obvious reasons, we stipulated to the presence of ice in the form of the glacier itself). The rover team examined these targets in-depth on Day 2.

*Day 1.* The rover team examined an initial panorama and first sketched the overall geologic setting; based on this information they then chose a traverse sequence that included moving up-section from the floor of the glacial valley to the top of the closest moraine ridge. Observations were taken at five points along the traverse; these observations included a three-image "mosaic" that yielded 120° of view at a resolution of ~5 cm/pxl from a ~30° downlook, a single image at about 5-10 mm/pxl from a ~70° downlook to systematically capture as much of the wide variation of clast mineralogy as possible, and MI-type 10μm/pxl images of 3-5 clasts at each stop. While these measurements were being acquired, the rover team determined from the panorama one primary and two secondary sites of subsurface ice within the ridge based on macromorphology, and chose a traverse for the rover for day 2. We explicitly chose to focus our efforts on gathering the most comprehensive data set and scrubbing it later.

*Day 2.* The rover team sent the rover to the primary potential ice target and while observations were being acquired, discussed the results of day 1 (scientifically and tactically). The field team explored much further afield, including exploring within glacier caves.

**Results:** The rover team identified four major rock types based on macromineralogy and morphology. Additionally, the rover team found not only subsurface ice, but liquid water flowing at their primary target.

By comparison, the field team noted several different igneous and metamorphic rock types within the moraine, including: andesite, andesitic porphyry, pyroxenite, amphibolite, biotite, schist, gneiss, and serpentinite. Several types of cross-cutting veins were also noted, and differentiated by mineral makeup, including quartz, pyrite, and actinolite. Veins, however, were so variable and so late-stage that the field team determined after the test that this was a poor way to characterize rocks. The field team also determined the likely presence of ice within the moraine ridges.

**Discussion:** The operational strategies and modest instrumentation invoked provided the rover team with-adequate information for the team to identify the major mineralogies represented in the Gulkana glacial moraine. Additionally, the team was able to confirm the presence of ice and liquid water at their primary target, and collect sufficient data to characterize the contextual geology (approximate thickness of ice layer, morphology and mineralogy of constituents in ice-bearing layer). However, the rover team could only determine the geologic regimes represented by the moraine materials in a very basic sense. Thus, the general geology of the surrounding region remained relatively opaque. Several factors contributed to this result:

1. The rocks that make up the Gulkana Glacier moraine are extremely diverse and in fact the field team using traditional methods found it difficult to characterize the area in the time allowed. Remote rover operations are time-limited as well, and will continue to be so, whether because of engineering constraints, communications constraints, or the press of competing science goals. It is thus important to understand how to refine observational strategies to meet the science goals within the timeframe of the mission.

2. As in previous field tests [1], the amount of time the rover science team spent planning observations lessened the time available to analyze acquired data, and thus decreased the usefulness of that data. In the case of Gulkana, however, even with more time for analysis rover team members focused on planning and executing imaging sequences, rather than conducting more in-depth analysis during down-times and potentially using that information to drive science observations. It is not clear whether this is because the very small number of rover team members (two) required both members to focus exclusively on tactical activities, because it was intuitively the most effective use of time, or because this is an inherent response by the human brain when tasked with "doing science" rapidly. In a lunar environment where the amount of data may be much greater, and transmission of that data potentially much more rapid than for MER, this human factor may significantly affect science return. Future work should include answering the questions: (1) Is focusing on gathering data the most effective use of the rover team's time, and (2) if not, what changes can be made to science observational choices that will support both tactical and strategic decision-making and analysis? One possible refinement of future tests might be to include additional rover team members, tasked specifically with data analysis during the field test (analogous to the MER payload downlink leads, except that their work would be conducted concurrently with the tactical process to take account of the more rapid lunar timeline).

3. The lack of orbital images was not analogous to a rover mission, which would presumably be supported by precursor orbital data. Lack of this data hampered efforts to decipher the overall geology of the area. Future work must balance the benefits of remoteness (undisturbed sites) with the consequent lack of available orbital/aerial imagery.

**References:** [1] Yingst, R.A. et al. (2011) *Mars, 6,* 13-31. [2] Bualat, M. (2006) *AIAA*. [3] Deans, M. et al. (2009) *AIAA*. [4] Fong T. et al. (2008) *AIAA,* 2008-7886. [5] Glass, B. et al. (2006) *LPS XXXVII*, 2300. [6] Greeley, R. et al. (1994) *Int'l Plaentary Rover Symposium*. [7] Lee, P. et al. (2007) *LPS XXXVIII*, 2426. [8] Roman, M.J. and Miller, D.P. (2004) *Int'l Lunar Conf., 6th*. [9] Stoker, C., and Hine, B. (1996) *AIAA*. [10] Stoker, C. (1998) *JGR*, *103*, 28557-28576. [11] Taylor, G.J. et al. (1995) NASA Ames Research Ctr. [12] Whittaker, W. et al. (1997) *ISAIRAS*, *7th*.