NEUTRON SPECTROMETER PROSPECTING DURING THE MOJAVE VOLATILES PROJECT ANALOG FIELD TEST.

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Introduction: We know there are volatiles sequestered at the poles of the Moon [1,2]. While we have evidence of water ice and a number of other compounds based on remote sensing, the detailed distribution, and physical and chemical form are largely unknown. Additional orbital studies of lunar polar volatiles may yield further insights, but the most important next step is to use landed assets to fully characterize the volatile composition and distribution at scales of tens to hundreds of meters. To achieve this range of scales, mobility is needed. Because of the proximity of the Moon, near realtime operation of the surface assets is possible, with an associated reduction in risk and cost. This concept of operations is very different from that of rovers on Mars, and new operational approaches are required to carry out such realtime robotic exploration.

The Mojave Volatiles Project (MVP) is a Moon-Mars Analog Mission Activities (MMAMA) program effort aimed at (1) determining effective approaches to operating a realtime but short-duration lunar surface robotic mission, and (2) performing prospecting science in a natural setting, as a test of these approaches. Here we describe some results from the first such test, carried out in the Mojave Desert between 16 and 24 October, 2014. The test site was an alluvial fan just E of the Soda Mountains, SW of Baker, California. This site contains desert pavements, ranging from the late Pleistocene to early-Holocene in age, as shown in Figure 1. These pavements are undergoing dissection by the ongoing development of washes. A principal objective was to determine the hydration state of different types of desert pavement and bare ground features [3]. The mobility element of the test was provided by the KREX-2 rover, designed and operated by the Intelligent Robotics Group at NASA Ames Research Center. The MVP project was described by [4].

Fig. 1. The MVP field site in the E Soda Mountains area of the Mojave Desert. Outlines denote areas containing strategic and tactical objectives. Rover Start Pt: 35.180720°, -116.190414°.

MVP Field Test Setup and Instruments: The MVP field test consisted of two operations centers: the Ames Science Operations Center (ASOC) at Moffett Field and the Mojave Remote Operations Center (MROC) at the field site. The ASOC was responsible for assessment of realtime telemetry, traverse planning, and overall operational management, while the MROC was responsible for rover operations, instrument configuration management, telemetry flow to the ASOC, and traverse plan execution.

Fig. 2. KREX-2 rover traversing desert pavements and nearby features during the MVP test. The neutron spectrometer is mounted between the two wheels on the right.

KREX-2 hosted several instruments: stereo cameras and a lidar for navigation and hazard assessment, a downward-looking camera to characterize the pavement and/or bare ground type, a near-IR volatile spectrometer system (NIRVSS) for assessing surficial hydration and mineral mixtures, and the neutron spectrometer system (NSS) to gauge volumetric hydration and elemental composition variations. A ^{252}Cf neutron source was used to interrogate the surface materials (needed only in terrestrial settings). KREX-2 is shown in operation in Figure 2.

Concept of Operations: Mission planning was carried out in two steps: strategic plans were created that identified broad areas of different pavement types and nearby features, while tactical plans were constructed within the strategic planning areas in order to achieve specific waypoints within the pavements, bare ground areas and washes. The prioritized set of strategic planning areas are shown in cyan in Figure 1, focused on areas of dark-, medium- and light-toned desert pavements. Tactical traverse plans were created by the ASOC to explore features within each of the strategic zones. These tactical traverse plans were relayed to the MROC for execution by the rover.

Initial Results for Neutron Spectroscopy: NSS measured the neutron albedo at both thermal and epithermal energies. Assuming uniform geochemistry and material bulk density, hydrogen as either hydroxyl/water in mineral assemblages or as moisture will significantly enhance the return of thermalized neutrons. However, in the Mojave setting there is little uniformity, especially in bulk material density.

Figure 3 shows some results of neutron prospecting during the MVP test. It can be clearly seen that lighter toned materials (immature pavements, bar and swale, and wash materials) have lower thermal neutron flux, while mature, darker pavements with the greatest desert varnish development have higher neutron fluxes. (Note: the darkest blue traverse was performed with no neutron source – the data are offscale low.)

A predictive model based on physical parameters such as slope and runoff, albedo (as a proxy for varnish formation and pavement maturity), insolation, etc. can be developed. As the rover begins the traverse and collects data, the orbital maps and ground data are fed into a Gaussian process model and predictions are made about the neutron flux at unvisited pixels. Due to the high correlation between albedo and neutron flux at the test site, we found that the most important predictive parameters in the system were albedo, water flow, and insolation, in that order. Furthermore, we found that the use of predicted physical processes improved the accuracy of neutron flux predictions by approximately 8% when compared to a traditional Gaussian process approach using only albedo. Since the clay-bearing Av1 soil horizon is most well developed under mature (and old) desert pavements, albedo could be a proxy for this hydrogenous material.

Such predictive models can help realtime mission operations for future surface lunar missions.

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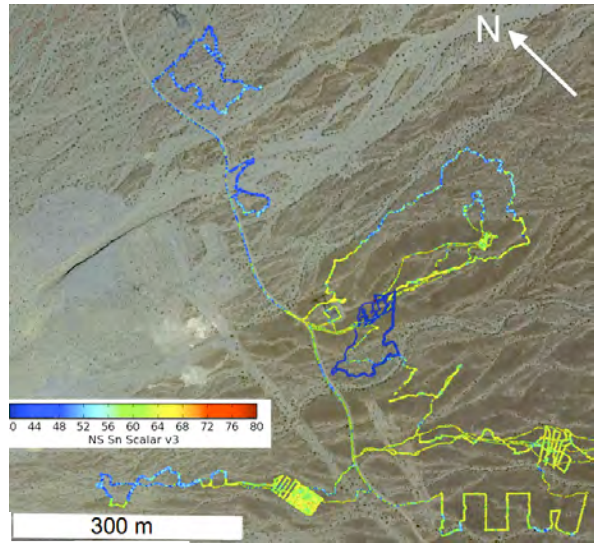

Fig. 3. Results of neutron prospecting during the MVP field test. Note the anticorrelation between surface albedo and color, and neutron flux. In general, the thermal neutron flux is lower over lighter toned materials, and higher over the darkest pavements.

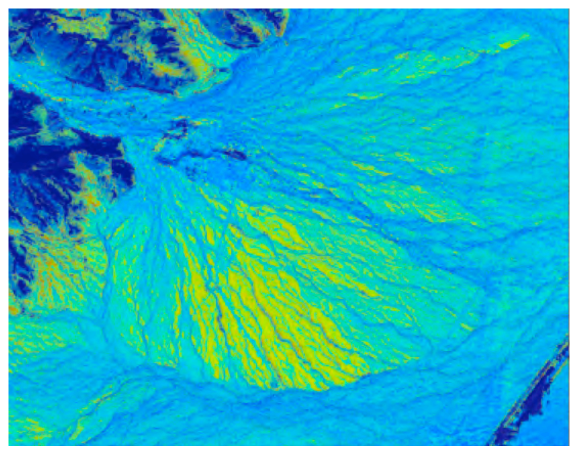

Fig. 4. Predictive model for neutron flux based on visible albedo, slopes, wind.

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