**PROSPECTING FOR POLAR VOLATILES: RESULTS FROM THE RESOLVE FIELD TEST.** Richard C Elphic[1], Anthony Colaprete[1], Matthew Deans[1], Jennifer Heldmann[1], Gerald Sanders[2], William Larson[3], [1]NASA Ames Research Center, Moffett Field, CA, United States. [2]NASA Johnson Space Center, Houston, TX, United States, [3]NASA Kennedy Space Center, FL, United States,

**Introduction:** Both the Moon and Mercury evidently host ice and other volatile compounds in cold traps at the planets' poles. Determining the form, spatial distribution, and abundance of these volatiles at the lunar poles can help us understand how and when they were delivered and emplaced. This bears directly on the delivery of water and prebiotic compounds to the inner planets over the solar system's history, and also informs plans for utilizing the volatiles as resources for sustained human exploration as well as the commercial development of space.

Temperature models and orbital data suggest near-surface volatile concentrations may exist at polar locations not strictly in permanent shadow. Remote operation of a robotic lunar rover mission for the 7-10 days of available sunlight would permit key questions to be answered. But such a short, quick-tempo mission has unique challenges and requires a new concept of operations. Both science and rover operations decision-making must be done in real time, requiring immediate situational awareness, data analysis, and decision support tools.

**RESOLVE Prototype and Mission Simulation**: The Regolith and Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) project aims to demonstrate in situ resource utilization (ISRU). RESOLVE is developing a rover borne payload that (1) can locate near subsurface volatiles, (2) excavate and analyze samples of the volatile-bearing regolith, and (3) demonstrate the form, extractability and usefulness of the materials. Here we describe an analog field demonstration of the prospecting approach RESOLVE would use for lunar mission. To meet mission requirements, a third generation RESOLVE payload and rover was developed and used in a roughly one-week field exercise simulating a mission.

The mission simulation was performed in July 2012 at 2470-m elevation on the south flank of Mauna Kea, in the vicinity of Pu'u Haiwahine (+19° 45' 41.09"N, -155° 28' 4.86"E). The test was carried out from a Mission Operations Center (MOC) located at Hale Pohaku about 1.3 km to the east (+19° 45' 41.46"N, -155° 27' 20.86"E). Additional support was provided by networked teams at NASA Ames Research Center, the Canadian Space Agency, NASA KSC and JSC.

**Site Preparation**: The test site was cleared of vegetation to the maximum extent possible, and targets were placed along the pre-planned traverse paths. The traverse plans were developed on the basis of interesting features identified in orbital imagery; after arrival in Hawai'i, a subset of the team emplaced targets. To avoid the difficulties of using water ice as prospecting targets, buried polyethylene sheets were used as ice proxies. Other materials (eg., camouflage netting) were used for near-IR targets. It was not practical to populate the entire test site with randomly distributed

Fig. 1. RESOLVE payload aboard Artemis Jr. rover, near lander mock-up.

targets, so these were placed at selected points along the traverse paths; their locations were not known to the prospecting ops team. These targets would be "discovered" by the prospecting instruments, and real-time decisions would have to be made, whether to stop and investigate further, or continue along the planned traverse. A mockup lander was utilized to 'deliver' the RESOLVE/rover to the mission start location and provide communication, situational awareness, and relative navigation to the RESOLVE/rover mission team (Figure 1). All operations were performed remotely from either the main MOC near the test site, or by personnel at the control centers in the US and Canada.

**Traverse Execution and Re-planning**. The mission simulation used a realistic process of pre-mission activity planning and scheduling, together with real time monitoring of status and progress through the activity plans. The Flight Control Team, led by the Flight Director, was responsible for executing the daily plan, and included a Timeline coordinator, as well as Systems, Rover and Science consoles. The latter were in turn supported by other consoles monitoring subsystem health and status.

Under Science, the prospecting activity was monitored via a Spectrometer console and a Real-Time Science console position, responsible for recommending rover operations modifications (e.g., rover all-stop when traversing a high-volatile content area, hydrogen hotspot localization to map the volatile distribution at high resolution, drill/auger procedure to sample the subsurface, rover speed adjustment based on spectrometer readings as needed, etc). Locating Real-Time Science position next to the Rover Navigation console position was key to enabling rapid and efficient updates changes to the traverse plan, especially when a volatile hotspot was found. Supporting these real-time positions was a Science Backroom at NASA Ames Research Center tasked with monitoring real-time data, conducting in-depth data analysis to support mission decision-making, and conducting any rover traverse replanning as required based on the data and information gleaned from prior roving activities.

**Results:** Figure 2 shows maps of all the traverses executed during the seven days of operations. In all, a total traverse distance of over 1 km was achieved. The maps also show color coded measurements by the neutron and near-IR spectrometers, and an inset shows the detail of a hotspot localization procedure. Nine "water ice" hotspots were identified, and seven of these were characterized by the localization procedure. Both augering and coring were performed at a subset of these sites.

These real-time science operations activities required innovative software to enable real-time monitoring of the prospecting data to support science decision-making. RESOLVE utilized customized exploration ground data system software (xGDS, used to make the maps in Figure 2) to monitor rover navigation telemetry, spectrometer data feeds, etc. Rover traverse plans as well as the paths actually executed by the rover were updated in real-time superimposed on a satellite image for context. Data displays included color-coded paths following the rover traverse which indicated relative amounts of volatile abundances with respect to geographic location and continually-updated strip charts plotting the instrument data as a function of time. Neutron data was displayed in terms of neutron count rate (directly proportional to hydrogen content). For the near-infrared data the raw spectra were monitored and data band depth algorithms were employed to automatically calculate and display the strength of several water bands for rapid assessment of water content.

Overall, the operation of the Field Demonstration was very successful. The infrastructure of the Flight Control team allowed for remote commanding and end-to-end operation of the RESOLVE payload and

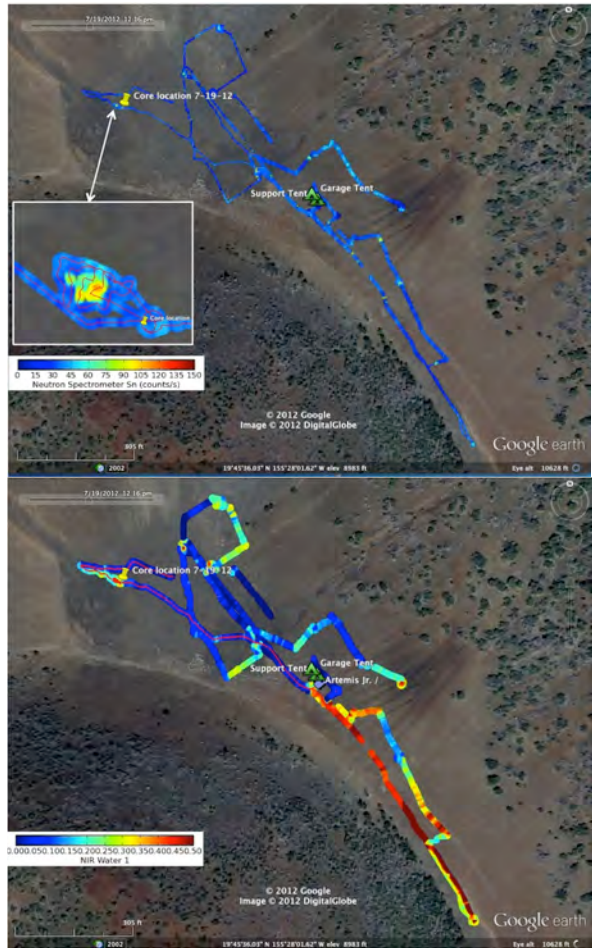


Fig. 2. (Top) Neutron spectrometer count rates mapped along traverse paths. Inset shows hotspot localization. Higher count rate means higher water-equivalent hydrogen abundance. (Bottom) Near-IR spectrometer band depth for 1.5 microns, corresponding to surficial hydration.

Artemis Jr. rover. Console tools, including software and console displays, were vital to the situational awareness in the Mission Operations Center. All operational objectives and the majority of the mission objectives were also met or exceeded.

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