

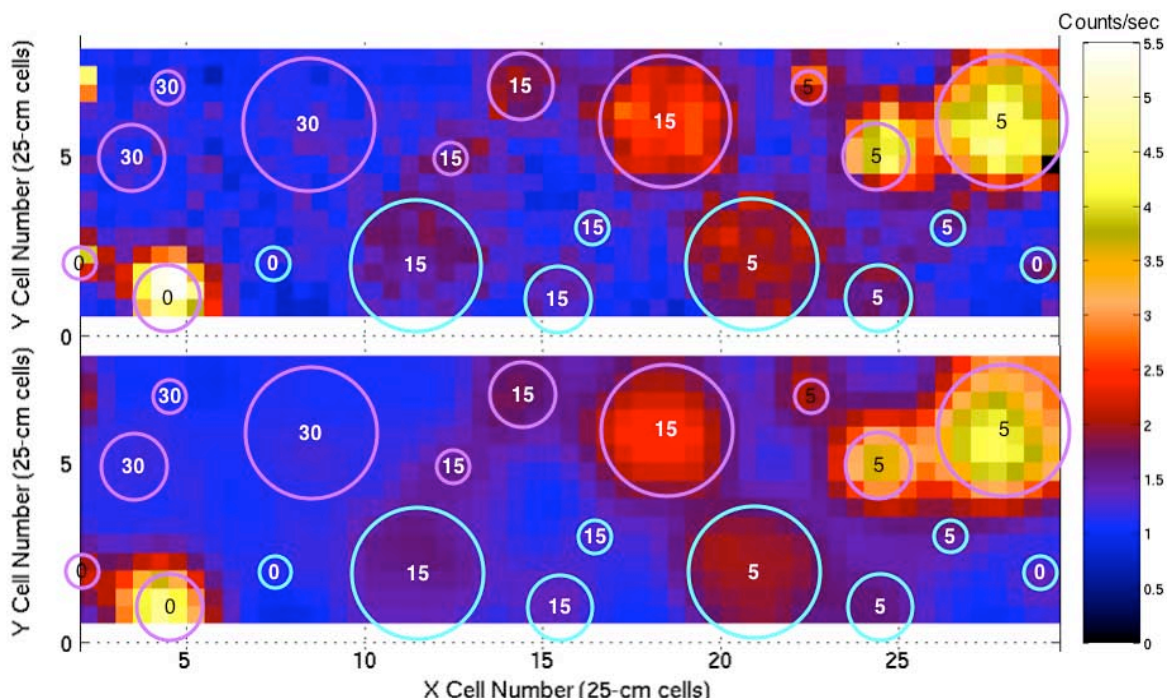
**NEUTRON PROBES FOR THE CONSTRUCTION AND RESOURCE UTILIZATION EXPLORER (CRUX).** R. C. Elphic<sup>1</sup>, S. Hahn<sup>1</sup>, D. J. Lawrence<sup>1</sup>, W. C. Feldman<sup>1</sup>, J. B. Johnson<sup>2</sup>, <sup>1</sup>Space Science and Applications, MS D466, Los Alamos National Laboratory, Los Alamos, NM 87545 USA ([relphic@lanl.gov](mailto:relphic@lanl.gov)), <sup>2</sup>US Army ERDC-Cold Regions and Engineering Laboratory, PO Box 35170, Ft. Wainwright, AK, 99703, USA.

**Introduction:** The Construction and Resource Utilization eXplorer (CRUX) project is developing a flexible integrated suite of instruments with data fusion software and an executive controller for *in situ* regolith resource assessment and characterization. CRUX includes two neutron detectors, the Surface Neutron Probe (SNeuP) and the Borehole Neutron Probe (BNeuP) to help locate and assess potential hydrogen-bearing deposits at the lunar poles. Carried on a rover, SNeuP locates near-surface water (or other hydrogenous volatiles) in a lightweight (481 g) package. BNeuP determines the stratigraphy of hydrogenous subsurface layers to depths of 10 meters (or more if an integrated neutron source is used) while operating within a drill string segment. It weighs 517 g, and consumes 2.25 W. The instruments' heritage includes the Lunar Prospector neutron spectrometer and numerous programmatic space instrument applications at Los Alamos. We have tested the SNeuP and BNeuP prototypes and have demonstrated their ability to detect near-surface hydrogenous materials. One important application

would be to assay near-surface water ice in permanently shadowed lunar polar craters such as Shackleton [1,2,3].

**Surface Neutron Probe Testing:** In October of 2005 we tested SNeuP's ability to detect near-surface deposits of 3- and 10-wt% H<sub>2</sub>O in the Army Corps of Engineers Cold Regions Research Engineering Laboratory (CRREL) in Hanover, New Hampshire. Deposits with diameters of 25, 50, and 100 cm were buried at depths of 30, 15, 5 and 0 cm. The soil used in the test was silica-rich with a minor contribution from micaceous minerals. When dried the soil moisture content was 0.1 wt% H<sub>2</sub>O, and the hydrous mineral contribution was equal to 0.39 wt% H<sub>2</sub>O. The entire setup was cooled to -40° C for the tests, and a stepper-motor-driven sled carried the SNeuP instrument and neutron source across the test area.

By compiling the traverses (15 in all), we can bin the count rate data spatially and create a map of the HeSn (thermal + epithermal) neutron count rates. This is shown in the top panel of Figure 1. Spatial smoothing using a Gaussian filter with a 26-cm full-



**Figure 1.** (Top) Map of HeSn (thermal+epithermal) neutron count rates binned in 12.5 cm square bins. Cyan and purple outlines denote 3 and 10 wt% H<sub>2</sub>O, respectively. (Bottom) HeSn count rates binned and smoothed using a gaussian with a 26-cm full-width at half-maximum. Icy deposit outlines are superimposed; numbers indicate depth of burial in centimeters.

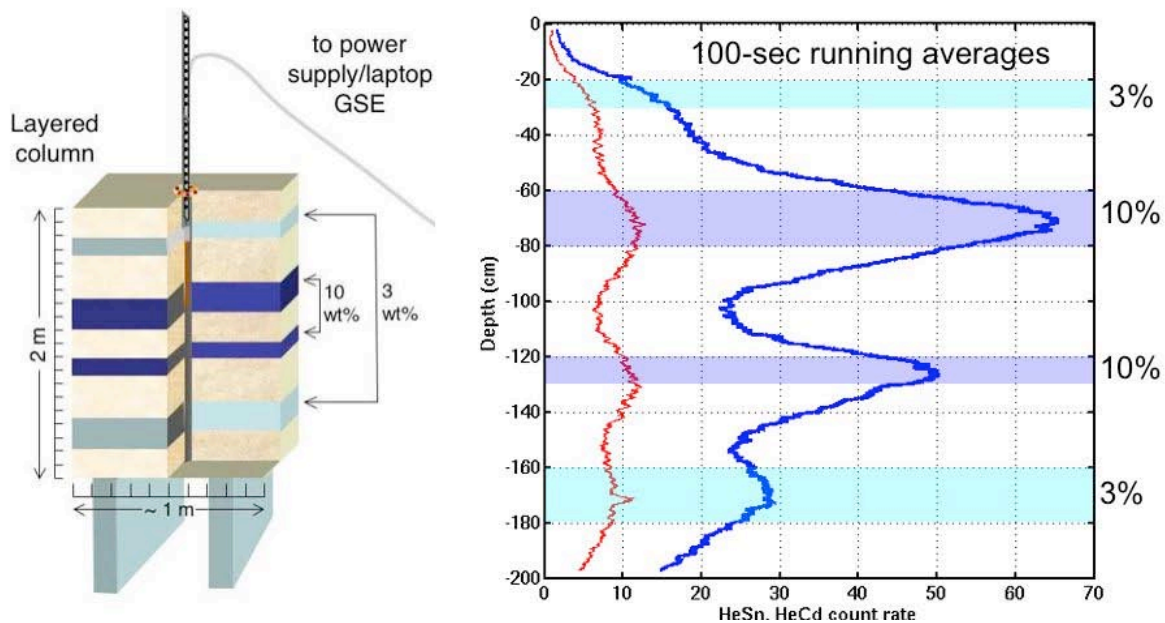
width at half-maximum spread helps improve signal fidelity, as can be seen in the lower panel of Figure 1. The 30-cm deep deposits are marginally detectable because the intervening 30-cm of 0.5-wt% H<sub>2</sub>O 'dry' material attenuates the deposit's signal (e-folding length is ~13 cm). In a realistic lunar surface scenario, in which cosmic rays generate the neutrons and the overburden has <0.5 wt% H<sub>2</sub>O, depth sensitivity of 70 cm or more can be achieved

**Borehole Neutron Probe Testing:** The CRREL cold room facility used for SNeuP testing also housed an experimental borehole setup for BNeuP testing in October of 2005. The left panel of Figure 2 shows a schematic diagram of the layered materials in the 2-m tall enclosure. Alternating layers of wet and dry soil were built from the bottom up. The instrument was raised and lowered through the layers by a stepper motor/cable arrangement. As with the HYDRA test, the facility was maintained at -40 C. As in the SNeuP testing, the material between layers has 0.5 wt% H<sub>2</sub>O:

The right panel of Figure 2 shows data from the

located 18 cm above the detectors. The peak counting rates are seen when the detectors are in the middle of an icy layer and the neutron source is above the layer. When the source itself is in a wet layer and the detectors are below, elevated count rates are seen because more of the source neutrons are being moderated and thermalized in the layer. These additional neutrons leak out and are detected. The resulting full-width, half-maximum response is roughly 35 cm.

**Conclusions:** SNeuP is an effective *in situ* surveying tool for locating and assessing near-surface, accessible hydrogen-bearing materials while on a roving platform; BNeuP complements this function by assessing the stratigraphic column of buried hydrogenous materials at a particular site. The instruments perform as expected, providing both localization and an assessment of "ore value," in terms of total hydrogen present. The neutron probes complement other *in situ* and remote sensing techniques in providing comprehensive situational awareness for mapping and decision making, both for surface op-



**Figure 2.** (Left) Schematic diagram of the borehole test configuration. Four layers of 3 and 10 wt% H<sub>2</sub>O soil with varying thicknesses were interleaved between 0.4 wt% H<sub>2</sub>O soil. (Right) Borehole log of HeCd epithermal (red) and HeSn thermal+epithermal (blue) energy ranges versus depth.

CRREL borehole test of BNeuP. The instrument responds to the enhanced hydrogen abundance in 10- and 20-cm thick layers of 3- and 10-wt% H<sub>2</sub>O soil (horizontal cyan and purple bars, respectively). Enhancements in thermal and epithermal neutron count rates are seen at the icy layers. The asymmetry in count rate enhancements is due to the source being

erations and for drilling.

**References:** [1] Feldman W. C. et al. (1998) *Science*, 281, 1496–1500. [2] Feldman, W. C. et al. (2001) *JGR-Planets*, 106, 23,231-23,251. [8] Bussey, D. B. J. et al. (2003) *GRL*, 30, doi:10.1029/2002GL016180.