**Recalibrated South Polar Observations from the Lunar Exploration Neutron Detector Onboard the Lunar Reconnaissance Orbiter.** T. P. McClanahan[1] (timothy.p.mcclanahan@nasa.gov), I. Mitrofanov[2], W. V. Boynton[3], G. Chin[1], M. Litvak[2], T. Livengood[1,4], A. Parsons[1], A. Sanin[2], R. D. Starr[3], J. Su[4], D. Hamara[3], K. Harshman[3], [1]NASA Goddard Space Flight Center, Bldg. 34 Room W218, Greenbelt, MD 20771 USA. [2]Institute for Space Research, Moscow, Russia, [3]Lunar and Planet. Lab., Univ. Ariz., Tucson AZ USA, [3]The Catholic Univ. Wash. D.C. USA, [4]Univ. of Mary., College Park MD USA.

**Introduction:** Recent efforts to recalibrate observations from the Lunar Exploration Neutron Detector (LEND), which is presently operating on the Lunar Reconnaissance Orbiter (LRO), have yielded an improved understanding of the instrument, as well as more accurate calibration of its epithermal neutron detectors [1,2,3]. Results from the study have provided important new results and capabilities which will be valuable in our ongoing studies of the Moon's hydrogen-bearing volatiles. The new methods predict the expected counts of several sources of lunar-induced and background sources to LEND's Collimated Sensor for EpiThermal Neutrons (CSETN)'s four helium 3 ($^{3}He$) proportional counter detectors. CSETN raw count-rates are increased by the addition of two detector channels of CSETN spectra, thus improving its signal to noise, as compared to prior LEND calibration methods [4,5].

A second contribution of the study is the successful recovery and calibration of LEND's uncollimated Sensor for EpiThermal Neutrons (SETN) observations. Six-plus years of observations, thought to be lost, are now fully recovered, thus reviving the SETN observation campaign. Perhaps the most important contribution of the SETN recovery, is the development of a new low-altitude hydrogen map, averaging 37 km altitude near the south-pole. We evaluate the new LEND CSETN and SETN calibrations and contrast the new hydrogen maps.

Since the Lunar Reconnaissance Orbiter (LRO) mission began studies of the Moon in July 2009, the LEND instrument has been in nearly continuous operations providing an unparalleled history of the Moon's neutron emission flux, over eight-plus years. During that time LEND has discovered important clues into the spatial distribution of the Moon's hydrogen-bearing volatiles and possibly diurnal cycling of hydrogen-bearing species near the surface [5-9].

However, fully calibrating LEND's CSETN detectors has proven to be a challenging endeavor due to conditionally variant background contributions from primarily charged particles and scattered neutrons. The relative contributions of these sources are convolved effects by observing altitude, solar-flux, galactic-cosmic ray flux and detector efficiency variation, which complicate the calibration. Neutron transport studies conclude that the uncollimated contributions to CSETN's detectors may approach 85% of the total raw signal, so accurate and precise calibration is critical for mapping studies [4].

Early mission analysis of LEND observations showed that non-lunar contributions to the detectors are primarily registered in the lower spectral channels of CSETN's 16-channels spectra$^{-1}$. To improve the signal to noise, the observations were constrained to sums of the 7 upper-channels, 9 to 15 inclusive [4]. The constraint improved the lunar signal-to-noise, but lowered the detector raw count-rates, then averaging 3.296 counts sec$^{-1}$ during the first six mission years. In our study, we broaden the set of usable spectral channels to span 9 channels, 7 to 15 inclusive, thereby raising the averaged raw mission count-rates to 4.416 counts sec$^{-1}$, over the same period, yielding a 34% averaged increase in rates. Expanding the set of channels is particularly important because the CSETN detector's raw count-rates are low, and their sensitivity has varied through the solar cycle, reaching minimal-levels at solar-maximum near 2014, and since rebounding in ensuing years. We evaluate the new CSETN revised calibration methods and derived south polar map in this study.

Prior to May 2011 SETN observations were, similar to CSETN, constrained to sums of spectral channels 9 to 15 inclusive. At that time SETN lost its pulse height discrimination capability, thereby all detected events were integrated to channel 0, thus SETN's other spectral channels were 0's, and SETN's observation campaign was effectively ended. However, recent studies by [1] found that because of SETN's position outside the collimator, its signal-to-noise is not degraded to the level of CSETN. The finding implies that all SETN channels can be summed, yielding spectrally identical observations, regardless of mission phase. So, integrating all 15 channels prior to May 2011, or just channel 0 after May 2011, yields equivalent observations. Thus, six-plus years of SETN observations are recovered and SETN's observation campaign is revived and ongoing.

The SETN discovery, with its inherently high signal-to-noise, coupled with now eight-plus and ongoing years of observations, makes possible important new comparative studies, achieved by splitting the observations by time, altitude or any other factors, into statistically independent maps.

In the present study, we present SETN low-altitude and high-altitude south-polar maps discriminated by observation altitude, being above or below 45 km.

Averaged altitudes for the low-altitude map poleward of -75° is 36.9 km and North, 53.6 km. The split above -75° latitude yields a low-altitude H map with 1.47e07 1-sec observations, the high-altitude H map contains 1.67e07 1-sec observations. In comparison, the Lunar Prospector Neutron Spectrometer has 1.31e05 8-second observations of the same region taken during its 3-month-long, low-altitude mission phase, as described in NASA's Planetary Data System (PDS).

**Results:** The CSETN south-polar map shows independent neutron suppression spots (*pink*) associated with the permanently shadowed regions (PSR)'s at Cabeus, Haworth, Shoemaker and Faustini craters, also observed in [5, 7, 8]. Neutron suppressed spots in the PSR's is consistent with hydrogen accumulations approaching 0.6% water-equivalent hydrogen (WEH %) entrained in the top-meter of regolith. Note that some sources of epithermal neutron flux variation may not be due to hydrogen. Comparison of CSETN and SETN maps shows differences in the locations of maximum WEH% concentration. CSETN shows the highest WEH% concentration is near the poleward facing slope of the Cabeus PSR [9]. Indicated as a '+' on the Lunar Observing Laser Altimeter (LOLA) elevation map. Independent SETN high and low-altitude maps indicate the maximum WEH% lies within the Faustini PSR. An explanation is that SETN's low spatial resolution is convolving the already low neutron emission flux from the surrounding cluster of large PSR's around Faustini. While CSETN's high WEH% detection at Cabeus is due to its high-spatial resolution, which better discriminates Cabeus and the cluster of PSR's around Faustini. Greater relative WEH% concentrations in the SETN low-altitude map are consistent with higher spatial resolution at low altitude vs high.

**Conclusions:** In this presentation we compare the new LEND's CSETN and SETN calibration methods and WEH% maps at the south pole. We consider a multi-spatial resolution view of the Moon's south pole and develop new results and strategies for investigating the Moon's hydrogen-bearing volatiles.

**References:** [1] Su *et al. LPSC* #49 #TBD [2] Mitrofanov *et a*l.(2010) *Sp. Sci. Rev., 150(1-4)* [3] Chin *et al., Sp. Sci Rev.* (129)-4 (2010) [4] Litvak *et al., JGR-Planets* (2011) [5] Boynton *et al., JGR-Planets* (117)-E12 (2012) [6] Livengood *et al*., *Icarus* Vol. 255 (2016) [7] Mitrofanov *et al., #43-6 Science* (2010) [8] Sanin *et. al*., #283 *Icarus* (2016) [9] McClanahan *et al*., #255 *Icarus* (2014)