**LUNAR EXPLORATION NEUTRON DETECTOR (LEND) FOR NASA LUNAR RECONNAISSANCE ORBITER.** A. B. Sanin[1], W. Boynton[3], L. Evans[4], K. Harshman[3], A. Kozyrev[1], M. Litvak[1], A. Malakhov[1], G. Milikh[2], I. Mitrofanov[1], M. Mokrousov[1], R. Sagdeev[2], V. Shevchenko[5], V. Schvetsov[6], R. Starr[7], J. Trombka[8], A. Vostrukhin[1]

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**Introduction:** The Russian-made, Russian-funded instrument LEND (Lunar Exploration Neutron Detector) is a younger brother of another Russian instrument HEND (High Energy Neutron Detector), which continues to perform well in its fifth year of science measurements onboard NASA's Mars Odyssey [1]. LEND and HEND have similar types of neutron sensors, and valuable science data from HEND regarding Martian water resources has demonstrated benefits of these sensors for purposes of orbital planetary "neutronography".

The Lunar Exploration Neutron Detector (LEND) has been selected for Lunar Reconnaissance Orbiter mission to provide the global search of hydrogen distribution through 1 – 2 meters of lunar subsurface from 50 km circular polar orbit of LRO [2].

**Instrument design:** The most important property of LEND (see Fig. 1) is its capability to provide high spatial resolution mapping of epithermal neutrons with collimated neutron detectors. LEND is able to detect hydrogen-rich spot at a pole with sensitivity about 100 ppm of hydrogen with spatial resolution of 5 km (Half Width at Half Maximum) and to produce global mapping of hydrogen content with resolution of 5 – 20 km. If hydrogen is associated with water, detection limit of 100 ppm of hydrogen corresponds to ~ 0.1 wt% of water in the regolith.

Neutron radiation from the regolith could have as large an impact on astronaut safety as charged energetic particles from Galactic Cosmic Rays and Solar Particle Events. LEND will have a full set of sensors for thermal (STN 1 - 3), epithermal (CSETN 1 - 4) and high energy neutrons (SHEN) to provide data for neutron component of radiation environment in the broad range of more than 9 decades of energy.

The primary type of LEND sensor is $^3$He counter, which is used for LEND detectors CSETN, STNs and SETN. The $^3$He nucleus has large cross section to capture neutrons in the reaction $n + {}^3He \rightarrow {}^3H + p + 764$ keV. The Cd shield around CSETN and STN absorbs neutrons with energies below ~ 0.4 eV, which exclude thermal neutrons from detection. The major difference of LEND in comparison with HEND is collimation of neutron flux. Collimating modules around $^3$He counters CSETN effectively absorb neutrons that have large angles of incidence with respect to the normal to the surface of the Moon and provide high spatial resolution of LEND for mapping.

The second type of LEND neutron sensor is sthylbene scintillator SHEN, which produces a flash of light each time when a high energy neutron in the range 0.3 – 15.0 MeV collides with a hydrogen nucleus and creates a recoil proton. Special electronics distinguishes protons from electrons, and active anti-coincidence shield eliminates the external charged particles.

The LEND Mechanickal-Mass Mock-up was ready for mechanical testing at end of 2006. Mechanikal structures for Qualification Unit and First Flight Unit of the instrument where at final stages of manufacturing.


**Fig. 1.** The Lunar Exploration Neutron Detector. Four sensors of neutrons are shown: 2 open filed sensors of thermal (STN 3) and epithermal neutrons (SETN), 2 sensors of Doppler filter for thermal neutrons (STN 1 and STN 2). Other five sensors are inside the collimator module: 4 collimated sensors (CSETN 1- 4) of epithermal neutrons and 1 collimated sensor of high energy neutrons (SHEN).

**Expected Results**. The most important property of LEND is its capability to provide high spatial resolution for mapping of epithermal neutrons due to the collimation of detected epithermal neutrons. So the data form CSETN will be used to detect hydrogen-rich spots on a circumpolar regions with sensitivity more than 100 ppm of hydrogen (3σ detection limit) with spatial resolution of 5 km (Half Width Half Maximum) and to produce global mapping of hydrogen content with the resolution of 5 – 20 km.

Data for high energy neutrons from another collimated sensor on LEND (SHEN) could help to distinguish a spot with enhancement of implemented hydrogen in the regolith from a spot with water ice deposits. However, the most conclusive results from the reconnaissance of lunar water/hydrogen resources would come from the joint analysis of all mapping science instrument onboard LRO.

Using the present knowledge of lunar polar regions, detaled numerical 3D model of instrument and sophisticated Monte-Carlo calculations based MCNPX code one may predict results for detection of water-ice rich craters (so called 'cold traps', see Fig. 2) and perform preliminary estimations of LEND detection limits for them. There are quite promising estimations for these limits to ensure reliable detection of water ice deposits which probably exist in the Moon craters.

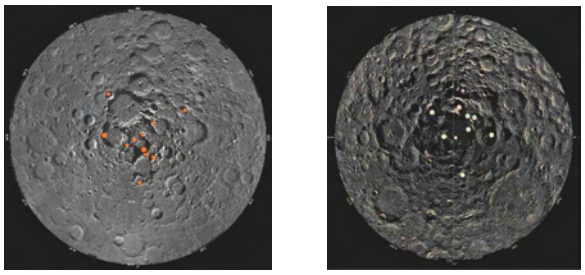

**Fig. 2.** Cold traps in the northern (left) and southern (right) hemisphere of Moon.

**References:**

[1] Mitrofanov I. et al. Science 297, 78, 2002.
[2] Chin G. et al. Space Sci. Rev. in press.