ACCOUNTING OF THE LUNAR GRAVITY FIELD AT THE WATER EQUIVALENT HYDROGEN ESTIMATION BASED ON LEND/LRO DATA. A. B. Sanin[1], I. G. Mitrofanov[1], B. N. Bakhtin[1] and M. L. Litvak[1], [1]Space Research Institute, 84/32 Profsoyuznaya st., Moscow, Russia, 117997.

Introduction: Since 1966 a number of scientific instruments operated in space that use nuclear planetology methods to investigate concentration of major rockforming elements, natural radioisotopes and distribution of volatiles in the subsurface soil of planets, moons and small bodies in the Solar system. For example, it is possible to study distribution of hydrogen-bearing compounds in the upper 1 – 2 m subsurface soil layer of atmosphereless celestial bodies or planets with thin atmospheres like Mars by measuring neutron spectra leak from the surface [1]. For this study one needs not only to measure neutron spectra but to perform also a set of numerical simulations of the neutron production by the Galactic Cosmic Rays (GCRs) in subsurface soil, leakage of these neutrons from the surface, their transport to the instrument on the orbit and processes of neutron interactions with the instrument's detectors. These simulations allow to perform a model dependent deconvolution of the measured data to obtain the hydrogen concentration and/or other soil properties at a particular region of the planet. Currently a number of numerical codes utilized the Monte Carlo method are quite usable for simulations of the neutron production, propagation and interaction with mater and detectors in complex-geometry and time-dependent tasks. It is thought the following codes are most popular currently: MCNP/MCNPX [2], Geant4 [3], FLUKA [4], etc. All these codes provide a reasonable precision in modeling not only in case of laboratory applications but also in case of nuclear planetology tasks. However, these codes do not include gravitational field description suitable for simulation of a neutron propagation on planetary scales. This disadvantage may be significant when determining hydrogen-bearing volatile compounds in the soil.

Method: A neutron escaping from the surface of atmosphereless celestial body propagates along the elliptic, parabolic or hyperbolic trajectory depending of its energy. In case of elliptical orbit the neutron may cross the spacecraft orbit two times or even do not reach it at all and return back to the surface of the celestial body. The neutron kinetic energy is a function of distance from the center of the celestial body. Non-constant neutron kinetic energy, its non-linear trajectory while propagation and finite neutron lifetime lead to the change in probability for the neutron to reach the spacecraft orbit and to be detected. It is obvious that the neutron's motion in the gravity field of the celestial body may be considered using the Newton's laws and equations of celestial mechanics. To quantitatively estimate how the gravity field of the celestial body affects the neutron propagation after it escapes from the surface and, hence, affects the angular distribution and spectra of the neutron flux at the altitude of spacecraft we built a code based on the Geant4 simulation toolkit [3] release 10.4 and introduced into this code an ability to track each neutron as it moves along an elliptical, parabolic or hyperbolic trajectory after it escapes from the surface according its kinetic energy.

Discussion: Data gathered by collimated epithermal neutron detectors of LEND instrument on-board NASA LRO mission are used for hydrogen/water reconnaissance in the top layer of lunar regolith with high spatial resolution [5-6]. There was developed a model dependent data deconvolution method to convert LEND neutron counting rate into the concentration of water equivalent hydrogen (WEH) [7]. Numerical simulations based on MCNPX simulations of the leakage neutron flux are widely used in this method. However, the lunar gravity field and neutron lifetime were not accounted for in these simulations since this code does not consider them both. Using our Geant4 based code, we have modeled the neutron counting rate in detectors of LEND instrument using at different altitudes of spacecraft orbit in the spacecraft rest frame while taking into account the corresponding spacecraft orbital velocity. Based on these simulations and earlier developed method for WEH estimation, we have re-estimate the WEH at the Lunar circumpolar regions and found that the new values are systematically slightly higher but almost all of them agree with values published in the paper [21] within the statistical uncertainty of the neutron flux suppression in the considered locations. Also, using the new code we have estimate the spatial resolution of the omnidirectional thermal and epithermal and collimated epithermal neutron detectors of LEND. Thus, we are planning to present in our talk the updated and re-processed WEH maps based on LEND data.

References: [1] Drake D., Feldman W. C., Jakosky B. M. (1988) *JGR, 93*, 6353-6368. [2] Werner C. J. et al. (2018), Los Alamos National Laboratory, report LA-UR-18-20808. [3] Agostinelli S. et al. (2003), *NIMPA*, *506*, 3, 250-303. [4] Battistoni G. et al. (2015) *Annals Nucl. Energy*, *82*, 10-18. [5] Mitrofanov I. G. et al. (2010) *Science*, *330*, (6003), 483. [6] Mitrofanov I. G. et al. (2012) *JGR*, *117*, CiteID E00H27. [7] Sanin A. B. et al. (2017) *Icarus, 283,* 20-30.