Radiation Environment Characterization on the Lunar Surface from SPE and GCR interactions

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INTRODUCTION

In 2009, USA launched the Lunar Reconnaissance Orbiter (LRO), a NASA mission to create a comprehensive assessment of the lunar surface including the radiation environment. Two of the six instruments on LRO are designed to understand the radiation environment; (1) The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) and (2) The Lunar Exploration Neutron Detector (LEND). The data from these instruments will provide most recent and direct measurements of the human-relevant radiation environment in the lunar orbit [1]. This data will complement the verification and validation efforts of the transport calculations performed by various groups globally including ours.

On the lunar surface the two primary radiation environment of concern are the Solar Particle Events (SPE) and Galactic Cosmic Rays (GCR). The resulting secondary radiation environment generated from these primaries consists of albedo neutrons, photons and other particles. Albedo neutron production on lunar surface using Monte Carlo simulations has been studied by various investigators for GCR interactions [2, 3]. McKinney et al performed an extensive investigation of the neutron production from GRC on the lunar surface using the Monte Carlo code MCNPX. However, this paper did not address SPE environment. The high intensities of SPE can be a serious radiation hazards in space, particularly on the lunar surface.

MATERIALS AND METHODS

This paper will present radiation environment characterization on the lunar surface using Monte Carlo (MCNPX) simulations for two primary environments: (1) Solar Particle Events (SPE); and (2) selected GCR heavy ions (Carbon, Oxygen and Iron). The SPE features large flux and low energy of mostly protons particles [4,5]. We used the 1956 Webber SPE for our SPE environment and Badhwar & O'Neill model to produce the GRC input GCR [5,6]. The Badhwar & O'Neill model can be used to produce the spectra for Z=1 to 28 heavy particles. For this paper we choose Carbon, Oxygen and Iron. Our decision was based on their abundance and the biological effect considerations (bio-effect is proportional to Z^2).

Fig. 1 shows the thermal, epithermal and fast neutron flux on the lunar surface produced due to the primary SPE interactions with the lunar surface. Similar curves for GCR input spectrum are also produced and will be presented. Additionally, the albedo neutron and photon spectrum will be presented. For the GCR interactions, the results will include proton and alpha interactions and the heavy ion interactions using the recently added heavy ion transport capability in MCNPX [7, 8].

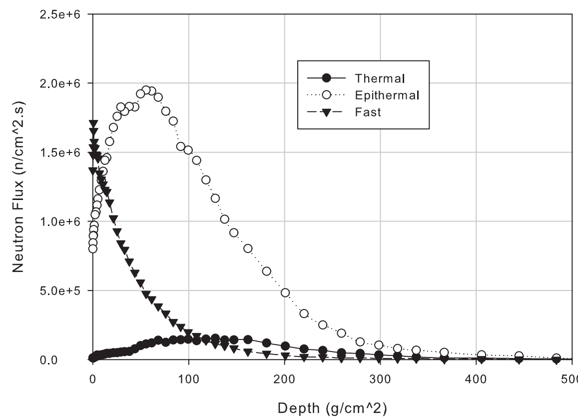

Fig.1 Neutron fluxes on lunar surface due to SPE.

REFERENCES

[1] Gordon Chin, Scott Brylow, et al. Space Science Reviews Vol. 129, No. 4 (2007), 391-419.
[2] McKinney, G. W. Lawrence, D. J. Prettyman, T. H. Elphic, R. C. Feldman, W. C. Hagerty, J.J. (2006) *J. of Geophysics. Research*, Vol. 111, E06004.
[3] Hu, X. Aghara, S.K. Grice, J. (2011), 22rd Annual NASA Space Radiation Investigator workshop.
[4] Guidance on Radiation Received in Space Activities, NCRP Report No. 98, 1989.
[5] S.I. Sriprisan, S.K. Aghara, R. C. Singleterry, "A study of secondary neutron spectra for Solar Particle Events," ANS annual winter meeting, Washington D.C., Nov 2011.
[6] Patrick M. O'Neill, 2010, Badhaear-O'Neill 2010 Galactic Cosmic Ray Flux Model – Revised.
[7] Michael R. James, G.W. McKinney, John S. Hendricks, Michael Moyers. Nucl Instr. & Meth. In Phy. Res. Sec. A 562 (2206) 819-822.
[8] S.K. Aghara, S. R. Blattnig, J. W. Norbury and R. C. Singleterry, "Monte Carlo Analysis of Pion Contribution to Absorbed Dose from Galactic Cosmic Rays," Nucl. Insrtum. Meth. B, 267 (2009) 1115–1124.

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