

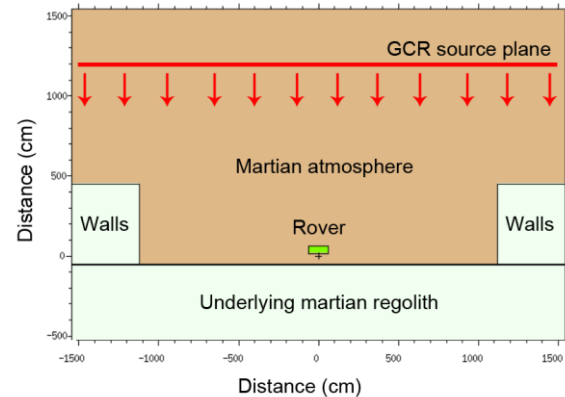
# INFLUENCE OF NEARBY TOPOGRAPHY ON PASSIVE NEUTRON COUNT RATES FROM THE DYNAMIC ALBEDO OF NEUTRONS INSTRUMENT ON THE MARS SCIENCE LABORATORY ROVER.

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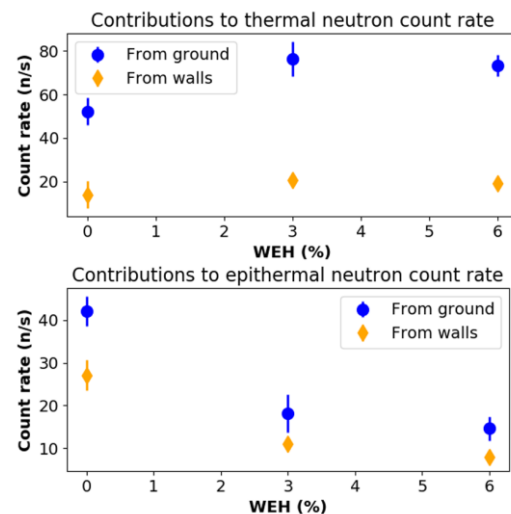
**Introduction:** The Dynamic Albedo of Neutrons (DAN) instrument on the Mars Science Laboratory (MSL) rover provides *in situ* hydrogen abundance of the top ~1 meter of the martian surface in Gale Crater using galactic cosmic ray (GCR) interactions in passive mode and a pulse neutron generator (PNG) in active mode [1, 2]. The field of view of the DAN instrument in both modes is statistical in nature and is spatially broad (~meters). The footprint of DAN in active mode is approximately 3 meters in diameter centered on the back two rover wheels [3]. In passive mode, GCRs produce neutrons that interact with the hydrogen and neutron absorbing elements within the surrounding terrain [4]. As MSL traverses further up Aeolis Mons, topographic relief increases along with the abundance of small valleys and slot canyons. As the DAN passive count rates are dependent upon interactions of GCRs with the surrounding terrain, it is important to consider how passive count rates may be influenced by nearby topographic features.

Interpretation of DAN data relies on modeling of neutron transport through different possible local geochemistries. These models, using the Monte Carlo N-Particle (MCNP) transport code, capture a simplified version of the local environment of the rover [5]. Although it is typical to assume a flat plane around the rover, MCNP models of neutron transport can be constructed to include local topographic features (Figure 1). In general, variation of topography around the rover represents significant change in the abundance of nearby neutron moderating elements (*e.g.*, H, Fe, and Cl). Constraining measured DAN passive count rates due to nearby topographic features will be important for future tactical measurement planning, particularly due to the limited lifetime of DAN's PNG which will reduce the efficiency of DAN active measurements [3].

**Method:** To test our hypothesis that nearby topography contributes to the DAN passive count rate, we used MCNP simulations to separate the contribution to the count rate by neutrons coming from the walls and from the ground beneath the rover. Preliminary results are shown in Figure 2 for a simulation that incorporates 5 meter high walls, set 10 meters away from the rover with variable WEH content in the ground and walls (Figure 1). In this geometry, we find that walls contribute ~20% of the total thermal neutron count rate and ~35-40% of the epithermal neutron count rate for all values of WEH (Figure 2). Thus, further investigation



**Figure 1.** Schematic cross-section of MCNP simulations used in this study. The walls in this model are 5 meters high and 10 meters away. The DAN instrument is located at the rear of the rover in this model.



**Figure 2.** Contribution to the count rates from the walls (●) and the ground (◆) as a function of WEH. When present, walls contribute ~20% of the thermal count rate and 35-40% of the epithermal count

into the influence of topography on measured DAN passive count rates is warranted. Therefore, we modified the standard MCNP model used for DAN data analysis to include two idealized cliff walls at various heights and distances, with heights of 1, 5 or 10 meters, set at 1, 10, or 25 meters away from the rover. These values were chosen to represent possible surface topographic features that the rover has or may encounter (*e.g.*, the Murray Buttes). These simulations used the same composition for the underlying regolith and the walls, taken from major oxide analyses measured at the Sebina drill site [6]. Sebina represents a lacustrine mudstone composed of approximately 30% phyllosilicates, 25%

feldspar, 20% Ca-sulfate, 15% hematite, 7% pyroxene, and 3% jarosite [6]. We modify the abundance of hydrogen (reported as water-equivalent hydrogen, WEH) in our simulations to determine if adding local topography has a comparable effect.

We use the method of [7] to convert MCNP output to neutron count rates, assuming an average value of the GCR flux over the first ~700 sols of the mission. We then multiply the product of the MCNP output and the GCR source strength by the individual detector surface area (~48.8 cm<sup>2</sup>) and a scale factor to account for the contribution to the passive count rate by the rover's MMRTG power source [8]. This allows direct comparisons to measured DAN passive data and therefore interpretations about the inferred WEH values.

**Results:** Our preliminary simulation results indicate a significant increase (greater than the associated MCNP uncertainty) in thermal neutron count rates for topographic features greater than 1 meter in height when they are within ~5 meters of the rover. A significant increase in the simulated epithermal neutron count rate is observed for a 1 meter topographic feature within ~1 meter of the rover. Thermal and epithermal neutron count rates for the case of 5 meter high walls set 10 meters away for a variety of WEH values are given in Figure 3 and compared to a case with no walls.

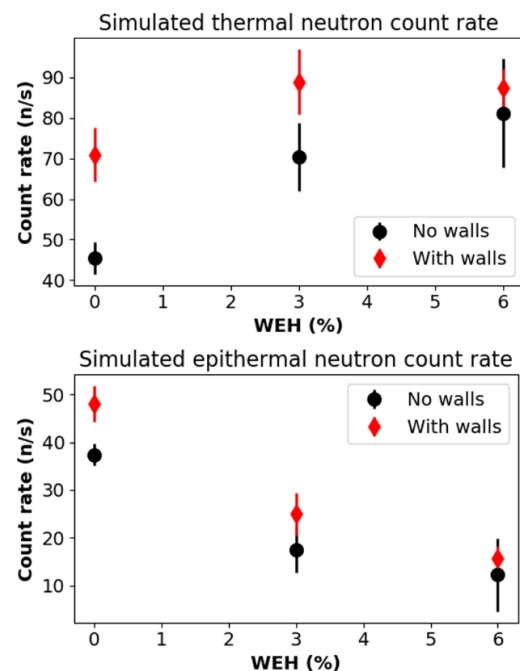
The range of thermal neutron count rates for the 'no walls' case in Figure 3 is very similar to reported DAN passive count rates [4,7]. Secondly, for the cases with no walls, trends of the thermal and epithermal neutron count rates with increasing WEH are similar to what is reported in [4,8] for GCR-induced neutrons. Finally, for both topographic cases (*i.e.*, with and without walls) thermal and epithermal neutron count rates trend as expected for increasing WEH.

**Discussion:** Our results show: 1) the introduction of nearby topography increases thermal and epithermal neutron count rates, and 2) this increase in count rates becomes indistinguishable from the 'no walls' scenario at WEH values greater than 3%. This can be qualitatively explained by the higher abundance of neutron scattering *and* absorbing elements in the walls that contribute to the neutron signal observed by DAN as compared to the 'no walls' geometry. Because neutron count rates are influenced by the addition of topography, an elevated thermal neutron count rate, which is typically interpreted as a high WEH abundance, might instead be caused by variations in the local topography. This analysis will assist in DAN passive interpretations where avoiding extreme topography is not possible and estimated water abundance is low. It also provides insight into how DAN may be sensitive to the hydrogen or neutron absorber abundances of nearby cliff faces or other exposed geologic features. These situations could be

encountered as the rover continues to higher elevations on Aeolis Mons.

Future missions carrying neutron spectrometers to the surface of other planets will benefit from including topography in the analyses of neutron data. For example, missions to search for water ice in permanently shadowed regions at the poles of the Moon using landed instruments will benefit from an accurate analysis that includes nearby topography [*e.g.*, 9]. Missions to explore the surface of hydrogen-rich targets in the outer solar system, like Saturn's moon Titan, could also benefit from incorporating topography (dunes) in their analysis [*e.g.*, 10]. Quantifying the influence of topography will enable more detailed investigations of the hydrogen or neutron absorber contents in the near-field of the lander/rover, particularly when geologic units are present near the landing site with low hydrogen content.

**References:** [1] Litvak, M. L., et al., (2008) *Astrobiology* 8.3: 605-612. [2] Mitrofanov, I. G., et al., (2012) *Space Sci. Rev.* 170.1-4: 559-582. [3] Sanin, A. B., et al., (2015) *Nuclear Instr. and Methods in Phys. Research A* 789: 114-127. [4] Tate, C. G., et al., (2015) *Icarus* 262: 102-123. [5] Goorley, T., et al., (2012) *Nuclear Technology* 180.3: 298-315. [6] Jackson, R. S., et al., (2018). *LPSC XLIX*, Abstract #2314. [7] Tate, C. G., et al., (2018) *Icarus* 299: 513-537. [8] Jun, I., et al., (2013) *JGR: Planets* 118.11: 2400-2412. [9] Abercromby, A., et al., (2015) AGU Fall Meeting, Abstract P53C-2148. [10] Turtle, E. P., et al., (2017). *LPSC XLVII*, Abstract #1958.



**Figure 3.** Thermal and epithermal count rates as a function of water equivalent hydrogen (WEH) abundance for simulations with no walls (●) and for simulations with 5 meter high walls, 10 meters away (◆).