EFFECTS OF AN RTG POWER SOURCE ON NEUTRON SPECTROSCOPY MEASUREMENTS ON THE MARTIAN SURFACE.

D. J. Lawrence, R. C. Elphic, T. H. Prettyman, and R. C. Wiens, Los Alamos National Laboratory, Los Alamos, NM 87545 (djlawrence @lanl.gov)

Introduction: A continuing goal of Mars science is to identify the exact locations of near-surface water and/or hydrated minerals using in situ measurements. Recent data [1] from Mars Odyssey has used both neutron and gamma-ray spectroscopy to measure large amounts of water ice near both polar regions. Furthermore, these data have also determined that in the mid-latitude regions, there likely exist relatively large amounts of hydrogen. While these are exciting results, one drawback of these measurements is that they are averaged over a large (~400 km) footprint and do not reflect potential small (<1 km) inhomogenieties in hydrogen abundance that likely exist at the Martian surface. For any future in situ mission (e.g., Mars Smart Lander (MSL)) that seeks to measure and characterize near-surface H_2O, it will be necessary to know the locations of the H_2O.

In previous work [2], we studied the feasibility of using neutron spectrometers (NS) at the Martian surface for making such an identification and measurement. In that work, we concluded that attaching a NS to a surface-based rover does not substantially degrade its ability to detect water.

However, in order to extend the surface life of a rover, there have been suggestions of powering the rover using a Cassini-like radioactive thermal generator (RTG). While this extends the life of the rover mission, the intense radiation environment of an RTG-based rover also raises questions regarding the NS measurement technique: 1) Will the background radiation from the RTG's be too intense and overwhelm the NS sensors, thereby preventing a measurement of surface hydrogen content? 2) Conversely, is it possible to use the RTG radiation as a source that enables the measurement of the surface hydrogen content? Here we investigate these questions.

Instrument Modeling: In this study, we modeled a scenario similar to what was done in our previous study where we modeled the effects of galactic cosmic ray (GCR) produced neutrons. For simplification, we modeled the rover as 150 kg of material spread over a $(50\ \mathrm{cm})^3$ cube (Fig. 1, [3]). We assumed that 90% of this mass was Al and 10% of the mass was computer board material. The computer board material was assumed to be 60% fiberglass and 40% epoxy. For the neutron sensors, we used two standard Sn (thermal) and Cd (epithermal) covered ^{3}He proportional tubes (1cm dia. x 10 cm active length) attached to a computer board. For the Martian surface, we assumed a two-layer stratigraphy such that the top dry layer has a Pathfinder-type composition [4] and the semi-infinite bottom layer has increasing admixtures (1–100 wt.%) of H_2O. Finally, for the input neutron spectrum, we used a spectrum similar to what comes from Cassini-type RTG's [5], which are being considered for the future MSL mission. The total energy-integrated flux is 1.2×10^{11} n cm^{-2} s^{-1}. We note that there is also a substantial gamma-ray flux in the vicinity of the RTG. However, we will ignore the gamma-ray component in this study for two reasons: 1) gamma-rays are more easily shielded than neutrons, thereby decreasing their flux at the neutron sensor; 2) ^{3}He neutron sensors are highly insensitive to gamma-rays [6], therefore reducing the effect of gamma-rays on the neutron measurements. Finally, we modeled the particle transport using MCNPX [7], which has been used extensively for modeling gamma-ray and neutron transport effects in planetary and Martian science [1].

Results: Fig. 2 shows the modeling results for epithermal neutrons versus H_2O content in the bottom soil layer. The counting rate (in units of counts per second) for RTG neutrons is shown by the black symbols and the left scale. For comparison, the counting rate for GCR-induced neutrons is shown by the red symbols and the right scale bar. A few conclusions can be immediately drawn from this plot. First, the neutron counting rate from the RTG-based neutrons is over 50 times that of the counting rate from GCR-induced neutrons. This allows high-precision measurements to be made more quickly using RTG-induced neutrons compared to GCR-induced neutrons. For example, in a soil with 10 wt.% H_2O overlain with dry material, the expected counting rates are 92 c/s (RTG) and 1.1 c/s (GCR). In order to make a measurement with 1% precision (i.e., 10,000 total counts), it will take 1.8 minutes with an RTG, but 2.5 hours with GCR-induced neutrons. This high counting rate truly enables high precision neutron measurements to be made while driving, which greatly increases mission planning flexibility. Furthermore, even though the counting rate in Fig. 2 is relatively high, it is still three orders of magnitude lower than counting rates that are often measured with ^{3}He tubes [6]. The RTG radiation environment is therefore not a hindrance for making high-quality neutron measurements.

Fig. 3 shows the same results of Fig. 2, but now the counting rates have been normalized to the lowest H_2O case, so as to illustrate differences in relative counting rates. Here, we see that the relative counting rate change is much less for the RTG case compared to the GCR case. This reflects the fact that the signal to background is lower with an RTG. This decrease in sensitivity, however, is offset to a large degree by the significantly higher counting rate with RTG's. Furthermore, there still exist various options that have not yet been explored for shielding the NS from primary RTG neutrons.

Fig. 4 shows the expected counting rate of thermal neutrons (i.e., Sn – Cd counting rate). Here, a major qualitative difference is seen between the RTG and GCR cases. While there is a general decrease in the counting rate for GCR-induced thermal neutrons versus H_2O content, the thermal neutron counting rate profile is drastically different with RTG-induced neutrons, such that for a thin dry layer, there is a strong increase in thermal neutrons for increasing H content in the bottom layer. However, at a depth of 70cm, the water rich layer has very little effect on the thermal neutrons. While this needs to be studied in more detail, it likely reflects the different penetration depths of GCR and RTG primary neutrons.

Conclusions: Based on these results, we conclude the following: 1) The neutron spectroscopy technique of measuring near-surface water on the Martian surface is not only feasible with an RTG-power source, but may increase the flexibility of surface science operations by enabling high-precision measurements to be made in minutes; 2) While the signal to background sensitivity is lower with an RTG power source, there is still sufficient sensitivity to make measurements over a wide range of H contents; 3) Another sensitive discriminator of very near surface water (~15 cm) can be provided by RTG-induced thermal neutrons.

References: [1] Boynton et al., Science, 297, 81, 2002; Feldman et al., Science, 297, 75, 2002; Mitrofanov, et al., Science, 297, 78; [2] Lawrence et al., 33rd LPSC, Abstract #1597, 2002; [3] Sevilla, D., JPL, pers. comm., 2002; [4] Bruckner et al., 32nd LPSC, Abstract #1293, 2001; [5] Jun I., JPL, pers. comm., 2002; [6] Hahn et al., IEEE Trans. Nuc. Sci., submitted, 2002; [7] Waters, MCNPX Users Manual, LA-UR 02-2607, 2002.

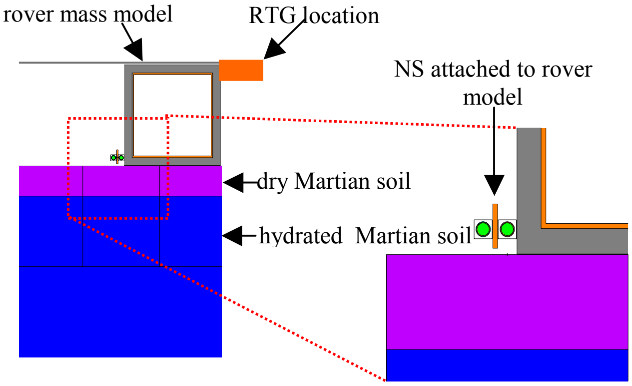

Figure 1. Schematic diagram of the NS, rover, and Martian surface model used for this study.

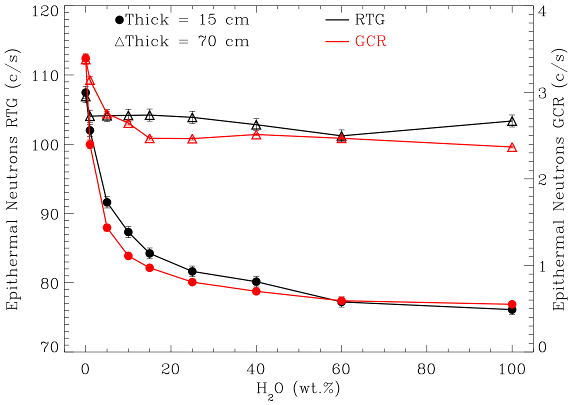

Figure 2. Epithermal neutrons (counts per second) versus H_2O content for the bottom dry layer. Black and left scale are for the RTG case; red and right scale are for the GCR case. Solid circles are for a 15 cm thick dry layer; open triangles are for a 70 cm thick dry layer.

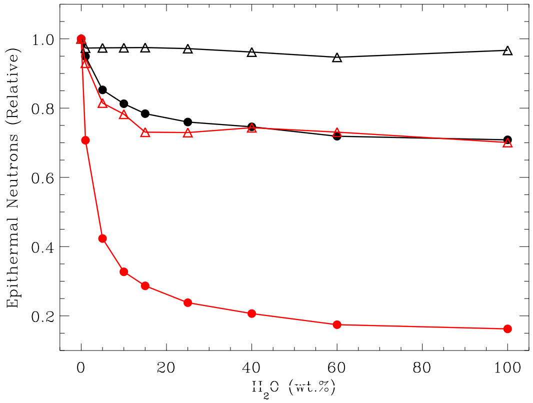

Figure 3. Relative epithermal neutrons versus H_2O content for the bottom dry layer. Black symbols are for the RTG case; red symbols are for the GCR case. Solid circles are for a 15 cm thick dry layer; open triangles are for a 70 cm thick dry layer.

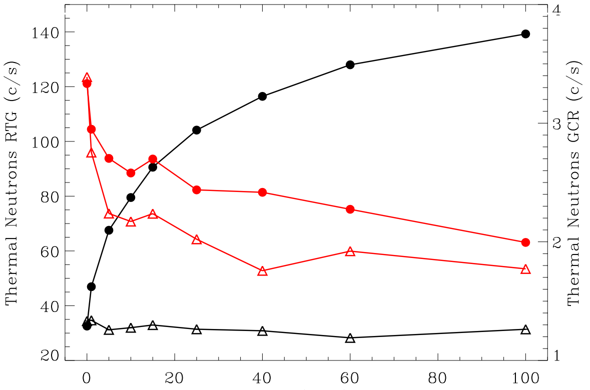

Figure 4. Thermal neutrons (counts per second) versus H_2O content for the bottom dry layer. Black and left scale are for the RTG case; red and right scale are for the GCR case. Solid circles are for a 15 cm thick dry layer; open triangles are for a 70 cm thick dry layer.