Title: DEVELOPMENT OF AN ULTRACOMPACT NEUTRON SPECTROMETER FOR IDENTIFYING NEARSURFACE WATER ON MARS

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 DEVELOPMENT OF AN ULTRACOMPACT NEUTRON SPECTROMETER FOR IDENTIFYING NEAR-SURFACE WATER ON MARS. D. J. Lawrence, R. C. Wiens, K. R. Moore and T. H. Prettyman, Los Alamos National Laboratory, Group NIS-1, MS D466, Los Alamos, NM 87545 (djlawrence@lanl.gov).

Introduction: One of the major goals of the Mars science program is to identify exact locations of near-surface water or hydrated minerals on Mars. Evidence is mounting that Mars may have contemporary near-surface groundwater activity. Though very water-poor by terrestrial igneous standards, the SNC meteorites were found to contain evaporite minerals suggestive of groundwater activity within the past 1.3 Ga [1]. More recently, the Mars Surveyor camera recorded images of geologically young seepage and outflow channels attributed to liquid water. The sources of these channels were suggested to be only a few hundred meters or less below the surface [2]. If these channels are truly geologically young, thinly buried ice may still exist at the termination of these channels.

The identification of sedimentary rocks and in particular, hydrous minerals is also of great importance. However, experience so far shows that such an identification is not a simple task. The orbiting Thermal Emission Spectrometer (TES) found evidence for abundant, large-grained hematite in the Sinus Meridians region [3], suggesting again that liquid water was at some point on the surface of Mars. However, there is no evidence of hydrated minerals in the TES spectra. Unfortunately, actual hydrated minerals are very unlikely to be found close enough to the surface to be revealed by imaging techniques, given the desiccating effect of the Mars atmosphere and the reactive nature of the Martian soil [4]. Thus, the very minerals of greatest interest (as well as water) will most likely be found at some depth below the surface. The best way to identify them directly is to drill for them. However, drilling is highly energy- and time-intensive. It is absolutely essential to know a priori where to drill. The present rover-based drilling technology, e.g., the mini-corer on the FIDO rover, has a depth of only five centimeters. While deep drilling technologies are being explored, it is quite likely that the next decade will only see drilling to depths of ~1 m on Mars.

It is for these reasons we see the need to develop instrumentation that can identify water or hydrated minerals very near the surface. Here we explore an extension of orbital neutron spectroscopy to make in situ measurements of hydrogen abundances on the Martian surface using two $^3$He neutron detectors. This type of instrument would be ideal for rovers as it could be small, low mass, low power, and have a low data volume per measurement.

Planetary Neutron Spectroscopy: Using neutron spectroscopy as a means to detect and measure hydrogen abundances on a planetary surface was first demonstrated with the Lunar Prospector Neutron Spectrometer (LP-NS) [5]. The LP-NS measured enhanced hydrogen abundances on the poles of the Moon using $^3$He gas proportional counter neutron detectors. The $^3$He neutron detectors were mounted on the end of 3 m boom so that interferences from the spacecraft body were reduced. The technique used for lunar measurements has been extended to Mars with the Mars Odyssey Neutron Spectrometer (MO-NS) [6]. Here, a scintillator based neutron detector is mounted directly on the spacecraft. Interferences from the spacecraft are reduced by using a doppler filter technique to measure broad ranges of neutron energies. One goal of the MO-NS is to measure hydrogen abundances to a depth of 30 cm over the entire Martian surface with a footprint of 600 km$^2$.

While the basic technique of planetary neutron spectroscopy is sufficiently well-developed to make robust measurements from orbit, studies still need to be done to understand how well in situ neutron spectroscopy measurements can be made on the surface of Mars. Issues to study include the following:

1) It is likely that any rover-based neutron detector will have to be mounted directly on the rover. What is the effect of the rover body material, including hydrogen, on the hydrogen detection capabilities of a neutron detector? Will this material degrade the hydrogen detection capabilities of a rover based-neutron detector? 2) What is the expected counting rate for a given detector size and configuration? 3) What is the influence of Martian elemental composition on the hydrogen detection capabilities of a neutron detector system? 4) What are the hydrogen detection capabilities for various mission scenarios using a neutron detector?

All of the above questions are part of a larger effort to understand how well a neutron detector would work for detecting near surface water as part of a Mars rover mission. For this study, we are focusing on the first question, namely, what effect does the rover body have on making near-surface hydrogen measurements using neutron spectroscopy?

Modeling a rover based neutron detector: It is standard practice to use Monte Carlo calculations to model neutron detector designs [6]. A new code...
called MCNPX has been developed at Los Alamos National Laboratory that models both high-energy charged particle interactions as well as neutron and gamma-ray transport interactions within materials [7]. Here we use the MCNPX code for exploring how a rover based neutron detector is expected to operate.

Figure 1 shows a schematic diagram of a neutron detector that could be easily built using existing technology. The instrument consists of two $^3\text{He}$ gas proportional counters (10 cm x 1 cm diameter). One of the $^3\text{He}$ counters is wrapped in Sn and measures thermal plus epithermal neutrons and one $^3\text{He}$ counter is wrapped in Cd and only measures epithermal neutrons. Between the two counters is an electronics board that can house all the analog and digital electronics as well as the high voltage supply needed to power the detector.

![Figure 1: Schematic diagram of a rover based neutron detector.](image)

For our model, we set up two test cases. Case 1 is the situation with only $^3\text{He}$ tubes on a Martian surface. For a Martian surface composition, we used the average Pathfinder soil composition of [8]. To see how sensitive the $^3\text{He}$ detectors are to subsurface water, we kept the top 30 cm of the surface dry, and then added varying amounts of water (from 1 to 40 wt.% H$_2$O) to the soil below 30 cm. For Case 2, we attached the $^3\text{He}$ neutron detectors to an electronics board (Figure 1) and rover mass. We simulated the electronics board material as being roughly 60% fiberglass and 40% epoxy. For the rover, we assumed the total mass was 150 kg, after the MER design (D. Sevilla, JPL, pers. comm.). For simplicity, we divided this mass into 90% aluminum and 10% electronics board material. We then spread the material over a 50 cm x 50 cm x 50 cm cube. As our study progresses, we will use more accurate estimations of the rover body.

**Results:** Figures 2 and 3 show results from the initial modeling of the two cases. Figure 2 shows the modeled epithermal neutron counting rate (in arbitrary units) as a function of water content. In both cases, we see that the epithermal counting rate decreases as the water content increases, with a clear difference between non-hydrated soil and soil with even only 1% hydration. In addition, we see that the counting rate for the rover based tubes is about a factor of two higher compared to the bare tube case. Figure 3 shows that the counting rate normalized to the dry soil is very similar in both cases, with the rover-attached tube showing a somewhat lower percentage effect for increasing hydrogen abundances.

While additional work needs to be done in carrying out more realistic models and benchmark measurements, these results show that attaching a $^3\text{He}$ neutron detector to a rover does not substantially degrade its ability to detect water on the Martian surface.