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Neutron Sensors for Locating Sites of Planetary Water Deposits

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Abstract

This is the final report of a six-month, Laboratory Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). This project helped in exploration of the value and feasibility of use of collimated neutron detection methods for improving the sensitivity of neutron spectrometers specifically designed for deep-space missions to detect and identify both present-day deposits of near-surface water ice. We believe that this result helped enable a decision to include a Los Alamos-designed neutron sensor as a component of the NASA Mars Global Surveyor-01 Gamma-Ray/Neutron Spectrometer.

Background and Research Objectives

Discovery of small bacteria-like forms within an Antarctic meteorite from Mars has focused the priorities of NASA's Planetary Exploration Discipline on possible sites for living organisms, past or present, within our solar system. Mars, comets and asteroids are prime locations for such sites. A regular series of missions to these destinations is now planned for the next decade. A key goal is to determine the inventory of water ice and to search for evidence of ancient deposits of standing water. Whereas detection of hydrogen is an excellent proxy for finding water molecules, detection of carbonates strongly suggests existence of ancient deposits of standing water. We have previously shown that concentrations of water and carbonates have very distinctive and robust signatures in epithermal and thermal neutron-flux intensities, respectively, near planetary surfaces.

Most locations on Mars that could be sites for water ice and/or carbonates are rather small, having diameters that range between about 25 and 100 km. Surfaces of comets and asteroids are likewise thought to be finely heterogeneous. A valid search for such deposits on all such objects therefore requires either a collimated neutron sensor or one with intrinsic imaging capability.

The purpose of this modest LDRD project was to explore the feasibility of improving the sensitivity of neutron spectrometers specifically designed for deep-space missions to detect

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and identify both present-day deposits of near-surface water ice and evidence for ancient deposits of standing water on solar-system bodies. The strongest and most unique signature of water is a low flux of leakage epithermal neutrons. Because water deposits are expected to be small relative to the altitudes of orbiting spacecraft, some form of collimation is needed to enhance the signal-to-background ratio. This project examined how such collimation might be accomplished.

Importance to LANL's Science and Technology Base and National R&D Needs

Los Alamos has a major program in developing sensors for both defense nonproliferation and civilian applications. Understanding the limitations of the use of neutron detectors based in space and how their resolution may be enhanced by use of appropriate collimation devices has immediate value to both these missions.

Scientific Approach and Accomplishments

We have explored the capabilities of slat collimators for the neutron sensor of the Mars Global Surveyor-2001 Gamma-Ray /Neutron spectrometer. Such a collimator, if it is effective for epithermal neutrons between about 1 eV and 500 keV, would enhance the detectability of hydrated silicates in the Valles Marineris, which is a very long and deep canyon thought to have been filled with running water early in martian history. Our design used borated polyethylene slats that fit the MGS-01 neutron sensor.

A computer code was written to generate input decks containing parameterized lengths and thickness of these slats. A total of nine geometries were run for plane-wave neutron inputs that cover 10 angles between 0 and 90 degrees and ten energies that span 0.01 eV to 7 MeV. The simulations we performed indicated that the collimators provided effective angular cutoffs in accordance with their geometries (width and length) for energies up to about 100 eV as long as their thickness were greater than about 2 cm. All collimators were not effective above about 100 eV. However, forward-backward asymmetry could be recovered by using a multi-element sensor in an active shielding detection mode. This technique works up to neutron energies in the MeV range, but with ever decreasing efficiency with increasing energy.

Because of weight limitations on the Mars-01 spectrometer, we have chosen an active-shielding design. This will be valuable for any space-based application. To test our modeling, we procured two sets of borated-plastic scintillators and photomultiplier tubes for this detector and used these in the assembly of an experimental engineering model for feasibility testing and verification.

The calculations that were undertaken by this project were very important for exploring option space and for eventually choosing a feasible design. It is expected that this design will be adopted for use in the exploration probe that will be launched to Mars in early 2001.