DOSE SPECTRA FROM ENERGETIC PARTICLES AND NEUTRONS (DoSEN)

P. F. Bloser[1], N. Schwadron[1], C. Bancroft[1], J. Legere[1], J. Ryan[1], S. Smith[1], H. Spence[1], J. Mazur[2], and C. Zeitlin[3]
[1]Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire, USA
[2]The Aerospace Corporation, Chantilly, Virginia, USA
[3]Southwest Research Institute, Boulder, Colorado, USA

Introduction: As we prepare to have human explorers leave the safety of near-Earth orbit, the need for assessment of the radiation environment in deep space is more important than ever. For long journeys to anticipated exploration destinations (such as the Moon, Mars, asteroids, or beyond), radiation risk reduction depends on accurate knowledge of the many sources of ionizing radiation facing manned and robotic missions, including galactic cosmic ray (GCR) ions and solar energetic particles (SEP).

DoSEN is an early-stage space technology research project that combines two advanced complementary radiation detection concepts with fundamental advantages over traditional dosimetry [1]. DoSEN measures not only the energy but also the charge distribution (including neutrons) of energetic particles that affect human (and robotic) health in a way not presently possible with current dosimeters. The technology used for DoSEN allows for significant reductions in size, mass, and power needed to provide measurements of dose, neutron dose, dose equivalents, LET spectra, and organ doses. Such a compact instrument could be flown on future planetary mission orbiters to characterize the radiation environment (GCR, SEP, and planetary neutrons) throughout the solar system.

Measurement Principle: For heavy ions and protons, DoSEN provides a direct measurement of the lineal energy transfer (LET) spectra behind shielding material. For LET measurements, DoSEN contains stacks of thin-thick Si detectors similar in design to those used for the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) [2]. Fig. 1 shows a CRaTER "cross plot," the LET spectra from the D1/D2 detectors versus the LET spectra from the D3/D4 detectors, measured in Lunar orbit. D1/D2, D3/D4, and D5/D6 refer to the three thin (~150 μm)/thick (~1000 μm) silicon detector pairs; each detector pair is separated by tissue equivalent plastic (TEP). CRaTER cleanly resolves the different GCR ion species that contribute to the radiation dose and dose equivalent.

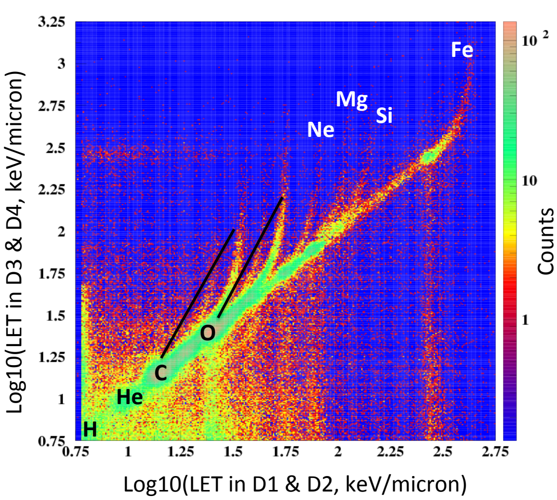

Fig. 1 – CRaTER cross plot.

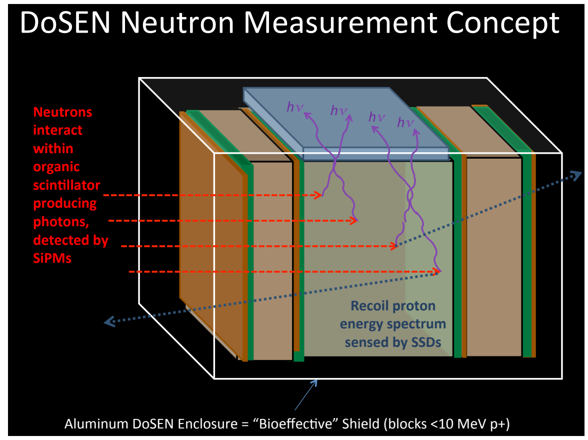

Fig. 2 – DoSEN neutron measurement principle.

With LET spectra, we can now directly break down the observed spectrum of radiation into its constituent heavy-ion components and through biologically based quality factors that provide not only doses and dose rates but also dose equivalents, associated rates, and even organ doses.

DoSEN also measures neutrons from 10 to 100 MeV, which requires enough sensitive mass to fully absorb recoil particles that the neutrons produre (Fig. 2). Organic stilbene scintillator is used to record neutron interactions, which can be distinguished from gamma-ray interactions via pulse shape discrimination (PSD). The scintillator light is recorded using compact, low-voltage silicon photomultipliers (SiPMs) [3].

DoSEN develops the new concept of combining these independent measurements and using the coincidence of LET measurements and neutron detection to significantly reduce backgrounds in each measurement.

DoSEN Laboratory Prototype: The DoSEN measurement principles have been demonstrated through the construction and testing of a laboratory benchtop prototype (Fig. 3). The prototype consists of four Si SSDs, TEP plastic, a 1-inch cylindrical stilbene crystal wrapped in white Teflon tape, and a 2 × 2 array of multi-pixel photon counter SiPMs purchased from Hamamatsu Corp.

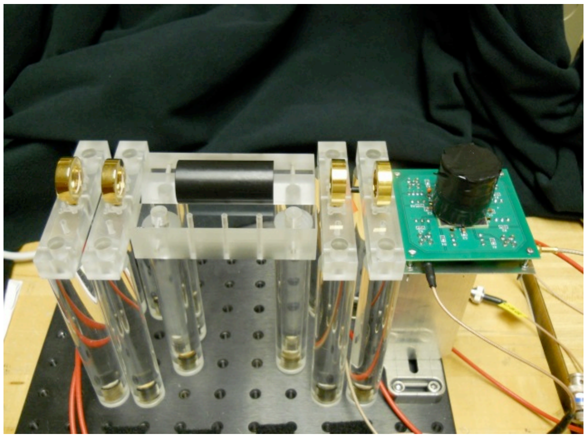

Fig. 3 – DoSEN prototype.

The SSDs and stilbene scintillator were individually calibrated using laboratory gamma-ray and neutron sources. The prototype was then taken to the Francis H. Burr Proton Therapy Center at Massachusetts General Hospital (MGH) and for measurements making use of the 230 MeV proton beam. A thick Al target was placed in the beam, producing protons, electrons, neutrons, gammas, heavy ions, pions and array of elementary particles. With DoSEN placed 30º off the beamline and aimed at the target, we were able to detect the array of elementary particles produced through the beam-Al interactions. Fig. 4 shows a cross plot between the stilbene (D5) and an SSD (D4).

DoSEN Engineering Model: The next step in the development of DoSEN is the construction and testing of an engineering model (EM) using a more realistic, compact configuration (Fig. 5) and custom readout electronics. At the core of the EM is a new, more rugged organic crystal, p-terphynl, that is sensitive to gamma, neutron, and charged particle radiation. The EM will have a plastic scintillator that has its center machined out to fit the p-terphynl crystal and will provide an anti-coincidence signal. This anti-coincidence signal will help us in determining the particle species that interacts in the p-terphynl crystal (neutral vs. charged). Tightly packed above and below the p-terphynl are SSDs that have been purchased from Micron Semiconductor. They provide a large surface area read out for charged particles, demonstrated with the prototype, and also an anti-coincidence for the p-terphynl form above an below.

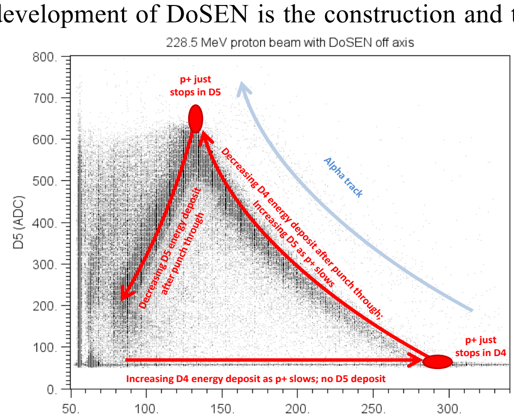

Fig. 4 – DoSEN proton beam data.

The EM will use custom electronics boards and a National Instruments cRIO digital controller. The EM will be self contained and portable within a Pelican case or similar container. We are currently exploring a high-altitude balloon test flight of the EM with NASA's Columbia Scientific Balloon Facility to validate its operation in a realistic space environment.

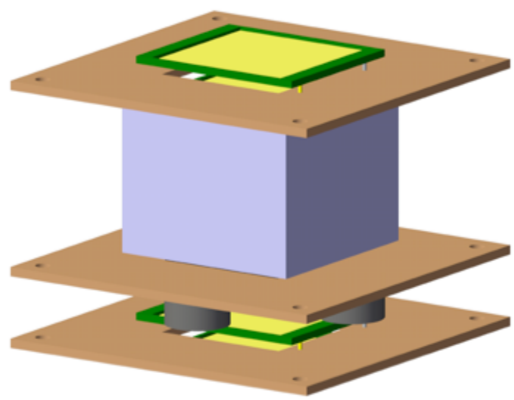

Fig. 5 – DoSEN engineering model concept.

References:

[1] Schwadron, N., et al. (2013) *Space Weather, 11,* 547.

[2] Spence, H. E., et al. (2010) *Spa. Sci. Rev., 150,* 243.

[3] Bloser, P. F., et al. (2013) *Proc. SPIE*, 8859, 885909.