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Project Title:	Lunar EVA Dosimetry: Design of a Radiation Dosimeter for Astronauts During Lunar Extravehicular Activities		
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Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Radiation Effects Team		
Joint Agency Name:		**TechPort:**	Yes
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Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Contact Monitor:		**Contact Phone:**	
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COI Name (Institution):	Heilbronn, Lawrence (Lawrence Berkeley National Laboratory) Braby, Leslie (Texas A&M University) Miller, Jack (Lawrence Berkeley National Laboratory) Benton, Eric (Oklahoma State University) Zeitlin, Cary (Lawrence Berkeley National Laboratory)		
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Task Description:

Task 1: Design and fabrication of a Mod1 prototype detector
The purpose of this task was to design, build and assemble a prototype Tissue Equivalent Proportional Counter (TEPC) that would satisfy the basic specifications outlined by NASA for an EVA dosimeter for astronauts during lunar EVAs. This Mod1 design would include the proportional counter, and first stage preamplifier that are contained in a small vacuum chamber suitable for testing with PuBe neutron sources and charged particle beams.

We have used Solid Works to facilitate the design of Mod1. The spherical TEPC is based on a single-wire anode with recessed guard ring insulators to shape the electric field near the poles. The diameter of the gas cavity is 18mm and the wall thickness is 3mm for a total diameter of 24mm (~ 1 inch).

The preamplifier board has been designed and bench tested for noise at TAMU. The stainless steel vacuum chamber designed to accommodate the TEPC and pre amplifier has been fabricated and leak tested. The hemispherical dome surrounding the TEPC has a wall thickness of 1 mm. This is welded to a cylindrical sleeve with a vacuum tight flange that can be easily removed whenever modifications to the components are necessary.

The final printed circuit boards have been designed and are being fabricated. This will serve as the connection between the pre amplifier and the base plate of the vacuum chamber that also contains the voltage and signal feed-throughs.

Task 2: Modeling Detector Response

The objective of this task is to determine the response of the TEPC under ambient conditions and during SPE events on the lunar surface. Computations using the Monte Carlo Code PHITS have been made to determine the energy spectrum of protons entering the gas cavity for mono-energetic protons that are uniformly incident upon the detector. The purpose of this is to establish the low energy cutoff for protons that do not penetrate the vacuum chamber and plastic wall as well as the attenuation of energy for protons that do reach the gas cavity.

These data show that protons incident at 100 MeV have their energy attenuated by about 10%, whereas protons entering at 50 MeV have an energy attenuation of about 40%. Protons less than 30 MeV do not reach the gas cavity and therefore are not detected by the TEPC.

Computations are underway to model these effects using the spectrum of incident protons from various SPE events. This will be important in determining the dose and dose rate response of the EVA dosimeter during high intensity SPE episodes.

Task 3 Modeling the Variance-Covariance Method

The original proposal for the EVA dosimeter was based on the concept of having two independent proportional counters that would be used to obtain estimates of dose, D, and a quality factor, Q, based on estimating using the variance-covariance method. It was recognized that because of size limitations, the proportional counters would have to be located too close to one another to satisfy the condition that a single particle could not intercept both detectors. The additional constraint that one of the detectors must measure the dose at the skin surface and the other at a depth corresponding to the blood forming organs, makes the original variance-covariance method with paired detectors impractical.

It was suggested that it might be possible to use one detector in a variance-covariance scheme. The concepts are based on collecting the charge, zi, in a single TEPC for n successive intervals.

One method proposed by Borak at CSU separated the data set into two groups of n/2 entries of values for zi based on odd and even indices. The n/2 pairs of data (odd and even) are used to obtain the covariance and each of the two sets of n/2 values (odd or even) to estimate a variance.

John Lakness, from NASA Ames Research Center, used a method based on the derivative of the discrete data set by taking the difference between successive measurements. There are clear similarities between the two methods. Both processes rely on summing values of z, z2 and pairs zi,zj.

The Borak process separates the data set into two parts to estimate a covariance for the paired data and then combines them in the end to estimate by taking the average of the variance minus covariance obtained from the two parts.

The Lakness process in effect gets the covariance by pairing successive values of z and sums up z2 twice.

Several data sets were simulated using a constant value of D for each interval and a variable value of D to evaluate dose rate effects on the estimate of which is used to determine quality factor.

The results indicated that both methods converged toward the true value of for the simulated data sets. We plan to continue these investigations to evaluate both methods at very high dose rates and very low dose rates where there may be no events in a given timing interval.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

The instrument being proposed here is specifically designed to meet the dosimetry requirements inherent in Lunar EVA. However, the tissue equivalent chamber that forms the core can also be used as the basis for radiation area monitors aboard exploration spacecraft or as a TEPC on a robotic lander to assess the radiation environment on Mars or other planetary bodies. By adopting a single tissue equivalent chamber design, NASA can simplify the interpretation, evaluation, and comparison of dosimetric data collected aboard different spacecraft, since differences in detector operating principles, design, and sensitivity will be largely eliminated. In addition, the process of calibrating the detectors will be greatly simplified, since all detectors will be of a common design. We view the development of this dosimeter system as being the next logical step in the evolution of space flight instrumentation for the measurement of space radiation.

Task Progress:

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Bibliography Type: Description: (Last Updated: 03/20/2019)

Articles in Peer-reviewed Journals

Taddei PJ, Zhao Z, Borak TB. "A comparison of the measured responses of a tissue-equivalent proportional counter to high energy heavy (HZE) particles and those simulated using the Geant4 Monte Carlo code." Radiation Measurements, 2008 Oct-Nov;43(9-10):1498-505. http://dx.doi.org/ ; PMID: 20862212 , Oct-2008