SPACEFLIGHT VALIDATION OF HZETRN CODE

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INTRODUCTION

HZETRN is being developed as a fast deterministic radiation transport code applicable to neutrons, protons, and multiply charged ions in the space environment. It was recently applied to 50 hours of IMP8 data measured during the August 4, 1972 solar event to map the hourly exposures within the human body under several shield configurations. This calculation required only 18 hours on a VAX 4000 machine. A similar calculation using the Monte Carlo method would have required two years of dedicated computer time. The code has been benchmarked against well documented and tested Monte Carlo proton transport codes with good success. The code will allow important trade studies to be made with relative ease due to the computational speed and will be useful in assessing design alternatives in an integrated system software environment. Since there are no well tested Monte Carlo codes for HZE particles, we have been engaged in flight validation of the HZETRN results. To date we have made comparison with TEPC, CR-39, charge particle telescopes, and Bonner spheres. This broad range of detectors allows us to test a number of functions related to differing physical processes which add to the complicated radiation fields within a spacecraft or the human body, which functions can be calculated by the HZETRN code system. In the present report we will review these results.

METHOD

The estimation of the radiation within the tissues of an astronaut aboard a geometrically complicated spacecraft requires an adequate representation of the fragmentation of primary ions, the production of particles in collision with spacecraft structures and human tissues, and the correlated secondary electron distributions about the ion paths. Included in this representation must be the abundant neutrons and low energy target fragments which add to the high LET components of the radiation fields along with the HZE ions. To obtain accurate information from the above mentioned detectors one must pay close attention to the individual instrument response functions for the various components. The AP8 trapped environmental model, the Badhwar/O'Neill model for the galactic cosmic rays, the geomagnetic cutoffs of Smart and Shea, and estimates of the neutron albedo are used to represent the LEO environment. These are used with the Shuttle geometry, the HZETRN Code, and the instrument response functions to predict the outcome of the measurements within the Shuttle interior at the specific sites where the instruments are located.

RESULTS

The lineal energy distribution of the JSC TEPC during June 1993 resulting from the trapped protons in STS-57 in a 28.5^{o} inclined 252 nmi orbit is shown in figure 1. Also shown are the HZETRN calculated distributions for comparison. There are slight

differences near 10 and 100 keV/micron. Similar results are obtained for galactic cosmic ray contributions as shown in figure 2. The is a difference at the lowest lineal energies which may be due to meson production which is not yet in the HZETRN model or low LET events of passing HZE ions outside the active region of the detector. Generally, however, there is good agreement between the computational models and measurements. Another example is the CR-39 measurements of Heinrich et al. on the D1 mission shown in figure 3. The LET spectrum at the site of the measurement is shown as the dashed curve. Many of the high LET target fragmentation events were etched away in the processing of the foils. Our estimate of the etching losses are shown as the solid curve which agrees well with the measurements. But note, the CR-39 foils do not generally measure the full LET spectrum.

FINAL REMARKS

All detector types have certain limitations regarding their ability to detect radiation, their specificity for a particular radiation type(s), and their accuracy. For example, although the detectors used to obtain the data reported in figures 1-3 are largely driven by the charged particle environment, the TEPC device also responds to some extent to the neutron environment as well but there is no clear separation. Charged particle telescopes and Bonner spheres can separate charged particle and neutron contributions in the radiation fields. All of the detectors have their own unique performance characteristics, and these characteristics must properly be taken into account when interpreting their measurement results. The characteristics and limitations of the several types of detectors are discussed in further detail in this presentation along with the spaceflight data and comparisons with the HZETRN Code results.

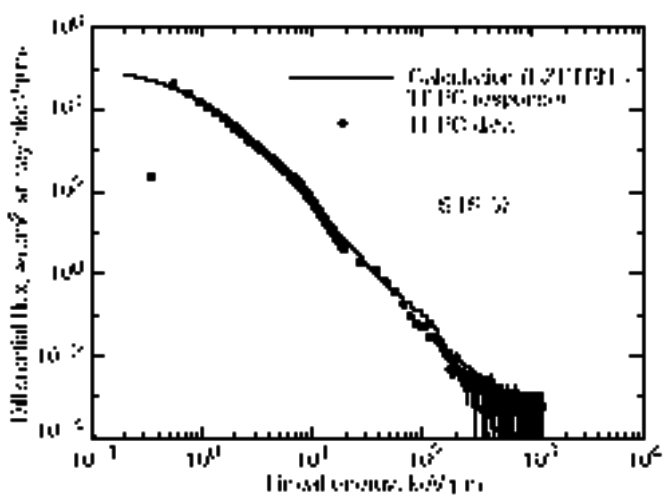

Figure 1. Measured and calculated lineal energy spectra induced by trapped protons in a 252 nmi x 28.5^{o} orbit in June 1993 aboard STS-57.

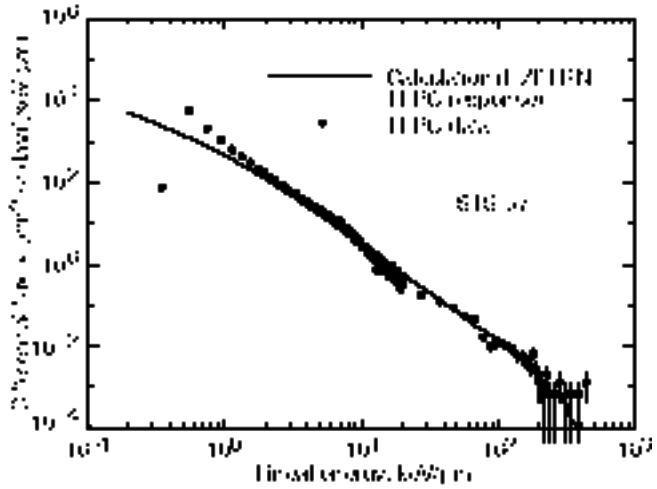

Figure 2. Measured and calculated lineal energy spectra induced by galactic cosmic rays in a 252 nmi x 28.5^{o} orbit in June 1993 aboard STS-57.

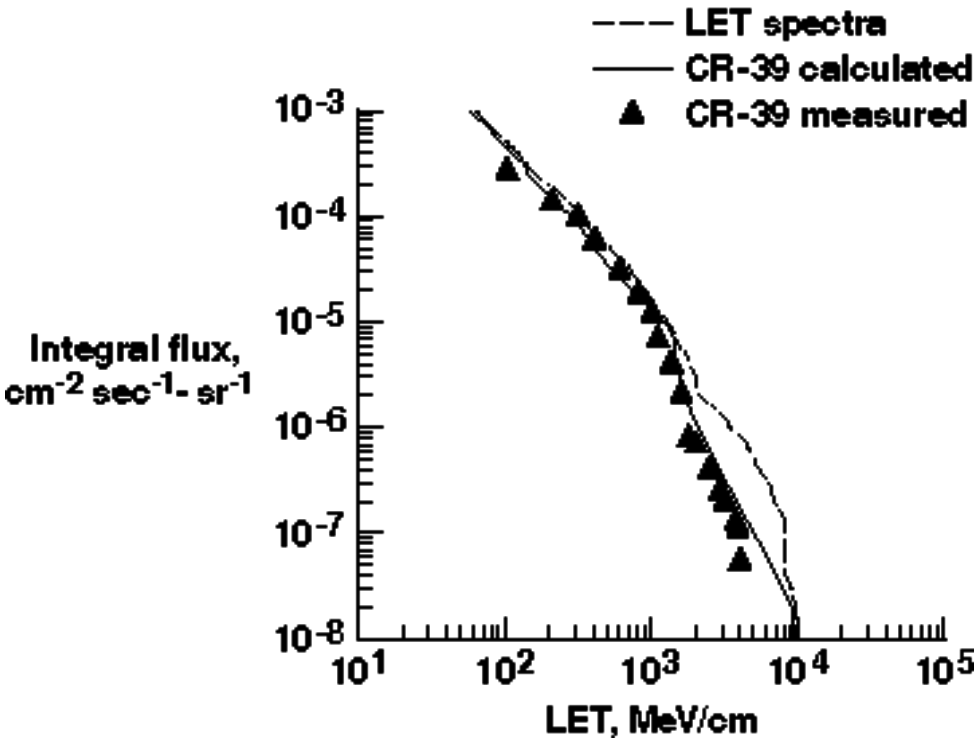

Figure 3. LET spectra measured and calculated using HZETRN Code.