Model for Cumulative Solar Heavy Ion Energy and LET Spectra

Mike Xapsos and Janet Barth
*NASA Goddard Space Flight Center*
Craig Stauffer
*Muniz Engineering, Inc.*
Tom Jordan
*EMPC Consultants*
Richard Mewaldt
*California Institute of Technology*

Outline

- Introduction to PSYCHIC* Model
- Solar Protons
  - Data
  - Results
  - Summary
- Solar Heavy Ions
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  - Results
  - Summary

*Prediction of Solar particle Yields to Characterize Integrated Circuits*
Introduction

- It is especially important to have predictive models for solar particle event fluences and fluxes for missions away from Earth's magnetic field.
  - Geosynchronous
  - Polar
  - Interplanetary
- Current solar heavy ion models:
  - CREME96 uses October 1989 event as a worst-case event
  - Cumulative fluence models not well developed
- This work is based on advanced statistical methods so that risk/cost/performance tradeoffs can be evaluated during design phase.

To be presented by Mike Xapsos at the IEEE Nuclear and Space Radiation Effects Conference (NSREC) Technical Session, July 23-27, 2007 and to be published on http://rahome.gsfc.nasa.gov

Solar Proton Model

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Solar Proton Data

- Based on the IMP and GOES series of satellite data spanning time period from 1966 to 2001
  - Energy range from 1 to 330 MeV
  - Solar maximum and solar minimum time periods treated separately

Distribution of Event Magnitudes

- Solar particle events appear to be probabilistic in nature so it is important to accurately model the distribution of event magnitudes.
- However, the data are limited
  - Can make selecting a distribution difficult and arbitrary
- **Maximum Entropy Principle**
  - Method for making arguably the best selection of a probability distribution compatible with known information
Distribution of Event Magnitudes

• Resulting solution using maximum entropy approach is a truncated power law function in the event magnitude during solar max
• Describes essential features of the distribution
  – Smaller event sizes follow power law function
  – Larger event sizes fall off much more rapidly

Cumulative Fluence During Solar Maximum

• Once the distribution of event fluence magnitudes is known, the cumulative fluence during a mission can be calculated.
Model Comparisons for Solar Maximum

- Solar minimum model is important for missions planned mostly or entirely for this time period.
- PSYCHIC model contains 3 solar minimum flux levels to allow varying degrees of conservatism to be used in design process.
Summary – Solar Proton Model

A complete solar proton model has been developed
- Cumulative fluences and worst case events
- Energy range 1 to 330 MeV
- Covers entire solar cycle
- Used at GSFC for spacecraft design
- Implemented in SPENVIS and OMERE 3.1
- Validated with measurements by CREDO instrument on MPTB*


Solar Heavy Ion Model

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Heavy Ion Data

<table>
<thead>
<tr>
<th>Predominant Elements:</th>
<th>Measurement Period:</th>
<th>Energy Range (MeV/n):</th>
<th>Data Source:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Particles</td>
<td>1973 - 2001</td>
<td>1 - 200</td>
<td>IMP-8, GOES</td>
</tr>
<tr>
<td>C, N, O, Ne, Mg, Si, S, Fe</td>
<td>1997 - 2005</td>
<td>7 - 140 (element dependent)</td>
<td>ACE/SIS</td>
</tr>
</tbody>
</table>

Less prevalent elements are scaled to above energy spectra using either ISEE-3 satellite data or a photospheric abundance model corrected for the first ionization potential effect.

Heavy Ion Energy Spectra

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